

INTERNATIONAL CONFERENCE ON

# SINTERING 2008

**November 16-20, 2008**

Hilton La Jolla Torrey Pines  
La Jolla, California

## *MEETING GUIDE*

[www.ceramics.org/sintering2008](http://www.ceramics.org/sintering2008)



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ELEMENTS**

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In the Final Program:  
\*denotes presenting author  
(Invited) after a title indicates this speaker  
was invited by the organizing committee

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# Welcome

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Greetings and welcome to the International Conference Sintering 2008. This is the fifth meeting in a series that started in 1995 as a continuation of a famous cycle of conferences on Sintering and Related Phenomena organized by G. Kuczynski. The last meeting was held in Grenoble, France, in September 2005.

The technical program at this meeting will address the latest advances in the sintering processes for the fabrication of powder-based materials in terms of fundamental understanding, technological issues and industrial applications. Recent developments in both sintering science and technology make this an ideal time for this conference. For example, in sintering science, significant progress has been made in multi-scale modeling of densification and microstructure development, and understanding of the processing of complex systems (multi-layered, composites and reactive systems). In sintering technology, innovative approaches like Field Assisted Sintering (FAST), sometimes referred to as Spark Plasma Sintering, are developing at a rapid pace. Another very timely and well-represented topic is sintering and microstructure development in nanostructured materials. Sintering of bio- and energy-related materials will also be discussed. The meeting is truly international with participants from North and Central America, Europe (both Eastern and Western), Asia, Australia and Africa.

To augment the traditional technical presentations, two additional program initiatives are planned. First, a Plenary Round Table Discussion on the “Challenges and Opportunities in Sintering Science and Technology” will identify critical avenues for research and development as well as the most exciting developments in the science and technology of sintering. Second, a very strong poster session with set-aside time is planned to encourage in-depth discussions

The meeting setting and atmosphere will provide ample time for discussions and networking. Several special activities have been planned in addition to the outstanding technical program. No technical sessions have been scheduled for Tuesday afternoon so that attendees may enjoy the La Jolla and San Diego area, which is an area of great natural beauty. The most compelling geographical highlights of La Jolla is its ocean front, where visitors can enjoy the alternating rugged and sandy coast line and view wild seal congregations.

On Sunday, November 16th, please join us for the conference reception and on Wednesday, November 19th for the Banquet.

The American Ceramic Society thanks you for participating in this meeting. We hope you have a stimulating and memorable experience in San Diego.

## Conference Co-Chairs

Rajendra K. Bordia  
University of Washington  
Seattle, WA U.S.A.



Eugene Olevsky  
San Diego State University  
San Diego, CA U.S.A.

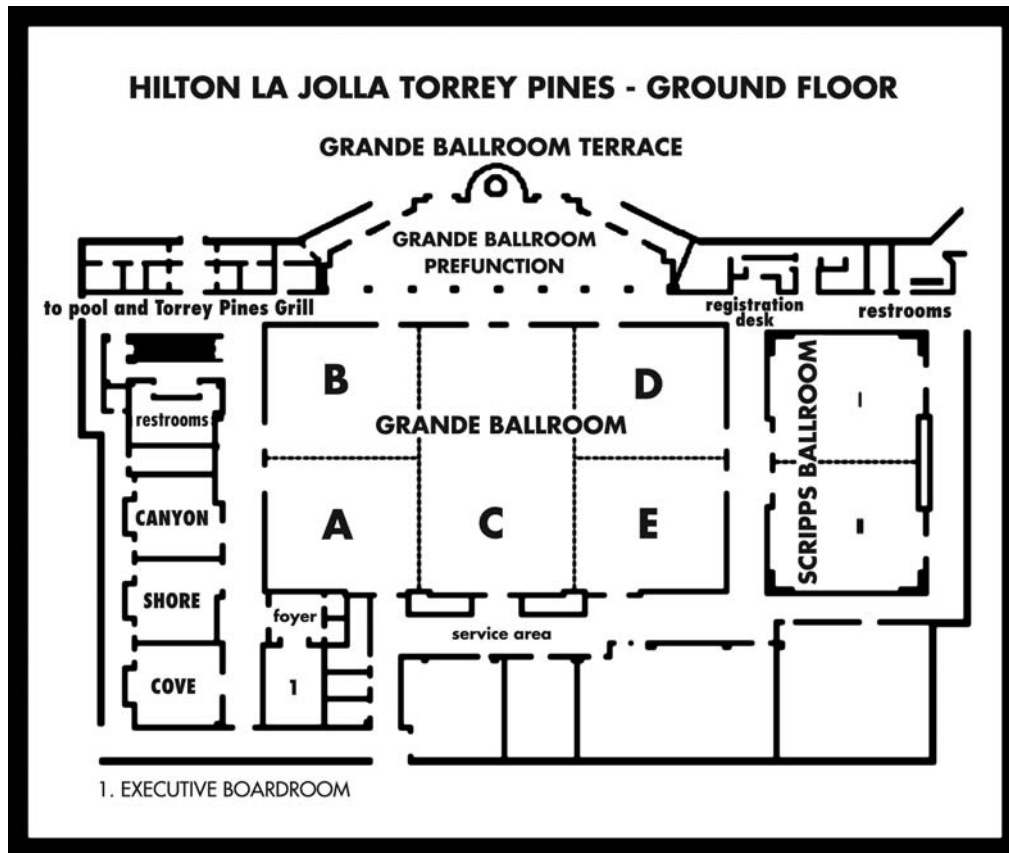


# Schedule At A Glance

<b>Program Schedule-At-A-Glance</b>							
<b>Time</b>	<b>Fairway Pavilion Ballroom</b>	<b>Ballroom C</b>	<b>Ballroom D</b>	<b>Ballroom E</b>	<b>Scripts I</b>	<b>Scripts II</b>	<b>Ballroom Foyer</b>
<b>Sunday, November 18</b>							
5 - 7 pm Welcome Reception		<b>Parterre Gardens</b>					
<b>Monday, November 17</b>							
8 - 9 am		Opening Remarks & Plenary Session I					
9:10 am - Noon			Microstructure I Measurements	In-Situ	Modeling I	Nano-Structured Materials I	
<b>Lunch</b>		<b>Parterre Gardens</b>					
1 - 2:30 pm							Poster Session
2:30 - 6 pm			Microstructure II	Novel Sintering Processes I	Modeling II	Nano-Structured Materials II	
<b>Tuesday, November 18</b>							
8 - 9:10 am		Plenary Session II					Poster viewing all day until 5 pm
9:10 am - 12:20 pm			Microstructure III	Novel Sintering Processes II	Modeling III	Nano-Structured Materials III	
<b>Lunch</b>		<b>Parterre Gardens</b>					
1:30 - end of day		<b>FREE TIME*</b>					
<b>Wednesday, November 19</b>							
8:10 am - Noon			Microstructure IV	Novel Sintering Processes III	Fundamentals I	Electronics I	
<b>Lunch</b>		<b>Parterre Gardens</b>					
1 - 3 pm		Round Table Discussion					
3 - 6:10 pm			Multi-Material I	Novel Sintering Processes IV	Fundamentals II	Electronics II/ Appl. of Sintering in Energy Applications	
7 - 9:30 pm	Conference Dinner						
<b>Thursday, November 20</b>							
8:10 - 11:20 am			Multi-Material II	Novel Sintering Processes V	Fundamentals III	Sintering of Bio-Materials	

\*Attendees participating in the optional San Diego by Land and Sea tour need to meet in the hotel lobby at 1:15 PM. Buses will be departing at 1:30 PM. Pre-Registration for tour was required.

# Hilton La Jolla Torrey Pines Floor Plan



## Special Events

### Welcome Reception

Sunday - November 16th

5:00 – 7:00 PM

Parterre Gardens

### Posters and Table Top Exhibits

Monday – November 20th; 1:00 – 2:30 PM (Posters will remain up all day)

Tuesday – November 21st; 8:00 AM – 5:00 PM

Grande Ballroom Prefunction area

### Panel Discussion – “Sintering - Challenges and Opportunities”

Wednesday – November 22nd

1:00 – 3:00 PM

Ballroom C

#### PANELISTS

Didier Bouvard, Grenoble INP

Vikram Jayaram, Indian Institute of Science

Ian Nettlehip, University of Pittsburgh

Joanna Groza, University of California, Davis

Suk-Joong Kang, Korea Advanced Institute of Science & Technology

Veena Tikare, Sandia National Laboratories

### Conference Dinner (included with registration fee)

Wednesday – November 22nd

Reception – 6:15 – 7:00 PM; Pavilion Garden

Dinner – 7:00 PM – 9:30 PM; Fairway Pavilion Ballroom (Lobby Level)

## Poster Presenters

Name	Date	Time	Room	Page Number	Name	Date	Time	Room	Page Number
Abe, K.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Le Gallet, S.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Adachi, S.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Leonelli, C.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Akarsu, A.C.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Martinez-Franco, E.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Busquets, D.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Meek, T.T.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Camacho, H.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Micháľková, M.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Chen, S.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Mitic, V.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Crochemore, G.B.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Nagai, H.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Dupuy, A.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Nam, S.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Estournès, C.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Oh, S.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Glozman, D.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Orban, R.L.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Godoi, G.S.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Orlova, Y.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Guney, O.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Park, K.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Hardin, C.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Quach, D.V.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Hatim, Z.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Ragulya, A.V.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Indrakanti, S.S.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Senos, A.M.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Isaka, N.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Skatkov, L.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Jaleel, S.A.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Suzuki, T.S.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Jiang, W.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Tamsu, N.	17-Nov	1:00PM	Grand Ballroom Foyer	10
Kawakami, S.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Tanju, S.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Khobta, I.V.	17-Nov	1:00PM	Grand Ballroom Foyer	10	Valsangiacom, C.	17-Nov	1:00PM	Grand Ballroom Foyer	11
Kim, Y.	17-Nov	1:00PM	Grand Ballroom Foyer	11	Wieg, A.T.	17-Nov	1:00PM	Grand Ballroom Foyer	11

## Oral Presenters

Name	Date	Time	Room	Page Number	Name	Date	Time	Room	Page Number
					Degenhardt, U.	17-Nov	3:40PM	Scripts II	12
					Delporte, M.	17-Nov	10:40AM	Ballroom E	9
					Demuyneck, M.	19-Nov	4:30PM	Ballroom E	16
					DiAntonio, C.	19-Nov	8:20AM	Scripts II	15
					<b>E</b>				
					Erauw, J.	18-Nov	12:00PM	Scripts I	14
					Estournès, C.	17-Nov	11:40AM	Scripts II	10
					Ewsuk, K.	19-Nov	3:10PM	Scripts I	16
					Exner, H.	19-Nov	9:00AM	Scripts I	15
					<b>F</b>				
					Fang, Z.Z.	17-Nov	5:00PM	Scripts II	12
					Fang, Z.Z.	18-Nov	10:00AM	Ballroom D	13
					Fliflet, A.W.	19-Nov	3:10PM	Ballroom E	16
					Frage, N.	18-Nov	11:00AM	Ballroom D	13
					<b>G</b>				
					Galusek, D.	20-Nov	9:20AM	Ballroom E	18
					Garay, J.E.	20-Nov	8:40AM	Ballroom E	18
					German, R.M.	18-Nov	9:20AM	Ballroom D	13
					German, R.M.	19-Nov	8:20AM	Scripts I	15
					German, R.M.	20-Nov	11:20AM	Scripts I	18
					Graeve, O.A.	18-Nov	10:00AM	Ballroom E	13
					Green, D.	20-Nov	8:20AM	Ballroom D	17
					Grigoryev, E.G.	19-Nov	5:30PM	Ballroom E	16
					Grossin, D.	20-Nov	10:20AM	Scripts II	18
					Groza, J.R.	18-Nov	11:00AM	Ballroom E	13
					Grupp, R.	17-Nov	10:00AM	Ballroom E	9
					Guillemet-Fritsch, S.	20-Nov	9:40AM	Ballroom E	18
					Guillon, O.	19-Nov	8:20AM	Ballroom D	14
					<b>H</b>				
					Halem, N.	19-Nov	5:30PM	Ballroom D	16
					Harmer, M.P.	20-Nov	8:20AM	Scripts I	18
					Hasan, M.M.	20-Nov	10:40AM	Scripts II	18
					Hayun, S.	18-Nov	11:40AM	Ballroom D	13
					Henderson, J.B.	17-Nov	11:20AM	Ballroom E	9
					Herrmann, M.	19-Nov	11:00AM	Ballroom E	15
					Hinklin, T.R.	19-Nov	5:30PM	Scripts I	17
					Hiratsuka, D.	19-Nov	3:50PM	Scripts I	16
					<b>A</b>				
Agrawal, D.	17-Nov	2:40PM	Ballroom E	11					
Akin, I.	19-Nov	4:50PM	Ballroom E	16					
Alaniz, J.	19-Nov	11:40AM	Ballroom E	15					
Allan, S.M.	19-Nov	11:20AM	Scripts II	15					
Ambrozio Filho, F.	19-Nov	3:30PM	Scripts II	17					
Anselmi-Tamburini, U.	18-Nov	9:20AM	Ballroom E	13					
Arguello, J.G.	18-Nov	10:00AM	Scripts I	13					
Atkinson, A.	19-Nov	4:30PM	Scripts II	17					
Azar, M.	17-Nov	4:40PM	Scripts II	12					
					<b>B</b>				
Bartel, T.	17-Nov	9:20AM	Scripts I	9					
Bäurer, M.	17-Nov	10:40AM	Ballroom D	9					
Benameur, N.	17-Nov	11:20AM	Ballroom D	9					
Bernard, D.	17-Nov	11:40AM	Ballroom D	9					
Bernard, F.	18-Nov	10:00AM	Scripts II	14					
Bernard-Granger, G.	20-Nov	10:20AM	Ballroom E	18					
Blaine, D.C.	19-Nov	4:30PM	Scripts I	17					
Boccaccini, A.	20-Nov	9:20AM	Scripts II	18					
Bouvard, D.	17-Nov	3:40PM	Ballroom E	12					
Bouvard, D.	19-Nov	10:20AM	Scripts I	15					
Brown, G.R.	17-Nov	10:00AM	Scripts I	9					
Brown, G.R.	19-Nov	5:30PM	Scripts II	17					
Busquets, D.	17-Nov	3:20PM	Scripts II	12					
					<b>C</b>				
Camacho, H.	17-Nov	2:40PM	Scripts I	12					
Campos, M.	19-Nov	5:10PM	Scripts II	17					
Cannon, W.	19-Nov	11:00AM	Scripts I	15					
Cannon, W.	19-Nov	9:20AM	Scripts I	15					
Carry, C.	17-Nov	3:20PM	Ballroom E	11					
Chen, T.	17-Nov	10:00AM	Ballroom D	9					
Chokshi, A.	17-Nov	9:20AM	Scripts II	10					
Cocks, A.	18-Nov	8:20AM	Ballroom C	13					
Corbin, S.F.	17-Nov	9:20AM	Ballroom E	9					
					<b>D</b>				
Dariel, M.P.	19-Nov	9:40AM	Ballroom E	15					
DeCarlo, K.J.	20-Nov	9:40AM	Scripts I	18					

# Presenting Author List

Name	Date	Time	Room	Page Number	Name	Date	Time	Room	Page Number
<b>I</b>					Raharijaona, J.	19-Nov	5:10PM	Ballroom D	16
Imgrund, P.	19-Nov	4:50PM	Ballroom D	16	Raj, R.	19-Nov	9:00AM	Ballroom E	14
Indrakanti, S.S.	17-Nov	5:00PM	Scripts I	12	Reimanis, I.	17-Nov	3:20PM	Ballroom D	11
Indrakanti, S.S.	19-Nov	10:20AM	Scripts II	15	Reiterer, M.W.	17-Nov	3:00PM	Scripts I	12
Ishizaki, K.	17-Nov	4:00PM	Ballroom E	12	Rivinius, C.	20-Nov	9:20AM	Ballroom D	17
<b>J</b>					Roentzsch, L.	17-Nov	11:20AM	Scripts I	10
Jayaram, V.	18-Nov	9:20AM	Scripts II	14	Rosinski, M.	20-Nov	8:20AM	Ballroom E	18
Johnson, J.L.	20-Nov	11:00AM	Scripts I	18	Ryu, S.	19-Nov	3:50PM	Ballroom D	16
Julien, G.	19-Nov	11:20AM	Ballroom E	15	<b>S</b>				
<b>K</b>					Sahin, F.C.	20-Nov	10:40AM	Ballroom E	18
Kaiser, A.F.	19-Nov	4:50PM	Scripts II	17	Samarov, V.N.	17-Nov	4:40PM	Scripts I	12
Kang, S.L.	17-Nov	9:20AM	Ballroom D	9	Sarraf, H.	20-Nov	10:20AM	Ballroom D	17
Khaleghi, E.	19-Nov	9:40AM	Ballroom D	14	Saunier, S.	19-Nov	10:20AM	Ballroom D	14
Kim, J.	19-Nov	5:10PM	Ballroom E	16	Schaffer, G.	20-Nov	9:20AM	Scripts I	18
Kim, Y.	17-Nov	2:40PM	Scripts II	12	Schubert, H.	19-Nov	5:50PM	Scripts II	17
Kimura, T.	17-Nov	4:40PM	Ballroom D	11	Schubert, T.	17-Nov	5:20PM	Ballroom E	12
Kloppenburg, M.	19-Nov	3:10PM	Scripts II	17	Schurwanz, M.	17-Nov	11:00AM	Ballroom E	9
Kodera, Y.	19-Nov	3:10PM	Ballroom D	16	Senos, A.M.	19-Nov	10:40AM	Scripts II	15
Koenig, M.	18-Nov	11:20AM	Scripts II	14	Shinagawa, K.	18-Nov	11:40AM	Scripts I	14
Kraft, T.	18-Nov	9:20AM	Scripts I	13	Shtern, M.	17-Nov	4:00PM	Scripts I	12
<b>L</b>					Siddique, M.N.	19-Nov	9:40AM	Scripts II	15
Langer, J.	18-Nov	11:40AM	Ballroom E	13	Sivanandam, A.	18-Nov	10:40AM	Scripts II	14
Leshchynsky, V.	20-Nov	9:00AM	Ballroom D	17	Sivaprahasam, D.	18-Nov	9:40AM	Ballroom D	13
Linch, D.C.	18-Nov	11:40AM	Scripts II	14	Skorokhod, V.V.	17-Nov	10:40AM	Scripts II	10
Lu, G.	19-Nov	3:50PM	Scripts II	17	Sohn, S.	19-Nov	9:20AM	Scripts II	15
Lu, K.	17-Nov	11:20AM	Scripts II	10	Stevenson, A.J.	17-Nov	4:00PM	Ballroom D	11
<b>M</b>					Sujirote, K.	20-Nov	9:00AM	Scripts II	18
Ma, J.	17-Nov	3:40PM	Scripts I	12	<b>T</b>				
Ma, S.	20-Nov	9:00AM	Scripts I	18	Tanaka, S.	17-Nov	5:00PM	Ballroom D	11
Maca, K.	17-Nov	5:20PM	Scripts II	12	Tatami, J.	17-Nov	10:00AM	Scripts II	10
Martin, C.L.	17-Nov	11:00AM	Scripts I	9	Theron, C.	18-Nov	10:40AM	Ballroom D	13
Martin, C.L.	18-Nov	10:40AM	Scripts I	14	Thomazic, A.	19-Nov	4:30PM	Ballroom D	16
Mashhadi, M.	18-Nov	11:20AM	Ballroom D	13	Tiruvalam, R.	18-Nov	11:00AM	Scripts II	14
Maximenko, A.	18-Nov	11:20AM	Scripts I	14	Trunec, M.	19-Nov	9:00AM	Ballroom D	14
Messing, G.	17-Nov	2:40PM	Ballroom D	11	Turriff, D.M.	17-Nov	11:40AM	Ballroom E	9
Minier, L.	20-Nov	9:00AM	Ballroom E	18	<b>U</b>				
Missiaen, J.	20-Nov	10:20AM	Scripts I	18	Uematsu, K.	19-Nov	5:50PM	Scripts I	17
Mitic, V.	19-Nov	9:00AM	Scripts II	15	<b>V</b>				
Morales, J.R.	19-Nov	11:00AM	Scripts II	15	Valdez-Nava, Z.	19-Nov	11:40AM	Scripts II	15
Müller, M.	19-Nov	8:40AM	Ballroom E	14	Valdivieso, F.	17-Nov	11:00AM	Ballroom D	9
Munir, Z.A.	17-Nov	8:20AM	Ballroom C	9	Van der Biest, O.	18-Nov	12:00PM	Ballroom E	13
<b>O</b>					Vats, A.	17-Nov	4:40PM	Ballroom E	12
Ohyanagi, M.	19-Nov	8:20AM	Ballroom E	14	Veronesi, P.	17-Nov	5:00PM	Ballroom E	12
Olevsky, E.	18-Nov	10:40AM	Ballroom E	13	<b>W</b>				
<b>P</b>					Wakai, F.	17-Nov	10:40AM	Scripts I	9
Pan, J.	18-Nov	11:00AM	Scripts I	14	Wang, H.	17-Nov	4:00PM	Scripts II	12
Pan, J.	19-Nov	11:20AM	Scripts I	15	Wonisch, A.	17-Nov	11:40AM	Scripts I	10
Park, S.	17-Nov	3:20PM	Scripts I	12	<b>Y</b>				
Park, S.	19-Nov	5:10PM	Scripts I	17	Yalamac, E.	20-Nov	9:40AM	Ballroom D	17
Polotai, A.V.	20-Nov	10:40AM	Ballroom D	17	Yoshida, K.	19-Nov	3:30PM	Ballroom D	16
<b>R</b>					<b>Z</b>				
Ragulya, A.V.	19-Nov	3:50PM	Ballroom E	16	Zavaliangos, A.	19-Nov	10:20AM	Ballroom E	15
Rahaman, M.N.	20-Nov	8:20AM	Scripts II	18	Zwick, M.	19-Nov	9:20AM	Ballroom D	14

\*Denotes presenting author  
(Invited) After a title indicates this speaker  
was invited by the organizing committee



## Monday, November 17, 2008

### Opening Remarks and Plenary Session I

Room: Ballroom C

**8:00 AM**

#### Opening Remarks

Eugene A. Olevsky, San Diego State University  
and Rajendra K. Bordia, University of Washington

**8:20 AM**

#### (SINTER-001-2008) Current Effects in the Sintering of Powders: Consolidation by the Pulsed Electric Current Sintering Method (Invited)

Z. A. Munir\*, University of California, USA

### Evolution and Control of Microstructure during Sintering Processes

#### Microstructure I

Room: Ballroom D

**9:10 AM**

#### Introductory Remarks by Session Chair

Gary Messing, Pennsylvania State University

**9:20 AM**

#### (SINTER-002-2008) Sintering Kinetics by Structural Transition at Interfaces (Invited)

S. L. Kang\*, Korea Advanced Institute of Science and Technology, South Korea

**10:00 AM**

#### (SINTER-003-2008) New Effective Diffusion Distance for Sintering Ceramic Microstructures

T. Chen\*, I. Nettleship, University of Pittsburgh, USA; T. R. Hinklin, K. G. Ewsuk, Sandia National Laboratory, USA

**10:20 AM**

Break

**10:40 AM**

#### (SINTER-004-2008) Grain Growth and Microstructure Control in Undoped Strontium Titanate

M. Bäurer\*, Universität Karlsruhe, Germany; M. P. Harmer, Lehigh University, USA; M. J. Hoffmann, Universität Karlsruhe, Germany

**11:00 AM**

#### (SINTER-005-2008) Microstructure Development during Sintering: Grain Growth Control Assisted by Gas Pressure

F. Valdivieso\*, C. Nivot, J. Bolland, ENSM-SE, France

**11:20 AM**

#### (SINTER-006-2008) Sintering and Grain Growth Kinetics of a Stoichiometric Alumina Spinel Powder

N. Benameur\*, G. Bernard-Granger, Saint-Gobain CREE, France; A. Addad, Université des Sciences et Technologies de Lille UMR 8008 CNRS, France; C. Guizard, Saint-Gobain CREE, France

**11:40 AM**

#### (SINTER-007-2008) Microstructural Evolution of Constrained Films through Synchrotron Computed Microtomography

D. Bernard\*, ICMCB-CNRS, France; O. Guillon, Technische Universität Darmstadt, Germany

### In-Situ Measurements in Sintering

#### In-Situ Measurements

Room: Ballroom E

**9:10 AM**

#### Introductory Remarks by Session Chair

Didier Bouvard, Grenoble INP

**9:20 AM**

#### (SINTER-008-2008) Investigating the Influence of Powder Size on beta-Ti Formation and Reactive Sintering of NiTi Using Differential Scanning Calorimetry (Invited)

S. F. Corbin\*, M. Whitney, D. Cluff, R. Gorbet, University of Waterloo, Canada

**10:00 AM**

#### (SINTER-009-2008) In-Situ Analysis of Particle Rotations during Sintering Applying High-Resolution Synchrotron Tomography of Focused-Ion-Beam-Marked Spheres

R. Grupp\*, M. Nöthe, B. Kieback, Technische Universität Dresden, Germany; J. Banhart, Hahn-Meitner-Institut Berlin GmbH, Germany

**10:20 AM**

Break

**10:40 AM**

#### (SINTER-010-2008) Characterization of Viscous Properties of Zirconia Tapes during Sintering

M. Delporte\*, Fraunhofer Gesellschaft ISC, Germany; U. Eisele, Robert-Bosch-GmbH, Germany; F. Raether, Fraunhofer Gesellschaft ISC, Germany

**11:00 AM**

#### (SINTER-011-2008) Combined Dilatometry and Mass Spectrometry Analysis of the Sintering of Strontium Titanate

M. Schurwanz\*, S. J. Lombardo, University of Missouri- Columbia, USA

**11:20 AM**

#### (SINTER-012-2008) Characterization of the Thermally-induced Response of Yttria-stabilized Zirconia during Sintering

J. B. Henderson\*, Netzsch Instruments, Inc., USA; J. Blumm, NETZSCH-Gerätebau GmbH, Germany

**11:40 AM**

#### (SINTER-013-2008) In Situ Neutron Diffraction Analysis of TLP Sintered Ni-Cu Powder Mixtures

D. M. Turriff\*, S. F. Corbin, University of Waterloo, Canada

### Modeling of Sintering at Multiple Scales

#### Modeling I

Room: Scripts I

**9:10 AM**

#### Introductory Remarks by Session Chair

Torsten Kraft, Fraunhofer IWM

**9:20 AM**

#### (SINTER-014-2008) Multi-Physics Model for Simulation of Sintering at the Mesoscale (Invited)

T. Bartel\*, V. Tikare, Sandia National Laboratories, USA

**10:00 AM**

#### (SINTER-015-2008) Meso-scale Monte Carlo Sintering Simulation with Anisotropic Grain Growth

G. R. Brown\*, R. A. Levine, E. A. Olevsky, San Diego State University, USA; V. Tikare, Sandia National Laboratories, USA

**10:20 AM**

Break

**10:40 AM**

#### (SINTER-016-2008) Dynamics of Microstructural Evolution in Ideal Sintering

F. Wakai\*, T. Akatsu, Y. Shinoda, Tokyo Institute of Technology, Japan

**11:00 AM**

#### (SINTER-017-2008) Evolution of Defects during Sintering: Discrete Element Simulations

C. L. Martin\*, L. Olmos, D. Bouvard, INP Grenoble, France; R. K. Bordia, University of Washington, USA

11:20 AM

**(SINTER-018-2008) Atomistic Modeling of Nanoparticle Sintering Using a 3D-Lattice Kinetic Monte Carlo Method**

L. Roentzsch\*, B. Kieback, Fraunhofer Institute for Manufacturing Engineering and Applied Materials Research, Germany

11:40 AM

**(SINTER-019-2008) Effect of Powder Size Distributions on Sintering Behavior: A DEM Simulation Study**

A. Wonisch\*, T. Kraft, M. Moseler, H. Riedel, Fraunhofer Institute for Mechanics of Materials, Germany

**Sintering of Nano-Structured Materials****Nano-Structured Materials I**

Room: Scripts II

9:10 AM

**Introductory Remarks by Session Chair**

Vikram Jayaram, Indian Institute of Science

9:20 AM

**(SINTER-020-2008) Densification and Grain Growth in Nanocrystalline Oxide Ceramics (Invited)**

A. Chokshi\*, Indian Institute of Science, India

10:00 AM

**(SINTER-021-2008) Development of CNT-dispersed Si<sub>3</sub>N<sub>4</sub> Ceramics Using Sintering Aids for Low Temperature Densification**

J. Tatami\*, S. Yoshio, K. Takahashi, D. Horikawa, T. Wakihara, K. Komeya, M. Takeshi, Yokohama National University, Japan

10:20 AM

Break

10:40 AM

**(SINTER-022-2008) Mechanisms of Viscous Flow on Sintering of Nanodispersed and Nanocrystalline Powders (Invited)**

V. V. Skorokhod\*, A. V. Ragulya, Frantsevich Institute for Problems in Materials Science, Ukraine

11:20 AM

**(SINTER-023-2008) Nickel-Boron Nanolayer Coated Boron Carbide Pressureless Sintering**

K. Lu\*, X. Zhu, Virginia Polytechnic Institute and State University, USA

11:40 AM

**(SINTER-024-2008) Spark Plasma Sintering of Mechanochemical Synthesised Nanodimensional Nickel Ferrites**

C. Estournès\*, CIRIMAT, France; E. Manova, Bulgarian Academy of Sciences, Bulgaria; G. Raimbeaux, G. Chevallier, CIRIMAT, France; J. Rehspringer, IPCMS, France; J. Grenèche, Laboratoire de Physique de l'Etat Condensé, France; E. Rivière, Institut de Chimie Moléculaire et des Matériaux d'Orsay, France; D. Paneva, B. Kunev, I. Mitov, Bulgarian Academy of Sciences, Bulgaria

**Posters****Room: Grand Ballroom Foyer**

Session Chairs: Olivia Graeve, University of Nevada, Reno; Javier Garay, University of California, Riverside.

1:00 PM

**(SINTER-P001-2008) Hydrogen Sorption Properties of Ti-Oxide/Chloride Catalyzed Na<sub>2</sub>LiAlH<sub>6</sub>**

E. Martínez-Franco\*, IPN-CIITEC, Mexico; T. Klassen, M. Dornheim, GKSS Research Center, Germany; R. Bormann, TUHH, Germany; D. Jaramillo-Vigueras, IPN-CIITEC, Mexico

**(SINTER-P002-2008) Effect of Al<sub>2</sub>O<sub>3</sub> Additions on the Sintering Behavior of 10% Y<sub>2</sub>O<sub>3</sub> - 10% ZrO<sub>2</sub> - CeO<sub>2</sub> (mol %) Ceramics**

G. S. Godoi\*, D. F. de Souza, Federal University of São Carlos, Brazil

**(SINTER-P003-2008) Effect of the Content of Gd in the Sintering of Ceria Doped Ceramics for SOFC Electrolytes**

G. B. Crochemore\*, D. F. de Souza, Federal University of São Carlos, Brazil

**(SINTER-P004-2008) Effect of Sintering Temperature on the Thermoelectric Properties of Bi<sub>0.5</sub>Sb<sub>1.5</sub>Te<sub>3</sub>**

K. Park\*, S. Nam, M. Heo, T. Saradha, Sejong University, South Korea; C. Lim, W. Cho, C. Lee, Inha University, South Korea

**(SINTER-P005-2008) High Density Green Pellets of ZrN Fabricated by Particle Processing**

T. T. Meek\*, K. Gwathney, University of Tennessee, Knoxville, USA; C. K. Narula, L. R. Walker, Oak Ridge National Laboratory, USA

**(SINTER-P006-2008) Research of the Synthesis Processes of TiN - TiB<sub>2</sub> Composition by Spark Plasma Sintering Method by Different Technological Conditions**

I. V. Khobta\*, A. S. Petukhov, A. V. Ragulya, Frantsevich Institute for Problems of Materials Science NAS of Ukraine, Ukraine

**(SINTER-P007-2008) Effects of Sintering Parameters on Stain Resistance of Polished Porcelain Stoneware Tiles**

N. Tamsu\*, E. Suvaci, Anadolu University Iki Eylul Campus, Turkey; H. Ozdemir, Vitra Tiles Inc., Turkey

**(SINTER-P008-2008) Low Temperature Sintering of Mgo-ZrO<sub>2</sub> Ceramics from Fine Powders Prepared Using Sol-Gel Process**

S. S. Indrakanti\*, NIT Warangal, India

**(SINTER-P009-2008) Effects of Crystallization and Vitrification on Sintering Properties of Bentonite Clay**

H. Camacho\*, P. E. Garcia-Casillas, C. A. Martinez-Perez, H. J. Ochoa-Dominguez, J. T. Elizalde-Galindo, A. Garcia-Reyes, IIT-UACJ, Mexico; A. Aguilar-Elguezabal, C. Dominguez-Rios, M. H. Bocanegra-Bernal, CIMAV, Mexico

**(SINTER-P010-2008) Influence of FeO Doping on the Kinetics of Forsterite (Mg<sub>2</sub>SiO<sub>4</sub>) Formation**

O. Guney\*, E. Demirkesen, Istanbul Technical University, Turkey

**(SINTER-P011-2008) Geopolymers Sintering by Optical Dilatometry**

E. Kameu, C. Leonelli\*, University of Modena and Reggio Emilia, Italy; D. Perera, ANSTO-Australian Nuclear Science and Technology Organisation, Australia

**(SINTER-P012-2008) Exploring Stress and Temperature Gradients in Current Assisted Sintering**

A. Dupuy\*, J. E. Garay, UC Riverside, USA

**(SINTER-P013-2008) Nanocomposites Fabricated by Spark Plasma and Rate-Controlled Sintering Technologies**

O. B. Zgalat-Lozyskyy, A. V. Ragulya\*, Frantsevich Institute for Problems of Materials Science, Ukraine; M. Herrmann, Fraunhofer Institute Keramische Technologien und Sinterwerkstoffe, Germany

**(SINTER-P014-2008) SPS Densification and Properties of Carbon Nanotube-Metal-Zirconia Nanocomposites**

F. Legorreta Garcia, C. Estournès\*, A. Weibel, A. Peigney, C. Laurent, CIRIMAT, France

**(SINTER-P015-2008) Finite Element Modeling of Current Activated Sintering Methods**

C. Hardin\*, J. E. Garay, UC Riverside, USA

**(SINTER-P016-2008) Reaction Kinetics and Sintering of Al<sub>2</sub>TiO<sub>5</sub> by Field-Assisted Sintering Technique**

D. V. Quach\*, J. R. Groza, University of California, Davis, USA

**(SINTER-P017-2008) Comparison of Microwave and Conventional Sinter-Forging of Aluminum Powder**

D. Glizman\*, E. Olevisky, SDSU, USA

**(SINTER-P018-2008) On the Reactive Sintering by Infiltration of Loose Al<sub>2</sub>O<sub>3</sub>-Ni Powder Mixtures with Molten Al**

R. L. Orban\*, Technical University of Cluj-Napoca, Romania; R. M. Piticescu, National Research and Development Institute for Non-ferrous and Rare Metals, Romania; M. Lucaci, National Research and Development Institute for Electrical Engineering ICPE-CA, Romania; M. Orban, Technical University of Cluj-Napoca, Romania

**(SINTER-P019-2008) SPS Sintering of Lead Phosphovanadates**

S. Le Gallet\*, Institut Carnot de Bourgogne, France; E. Courtois, L. Campayo, F. Bart, Nuclear Agency Division, France; Y. Grin, Max-Planck-Institut für Chemische Physik fester Stoffe, Germany; F. Bernard, Institut Carnot de Bourgogne, France

**(SINTER-P020-2008) Improved Sinterability of Panthal (J&K) Magnesite for Production of Dead Burnt Magnesia through Fuel Efficient Pressurized Shaft Kiln**

S. A. Jaleel\*, NMDC Ltd., India

**(SINTER-P021-2008) Densification of SiC by SPS without Sintering Additives**

T. S. Suzuki\*, T. Uchikoshi, Y. Sakka, National Institute for Material Science, Japan

**(SINTER-P022-2008) Spark Plasma Sintering of ZnS**

Y. Kim\*, T. Jo, Y. Lee, H. Kim, D. Kim, Hanyang University, South Korea

**(SINTER-P023-2008) Microstructure Change and Mechanisms in Dry Snow Sintering**

S. Chen\*, I. Baker, Dartmouth College, USA

**(SINTER-P024-2008) Analysis of Sintering of Titanium Porous Material Processed by the Space Holder Method**

L. Reig, V. Amigo, D. Busquets\*, M. Salvador, Universidad Politecnica de Valencia, Spain; J. Calero, AMES, SA, Spain

**(SINTER-P025-2008) Effect of Element Trace on the Crystalline Structure of Calcium Hydroxyapatite**

Z. Hatim\*, Université Chouaib Doukkali, Morocco

**(SINTER-P026-2008) Constrained Sintering and Microstructure Development of Strontium Titanate Thick Films**

A. M. Senos\*, L. Amaral, P. M. Vilarinho, University of Aveiro, Portugal

**(SINTER-P027-2008) Fabrication of  $Ni_{0.3}Zn_{0.7}Fe_{2.0+\delta}O_4$  ( $\delta = -0.2$  -  $+0.2$ ) -  $BaTiO_3$  Composites in Controlled Atmosphere**

K. Abe\*, N. B. Rahmat, Hokkaido University, Japan; S. Okada, N. Kitahara, Tokyo Polytechnic University, Japan; H. Kiyono, M. Higuchi, J. Takahashi, Hokkaido University, Japan

**(SINTER-P028-2008) Densification and Dielectric Properties of Glass-Ceramics in the  $BaTiO_3$ - $RE_2O_3$  ( $RE = La, Nd, Sm$ )- $SiO_2$ - $Al_2O_3$  System**

N. Isaka\*, T. Inoue, H. Iiyono, J. Takahashi, Graduate School of Engineering, Hokkaido University, Japan; H. Itoh, Kitami Institute of Technology, Japan; K. Kageyama, Murata Manufacturing Co. Ltd., Japan

**(SINTER-P029-2008) Influence of Sintering Temperature on VUV Characteristics for Red-emitting (Y,Gd)VO4:Eu,M Phosphor Powders**

S. Nam\*, C. Choi, Y. Kwon, M. Heo, T. Saradha, K. Park, Sejong University, South Korea

**(SINTER-P030-2008) Microstructure and Ferroelectric Characteristics of  $BaTiO_3$  Doped with  $Yb_2O_3$**

V. Mitic\*, V. Paunovic, D. Mancic, J. Purenovic, L. Zivkovic, University of Nis, Serbia

**(SINTER-P031-2008) Microstructure and Properties of Pressureless Sintered Alumina-based Metal Nanocomposites**

S. Oh\*, Seoul National University of Technology, South Korea; Y. Kim, Hanyang University, South Korea; J. Kim, University of Ulsan, South Korea

**(SINTER-P032-2008) Peculiarities of Sintering of Multi-Component Mixtures during Preparation of Ti/Ti-based Foams**

Y. Orlova\*, K. Maekawa, H. J. Rack, Ibaraki University, Japan

**(SINTER-P033-2008) An Investigation on the Properties of Nanometer Size Titanium Diboride Reinforced Hot Pressed Boron Carbide-Silicon Carbide Composites**

A. C. Arksu\*, O. Ademir, Istanbul Technical University, Turkey; T. Boyraz, Sivas Cumhuriyet University, Turkey

**(SINTER-P034-2008) Processing of Ceria based Nanoceramics for Solid Oxide Fuel Cell Electrolytes**

A. T. Wieg\*, J. E. Garay, UC Riverside, USA

**(SINTER-P035-2008) Ceria Twin Pair doped Powder Synthesis and Sintering**

C. G. Plapcianu, L. Stanciu, C. Valsangiacom\*, S. Yup, G. Aldica, E. Volceanov, National Institute of Materials Physics, Romania

**(SINTER-P036-2008) Fabrication of O-deficient Anatase Thin Films with Enhanced Ultraviolet Sensitivity by Molecular Precursor Method**

H. Nagai\*, M. Hasegawa, H. Hara, C. Mochizuki, M. Sato, Kogakuin University, Japan

**(SINTER-P037-2008) SAXS Investigation of the Sintered Niobium Powder: Method of Stabilizing Porosity and Fractal Properties**

L. Skatkov\*, PCB "Argo", Israel

**(SINTER-P038-2008) Standard and Two-stage Sintering of a Submicrometre Alumina Powder: The Influence on the Sintering Trajectory**

M. Michálková\*, D. Galusek, Vitrum Laugaricio – Joint Glass Center of the Institute of Inorganic Chemistry, Slovak Academy of Sciences, Slovakia

**(SINTER-P039-2008) Fabrication of conducting SnO2 thin film by molecular precursor method**

S. Adachi\*, H. Nagai, C. Mochizuki, M. Sato, Kogakuin University, Japan

**(SINTER-P040-2008) Wet Jet Milling and Sintering of SiC Nano Particles**

S. Kawakami\*, J. Tatami, T. Wakihara, K. Komeya, T. Meguro, Yokohama National University, Japan

**(SINTER-P041-2008) Grain Boundary Investigation in Nanocrystalline Oxides**

S. Tanju\*, J. E. Garay, UC Riverside, USA

**(SINTER-P042-2008) Atomistic Insights into Thermal Stability of Nanosized Ceria Particles on Metal-Oxide Surfaces**

W. Jiang\*, M. Wong, A. Rammohan, Y. Jiang, J. L. Williams, Corning INC, USA

**Evolution and Control of Microstructure during Sintering Processes**

**Microstructure II**

Room: Ballroom D

2:30 PM

**Introductory Remarks by Session Chair**

Suk-Joong Kang, KAIST

2:40 PM

**(SINTER-025-2008) Sintering of Transparent Yttrium Aluminum Garnet (YAG) Ceramics (Invited)**

G. Messing\*, S. Kochawattana, S. Lee, A. Stevenson, L. Kupp, J. Anderson, Penn State University, USA

3:20 PM

**(SINTER-026-2008) Sintering of Transparent  $MgAl_2O_4$ : LiF and Microstructure Evolution (Invited)**

I. Reimanis\*, C. Smith, H. Kleebe, Colorado School of Mines, USA

4:00 PM

**(SINTER-027-2008) Growth of Single Crystals by Solid State Conversion**

A. J. Stevenson\*, S. Lee, G. L. Messing, The Pennsylvania State University, USA

4:20 PM

Break

4:40 PM

**(SINTER-028-2008) Tailoring Microstructure in  $CaBi_4Ti_4O_{15}$  Textured by Templated Grain Growth Process**

K. Tamura, T. Kimura\*, Keio University, Japan

5:00 PM

**(SINTER-029-2008) Fabrication of  $SrBi_4Ti_4O_{15}$  Ceramics via Reaction Sintering of Crystal-oriented  $Bi_4Ti_3O_{12}$**

S. Tanaka\*, Nagaoka University of Technology, Japan; Y. Doshida, Taiyo Yuden Co., Ltd., Japan; K. Uematsu, Nagaoka University of Technology, Japan

**Novel Sintering Processes; Field-Assisted Sintering Techniques**

**Novel Sintering Processes I**

Room: Ballroom E

2:30 PM

**Introductory Remarks by Session Chair**

Umberto Anselmi-Tamburini, University of Pavia

2:40 PM

**(SINTER-030-2008) Microwave Sintering of Various Materials and Its Advantages (Invited)**

D. Agrawal\*, Penn State University, USA

3:20 PM

**(SINTER-031-2008) Direct and Hybrid Microwave Sintering of Yttria-Zirconia Ceramics in an Instrumented Single-mode Cavity**

S. Charmond, C. Carry\*, D. Bouvard, INPG-UJF, France

**3:40 PM****(SINTER-032-2008) Finite Element Modelling of Microwave Sintering**

D. Bouvard\*, S. Charmond, C. P. Carry, Grenoble INP, France

**4:00 PM****(SINTER-033-2008) Microwave Sintering Explored by X-Ray Microtomography**

K. Ishizaki\*, M. Battabyal, Y. Yamada Pittini, R. Nicula, S. Vaucher, EMPA, Switzerland

**4:20 PM****Break****4:40 PM****(SINTER-034-2008) Sintering of Combustion Synthesized TiB<sub>2</sub>-ZrO<sub>2</sub> Composite Powders in Conventional and Microwave Furnaces**

H. Khachatryan, Yerevan State University, Armenia; A. Vats\*, Z. Doorenbos, SDSM&amp;T, USA; S. Kharatyan, Yerevan State University, Armenia; J. A. Puszynski, SDSM&amp;T, USA

**5:00 PM****(SINTER-035-2008) Microwave Rapid Debinding and Sintering of MIM/CIM Parts**

P. Veronesi\*, C. Leonelli, G. Poli, L. Denti, A. Gatto, University of Modena and Reggio Emilia, Italy

**5:20 PM****(SINTER-036-2008) Rapid Hot Pressing of Diamond based Composites**

T. Schubert\*, FhG-IFAM, Germany; E. Neubauer, ARCS, Austria; T. Weissgärber, B. Kieback, FhG-IFAM, Germany

**Modeling of Sintering at Multiple Scales****Modeling II**

Room: Scripts I

**2:30 PM****Introductory Remarks by Session Chair**

Fumihiko Wakai, Tokyo Institute of Technology

**2:40 PM****(SINTER-037-2008) Sintering Powder Compact Densification and Deformation: Effects of Constitutive Behaviors and Macroscopic Conditions**

H. Camacho\*, P. E. Garcia-Casillas, C. A. Martinez-Perez, J. T. Elizalde-Galindo, IIT-UACJ, Mexico; A. Garcia-Reyes, Inter ceramic, Mexico; R. K. Bordia, University of Washington, USA

**3:00 PM****(SINTER-038-2008) Analysis of Four Different Approaches to Predict and Control Sintering**

M. W. Reiterer\*, Medtronic, Inc., USA; K. G. Ewsuk, Sandia National Laboratories, USA

**3:20 PM****(SINTER-039-2008) Atomistic Scale Study on Effect of Crystalline Misalignment on Densification during Sintering Nano Scale Tungsten Powder**

A. Moitra, S. Kim, S. Kim, S. Park\*, R. M. German, M. M. Horstemeyer, Mississippi State University, USA

**3:40 PM****(SINTER-040-2008) Numerical Simulation of Densification and Deformation of Porous Bodies in a Granular Pressure-Transmitting Medium**

J. Ma\*, Southeastern Louisiana University, USA; E. Olevsky, San Diego State University, USA

**4:00 PM****(SINTER-041-2008) Influence of External Constraints on the Stability of Sintering of Biporous Materials**

M. Shtern\*, A. Kuzmov, V. Skorokhod, E. Olevsky, Institute for Problems of Materials Sciences, Ukraine

**4:20 PM****Break****4:40 PM****(SINTER-042-2008) Evolution of Approaches to HIP Modeling and HIP Consolidation**

V. N. Samarov\*, V. Goloveshkin, D. Seliverstov, V. Neponyatschy, LNT P/M, USA

**5:00 PM****(SINTER-043-2008) Sintering of Copper Nanoparticles: A Molecular Dynamics Study**

S. S. Indrakanti\*, R. Jayanarasimha, NIT, India

**Sintering of Nano-Structured Materials****Nano-Structured Materials II**

Room: Scripts II

**2:30 PM****Introductory Remarks by Session Chair**

Christopher Diantonio, Sandia National Laboratories

**2:40 PM****(SINTER-044-2008) Two-step Sintering of Molybdenum Nanopowder (Invited)**

Y. Kim\*, D. Kim, S. Kim, M. Park, Hanyang University, South Korea

**3:20 PM****(SINTER-045-2008) Spark Plasma Sintering of Nanocrystalline WC-12Co Cermets**

V. Bonache, M. Salvador, V. Amigo, Universidad Politecnica de Valencia, Spain; M. Hungria, Centro Nacional de Investigaciones Metalúrgicas (CSIC), Spain; D. Busquets\*, Universidad Politecnica de Valencia, Spain

**3:40 PM****(SINTER-046-2008) Nano-scaled Si<sub>3</sub>N<sub>4</sub>/SiC Materials based on Pre ceramic Polymers and Ceramic Powder**

U. Degenhardt\*, G. Motz, University of Bayreuth, Germany; F. Stegner, K. Berroth, FCT Ingenieurkeramik GmbH, Germany; W. Harrer, R. Danzer, University of Mining Leoben, Austria

**4:00 PM****(SINTER-047-2008) Study of Sintering and Grain Growth of Nanocrystalline Tungsten Powder**

H. Wang\*, Z. Z. Fang, University of Utah, USA

**4:20 PM****Break****4:40 PM****(SINTER-048-2008) Control of Transformation and Sintering Paths in Nanostructured Transition Alumina**

M. Azar\*, J. Chevalier, V. Garnier, INSA-Lyon, France

**5:00 PM****(SINTER-049-2008) Grain Growth during Sintering of Nanosized Powders**

Z. Z. Fang\*, H. Wang, V. Kumar, X. Wang, University of Utah, USA

**5:20 PM****(SINTER-050-2008) Comparison of Pressureless and Spark Plasma Sintering of Bulk Nanoceramics**

K. Maca\*, M. Trunec, Brno University of Technology, Czech Republic; Z. Shen, Stockholm University, Sweden

## Tuesday, November 18, 2008

### Plenary Session 2

Room: Ballroom C

**8:00 AM**

#### Introductory Remarks by Session Chair

Rajendra Bordia, University of Washington

**8:20 AM**

**(SINTER-051-2008) Sintering of Constrained Films (Invited)**  
A. Cocks\*, University of Oxford, United Kingdom

## Evolution and Control of Microstructure during Sintering Processes

### Microstructure III

Room: Ballroom D

**9:10 AM**

#### Introductory Remarks by Session Chair

Ivar Reimanis, Colorado School of Mines

**9:20 AM**

**(SINTER-052-2008) Gravitational Role in Liquid Phase Sintering**  
R. M. German\*, S. Park, P. Suri, Mississippi State University, USA; J. L. John, ATI Alldyne, USA; L. G. Campbell, Eaton Corp., USA

**9:40 AM**

**(SINTER-053-2008) Effect of Cu on Sintering Behaviour of Nanostructured Fe Powder**  
D. Sivaprahasam\*, ARC-International, India; S. Bysak, Central Glass and Ceramic Research Institute, India; A. M. Sriramamurthy, G. Sundararajan, ARC-International, India; K. Chattopadhyay, Indian Institute of Science, India

**10:00 AM**

**(SINTER-054-2008) Sintering of Functionally Graded Cemented Tungsten Carbide**  
Z. Z. Fang\*, P. Fan, J. Guo, University of Utah, USA; P. Prichard, Kennametal Inc., USA

**10:20 AM**

Break

**10:40 AM**

**(SINTER-055-2008) Experimental Determination of Sintering Parameters for Second Stage Sintered of Silicon Nitride**  
C. Theron\*, Saint-Gobain HPM, USA; W. Cannon, Rutgers University, USA

**11:00 AM**

**(SINTER-056-2008) Effect of Particle Size Distribution on the Microstructure and the Mechanical Properties of Reaction Bonded Boron Carbide**  
N. Frage\*, A. Weizmann, S. Hayun, M. P. Dariel, Ben-Gurion University of the Negev, Israel

**11:20 AM**

**(SINTER-057-2008) Pressureless Sintering of Boron Carbide**  
M. Mashhadi\*, Department of Metallurgy and Materials Engineering, Faculty of Engineering, Tarbiat Modares University, Iran; V. M. Sglavo, Department of Materials Engineering and Industrial Technologies, University of Trento, Italy

**11:40 AM**

**(SINTER-058-2008) Effect of the Carbon Source on the Microstructure and Mechanical Properties of Reaction Bonded Boron Carbide**  
S. Hayun\*, M. P. Dariel, N. Frage, Ben Gurion University, Israel

## Novel Sintering Processes; Field-Assisted Sintering Techniques

### Novel Sintering Processes II

Room: Ballroom E

**9:10 AM**

#### Introductory Remarks by Session Chair

Dinesh Agrawal, Pennsylvania State University

**9:20 AM**

**(SINTER-059-2008) Synthesis of Bulk Fully Dense Nanocrystalline Functional Oxides with Grain Size Approaching 10 nm (Invited)**

U. Anselmi-Tamburini\*, University of Pavia, Italy

**10:00 AM**

**(SINTER-060-2008) Spark Plasma Sintering of Fe-Based Structural Amorphous Metals (SAM) with Yttria Nanoparticle Additions**

O. A. Graeve\*, R. Kanakala, K. Sinha, University of Nevada, Reno, USA; L. Kaufman, CAL-PHAD, Inc., USA; E. Wang, B. Pearson, G. Rojas-George, University of Nevada, Reno, USA; J. C. Farmer, Lawrence Livermore National Laboratory, USA

**10:20 AM**

Break

**10:40 AM**

**(SINTER-061-2008) Fundamental Aspects of Spark-Plasma Sintering**

E. Olevsky\*, San Diego State University, USA

**11:00 AM**

**(SINTER-062-2008) Field Activated Sintering Technique: Recent Developments (Invited)**

J. R. Groza\*, UCD, USA

**11:40 AM**

**(SINTER-063-2008) Direct Comparison between Hot Pressing and Field Assisted Sintering of Oxide Powders**

J. Langer\*, TU Darmstadt, Germany; M. J. Hoffmann, Institute of Ceramics in Mechanical Engineering, Germany; O. Guillon, TU Darmstadt, Germany

**12:00 PM**

**(SINTER-064-2008) Experimental Evidence for the Current Effect during Pulsed Electric Current Sintering**

O. Van der Biest\*, K. Vanmeensel, K.U.Leuven, Belgium; A. Laptev, Donbass State Engineering Academy, Ukraine; S. Huang, L. Staverescu, J. Vleugels, K.U.Leuven, Belgium

## Modeling of Sintering at Multiple Scales

### Modeling III

Room: Scripts I

**9:10 AM**

#### Introductory Remarks by Session Chair

Veena Tikare, Sandia National Laboratories

**9:20 AM**

**(SINTER-065-2008) Simulation of Sintering: From Grain Dimensions to Complex Parts (Invited)**

T. Kraft\*, A. Wonisich, I. Schmidt, H. Riedel, Fraunhofer IWM, Germany

**10:00 AM**

**(SINTER-066-2008) Verification, Performance, and Validation of a Modified SOVS Continuum Constitutive Model in a Nonlinear Large-Deformation Finite Element Code**

J. G. Arguello\*, Sandia National Laboratories, USA

**10:20 AM**

Break

**10:40 AM****(SINTER-067-2008) Effect of a Substrate on the Microstructure of Thick Films**

C. L. Martin\*, INP Grenoble, France; R. K. Bordia, University of Washington, USA

**11:00 AM****(SINTER-068-2008) Modelling Constrained Sintering and Cracking**

J. Pan\*, R. Huang, Leicester University, United Kingdom

**11:20 AM****(SINTER-069-2008) Direct Multiscale Modeling of Sintering**

A. Maximenko\*, A. Kuzmov, Institute for Problems of Materials Science, Ukraine; E. A. Olevsky, San Diego State University, USA

**11:40 AM****(SINTER-070-2008) Variations in Sintering Stress and Viscosity with Mixing Ratio of Metal/Ceramic Powders**

K. Shinagawa\*, Faculty of Engineering, Kagawa University, Japan

**12:00 PM****(SINTER-071-2008) Anticipating Shrinkage and Distortion during Sintering of Complex Ceramic Parts Manufactured by Stereolithography**

J. Erauw\*, C. Delmotte, F. Petit, F. Cambier, Belgian Ceramic Research Centre, Belgium

**Sintering of Nano-Structured Materials****Nano-Structured Materials III**

Room: Scripts II

**9:10 AM****Introductory Remarks by Session Chair**

Kathy Lu, Virginia Polytechnic Institute &amp; State University

**9:20 AM****(SINTER-072-2008) Densification and Deformation of Amorphous Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>-Y<sub>2</sub>O<sub>3</sub> Derived from Precursors (Invited)**

V. Jayaram\*, Indian Institute of Science, India

**10:00 AM****(SINTER-073-2008) MoSi<sub>2</sub> Formation Mechanisms during a Spark Plasma Synthesis from Mechanically Activated Powder Mixture**

F. Bernard\*, G. Cabouro, S. Chevalier, Institut Carnot de Bourgogne, France; E. Gaffet, NRG, UMR 5060 CNRS / Université de Technologie de Belfort-Montbéliard, France; Y. Grin, Max-Planck-Institut für Chemische Physik fester Stoffe, Germany

**10:20 AM**

Break

**10:40 AM****(SINTER-074-2008) Tribological Performance of Nano Alumina Composites**

A. Sivanandam\*, IIT Delhi, India; R. Janakarajan, IIT Kanpur, India

**11:00 AM****(SINTER-075-2008) Thermal Stability Studies of Gold Nanoparticle Arrays**

R. Tiruvalam\*, P. Clasen, R. Ristau, C. J. Kiely, M. P. Harmer, Lehigh University, USA

**11:20 AM****(SINTER-076-2008) Thin Film Sintering of Zinc Oxide**

M. Koenig\*, Technische Universität Darmstadt, Germany

**11:40 AM****(SINTER-077-2008) In Situ Formation and Densification of TiNi Shape Memory Alloy by Spark Plasma Sintering (Invited)**

D. C. Linch\*, Metal Processing Systems, USA; J. Meen, University of Houston, USA; B. G. Eranezhuth, Clarkson Aerospace, USA

**Wednesday, November 19, 2008****Evolution and Control of Microstructure during Sintering Processes****Microstructure IV**

Room: Ballroom D

**8:10 AM****Introductory Remarks by Session Chair**

Ian Nettleship, University of Pittsburgh

**8:20 AM****(SINTER-078-2008) Development of Anisotropy during Zero Shrinkage Experiments (Invited)**

O. Guillon\*, Technische Universität Darmstadt, Germany

**9:00 AM****(SINTER-079-2008) Microstructure Evolution in Zirconia Nanoparticle Compacts during Pressureless Sintering**

M. Trunec\*, K. Maca, Brno University of Technology, Czech Republic

**9:20 AM****(SINTER-080-2008) Reduction of Intra Crystalline Porosity in Ba<sub>0.5</sub>Sr<sub>0.5</sub>Co<sub>0.8</sub>Fe<sub>0.2</sub>O<sub>3-x</sub> Perovskite Ceramic**

M. Zwick\*, E. M. Pfaff, Aachen University, Germany

**9:40 AM****(SINTER-081-2008) Improved Dye-Sensitized Solar Cell Components by Uniaxial Freeze Drying and Sintering**

E. Khaleghi\*, E. A. Olevsky, SDSU, USA; M. A. Meyers, UCSD, USA

**10:00 AM**

Break

**10:20 AM****(SINTER-082-2008) Modification of Mass Transport during Sintering Induced by Thermal Gradient**

S. Saunier\*, F. Valdivieso, P. Goeuriot, Ecole des Mines de Saint-Etienne, France

**Novel Sintering Processes; Field-Assisted Sintering Techniques****Novel Sintering Processes III**

Room: Ballroom E

**8:10 AM****Introductory Remarks by Session Chair**

Arne Filiflet, Naval Research Laboratory

**8:20 AM****(SINTER-083-2008) Full Densification of SiC without any Additives by SPS**

M. Ohyanagi\*, N. Toyofuku, Y. Kodera, Ryukoku University, Japan; Z. Munir, University of California, Davis, USA

**8:40 AM****(SINTER-084-2008) Influence of Electric Fields During the Field Assisted Sintering Technique (FAST)**

M. Müller\*, R. Clasen, Saarland University, Germany

**9:00 AM****(SINTER-085-2008) Influence of Electrical Fields on Grain Growth in Ceramics (Invited)**

S. Ghosh, A. Chokshi, R. Raj\*, University of Colorado, USA

**9:40 AM**

**(SINTER-086-2008) Simultaneous Synthesis and Densification of Magnesium Aluminate Spinel by SPS**

M. P. Dariel\*, S. Maier, N. Frage, Ben-Gurion University, Israel

**10:00 AM**

**Break**

**10:20 AM**

**(SINTER-087-2008) Sintering under Electrical Current: Micro and Macro Considerations (Invited)**

B. McWilliams, A. Zavaliangos\*, Drexel University, USA

**11:00 AM**

**(SINTER-088-2008) Spark Plasma Sintering of Conductive and Nonconductive Composites**

M. Herrmann\*, J. Räthel, W. Beckert, IKTS, Germany

**11:20 AM**

**(SINTER-089-2008) Fe/Cr-Al<sub>2</sub>O<sub>3</sub> Ceramic Matrix Nanocomposites Sintered by SPS**

G. Julien\*, CIRIMAT, France; E. Claude, CNRS, France; W. Alicia, P. Alain, CIRIMAT, France; C. Geoffroy, CNRS, France; U. Guralp, P. Jean-yves, B. Jean-denis, D. Jean, ENIT, France; F. Joel, P. Yann, SCT, France; L. Christophe, CIRIMAT, France

**11:40 AM**

**(SINTER-090-2008) Sintering and Characterization of Telluride Materials Using Spark Plasma Sintering**

J. E. Garay, J. Alaniz\*, UC Riverside, USA

## Fundamental Aspects of Sintering

### Fundamentals I

Room: Scripts I

**8:10 AM**

**Introductory Remarks by Session Chair**

Deborah Blaine, Stellenbosch University

**8:20 AM**

**(SINTER-091-2008) Coarsening Laws in Sintering (Invited)**

R. M. German\*, Mississippi State University, USA

**9:00 AM**

**(SINTER-092-2008) Critical Overview of Porosity Coarsening during Solid State Sintering**

H. Exner\*, University of Technology, Darmstadt, Germany

**9:20 AM**

**(SINTER-093-2008) Anisotropy Shrinkage, Origin and Cure (Invited)**

W. Cannon\*, Rutgers University, USA

**10:00 AM**

**Break**

**10:20 AM**

**(SINTER-094-2008) Investigation of the Sintering of Heterogeneous Powder Systems by Synchrotron Microtomography and Discrete Element Simulation (Invited)**

L. Olmos, T. Takahashi, C. L. Martin, Grenoble INP, France; M. Di Michiel, ESRF, France; D. Bouvard\*, D. Bellet, Grenoble INP, France

**11:00 AM**

**(SINTER-095-2008) Experimental and Model Hot Pressing of Spherical Polycrystalline Zirconia Particles**

W. Cannon\*, Rutgers University, USA; C. Auechaitanukul, King Mongkut's University of Technology Thonburi, Thailand; A. Cuitino, Rutgers University, USA

**11:20 AM**

**(SINTER-096-2008) Sintering Kinetics of Materials Containing Large Pores (Invited)**

J. Pan\*, Leicester University, United Kingdom; A. Cocks, University of Oxford, United Kingdom; J. Rödel, Darmstadt University of Technology, Germany

## Sintering of Electronic Materials

### Electronics I

Room: Scripts II

**8:10 AM**

**Introductory Remarks by Session Chair**

David Green, Pennsylvania State University

**8:20 AM**

**(SINTER-097-2008) Characterization of the Anisotropic Sintering Behavior of Textured Lead-Free Piezoceramics (Invited)**

C. DiAntonio\*, Sandia National Laboratories, USA

**9:00 AM**

**(SINTER-098-2008) Influence of Rare-Earth Additives (Er and Ho) on Fractal Microstructure Characteristics and Dielectric Properties of BaTiO<sub>3</sub>**

V. Mitic\*, L. Kocic, V. Paunovic, D. Mancic, L. Zivkovic, Univeristy of Nis, Serbia

**9:20 AM**

**(SINTER-099-2008) Influence of Milling Condition on Sintering Behavior and Electrical Properties of BaTiO<sub>3</sub> Ceramics**

S. Sohn\*, K. Park, M. Hong, S. Song, Y. Yoon, J. Hong, Y. Kim, K. Hur, Samsung Electro-Mechanics Co., Ltd., South Korea

**9:40 AM**

**(SINTER-100-2008) Effect of Sintering Parameters of Nano-Structured BaTiO<sub>3</sub> on the Microstructure and Dielectric Properties**

M. N. Siddique\*, M. T. Chowdhury, M. F. Islam, Bangladesh University of Engineering and Technology, Bangladesh

**10:00 AM**

**Break**

**10:20 AM**

**(SINTER-101-2008) Low Temperature Sintering of Zinc Titanate (ZnTiO<sub>3</sub>) Ceramics Prepared by Modified Sol-Gel Method**

S. S. Indrakanti\*, S. B. Vadlamani, NIT Warangal, India

**10:40 AM**

**(SINTER-102-2008) Grain Boundary Structure and Dielectric Properties of Nonstoichiometric Strontium Titanate Ceramics**

A. M. Senos\*, L. Amaral, P. M. Vilarinho, A. Tkach, University of Aveiro, Portugal; I. M. Reaney, University of Sheffield, United Kingdom

**11:00 AM**

**(SINTER-103-2008) Step-like Magnetic Behavior of Nanocrystalline Iron Oxides**

J. R. Morales\*, J. E. Garay, UC Riverside, USA

**11:20 AM**

**(SINTER-104-2008) Sintering of Electronic Ceramics Using Microwave Assist Technology**

S. M. Allan\*, H. S. Shulman, M. L. Fall, I. Baranova, Ceralink Inc, USA

**11:40 AM**

**(SINTER-105-2008) Dielectric Properties of Aluminium Nitride Sintered by SPS**

Z. Valdez-Nava\*, S. Guillemet-Fritsch, CIRIMAT/LCMIE - UMR CNRS 5085, France; M. Ferrato, Boostec, France; S. Dinculescu, T. Lebey, LAPLACE, France

## Evolution and Control of Microstructure during Sintering Processes

### Panel Discussion

Room: Ballroom C

**1:00 PM**

#### Panel Discussion

Moderators: Eugene Olevsky and Rajendra Bordia

Panelists: Didier Bouvard, Grenoble INP;  
Joanna Groza, University of California, Davis;  
Vikram Jayaram, Indian Institute of Science;  
Suk-Joong Kang, Korea Advanced Institute of Science & Technology;  
Ian Nettleship, University of Pittsburgh;  
Veena Tikare, Sandia National Laboratories

## Sintering of Multi-Material and Multi-Layered Systems

### Multi-Material I

Room: Ballroom D

**3:00 PM**

#### Introductory Remarks by Session Chair

Mohamed Rahaman, Missouri University of Science & Technology

**3:10 PM**

#### (SINTER-106-2008) Preparation of SiC Composite with Hexagonal and Turbostratic BN by MA-SPS Method

Y. Kodera\*, H. Yamasaki, A. Mori, N. Toyofuku, M. Ohyanagi, Ryukoku University, Japan; Z. A. Munir, University of California, Davis, USA

**3:30 PM**

#### (SINTER-107-2008) Sinterability of Unidirectionally Structure-Controlled Hydroxyapatite/Zirconia Composites by Hot-Pressing and Their Mechanical Properties

K. Yoshida\*, Tokyo Institute of Technology, Japan; M. Ando, Chiba Institute of Technology, Japan; T. Yano, Tokyo Institute of Technology, Japan; K. Hashimoto, Y. Toda, Chiba Institute of Technology, Japan

**3:50 PM**

#### (SINTER-108-2008) Mechanical Properties of Optimized Crack-free Joining of Si<sub>3</sub>N<sub>4</sub> and Al<sub>2</sub>O<sub>3</sub> Using Polytypoidal Functional Gradient

S. Ryu\*, C. S. Lee, J. Park, Hanyang University, South Korea; D. Riu, Korea Institute of Ceramic Engineering and Technic, South Korea; S. Ahn, Seoul National University, South Korea

**4:10 PM**

Break

**4:30 PM**

#### (SINTER-109-2008) Optimization of Density, Microstructure and Interface Region in a Co-Sintered (Steel/Cemented Carbide) Bi-Layered Material

A. Thomazic\*, C. Pascal, J. Chaix, CNRS UMR 5266-Grenoble INP-UJF, France

**4:50 PM**

#### (SINTER-110-2008) Two-Component Metal Injection Moulding and Co-Sintering of Multi-Material Micro Parts

P. Imgrund\*, Fraunhofer IFAM, Germany

**5:10 PM**

#### (SINTER-111-2008) Coupling between Sintering and Liquid Migration to Process W-Cu Functionally Graded Materials

J. Missiaen, J. Raharjaona\*, INP Grenoble, France; R. Mitteau, CEA, France

**5:30 PM**

#### (SINTER-112-2008) Influence of the Aluminium Content on the Sintering Mechanisms of (Ni-Al) Alloys

N. Halem\*, Université Mouloud Mammeri, Algeria; M. Grosbras, Université de Poitiers, France

## Novel Sintering Processes; Field-Assisted Sintering Techniques

### Novel Sintering Processes IV

Room: Ballroom E

**3:00 PM**

#### Introductory Remarks by Session Chair

Nachum Frage, Ben-Gurion University of the Negev

**3:10 PM**

#### (SINTER-113-2008) Sintering Polycrystalline Laser Host Materials with a Millimeter-wave Beam (Invited)

A. W. Fiflet\*, M. K. Hornstein, S. H. Gold, M. A. Imam, Naval Research Laboratory, USA; R. W. Bruce, M. Kahn, Icarus Research Inc., USA

**3:50 PM**

#### (SINTER-114-2008) Progress in Spark Plasma Sintering of Ceramic Nanocomposites

A. V. Ragulya\*, Frantsevich Institute for Problems in Materials Science, Ukraine

**4:10 PM**

Break

**4:30 PM**

#### (SINTER-115-2008) Densification Kinetics of Alumina Compacts Undergoing Field Assisted Sintering

M. Demuyne\*, Belgian Ceramic Research Centre, Belgium; K. Vanmeensel, KULeuven, Belgium; J. Erauw, Belgian Ceramic Research Centre, Belgium; O. Van der Biest, KULeuven, Belgium; F. Cambier, Belgian Ceramic Research Centre, Belgium

**4:50 PM**

#### (SINTER-116-2008) Synthesis and Characterization of ZrB<sub>2</sub>-SiC Composites Produced by Spark Plasma Sintering (SPS)

I. Akin\*, F. Cinar Sahin, O. Yucel, Istanbul Technical University, Turkey; T. Goto, Tohoku University, Japan; G. Goller, Istanbul Technical University, Turkey

**5:10 PM**

#### (SINTER-117-2008) Sintering of Nanoscale Tungsten Powder Produced by Electrical Explosion Process

J. Kim\*, University of Ulsan, South Korea; Y. Kim, Hanyang University, South Korea; S. Oh, Seoul National University of Technology, South Korea; Y. Kwon, J. Kim, J. Ryu, University of Ulsan, South Korea

**5:30 PM**

#### (SINTER-118-2008) The Electro-Discharge Compaction of Powder Tungsten Carbide - Cobalt - Diamond Composite Material

E. G. Grigoryev\*, A. V. Rosliakov, Moscow Engineering Physics Institute, Russian Federation

## Fundamental Aspects of Sintering

### Fundamentals II

Room: Scripts I

**3:00 PM**

#### Introductory Remarks by Session Chair

Randall German, Mississippi State University

**3:10 PM**

#### (SINTER-119-2008) Process Understanding and Control Using the Master Sintering Curve (Invited)

K. Ewsuk\*, T. Hinklin, C. DiAntonio, Sandia National Laboratories, USA; M. Reiterer, Medtronic, Inc., USA; I. Nettleship, University of Pittsburgh, USA

**3:50 PM**

#### (SINTER-120-2008) New Master Sintering Curve Theory for Multiple Stage-Sintering

D. Hiratsuka\*, J. Tatami, T. Wakihara, K. Komeya, T. Meguro, Yokohama National University, Japan

**4:10 PM**

Break



**4:30 PM**

**(SINTER-121-2008) Linearization of Master Sintering Curve (Invited)**

D. C. Blaine\*, Stellenbosch University, South Africa; S. Park, R. M. German, Mississippi State University, USA

**5:10 PM**

**(SINTER-122-2008) Master Sintering Curve Formulated from Constitutive Models**

S. Park\*, P. Suri, Mississippi State University, USA; E. Olevsky, San Diego State University, USA; R. M. German, Mississippi State University, USA

**5:30 PM**

**(SINTER-123-2008) Extension of the Master Sintering Curve to Complex Systems**

T. R. Hinklin\*, Sandia National Laboratories, USA; M. Reiterer, Medtronic, Inc., USA; K. Ewsuk, Sandia National Laboratories, USA

**5:50 PM**

**(SINTER-124-2008) Examination of Particle Contact and Crystalline Axis as a Origin of Sintering Deformation**

K. Uematsu\*, S. Tanaka, K. Yamazaki, Nagaoka University of Technology, Japan

## Sintering of Electronic Materials

### Electronics II

Room: Scripts II

**3:00 PM**

**Introductory Remarks by Session Chair**

Markus Reiterer, Medtronic, Inc.

**3:10 PM**

**(SINTER-125-2008) Sintering of Inkjet-Printed Conductive Inks for Organic Electronic Devices**

M. Klokkenburg\*, S. Rucareanu, E. Rubingh, M. Tjink, Holst Centre, Netherlands

**3:30 PM**

**(SINTER-126-2008) Influence of the Milling Environment on the Sintered Structure of a W-Cu Composite**

F. Alves da Costa, F. Ambrozio Filho\*, A. Giuseppe Pereira da Silva, U. Umbelino Gomes, S. Jackson Guedes de Lima, Universidade Federal do Rio Grande do Norte, Brazil

**3:50 PM**

**(SINTER-127-2008) Low-Temperature Sintering of Nanoscale Silver Paste for Attaching Semiconductor Chips**

G. Lu\*, J. N. Calata, T. G. Lei, Virginia Tech, USA

**4:10 PM**

Break

## Application of Sintering in Emerging Energy Applications

### Application of Sintering in Energy Applications

Room: Scripts II

**4:30 PM**

**(SINTER-128-2008) Constrained Sintering of SOFC Electrolytes**

A. Atkinson\*, J. Kim, R. A. Rudkin, Imperial College, United Kingdom; J. Rödel, University of Darmstadt, Germany

**4:50 PM**

**(SINTER-129-2008) Sintering Behaviour of  $Ce_{0.9}Gd_{0.1}O_{1.95-δ}$  in Reducing Atmosphere**

A. F. Kaiser\*, M. Pihlatie, S. Ramousse, Z. He, Risø-DTU, Denmark

**5:10 PM**

**(SINTER-130-2008) Sintering of Composite from Nanopowder Ceramics**

M. Campos\*, A. Molina, A. Rosales, Simón Bolívar University, Venezuela; J. Quiñonez, Universidad Central de Venezuela, Venezuela

**5:30 PM**

**(SINTER-131-2008) Three-Dimensional Solar Cell Finite Element Sintering Simulation**

G. R. Brown\*, E. A. Olevsky, R. A. Levine, San Diego State University, USA; A. Shaikh, J. Salami, Ferro Corporation, USA

**5:50 PM**

**(SINTER-132-2008) Sintering of a MgO Substrate and Membrane with MgO/Li<sub>2</sub>O Functionalization for Methane Catalysis**

O. Goerke, M. Ziemann, D. Habel, M. Driess, H. Schubert\*, Berlin University of Science and Technology, Germany

## Thursday, November 20, 2008

## Sintering of Multi-Material and Multi-Layered Systems

### Multi-Material II

Room: Ballroom D

**8:10 AM**

**Introductory Remarks by Session Chair**

Olivier Guillon, Technische Univ. Darmstadt

**8:20 AM**

**(SINTER-133-2008) Effect of Constraining Layers on the Densification of Low-Temperature Co-Fired Ceramics (LTCC) (Invited)**

D. Green\*, Pennsylvania State University, USA; J. Ollagnier, J. Rödel, Technische Universität Darmstadt, Germany

**9:00 AM**

**(SINTER-134-2008) LIBS Micro-Analysis of Sintering Multilayer PM Composites**

V. Leshchynsky\*, University of Windsor, Canada; W. Scharff, M. Ignatjev, IFU GmbH, Germany

**9:20 AM**

**(SINTER-135-2008) Laser Sintering of Nano Scaled Alumina Powder for Scratch Resistant Transparent Coatings**

C. Rivinius\*, R. Clasen, Saarland University, Germany

**9:40 AM**

**(SINTER-136-2008) Co-Sintering Behaviours of Oxide based Bi-Materials**

C. Carry, E. Yalamac\*, INPG-UJF, France; S. Akkurt, Izmir Institute of Technology, Turkey

**10:00 AM**

Break

**10:20 AM**

**(SINTER-137-2008) Superplastic Functional Gradient Al<sub>2</sub>O<sub>3</sub>-CNT-ZrO<sub>2</sub> Thin Film Composites**

H. Sarraf\*, Tokyo Institute of Technology, Japan

**10:40 AM**

**(SINTER-138-2008) Property-Oriented Sintering Approach for State-of-the-Art Multilayer Ceramic Capacitors**

A. V. Polotai\*, G. Yang, D. P. Shay, E. C. Dickey, C. A. Randall, The Pennsylvania State University, USA

## Novel Sintering Processes; Field-Assisted Sintering Techniques

### Novel Sintering Processes V

Room: Ballroom E

**8:10 AM**

#### Introductory Remarks by Session Chair

Antonios Zavaliangos, Drexel University

**8:20 AM**

#### (SINTER-139-2008) Pulse Plasma Sintering Technique: Fundamentals and Applications

A. J. Michalski, M. Rosinski\*, Warsaw University of Technology, Poland

**8:40 AM**

#### (SINTER-140-2008) Consolidation of Bulk Nano-ceramics Using Current Activated Densification

J. E. Garay\*, UC Riverside, USA

**9:00 AM**

#### (SINTER-141-2008) Correlation between Current Distribution and Microstructure Evolution during a Spark Plasma Sintering

L. Minier\*, S. Le Gallet, Institut Carnot de Bourgogne, France; Y. Grin, Max-Planck-Institut für Chemische Physik fester Stoffe, Germany; F. Bernard, Institut Carnot de Bourgogne, France

**9:20 AM**

#### (SINTER-142-2008) Influence of Minor Additives on Densification and Microstructure of Submicrometre Alumina Ceramics Prepared by SPS and HIP

M. Mikoczova, IIC SAS, Slovakia; J. Sedlacek, TU Karlsruhe, Germany; D. Galusek\*, IIC SAS, Slovakia

**9:40 AM**

#### (SINTER-143-2008) Spark Plasma Sintering of TiN: The Role of AIN Addition

Z. Valdez-Nava, S. Guillemet-Fritsch\*, CIRIMAT/LCMIE - UMR CNRS 5085, France; M. Ferrato, Boostec, France; S. Dinulescu, T. Lebey, LAPLACE, France

**10:00 AM**

Break

**10:20 AM**

#### (SINTER-144-2008) Mechanisms Involved during Spark Plasma Sintering of Ceramic Powders

G. Bernard-Granger\*, Saint-Gobain CREE, France

**10:40 AM**

#### (SINTER-145-2008) Production and Characterization of WC-Co Cemented Carbides by Field Assisted Sintering

F. C. Sahin\*, R. E. Ozudogru, O. Yucel, Istanbul Technical University, Turkey

## Fundamental Aspects of Sintering

### Fundamentals III

Room: Scripts I

**8:10 AM**

#### Introductory Remarks by Session Chair

Jingzhe Pan, Leicester University

**8:20 AM**

#### (SINTER-146-2008) Role of Interface Complexions in Sintering (Invited)

M. P. Harmer\*, S. J. Dillon, Lehigh University, USA; G. S. Rohrer, Carnegie Mellon University, USA

**9:00 AM**

#### (SINTER-147-2008) Exploring the Role of Interface Complexions in the Sintering of Y2O3

S. Ma\*, C. Kiely, M. Harmer, H. Caram, Lehigh University, USA

**9:20 AM**

#### (SINTER-148-2008) Atmosphere as an Active Component in the Sintering of Aluminium

G. Schaffer\*, The University of Queensland, Australia

**9:40 AM**

#### (SINTER-149-2008) Dissolution of Alumina in Silicate Glasses and the Glass Formation Boundary

K. J. DeCarlo\*, T. F. Lam, K. Strong, W. M. Carty, Alfred University, USA

**10:00 AM**

Break

**10:20 AM**

#### (SINTER-150-2008) Discussion of Non-Conventional Effects in Solid-State Sintering of Cemented Carbides (Invited)

J. Missiaen\*, V. Bounhoure, S. Lay, INP Grenoble, France; E. Pauty, Sandvik Hard Materials, France

**11:00 AM**

#### (SINTER-151-2008) Effect of Volume Fraction on Grain Growth during Liquid Phase Sintering of Tungsten Heavy Alloys

J. L. Johnson\*, ATI Alldyne, USA; L. G. Campbell, Eaton Corporation, USA; S. Park, R. M. German, Mississippi State University, USA

**11:20 AM**

#### (SINTER-152-2008) Microstructure Relations and Input Knowledge Required in Liquid Phase Sintering

R. M. German\*, Mississippi State University, USA

## Sintering of Bio-Materials

### Sintering of Bio-Materials

Room: Scripts II

**8:10 AM**

#### Introductory Remarks by Session Chair

W. Roger Cannon, Rutgers University

**8:20 AM**

#### (SINTER-153-2008) Sintering of Bioceramics (Invited)

M. N. Rahaman\*, Missouri University of Science & Technology, USA

**9:00 AM**

#### (SINTER-154-2008) Sintering Zirconia for Dental CAD/CAM Technology

K. Sujirote\*, K. Sitthiseripratip, J. Jitsaard, K. Dateraksa, National Metal & Materials Technology Center, Thailand

**9:20 AM**

#### (SINTER-155-2008) Sintering and Crystallisation of Bioactive Glasses for Tissue Engineering Scaffolds (Invited)

A. Boccaccini\*, Imperial College London, United Kingdom; O. Bretcanu, Politecnico di Torino, Italy; D. Mohamad Yunus, Imperial College London, United Kingdom; L. Lefebvre, INSA Lyon, France; E. Verne, C. Vitale Brovarone, Politecnico di Torino, Italy; L. Gremillard, J. Chevalier, INSA Lyon, France

**10:00 AM**

Break

**10:20 AM**

#### (SINTER-156-2008) Spark Plasma Sintering of Biomimetic Nanocrystalline Apatites at Very Low Temperature

D. Grossin\*, C. Drouet, CIRIMAT UPS-INPT-CNRS, France; C. Estournes, E. Champion, R. Fabrice, SPCTS, France; C. Combes, C. Rey, CIRIMAT UPS-INPT-CNRS, France

**10:40 AM**

#### (SINTER-157-2008) Effect of Sintering Temperature and Time on Microstructure and Properties of Zirconia Toughened Alumina (ZTA)

M. M. Hasan\*, M. F. Islam, Bangladesh University of Engineering and Technology, Bangladesh

Monday, November 17, 2008

## Opening Remarks and Plenary Session I

Room: Ballroom C

8:20 AM

### (SINTER-001-2008) Current Effects in the Sintering of Powders: Consolidation by the Pulsed Electric Current Sintering Method (Invited)

Z. A. Munir\*, University of California, USA

The recent widespread use of the spark plasma sintering (SPS) method has provided considerable evidence of the benefits of this method relative to conventional consolidation methods. Efforts to understand the fundamental basis for these observations have been relatively limited. We present here results of investigations on the role of a current on sintering and reactivity of materials. The role of the pulsing of the DC current and the level of the current on reactivity in the SPS was investigated. Using the classic sphere-to-plate sintering geometry the effect of the current on neck formation in copper is demonstrated under the SPS conditions. The results are interpreted in terms of mass transport enhancement by electromigration. The effect of pressure in the sintering of nanopowders by the SPS was also investigated.

## Evolution and Control of Microstructure during Sintering Processes

### Microstructure I

Room: Ballroom D

9:20 AM

### (SINTER-002-2008) Sintering Kinetics by Structural Transition at Interfaces (Invited)

S. L. Kang\*, Korea Advanced Institute of Science and Technology, South Korea

Recent investigations have shown that a close correlation exists between sintering behavior and interface structure, either rough (atomically disordered) or faceted (atomically ordered). Normal grain growth occurred in rounded systems while abnormal grain growth or stagnant grain growth occurred for faceted systems during liquid phase sintering as well as solid state sintering. Based on this understanding, conditions for getting an ultrafine microstructure during liquid phase sintering were deduced and experimentally tested. The effect of two-step sintering in WC-Co was also analyzed and explained. In solid state sintering, densification was also greatly affected by grain boundary structure. When the boundary was fully faceted, densification stopped in BaTiO<sub>3</sub>, suggesting that the faceted boundary was no more an ideal source of atoms. Utilizing the characteristics of faceted boundaries, a new technique for densification with suppressed grain growth has been proposed and demonstrated.

10:00 AM

### (SINTER-003-2008) New Effective Diffusion Distance for Sintering Ceramic Microstructures

T. Chen\*, I. Nettlehip, University of Pittsburgh, USA; T. R. Hinklin, K. G. Ewsuk, Sandia National Laboratory, USA

A new, effective diffusion distance for material transport during sintering has been defined through microstructure characterization. In classical sintering models that assume an ideal (i.e., homogeneous) microstructure, this distance is commonly assumed to be half the distance between adjacent pores. The microstructure is often represented by a volume element comprised of one grain and its attendant pores. Unfortunately, this is not very representative of a real (i.e., heterogeneous) microstructure. A new effective diffusion distance, that is sensitive to the local arrangement of pores, has been defined based on length scale measurements in the actual microstructure using pore boundary tessellation. An analysis of the use of this measured length scale to represent the diffusion distance for the sintering of a submicron alumina powder compact and an aggregated nanocrystalline zirconia powder compact will be discussed.

10:40 AM

### (SINTER-004-2008) Grain Growth and Microstructure Control in Undoped Strontium Titanate

M. Bäurer\*, Universität Karlsruhe, Germany; M. P. Harmer, Lehigh University, USA; M. J. Hoffmann, Universität Karlsruhe, Germany

Grain growth kinetics after complete densification of the material are depending on the mobility of the grain boundaries. Nevertheless, this mobility is important during sintering, influencing the simultaneous effects of coarsening and densification. The mobility depends on composition of the boundary. In this study the grain growth of undoped strontium titanate was examined depending on annealing temperature and time. The material was chosen because an eutectic exists if titania is added and it has been shown that an eutectic can have influence on the growth behaviour even in the adjacent single phase region. The average mobilities of the boundaries were estimated from the evolution of the average grain sizes. A discontinuity of growth behaviour has been detected which allows to vary the resulting microstructure in a broad range. This discontinuity indicates a change in composition of the boundary at a temperature slightly below the bulk eutectic temperature.

11:00 AM

### (SINTER-005-2008) Microstructure Development during Sintering: Grain Growth Control Assisted by Gas Pressure

F. Valdivieso\*, C. Nivot, J. Bolland, ENSM-SE, France

Usually gas pressure is used to promote densification of materials which cannot densify easily under natural conditions: either by iso-static or by gas pressure sintering. Of course a gas pressure allow to create some particular porosity, depending on what material is applied. So we will show how the gas pressure acts to modify the and delay the sintering, but also the grain growth. Three materials was used : MgO, Al<sub>2</sub>O<sub>3</sub> and UO<sub>2</sub>. Finally, we will try to show how by control of pressure is it possible to activate the sintering process and to promote a micro-structural refinement. Also, we show that by gas pressure sintering the microstructure can be adaptive to the application: porous materials with, with large grains, or finer microstructure and dense materials.

11:20 AM

### (SINTER-006-2008) Sintering and Grain Growth Kinetics of a Stoichiometric Alumina Spinel Powder

N. Benameur\*, G. Bernard-Granger, Saint-Gobain CREE, France; A. Addad, Université des Sciences et Technologies de Lille UMR 8008 CNRS, France; C. Guizard, Saint-Gobain CREE, France

A pure and ultra-fine stoichiometric spinel powder has been shaped by slip casting. After debinding, pressureless sintering experiments have been conducted in air, at temperatures around the one corresponding to the maximal value of the linear shrinkage rate. The grain growth and densification kinetics have been established. The sintering path (grain size versus relative density trajectory) has been drawn. The mechanisms controlling grain growth and densification have been investigated. A comparison is then made with previous results obtained by Spark Plasma Sintering.

11:40 AM

### (SINTER-007-2008) Microstructural Evolution of Constrained Films through Synchrotron Computed Microtomography

D. Bernard\*, ICMCB-CNRS, France; O. Guillon, Technische Universität Darmstadt, Germany

X-Ray computer tomography offers a powerful tool to characterize microstructural evolution of materials in 3 dimensions. In order to reach high resolution level, high energy synchrotron radiation as well as coarse powders have to be used. Films made of spherical particles (average particle size: ~10 µm) were tape cast on substrates and subsequently sintered for different times. Aim of this work is to measure changes induced by a geometrical constraint on ceramics densifying by viscous flow (glass) and solid state diffusion mechanisms (alumina). Important parameters such as local densities as a function of distance to substrate, changes of particle sphericity, contact anisotropy (coordination number and neck size) and pore orientation are extracted and provide an experimental basis to understand how microstructure of sintering bodies is affected by substrate.

### In-Situ Measurements in Sintering

#### **In-Situ Measurements**

Room: Ballroom E

**9:20 AM**

##### **(SINTER-008-2008) Investigating the Influence of Powder Size on beta-Ti Formation and Reactive Sintering of NiTi Using Differential Scanning Calorimetry (Invited)**

S. F. Corbin\*, M. Whitney, D. Cluff, R. Gorbet, University of Waterloo, Canada

The primary purpose of this investigation was to develop an experimental technique using Differential Scanning Calorimetry (DSC) capable of elucidating phase formation during reactive sintering of pure Ni & Ti powders to form NiTi. Ni+Ti powder mixtures were made with a number of powder size combinations in the range of 1 to 90 microns. High temperature DSC analysis revealed that the use of fine powders prevented the initiation of a large exothermic (or combustion) reaction at temperatures above 950 C, while mixtures with the coarsest powder sizes exhibited a large combustion reaction. Quantitative analysis of phase formation using DSC, revealed a strong correlation between the amount of beta-Ti solid solution present at 950 C, the melting of this phase and the strength of the exothermic reaction. Fine powder mixtures removed beta-Ti from the structure and therefore prevented the combustion reaction.

**10:00 AM**

##### **(SINTER-009-2008) In-Situ Analysis of Particle Rotations during Sintering Applying High-Resolution Synchrotron Tomography of Focused-Ion-Beam-Marked Spheres**

R. Grupp\*, M. Nöthe, B. Kieback, Technische Universität Dresden, Germany; J. Banhart, Hahn-Meitner-Institut Berlin GmbH, Germany

A better fundamental understanding of the sintering process requires experimental data regarding particle rearrangement processes especially particle rotations. Synchrotron tomography was used to investigate the particle rearrangements during sintering in 3D. Focus ion beam was applied to mark spherical copper particles by milling a small hole into the surface. Using these holes the change in orientation of each sphere during sintering can be quantified. High-resolution tomography was carried out at the ESRF in an in-situ furnace. It can be shown that in the course of sintering the particles rotate with respect to their neighbours. By analysis the marker holes, local self-rotations of the particles were measured and found to be significantly higher than rotations in relationship to the contact partners. If grain boundary sliding as material transport mechanism is assumed the speed of rotation is in good agreement with the calculated one.

**10:40 AM**

##### **(SINTER-010-2008) Characterization of Viscous Properties of Zirconia Tapes during Sintering**

M. Delporte\*, Fraunhofer Gesellschaft ISC, Germany; U. Eisele, Robert-Bosch-GmbH, Germany; F. Raether, Fraunhofer Gesellschaft ISC, Germany

This study describes the acquisition of sintering kinetics under application of compressive loads. We developed an in-situ method which enabled the measurement of the viscous properties directly on stacks of tapes. Yttria-stabilized zirconia tapes were sintered with constant heat rates and under constant loads in the range between 0.5 N and 180 N. Dimensional changes along stress direction as well as in the normal plan to the compression stress were monitored in-situ over the complete sintering cycles. The free and loaded sintering kinetics in both directions were plotted into a novel three-dimensional field. This tool enables the prediction of sintering kinetics for any temperature cycles and for any compressive loads. The accuracy of this three-dimensional field was verified by the direct comparison of predicted and measured free sintering kinetics, as well as kinetics under constant loads.

**11:00 AM**

##### **(SINTER-011-2008) Combined Dilatometry and Mass Spectrometry Analysis of the Sintering of Strontium Titanate**

M. Schurwanz\*, S. J. Lombardo, University of Missouri- Columbia, USA

A combined dilatometer and mass spectrometer system (CDMS) has been used to study the real-time gas-phase chemistry that occurs during the sintering of a commercial strontium titanate powder. Over different temperature ranges in the heating cycle, gas-phase species are observed, some of which are correlated to dimensional changes of the sample. Gas-phase species of mass to charge ratios of 64, 48, and 32 may indicate that either TiO<sub>2</sub> or SO<sub>2</sub> is being evolved. The ratios of the naturally occurring isotopes of the atoms in these compounds can be used to clarify the chemical identity of the observed species. Preliminary analysis suggests that unreacted precursors from the powder synthesis step are still present, and that these are evolved only near the temperature at which sintering begins. In addition, the evolution and consumption of oxygen indicates at what temperatures oxygen defect chemistry is occurring.

**11:20 AM**

##### **(SINTER-012-2008) Characterization of the Thermally-induced Response of Yttria-stabilized Zirconia during Sintering**

J. B. Henderson\*, Netzsch Instruments, Inc., USA; J. Blumm, NETZSCH-Gerätebau GmbH, Germany

Accurate knowledge of thermophysical properties of post-sintered materials is critical for design purposes. Further, the evolution of these properties during sintering can yield valuable information regarding the sintering process. The purpose of this work was to measure the thermophysical properties of yttria-stabilized zirconia prior to, during and after sintering. The thermal expansion ( $\Rightarrow$ bulk density), specific heat, latent heat of binder burnout, thermal diffusivity ( $\Rightarrow$ thermal conductivity) and mass loss were measured. The results of these measurements will be presented in detail. Through cross-correlation of the experimental data, it will be shown how these properties yield valuable insight into the physical processes which occur during sintering. For example, with sufficient experimental data it is possible to identify and characterize mass transport mechanisms. This is possible due to the sensitivity of the thermal transport properties to small microstructural changes.

**11:40 AM**

##### **(SINTER-013-2008) In Situ Neutron Diffraction Analysis of TLP Sintered Ni-Cu Powder Mixtures**

D. M. Turriff\*, S. F. Corbin, University of Waterloo, Canada

Transient liquid phase sintering of liquid-rich Cu-Ni powder mixtures has the potential to be used for the development of variable melting point brazing filler metals. The success of such an application requires a better understanding of the isothermal solidification mechanism via interdiffusion during the process. Time/temperature-resolved in situ neutron diffraction experiments were conducted during TLP sintering of pure Ni and Cu powder mixtures at temperatures from 1090 C-1194 C. Analysis of the ND pattern evolution indicates that isothermal solidification during sintering is characterized by the rapid growth of a Cu rich solid-solution at the surface of Ni rich base metal particles. The concomitant decrease and broadening of the pure Ni peak is relatively slow. These findings indicate that the isothermal liquid solidification process occurs by epitaxial growth of a Cu-rich solid-solution and limited long-range diffusion into the Ni particles cores.

## Modeling of Sintering at Multiple Scales

### Modeling I

Room: Scripts I

9:20 AM

#### (SINTER-014-2008) Multi-Physics Model for Simulation of Sintering at the Mesoscale (Invited)

T. Bartel\*, V. Tikare, Sandia National Laboratories, USA

Traditionally, sintering has been simulated at the macroscale by mechanics using FEM or at the microscale by ceramists considering sintering of a few particles. We developed a mesoscopic model that can simulate sintering of hundreds of particles in a 3D powder compact. This model proved very successful at simulating the complex microstructural evolution in compacts when sintering stresses were homogeneous. In cases where stresses were not uniform, microstructural evolution during sintering could not be simulated. In this work, we present a hybrid mechanics-materials model MPAL (Material Point Arbitrary Lagrangian Eulerian), which is capable of simulating multiple physical phenomena present during differential sintering. MPAL is an evolution of particle-in-cell methods that has been developed to simulate a variety of microstructural evolution processes that require integration of multi-physics, which include mechanical stress and strain that fundamentally alter the microstructural evolution.

10:00 AM

#### (SINTER-015-2008) Meso-scale Monte Carlo Sintering Simulation with Anisotropic Grain Growth

G. R. Brown\*, R. A. Levine, E. A. Olefsky, San Diego State University, USA; V. Tikare, Sandia National Laboratories, USA

Although Monte Carlo (MC) computer simulations are widely used for understanding the microstructural evolution of sintering bodies, models currently in use do not incorporate anisotropic grain growth. This ability in our meso-scale modeling is necessary for the investigation of anisotropic granular development under several different situations to better understand some of the interesting observed anisotropic phenomena like patterning in sintered materials. A two-dimensional algorithm to simulate the evolution of granular structure with anisotropic materials using a Potts MC model which incorporates the sintering mechanisms of grain growth, pore migration and vacancy annihilation is presented. Limitations of this algorithm imposed by the underlying lattice structure are identified and analyzed. Solutions to mitigate these artifacts are proposed and implemented. Results are discussed and evaluated.

10:40 AM

#### (SINTER-016-2008) Dynamics of Microstructural Evolution in Ideal Sintering

F. Wakai\*, T. Akatsu, Y. Shinoda, Tokyo Institute of Technology, Japan

Microscopic models are presented which describe the sintering of particle clusters. The three-dimensional simulation is conducted to analyze various phenomena in sintering, e.g. bonding, pore channel closure, pore shrinkage, particle rearrangement, wetting, coarsening and grain growth. The naturally evolving surface and boundary change their topology during sintering. The formation and growth of interface between particles are expressed as a motion of surface triple junction. In sintering, as well as in grain growth, the deviation of dynamic dihedral angle from its equilibrium value is proportional to the triple junction velocity and inversely proportional to the triple junction mobility. Micromechanical principle of shrinkage is discussed with the use of sintering force and sintering stress, which can be defined rigorously from the knowledge of microstructure.

11:00 AM

#### (SINTER-017-2008) Evolution of Defects during Sintering: Discrete Element Simulations

C. L. Martin\*, L. Olmos, D. Bouvard, INP Grenoble, France; R. K. Bordia, University of Washington, USA

We use Discrete Element Method (DEM) simulations to study the evolution of well characterized defects during sintering. In DEM, the particulate nature of the sintering powder is taken explicitly into account since each particle is modelled as a discrete entity interacting with its neighbours. This allows particle rearrangement to be introduced naturally in the simulations. Particle rearrangements are dominant when local heterogeneities such as defects are present in the microstructure. We study the evolution of macropores of different sizes and show that there exists a critical size at which initial macropores cannot heal. Macropores are generated in the simulations as particles that are mixed with the sintering powder during the compaction process. These particles are then removed, thus forming pores, before the numerical sintering process. We also study the evolution of small initial cracks (generated for example during ejection or drying processes).

11:20 AM

#### (SINTER-018-2008) Atomistic Modeling of Nanoparticle Sintering Using a 3D-Lattice Kinetic Monte Carlo Method

L. Roentzsch\*, B. Kieback, Fraunhofer Institute for Manufacturing Engineering and Applied Materials Research, Germany

Sintering at nanoscale dimensions is becoming increasingly important in materials science and technology, e.g. in the area of printable electronics. Thus, atomistic insight into the sintering kinetics of nanoparticles (NP) is advantageous for further understanding and process development. Here, we present results of 3D-lattice KMC simulations describing NP sintering entirely on the atomistic level. Based on a cellular automaton principle, the KMC method mimics discrete diffusion jumps of atoms in a realistic manner. Thus, the spatio-temporal development of systems containing up to several  $1E5$  atoms can be studied in-situ for time spans over several orders of magnitude. The sintering scenarios presented reach from the classical two-particle over particle-plate up to complex multi-particle configurations for which the 2nd order mass moment is introduced as a measure of sintering progress. Further, the prospects of the KMC method are outlined, e.g. in view of sintering in external fields.

11:40 AM

#### (SINTER-019-2008) Effect of Powder Size Distributions on Sintering Behavior: A DEM Simulation Study

A. Wonisch\*, T. Kraft, M. Moseler, H. Riedel, Fraunhofer Institute for Mechanics of Materials, Germany

Employing a Discrete Element Method (DEM) based simulation allows investigating how microscopic properties on the grain-scale influence the macroscopic sintering behavior. However, most DEM studies so far assumed a monomodal size distribution of spherical particles, which is an unrealistic idealization for many commercial powders. In the present investigation DEM force laws for sintering are generalized in such a way that sintering of particles with different sizes can be simulated. Two sintering processes are investigated: solid-state and liquid-phase sintering. A wide range of different size distribution is considered, ranging from monomodal to bimodal and log-normal distributions. It is shown that the type and width of the distribution has a significant effect on the macroscopic strain rates and can enhance rearrangement effects. It is further demonstrated that the size distribution impacts microstructural anisotropy development when considering e.g. constrained sintering.

### Sintering of Nano-Structured Materials

#### Nano-Structured Materials I

Room: Scripts II

9:20 AM

##### (SINTER-020-2008) Densification and Grain Growth in Nanocrystalline Oxide Ceramics (Invited)

A. Chokshi\*, Indian Institute of Science, India

Grain growth and densification are usually coupled, so that there is extensive grain growth in the final stages of densification. Two different approaches to developing nanocrystalline bulk compacts will be discussed. In the two stage sintering approach, samples are initially sintered at a high temperature up to relative densities of ~75%, and then sintered for long durations at a lower temperature. A quantitative approach will be developed to examine critically the possibility of grain growth controlled by triple junctions. Sinter forging experiments can lead to bulk nanocrystalline ceramics, by enhancing densification and limiting grain growth. An analytical approach is developed to examine densification during sinter-forging, and this is compared with model experiments using samples containing latex spheres.

10:00 AM

##### (SINTER-021-2008) Development of CNT-dispersed Si<sub>3</sub>N<sub>4</sub> Ceramics Using Sintering Aids for Low Temperature Densification

J. Tatami\*, S. Yoshio, K. Takahashi, D. Horikawa, T. Wakihara, K. Komeya, M. Takeshi, Yokohama National University, Japan

Si<sub>3</sub>N<sub>4</sub> ceramics have been used for engineering components. Such Si<sub>3</sub>N<sub>4</sub> ceramics are insulator, so that static electricity sometimes causes problems. CNTs are good candidate as fillers to give electrical conductivity. However, the reaction between CNT and Si<sub>3</sub>N<sub>4</sub> or SiO<sub>2</sub> during sintering have to be suppressed. In this study, based on in-situ measurement of sintering of Si<sub>3</sub>N<sub>4</sub> ceramics, the effect of TiO<sub>2</sub> and/or HfO<sub>2</sub> addition as sintering aids on densification behavior was investigated in order to develop CNT dispersed Si<sub>3</sub>N<sub>4</sub> ceramics. TiO<sub>2</sub> addition lowered the onset temperature of densification by dissolution and precipitation due to phase transformation from α-Si<sub>3</sub>N<sub>4</sub> to β-Si<sub>3</sub>N<sub>4</sub>. HfO<sub>2</sub> additive resulted in the rapid densification with grain growth of β-Si<sub>3</sub>N<sub>4</sub>. As a result, optimization of sintering temperature and additives led to the dense CNT-dispersed Si<sub>3</sub>N<sub>4</sub> ceramics. The developed CNT-dispersed Si<sub>3</sub>N<sub>4</sub> ceramics showed high strength and electric conductivity.

10:40 AM

##### (SINTER-022-2008) Mechanisms of Viscous Flow on Sintering of Nanodispersed and Nanocrystalline Powders (Invited)

V. V. Skorokhod\*, A. V. Ragulya, Frantsevich Institute for Problems in Materials Science, Ukraine

This overview represents results of theoretical and experimental analysis of all the phenomena inherent in sintering of nanosized particles. The classical mechanism of viscous flow has been described by Frenkel for amorphous particles. In nanoparticles, amorphous shell co-existing with crystalline core contributes to viscous behavior of particles. Amorphous phase located on grain boundaries defines the rheology of nanomaterials as well. The diffusion controlled viscous flow can be driven by abnormally large capillary forces between nanoparticles. The mean free paths for volume and grain boundary diffusion in nanos are comparable with particle size. In n-Cu, n-Ni the mean free path is about 100 nm at 500 K. Particles smaller than 100 nm may flow viscously. The viscous-like coalescence, coagulation and accommodation mechanisms become the main feature for nanoparticles sintering, especially on the initial stages. Size effect can be influenced by application of external fields.

11:20 AM

##### (SINTER-023-2008) Nickel-Boron Nanolayer Coated Boron Carbide Pressureless Sintering

K. Lu\*, X. Zhu, Virginia Polytechnic Institute and State University, USA

The rigid covalent bonds and associated low diffusivity of B<sub>4</sub>C make it very difficult to sinter by pressureless sintering. In our work, a Ni-B nanolayer has

been coated onto B<sub>4</sub>C particle surfaces; the coated B<sub>4</sub>C has been compacted to ~75% density by combustion driven compaction. This study will focus on pressureless sintering of B<sub>4</sub>C/Ni. The interaction of B in the nanolayer with the B<sub>4</sub>C particles will be evaluated. The evolution of the Ni-B nanolayer around the B<sub>4</sub>C particles will be analyzed. The wettability of Ni on the B<sub>4</sub>C particles and the interfacial energy between B<sub>4</sub>C and Ni will be studied for the first time. B in the nanolayer is expected to react with the excessive C in the B<sub>4</sub>C particles but the effect on the sintering densification needs to be studied. The Ni-B nanolayer is expected to play critical roles in B<sub>4</sub>C diffusion, shape accommodation, and possible new B<sub>4</sub>C formation. The correlation between densification and microstructural evolution of B<sub>4</sub>C/Ni will also be discussed.

11:40 AM

##### (SINTER-024-2008) Spark Plasma Sintering of Mechanochemical Synthesised Nanodimensional Nickel Ferrites

C. Estournès\*, CIRIMAT, France; E. Manova, Bulgarian Academy of Sciences, Bulgaria; G. Raimbeaux, G. Chevallier, CIRIMAT, France; J. Rehspringer, IPCMS, France; J. Grenèche, Laboratoire de Physique de l'Etat Condensé, France; E. Rivière, Institut de Chimie Moléculaire et des Matériaux d'Orsay, France; D. Paneva, B. Kunev, I. Mitov, Bulgarian Academy of Sciences, Bulgaria

Nickel ferrite nanoparticles with dimensions below 10 nm have been prepared by the combination of chemical precipitation and mechanical milling. The consolidation of the obtained material was performed using the spark plasma sintering (SPS) method under three different sintering conditions: holding time, heating temperature and applied pressure. Effects of the SPS conditions on the phase composition and structural properties of the obtained materials were investigated by X-ray diffraction, Mössbauer spectroscopy, magnetization measurements and thermo-programmed reduction. Materials with different density and particles dimensions between 10 and 30 nm were obtained after SPS treatment. All measurement techniques employed indicates that longer treatment time induce particles growth. The magnetic and reduction properties exhibit a strong dependence on the particle size.

### Poster Session

Room: Grand Ballroom Foyer

1:00 PM

##### (SINTER-P001-2008) Hydrogen Sorption Properties of Ti-Oxide/Chloride Catalyzed Na<sub>2</sub>LiAlH<sub>6</sub>

E. Martinez-Franco\*, IPN-CIITEC, Mexico; T. Klassen, M. Dornheim, GKSS Research Center, Germany; R. Bormann, TUHH, Germany; D. Jaramillo-Vigueras, IPN-CIITEC, Mexico

Mechano-synthesis through mechanical alloying (MA) has been employed in this research to obtain a nanocrystalline complex sodium lithium alanate, namely, Na<sub>2</sub>LiAlH<sub>6</sub> from starting materials NaH and LiAlH<sub>4</sub>. Different Ti-based catalysts were together milled with starting materials in order to achieve improved hydrogen sorption kinetics. Among the as milled materials without catalyst, with 5 mol% of TiO<sub>2</sub> and with 5 mol% TiCl<sub>3</sub>. Titration experiments show that the material with 5 mol% TiCl<sub>3</sub> has the fastest ab- and desorption kinetics, but at the sacrifice of hydrogen capacity. This could be corresponding to the formation of NaCl during milling. Differential scanning calorimetry (DSC) results demonstrate that the endothermal peak of TiCl<sub>3</sub> doped material shifted 53°C to lower temperatures.

##### (SINTER-P002-2008) Effect of Al<sub>2</sub>O<sub>3</sub> Additions on the Sintering Behavior of 10% Y<sub>2</sub>O<sub>3</sub> - 10% ZrO<sub>2</sub> - CeO<sub>2</sub> (mol %) Ceramics

G. S. Godoi\*, D. F. de Souza, Federal University of São Carlos, Brazil

The effect of 0.5 mol of Al<sub>2</sub>O<sub>3</sub> on the sintering behavior of 10% ZrO<sub>2</sub> -10% Y<sub>2</sub>O<sub>3</sub> - CeO<sub>2</sub> (mol %) (CZY) were investigated by constant heating rate dilatometry (CHRD) and scanning electron microscopy (SEM). The additive enhanced the sinterability of the powder compacts. However, low densities were obtained for samples sintered at lower heating rate even on the additive presence. Microstructure analysis by SEM showed that the sintering occurs through liquid phase mechanism. The heating rate has strong effect on the amount and distribution of the liquid phase produced during sintering which

determines the densification degree attained. The activation energies at the initial stage of sintering were also evaluated by analyzing the densification curves.

**(SINTER-P003-2008) Effect of the Content of Gd in the Sintering of Ceria Doped Ceramics for SOFC Electrolytes**

G. B. Crochemore\*, D. F. de Souza, Federal University of São Carlos, Brazil

Solid oxide fuel cells (SOFCs) produce electricity directly from electrochemical combination of fuel and oxidant agent with high efficiency. Rare earths doped ceria exhibits high ionic conductivity. Due to this characteristic, doped ceria is a potential electrolyte for solid oxide fuel cell.  $Gd_2O_3$  produces ceria solid solution with the highest electrical conductivity. However, this solid solution is a mixed conductor at high temperature and low oxygen partial pressure. In this work it was studied the microstructural development of gadolinium doped ceria (>99,9%). The powders were prepared by oxide mixture, which were calcinated at 550°C and then sintered at different temperatures in air atmosphere. The sintered samples were characterized by X-ray diffraction (XRD), impedance spectroscopy (IS), and scanning electron microscopy (SEM). It was observed that the content of Gd affects the distribution of the liquid phase during the sintering, and consequently the electrical conductivity.

**(SINTER-P004-2008) Effect of Sintering Temperature on the Thermoelectric Properties of Bi<sub>0.5</sub>Sb<sub>1.5</sub>Te<sub>3</sub>**

K. Park\*, S. Nam, M. Heo, T. Saradha, Sejong University, South Korea; C. Lim, W. Cho, C. Lee, Inha University, South Korea

$Bi_{0.5}Sb_{1.5}Te_3$  thermoelectric materials have been widely used to cool electronic components. The Te-doped p-type  $Bi_{0.5}Sb_{1.5}Te_3$  compounds were fabricated by cold compaction followed by sintering in the temperature range 400-500°C. The Seebeck coefficient, electrical resistivity, and thermal conductivity were measured as a function of sintering temperature to calculate the figure of merit. The morphology of grains and preferred orientation depended strongly on sintering temperature. The density of the compounds increased with increasing sintering temperature. The highest figure of merit ( $2.82 \times 10^{-3}/K$ ) was obtained at a sintering temperature of 500°C. We discussed the effect of sintering temperature on the microstructure and figure of merit.

**(SINTER-P005-2008) High Density Green Pellets of ZrN Fabricated by Particle Processing**

T. T. Meek\*, K. Gwathney, University of Tennessee, Knoxville, USA; C. K. Narula, L. R. Walker, Oak Ridge National Laboratory, USA

Fabrication of nitride nuclear fuels has generally been not successful due to instability of nitrides (loss of americium nitride during the high temperature sintering process) under hot pressing or conventional 1 atm sintering conditions to make net shapes. A low temperature-processing route that enables near net shapes in almost theoretical density is highly desirable. In order to carry out low-temperature pressing, it is necessary to synthesize nitride materials with controlled particle size. A compact made of the right mix of particles can be pressed at room-temperature to near theoretical density. In order to achieve controlled nitride powder synthesis, we are developing ceramic precursor processing that has been shown to offer unique advantages over conventional synthesis of advanced materials. In general, the precursors for metal nitrides already contain M-N bonds that are terminated into organic groups.

**(SINTER-P006-2008) Research of the Synthesis Processes of TiN – TiB<sub>2</sub> Composition by Spark Plasma Sintering Method by Different Technological Conditions**

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The aim of the present study was the research of synthesis processes of dense TiN – TiB<sub>2</sub> composition with different ratio of components by spark plasma sintering (SPS) method by variation of technological conditions (temperature, time, protective atmosphere). The synthesis and the sintering were carried out by 2 methods. The method 1. The sintering in the graphite die on air by immediate passage of electric currents superposition. The method 2. The sintering by pulsating current in the graphite die on argon atmosphere with previous dehydrogenation in vacuum. TiN – TiB<sub>2</sub> compositions with relative density 64-99 % were synthesized. The compositions with TiB<sub>2</sub> content 60 wt.% and properties: HV=32,8 GPa (the load was P=100 g), fracture strength

K1C = 10,6MPa\*m<sup>1/2</sup> (P = 2 kg), K1C = 5,80 MPa\*m<sup>1/2</sup> (P = 20 kg) were obtained.

**(SINTER-P007-2008) Effects of Sintering Parameters on Stain Resistance of Polished Porcelain Stoneware Tiles**

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Porcelain stoneware tiles, which have excellent technical characteristics are extensively utilized in indoor and outdoor applications. Nowadays, not only technical properties but also aesthetical appearance of porcelain tile has become important in tile industry. Polishing process provides smooth and highly glossy surfaces; however, this operation induces a significant degradation of surface characteristics due to opening of closed pores. Therefore closed porosity is an undesirable result of the sintering process which is obtained by viscous flow in the ceramic bodies. During sintering many reactions occur and amount of porosity changes. Thus sintering is a crucial step in porcelain tile production process. In this study, effects of sintering time, temperature and dwell time at the peak temperature on the densification behaviour and the amount of closed pores in the porcelain tile body were investigated by using optical dilatometer and TMA (Thermomechanical Analyser) equipments.

**(SINTER-P008-2008) Low Temperature Sintering of MgO-ZrO<sub>2</sub> Ceramics from Fine Powders Prepared Using Sol-Gel Process**

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MgO-ZrO<sub>2</sub> powders with 9mole% MgO were prepared by sol-gel process starting from zirconium oxychloride and magnesium chlorides. The precipitated hydroxides were dried in a controlled manner and were calcined at different temperatures up to 1000°C to obtain optimized surface area and phase content. During calcination the powders underwent a series of transformations from metastable cubic to metastable tetragonal to monoclinic phase. The calcined powders were sintered at just above the two phase region (1400-1500°C) for 2 hours to obtain high density ceramics. The sintered material required no further heat treatment and consisted of cubic, tetragonal and monoclinic phase with tetragonal precipitates present within the grains. The latter is similar to those observed in a conventional solution annealed and aged materials of similar compositions.

**(SINTER-P009-2008) Effects of Crystallization and Vitrification on Sintering Properties of Bentonite Clay**

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Bentonite clays are frequently used in the formulation of structural ceramics at low concentration in spite of its chemical composition which is similar to kaolinite, the most used clay for this purpose. During the study of the sintering properties of a natural bentonite clay we found that the studied bentonite can be used as main component to formulate structural ceramic products where control of dimension is fundamental. According to our study, with ceramic formulation based on bentonite clay, during thermal treatment a plateau where dimensional changes are minimal can be used to sinter the ceramic pieces. This process represents a significant advance related to the conventional process where CaCO<sub>3</sub> is used to promote the crystallization/vitrification process of several phases by reaction of amorphous silica and amorphous meta kaolinite with the CaO produced during the thermal decomposition of CaCO<sub>3</sub>.

**(SINTER-P010-2008) Influence of FeO Doping on the Kinetics of Forsterite (Mg<sub>2</sub>SiO<sub>4</sub>) Formation**

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Forsterite is a one of the important member of the magnesia – silica system which is commonly used as a refractory in the iron & steel industry. In this study, effect of 8 wt FeO addition on the kinetics of forsterite formation was investigated. Analytical reagent grade chemicals were used as raw materials. Homogenized mixtures were pressed into disks and fired at 1500° C. Phases developed in the FeO – free and FeO containing samples were determined by quantitative X – ray diffraction using Rietveld Method, depending on duration ranging from 15 to 480 minutes. In the early stages of sintering, low melt-

ing enstatite ( $\text{MgSiO}_3$ ) was determined beside the main phase forsterite. The weight percent of forsterite, which was measured depending on the sintering period and finally the results of the FeO – free and FeO containing compositions, was compared.

### (SINTER-P011-2008) Geopolymers Sintering by Optical Dilatometry

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The effects of geopolymer binder systems exposed to elevated temperature are [were] examined. Specimens synthesized from metakaolin, activated by sodium/potassium hydroxide and sodium/potassium silicate were treated up to  $1000^\circ\text{C}$  in an optical dilatometer at a heating rate of  $20^\circ\text{C}/\text{min}$ . Shrinkage curves were compared to DSC measurements and correlated to XRD and SEM observations to assign the proper transformation to each sintering step. Results indicated slow, but constant expansion from 200 up to  $800^\circ\text{C}$ , preceded by 2 to 4% contraction due to loss of water, depending on the composition. Shrinkage starting from about  $800\text{--}900^\circ\text{C}$  is in the order of 12–16%, and it is exponential; it can be ascribed to mullite formation from unreacted metakaolin phase. Further heating to about  $1000^\circ\text{C}$  leads to the formation of a vitreous phase. Geopolymers with potassium based compounds showed to be more refractory compared to sodium based formulations. Microstructural and mineralogical modifications were followed by changes in mechanical properties.

### (SINTER-P012-2008) Exploring Stress and Temperature Gradients in Current Assisted Sintering

A. Dupuy\*, J. E. Garay, UC Riverside, USA

Current Activated Pressure Assisted Densification (CAPAD) is quickly gaining in popularity because of its proven efficiency in densification of materials that are often hard to sinter. Further development of this technique could be hindered by heterogeneities of the sintered products, leading to unreliable parts. The purpose of this project is to examine the extent and the cause of the microstructural and property heterogeneities. Copper samples created at a variety of temperatures provide a platform for evaluation of gradients in the CAPAD technique. The role of temperature and stress gradients on grain size, density, and hardness will be presented.

### (SINTER-P013-2008) Nanocomposites Fabricated by Spark Plasma and Rate-Controlled Sintering Technologies

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The present work illuminate the key principles how to fabricate bulk dense high melting point nanocomposites using up-to-date methods of consolidation. Consolidation of nanostructured powders of titanium carbonitride of different origination, composition in the system Si-N-C-Ti, nanopowders composition TiN-TiB<sub>2</sub> and TiN - Si<sub>3</sub>N<sub>4</sub> have been performed by spark-plasma-sintering (SPS) and Rate-Controlled Sintering (RCS) at the temperatures  $1400\text{--}1600^\circ\text{C}$  in non-linear regimes of heating and loading. Sintering experiments for TiCN were carried out in vacuum and nitrogen to estimate the influence of process medium on the structure formation.

### (SINTER-P014-2008) SPS Densification and Properties of Carbon Nanotube-Metal-Zirconia Nanocomposites

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Stabilized-zirconia powders ( $\text{Zr}_{0.8}\text{Y}_{0.1}\text{Mo}_{0.1}\text{O}_{1.95}$  and  $\text{Zr}_{0.8}\text{Y}_{0.1}\text{Mo}_{0.02}\text{Fe}_{0.02}\text{O}_{1.95}$ ) were reduced in pure  $\text{H}_2$ , producing metal-YSZ nanocomposite powders or in  $\text{H}_2\text{-CH}_4$ , directly producing carbon nanotube-metal-YSZ nanocomposite powders without any mixing step. The oxide and nanocomposite powders were densified by SPS ( $1500^\circ\text{C}$ , 150 MPa, diameter 20 mm). The metal-YSZ powders densify slightly more (reaching 100%), and the carbon nanotube-metal-YSZ powders slightly less, than do the YSZ powders. The presence of metal particles provokes a decrease in the YSZ grains size. This effect is much more pronounced in the presence of CNT. The powders and the densified materials were characterized notably by XRD and

SEM. The Vickers microhardness, fracture strength and toughness were measured and discussed in the light of the microstructure of the materials. In particular, the properties of the metal-YSZ composites compare favourably with the results reported by other authors for cubic zirconia.

### (SINTER-P015-2008) Finite Element Modeling of Current Activated Sintering Methods

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Electric current activated sintering has received a lot of attention during recent years. We present a finite element model that simulates both the temperature and stress distribution in the process. Our model simulates our electric current activated sintering device and allows us to analyze the following factors: load applied, current or voltage applied, geometry of sample, geometry of die, etc. We can also adjust the material properties of the electrode, spacer, die, and sample. Temperature effects are modeled with a triangular mesh and stress effects are modeled with a Gaussian mesh. We present a parametric study of the effects of geometry, size, and material properties on stress and temperature. Model data will then be compared to experimental results.

### (SINTER-P016-2008) Reaction Kinetics and Sintering of $\text{Al}_2\text{TiO}_5$ by Field-Assisted Sintering Technique

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Bulk  $\text{Al}_2\text{TiO}_5$  is formed from a stoichiometric mixture of  $\text{Al}_2\text{O}_3$  and  $\text{TiO}_2$  powders by field-assisted sintering technique (FAST). Results show that the reducing atmosphere created by vacuum condition and graphite die employed in this method greatly increases the nucleation of  $\text{Al}_2\text{TiO}_5$  product. The activation energy for the growth of  $\text{Al}_2\text{TiO}_5$  is found to be 440 kJ/mol which is different from available data in the literature for the reaction in both air and vacuum. FAST also enhances the densification of this powder mixture and produces almost fully dense samples. On the other hand, same powder mixtures sintered in a similar reducing atmosphere in a tube furnace have lower density. Discrepancies between results from FAST and conventional methods are addressed.

### (SINTER-P017-2008) Comparison of Microwave and Conventional Sinter-Forging of Aluminum Powder

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During the last two decades comparisons of different materials sintered in microwave and conventional ovens have become a popular interest for researchers. In many cases, materials sintered in microwaves have superior properties than materials obtained in conventional ovens. Until now, microwave sinter-forging has not been explored. A unique microwave sinter-forging device has been developed and both microwave and conventional sinter-forging were compared to each other in this research. All specimens were prepared from Aluminum powder. Various loads were applied to specimen during microwave and conventional sintering. Initial and final densities and grain size were measured to compare both techniques.

### (SINTER-P018-2008) On the Reactive Sintering by Infiltration of Loose $\text{Al}_2\text{O}_3\text{-Ni}$ Powder Mixtures with Molten Al

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The high brightness of bulk alumina can be alleviated, without its oxidation/corrosion resistance notable decreasing, by reinforcing with NiAl. Its in-situ synthesis with liquid phase formation at alumina sintering is preferable, leading to cleaner interfaces. However, at NiAl synthesis in  $\text{Al}_2\text{O}_3\text{-Ni-Al}$  powder mixture the liquid phase formation is difficult,  $\text{Al}_2\text{O}_3$  acting as diluent. On the other hand, the  $\text{Al}_2\text{O}_3$  pre-sintered skeleton infiltration with molten NiAl requires high temperatures. This paper investigates an alternative route: reactive sintering by infiltration of loose  $\text{Al}_2\text{O}_3\text{-Ni}$  powder mixture with molten Al, able to overcome these drawbacks. Adopting Ni proportion/Ni:Al atomic ratio in correlation with porosity, near stoichiometric NiAl formation and quite full infiltration was assured, proved by XRD, SEM and EDS. Compression testing at temperatures up to  $800^\circ\text{C}$  proved the NiAl reinforcing ef-



fect, determined toughness of the obtained composites being higher than of bulk alumina.

**(SINTER-P019-2008) SPS Sintering of Lead Phosphovanadates**

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Lead phosphovanadates are used as reactants for the synthesis of iodine-bearing apatite. Because of high chemical durability, iodine apatite presents a strong potential in the radioactive iodine conditioning. Synthesis and consolidation of iodine compounds require to work at low temperatures in order to avoid the iodine volatilisation. Consequently, Spark Plasma Sintering appears as an adequate treatment because of its short processing time. The present paper deals with the SPS sintering of lead phosphovanadate powders, prepared by mechanical routes: attrition and planetary ball milling. The influence of sintering parameters such as the heating rate, the temperature, the holding time on the densification degree and the microstructure of bulk materials will be presented. The obtained bulk characteristics have been directly correlated to the shrinkage evolution. The powders have been well characterised (grain size and size distribution, specific area...) in order to explain the singular sintering behaviour of the attrited one.

**(SINTER-P020-2008) Improved Sinterability of Panthal (J&K) Magnesite for Production of Dead Burnt Magnesia through Fuel Efficient Pressurized Shaft Kiln**

S. A. Jaleel\*, NMDC Ltd., India

To meet growing demand of steel and quality requirements of Dead Burnt Magnesia (DBM) from the Indian refractory industry, improved and fuel efficient pressurized shaft kilns are available up to 150 TPD for production of High grade Dead Burnt Magnesite in comparison with conventional Rotary Kilns. Based on both process economics and product quality, pressurized shaft kilns are highly effective for production of sintered Magnesia. Process data pertaining to feed size, energy consumption, product characteristics, maintenance cost shall be compared and discussed for a 100 TPD DBM sintering facility.

**(SINTER-P021-2008) Densification of SiC by SPS without Sintering Additives**

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Silicon carbide is one of the most important ceramics used as a structural and functional material in a wide variety of applications. Many studies have reported the densification of SiC using oxide and nonoxide additives such as  $Al_2O_3$ ,  $B_4C$  and Al-B-C system. We attempted to densify SiC using colloidal processing and spark plasma sintering (SPS) without sintering additives. A commercially available SiC (6H) powder with the average particle size of 0.55  $\mu m$  was used as the starting materials. Aqueous suspensions with dispersed particles were prepared by adjusting pH and consolidated by slip casting to prepare the dense green compacts. And then, the green bodies were sintered by SPS. The density of SiC prepared by SPS increased with increasing the sintering temperature. The relative density of SiC prepared by SPS was more than 97% at the sintering temperature of 1950 °C. The average grain size was a few  $\mu m$ . However, the microstructure and densification were inhomogeneous in the sintered bodies with the diameter of 30 mm.

**(SINTER-P022-2008) Spark Plasma Sintering of ZnS**

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Raw ZnS and ZnS-SiO<sub>2</sub> powders mixed by a 3-D mixer or by using high energy ball-milling with attritor mixing were successfully densified by spark plasma sintering. The mechanical properties of the sintered part were evaluated in terms of microhardness and fracture toughness. microstructure. Because of a finer and more homogeneous microstructure, the mechanical properties of the ZnS-SiO<sub>2</sub> composite prepared from the ball-milled powder showed the best properties among those investigated. Due to the effect of dispersion hardening and crack deflection by the second phase of fine SiO<sub>2</sub>, the hardness and fracture toughness were increased to 3.031 GPa and 1.014 MPam<sup>0.5</sup>, respectively.

**(SINTER-P023-2008) Microstructure Change and Mechanisms in Dry Snow Sintering**

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The practical significance of the instability of snowpacks and the occurrence of avalanches is the reason for our interest in studying dry snow sintering. During sintering ice crystals are bonded together by forming necks and the density of snowpack increases due to mass diffusion. The microstructure change in turn affects the sintering rate and the mechanisms. In order to understand the influence of thermal conditions, including temperature and temperature gradient, and pressure on snow sintering, we have characterized structure changes of both lab-produced samples and natural snow by using an optical microscope for recording the neck growth, a low-temperature scanning electron microscope (SEM) for high-resolution images, and a micro X-ray computed tomography (micro CT) for three-dimensional information. The necks experience fast growth during the early stage of sintering due to vapor transport and surface diffusion, which is accelerated by an external temperature gradient.

**(SINTER-P024-2008) Analysis of Sintering of Titanium Porous Material Processed by the Space Holder Method**

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In this work the sintering behaviour titanium and Ti-6Al-4V titanium alloy porous materials prepared by the space holder method have been analysed in terms of mechanical properties and microstructural characterisation. The porous materials were processed under vacuum and different sintering cycles analysed. Other variables studied were space holder size fraction and content, and compaction pressure. The influence of these factors on both compression behaviour and strength was analysed. Microstructural observation was carried out by means of optical and electron microscopy in order to correlate microstructure to the observed mechanical behaviour. Results showed that both compaction pressure and sintering temperature have a higher influence for samples with low space holder content. Minimising the contact time between alloy powders and space holder revealed to be a critical point in the processing of these materials.

**(SINTER-P025-2008) Effect of Element Trace on the Crystalline Structure of Calcium Hydroxyapatite**

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Pure hydroxyapatite has the formula  $Ca_{10}(PO_4)_6(OH)_2$ : HAP, while a biological apatite contains several other ions in traces like Mg, Na. The pure prepared hydroxyapatite due to the same structure of the natural bone, has good compatibility with the human organism, and is widely used in medical applications as implant. Different techniques have been used for HAP powders preparation. Depending upon the technique, materials with various composition, morphology, stoichiometry, and level of crystallinity, have been obtained. These properties affect biological properties. The majority of the work, reported in the literature concerning the preparation of the hydroxyapatite, is interested only in the proportioning of the calcium and phosphorus elements. The generated materials will have a profile of biological behaviour. Metal traces can also influence the biological properties of hydroxyapatite.

**(SINTER-P026-2008) Constrained Sintering and Microstructure Development of Strontium Titanate Thick Films**

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Dielectrics with high permittivity, excellent tunability and small losses (high Qf) are required for tunable capacitors and microwave devices. SrTiO<sub>3</sub> (ST) is particularly attractive for these applications because of its high Qf. Current trends in communication towards increased integration include the use of high frequencies and miniaturization. Consequently, replacement of dielectric components utilized in bulk ceramics by thick-films is being considered. In this work, the effect of stoichiometric deviations ( $0.997 \leq Sr/Ti \leq 1.02$ ) on the constrained sintering of ST thick films was investigated and compared with equivalent ceramics. ST films were deposited by electrophoretic deposition on platinum substrates and sintered under different conditions. XRD and SEM were used for crystallographic and microstructure characterization. The structure and composition of the grain boundaries were further characterized

by TEM. AFM was complementary applied for characterization of films topography.

**(SINTER-P027-2008) Fabrication of  $\text{Ni}_{0.3}\text{Zn}_{0.7}\text{Fe}_{2.0+\delta}\text{O}_4$  ( $\delta = -0.2 - +0.2$ ) -  $\text{BaTiO}_3$  Composites in Controlled Atmosphere**

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$\text{NiZn}$ -ferrite -  $\text{BaTiO}_3$  (BT) composites exhibited much higher permittivity than that calculated from logarithm mixture law. In this study, the effects of Fe content ( $\delta$ ) and annealing atmosphere on the dielectric property of the composites were examined.  $\text{Ni}_{0.3}\text{Zn}_{0.7}\text{Fe}_{2.0+\delta}\text{O}_4$  ( $\delta = -0.2 - +0.2$ ) - BT composites ( $\text{NiZn}$ -ferrite / BT = 100/0 - 85/15 vol%) were sintered at 1250 °C for 4 h followed by annealing in  $\text{N}_2$  or air. When the samples were annealed in air, the permittivity of the composites increased with an increase in the Fe-content of ferrite and/or BT ratio. The higher permittivity might be mainly attributable to the increasing  $\text{Fe}^{2+}$  in the  $\text{NiZn}$ -ferrite phase caused by Ti-substitution. However, in case of annealing in  $\text{N}_2$ , the permittivity of the composites with the Fe-rich ferrite inversely decreased with increasing BT ratio. The changes in solid phases produced and microstructure with annealing atmosphere were investigated for the ferrite - BT composites.

**(SINTER-P028-2008) Densification and Dielectric Properties of Glass-Ceramics in the  $\text{BaTiO}_3$ - $\text{RE}_2\text{O}_3$  (RE = La, Nd, Sm)- $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$  System**

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The  $(\text{Ba,Sr})\text{TiO}_3$  solid solution (BST) is one of the most promising materials for frequency-tunable microwave devices. Since LTCC (Low Temperature Co-fired Ceramics) processing is also an important technology for the integration and downsizing of the microwave devices, low-temperature fabrication of the tunable glass-ceramics is an attractive issue for the development of advanced microwave telecommunication system. In this study, the glass-ceramics in the  $\text{BaTiO}_3$ - $\text{RE}_2\text{O}_3$  (RE = La, Nd, Sm)- $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$  system were fabricated from glass powders prepared by melt-quenching method to examine the role of the RE cations as Tc shifter.  $\epsilon_r$ -temperature curves of the samples sintered at 950 °C for 10h showed broadened character with their Tc shifting to lower temperature in an order of  $\text{Sm} \rightarrow \text{Nd} \rightarrow \text{La}$ . A dense glass-ceramic having  $\epsilon_r(\text{max})$  at around 0 °C was obtained for a glass powder of  $\text{Ba:Nd} = 9:1$ .

**(SINTER-P029-2008) Influence of Sintering Temperature on VUV Characteristics for Red-emitting (Y,Gd)VO4:Eu,M Phosphor Powders**

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$(\text{Y}_{1-x}\text{Gd}_x)\text{VO}_4$ :Eu,M phosphors ( $0 \leq x \leq 1$ ,  $y=0.06$ , and  $0 \leq z \leq 0.1$ ) doped with Eu and various metal ions (M=Zn, Al, and Mn) were synthesized by ultrasonic spray pyrolysis and their fluorescence properties were investigated in the VUV region. The droplets generated by the ultrasonic nebulizer were carried into a hot furnace by air. The phosphor powders gathered in the precipitator were sintered at 1050-1150 °C for 4h in air. Simultaneous TG-DTA curves were obtained to understand thermal behavior during the synthesizing process and to determine the sintering temperature of the powders. The (Y,Gd)VO4:Eu,M phosphors sintered at various temperatures had a spherical and regular morphology, narrow size distribution, and non-agglomeration. The characteristic luminescence peaks which were caused by the 5D0 to 7Fj (j=0-4) transitions of  $\text{Eu}^{3+}$  were detected at 594, 619, 651, and 699nm, respectively.

**(SINTER-P030-2008) Microstructure and Ferroelectric Characteristics of  $\text{BaTiO}_3$  Doped with  $\text{Yb}_2\text{O}_3$**

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In this article,  $\text{Yb}_2\text{O}_3$  is used as doping materials for  $\text{BaTiO}_3$ -based multilayer devices.  $\text{BaTiO}_3$ -ceramics doped with 0.1 and 0.5 wt% of  $\text{Yb}_2\text{O}_3$  is prepared by conventional solid state procedure and sintered in temperature interval from 1320 °C to 1380 °C for four hours. Microstructure characterizations for vari-

ous samples have been carried out by scanning electron microscope of the JEOL-JSM 5300 equipped with energy dispersive spectrometer (EDS) system. It has been noticed that, with the higher dopant concentration the abnormal grain growth is inhibited and the grain size ranged between 2-10 $\mu\text{m}$ . With prolonged sintering time the increase of grain size is observed. The measurements of capacitance and dielectric losses as a function of frequency and temperature have been done in order to correlate the microstructure and dielectric properties of doped  $\text{BaTiO}_3$ -ceramics.

**(SINTER-P031-2008) Microstructure and Properties of Pressureless Sintered Alumina-based Metal Nanocomposites**

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Alumina-based metal (alumina/metal) nanocomposites fabricated by hot-pressing techniques are found to exhibit the improved mechanical and functional properties. However, there are a few reports to make alumina/metal nanocomposites by pressureless sintering. The purpose of this work, therefore, is to fabricate alumina/metal nanocomposites with homogeneous microstructure and enhanced mechanical properties by pressureless sintering. The nanocomposite powders were prepared by hydrogen reduction of alumina and metal oxide powders. Pressureless sintering was done by using infrared heating furnace with a heating rate 100 °C/min. The alumina/metal nanocomposites showed sound microstructure with nano-sized metal particles and improved mechanical properties compared with monolithic alumina.

**(SINTER-P032-2008) Peculiarities of Sintering of Multi-Component Mixtures during Preparation of Ti/Ti-based Foams**

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Solid State Foaming that involves blending and sintering of powders having differing chemistry, size and morphology is frequently used to produce metallic foams. Usually such multi-component systems contain mixtures of two, three or more populations of particles with significantly different mechanical properties. In the simplest instances such multi-component systems contain a base metallic powder with various nonmetallic sacrificial materials that either vaporize during sintering or are dissolved thereafter. This study has focused on the sintering behavior of three-component mixtures containing spherical commercial purity titanium and 5%YSZ ceramics powders combined with either  $\text{NH}_4\text{Cl}$  and  $\text{NaCl}$  friable sacrificial powder. Sintering of these mixtures has resulted in preparation of bodies have up to 70 pct porosity. This presentation will review the sintering phenomena observed through characterization utilizing scanning electron microscopy and x-ray diffraction techniques.

**(SINTER-P033-2008) An Investigation on the Properties of Nanometer Size Titanium Diboride Reinforced Hot Pressed Boron Carbide-Silicon Carbide Composites**

A. C. Akarsu\*, O. Addemir, Istanbul Technical University, Turkey; T. Boyraz, Sivas Cumhuriyet University, Turkey

The effect of nanometer size  $\text{TiB}_2$  addition on microstructural, physical and mechanical properties of hot pressed  $\text{B}_4\text{C}$ -SiC composites were investigated. Different amounts of  $\text{TiB}_2$  0 to 4 vol.% were added to the  $\text{B}_4\text{C}$ -SiC composites with different  $\text{B}_4\text{C}$ /SiC vol.% ratios 1.5 to 4. The ternary powder composites were homogeneously mixed in an attritor with SiC balls for 8h and hot pressed at 2250 °C with 100MPa in vacuum. The microstructural and mechanical properties are determined by using XRD, SEM, microhardness and fracture strength testing methods. These results has shown that  $\text{TiB}_2$  addition play an important role on mechanical properties. Adding  $\text{TiB}_2$  decreased the hardness but existence of  $\text{TiB}_2$  increased the fracture strength of the  $\text{B}_4\text{C}$ -SiC composite system.

**(SINTER-P034-2008) Processing of Ceria based Nanoceramics for Solid Oxide Fuel Cell Electrolytes**

A. T. Wieg\*, J. E. Garay, UC Riverside, USA

Solid oxide fuel cells (SOFCs) are an increasingly important source of clean power generation. Doped cerium oxide has shown significant potential for lowering the operating temperature of SOFCs. The benefits should be enhanced by very fine grain size. We present the effect of processing parameters on the microstructure (grain size, density) and oxygen ion conductivity in Gd,

Sm, and Yb doped ceria densified using a current activated pressure assisted densification (CAPAD) process.

**(SINTER-P035-2008) Ceria Twin Pair doped Powder Synthesis and Sintering**

C. G. Plapcianu, L. Stanciu, C. Valsangiacom\*, S. Yup, G. Aldica, E. Volceanov, National Institute of Materials Physics, Romania

Ceria twin pair doped powders have been prepared by the sol-gel and complexant route, using Sm-Gd, Yb-Gd, Sm-Yb twin pairs to improve ionic conductivity. The nano-scale powders having the same nominal composition,  $Ce_{0.8}(Ln_1+Ln_2)_{0.2}O_2$ , were sintered by applying classic and/or SPS sintering processing, in order to get improved physicochemical properties of ceria. The compact samples revealed high density values (>96% TD) even when classic sintering processing was performed, reaching full density for SPS sintering way. The use of twin doping pairs increased the oxide precursors reactivity, X-ray patterns revealed a well crystallized structure very close to the one observed after applying sintering procedure. The use of twin pair cations, especially those containing Gd, favors the mixed solid solution presence, responsible for higher ionic conductivity values.

**(SINTER-P036-2008) Fabrication of O-deficient Anatase Thin Films with Enhanced Ultraviolet Sensitivity by Molecular Precursor Method**

H. Nagai\*, M. Hasegawa, H. Hara, C. Mochizuki, M. Sato, Kogakuin University, Japan

The O-deficient anatase thin films with high UV-sensitivity were fabricated by annealing anatase thin films, which were formed by heat-treating precursor films involving a Ti complex of EDTA on an FTO glass substrate at 773 K for 30 min in an Ar gas flow, at the same temperature in air. The crystal structure of the thin films was characterized as typical anatase by XRD. The averaged peak ratio of O 1s toward Ti 2p determined by XPS of the resulting film was 1.5. The UV-sensitivity of the resulting films with even surface was evaluated by photocatalytic activity measured by the decomposition rate of methylene blue. The photocatalytic activity is 3.5 times as compared with that formed by a sol-gel method under both usual and same conditions described above, although the crystallite size of the resulting films is significantly smaller. The Ti-EDTA complex plays an important role in the thin film fabrication of the O-deficient anatase with high UV-sensitivity.

**(SINTER-P037-2008) SAXS Investigation of the Sintered Niobium Powder: Method of Stabilizing Porosity and Fractal Properties**

L. Skatkov\*, PCB "Argo", Israel

We present the SAXS investigations of the method of stabilizing porosity in sintered structures by using both Nb powder hydrogenation and nitriding of niobium hydride sintered powder ( Part A ) and also an experimental study of sintered niobium powder surface fractal dimension D (Part B ). The results of Part A investigations are: A1. Niobium powder hydrogenation leads to the formation of porous structures with predominance of open submicrometre pores (SMP); A2. Nitriding of NbH sintered powders stabilizes the porous structure through coarsening, i.e. the volume contribution reductions of small SMP. In Part B we present observation of the modified Porod law and also give stipulations of the obtained dimension D. The results of Part B investigations are: B1. The dimension D is stated to be of the order 2.8 which is a stipulation of a highly developed porous structure; B2. Our results provide experimental support to the SAXS theory developed earlier.

**(SINTER-P038-2008) Standard and Two-stage Sintering of a Submicrometre Alumina Powder: The Influence on the Sintering Trajectory**

M. Micháľková\*, D. Galusek, Vitrum Laugaricio – Joint Glass Center of the Institute of Inorganic Chemistry, Slovak Academy of Sciences, Slovakia

Two-stage sintering has been reported in many submicrometre powder systems ( $Y_2O_3$ , ZnO,  $BaTiO_3$ ...) as an efficient way for preparation of dense bulk ceramics without final stage grain growth. Our preliminary results indicate that the method is, to certain extent, applicable also to sintering of submicrometre  $\alpha$ -alumina powders: although the grain growth was not entirely suppressed, finer grained microstructures resulted from the two-stage sintering than in specimens sintered in a standard way. The present work summarizes

the results of two-stage sintering experiments, and attempts to identify the optimum temperature T1 (residual porosity is unstable against further shrinkage) and the T2 temperature interval ("kinetic window") at which the ceramics can be sintered to full density without further grain growth. The influence of forming methods (AP, CIP and pressure filtration) on sintering trajectories is studied and compared to specimens sintered in the standard way.

**(SINTER-P039-2008) Fabrication of conducting SnO<sub>2</sub> thin film by molecular precursor method**

S. Adachi\*, H. Nagai, C. Mochizuki, M. Sato, Kogakuin University, Japan

Molecular precursor method, which was developed by our recent study, is a facile procedure for film fabrication of various metal oxides or phosphates. SnO<sub>2</sub> is one of promising alternative materials for indium tin oxide, which is facing a serious indium depletion problem. A conducting SnO<sub>2</sub> thin film was fabricated by heat-treating a precursor film involving a Sn complex of EDTA on a quartz glass substrate at 773K for 30 min in an Ar gas flow. The transmittance of the film of 50 nm thickness was ca. 85 % in the visible region. The specific resistivity of the film was  $4 \times 10^{-2} \Omega cm$  which was measured by four-probe method, although that fabricated in air under the same conditions was too high to measure. The formation mechanism of the SnO<sub>2</sub> thin films with low resistivity will be discussed with comparing those fabricated by heat-treating precursor films in air.

**(SINTER-P040-2008) Wet Jet Milling and Sintering of SiC Nano Particles**

S. Kawakami\*, J. Tatami, T. Wakihara, K. Komeya, T. Meguro, Yokohama National University, Japan

Wet jet milling is a method of the grain refinement and homogenization using turbulent flow, shear flow and cavitation generated by the high speed flow and rapid pressure release. Since wet jet milling uses these effects, the grain refinement and homogenization in this process are achieved within a short period of time with no grinding media. We carried out wet jet milling of SiC nano particles and sinter them to obtain dense SiC ceramics. As a result, aggregation of SiC nano particles was dispersed very well by wet jet milling in water without oxidation. Higher density of SiC sintered body was obtained by spark plasma sintering using wet jet milled SiC nano particles without sintering aids compared with as received SiC. Consequently, wet jet milling is the effective technique to disperse aggregated SiC nano particles and to obtain dense and pure SiC ceramics.

**(SINTER-P041-2008) Grain Boundary Investigation in Nanocrystalline Oxides**

S. Tanju\*, J. E. Garay, UC Riverside, USA

The aggressive downscaling of nanoscale devices require to capture physics of the materials in atomic scale. We present results on processing and microstructural characterization of nanocrystalline oxide ceramics. Iron oxide has shown prominent applications in nanoscale devices such as spin field effect transistors (spinFET), memory storage devices, nuclear magnetic resonance (NMR) imaging. The effects of the grain size on the mechanical properties of iron oxide have been reported, however, there have been very few reports of the effects that grain boundaries have on the interaction between different magnetic phases of iron oxide. We use a current activated pressure assisted sintering (CAPAS) method to produce iron oxide to study these issues. Transmission electron microscopy (TEM) studies were undertaken to elucidate the role of grain boundaries and nanograin phases. The role of the coexistence of Different nanograin crystal structures (hexagonal, cubic) will also be discussed.

**(SINTER-P042-2008) Atomistic Insights into Thermal Stability of Nanosized Ceria Particles on Metal-Oxide Surfaces**

W. Jiang\*, M. Wong, A. Rammohan, Y. Jiang, J. L. Williams, Corning INC, USA

A large surface area enhances the chemical and physical performance of nanosized materials. However, this enhancement could come at a cost of lowered thermal stability (a shortened life time) of these materials. In this work, we performed atomistic simulations to assess the thermal behavior of nanoparticles on metal oxides. The studies focused on the binding and aggregation of pure and Zirconia doped Ceria nanoparticles on a commonly used metal oxide surface, alumina (100). Some insights were gained into the thermal sta-

bility of these nanosized materials. Detailed discussion on binding energy, impacts of particle size, Ceria loading and Zirconia doping will be presented.

### **Evolution and Control of Microstructure during Sintering Processes**

#### **Microstructure II**

Room: Ballroom D

**2:40 PM**

#### **(SINTER-025-2008) Sintering of Transparent Yttrium Aluminum Garnet (YAG) Ceramics (Invited)**

G. Messing\*, S. Kochawattana, S. Lee, A. Stevenson, L. Kupp, J. Anderson, Penn State University, USA

Transparent YAG is a prime candidate to replace single crystal YAG in high power laser applications. Densification and grain growth in pure YAG, SiO<sub>2</sub> doped YAG and SiO<sub>2</sub> doped Nd:YAG were explored. The activation energy for densification (235 kJ/mol) in pure YAG is lower than that of grain growth (946 kJ/mol). Pure YAG sinters to near full density (> 99.9%) at 1700°C with little grain growth (1.2 μm average grain size). The remaining large pores (radius > 2 μm) were determined to be thermodynamically stable because their coordination number with grains was > 6. The stability of these pores underscores the importance of powder processing and forming in fabricating transparent YAG. SiO<sub>2</sub> doped YAG sinters to near full density 100°C lower than pure YAG because SiO<sub>2</sub> enables liquid phase sintering and the removal of large pores. The addition of Nd<sub>2</sub>O<sub>3</sub> further enhances both densification and grain growth.

**3:20 PM**

#### **(SINTER-026-2008) Sintering of Transparent MgAl<sub>2</sub>O<sub>4</sub>: LiF and Microstructure Evolution (Invited)**

I. Reimann\*, C. Smith, H. Kleebe, Colorado School of Mines, USA

The art of making transparent magnesium aluminate spinel (MgAl<sub>2</sub>O<sub>4</sub>) has strangely eluded fundamental scientific understanding for about thirty years. As a result, its fabrication is unreliable, expensive and has even led to the bankruptcy of one company. Efforts over the years on LiF-doped spinel have mainly revealed that the sintering and densification of spinel are extremely sensitive to processing conditions, suggesting that a complex mechanism is at work. Recent fundamental studies have shown that LiF reacts with spinel to produce a transient liquid phase which promotes early stage densification via liquid phase sintering. The mechanism behind later stage densification is still not entirely clear but evidence is shown to suggest that enhanced diffusion occurs because spinel grains containing defects form out of the liquid melt. These results are discussed in the present paper along with new studies that examine the microstructure development.

**4:00 PM**

#### **(SINTER-027-2008) Growth of Single Crystals by Solid State Conversion**

A. J. Stevenson\*, S. Lee, G. L. Messing, The Pennsylvania State University, USA

Solid state conversion (SSC) utilizes growth of a single grain into polycrystalline materials to achieve crystals without the compositional heterogeneities inherent to most single crystal growth methods. SSC has been used to produce a variety of crystals including BaTiO<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, (1-x)Pb(Mg<sub>1/3</sub>Nb<sub>2/3</sub>)O<sub>3</sub>-xPbTiO<sub>3</sub>, Nd<sub>3x</sub>Y<sub>(3-3x)</sub>Al<sub>5</sub>O<sub>12</sub> (Nd:YAG), and commercial (Mn,Zn)Fe<sub>2</sub>O<sub>4</sub>. In this presentation, factors affecting nucleation, growth kinetics, and quality of SSC single crystals will be discussed and models for the SSC process will be analyzed. Finally, recent results regarding the growth and properties of SSC Nd:YAG single crystals will be presented.

**4:40 PM**

#### **(SINTER-028-2008) Tailoring Microstructure in CaBi<sub>4</sub>Ti<sub>4</sub>O<sub>15</sub> Textured by Templated Grain Growth Process**

K. Tamura, T. Kimura\*, Keio University, Japan

Microstructure control is necessary to improve properties of lead-free piezoelectric ceramics textured by the templated grain growth process. This work deals with the preparation of textured CaBi<sub>4</sub>Ti<sub>4</sub>O<sub>15</sub> (CBT) ceramics with controlled microstructure grain size. At first, the factors determining microstructure were examined. It is found that the origin of texture development is not the growth of template grains but the morphological change of matrix grains from equiaxed to platelike in the presence of template grains and the matrix grains, which change to be platelike, grow up to the size of template grains. Therefore, the grain size in the final microstructure is determined by the size of template grains. Based on the mechanisms of microstructure development, the textured CBT ceramics with controlled grain size were prepared using the platelike CBT grains with various sizes.

**5:00 PM**

#### **(SINTER-029-2008) Fabrication of SrBi<sub>4</sub>Ti<sub>4</sub>O<sub>15</sub> Ceramics via Reaction Sintering of Crystal-oriented Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub>**

S. Tanaka\*, Nagaoka University of Technology, Japan; Y. Doshida, Taiyo Yuden Co., Ltd., Japan; K. Uematsu, Nagaoka University of Technology, Japan

SrBi<sub>4</sub>Ti<sub>4</sub>O<sub>15</sub> ceramics with high orientation degree and dense was fabricated by a forming processing in a high magnetic field and by a subsequent reaction sintering. The raw powders consisting from Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub> and SrTiO<sub>3</sub> were dispersed into distilled water. The particle sizes were 1.0 μm for Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub> and varied for 0.1-0.5 μm for SrTiO<sub>3</sub>. Slurry was set inside a high magnetic field (10T). Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub> particles in the slurry were oriented in magnetic field. The green body after dried was composed of crystal-oriented Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub> and random-oriented SrTiO<sub>3</sub>. The reaction sintering of Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub> and SrTiO<sub>3</sub> resulted in the a,b,-axes SrBi<sub>4</sub>Ti<sub>4</sub>O<sub>15</sub> ceramics without magnetic field. The oriented structure was maintained after reaction sintering. Using 0.1 μm SrTiO<sub>3</sub>, high orientation and density were obtained; the maximum Rotgering factor was about 0.9 and the relative density was 97%. The piezoelectric constant of the oriented sample was 40pC/N, twice of the random structure.

### **Novel Sintering Processes; Field-Assisted Sintering Techniques**

#### **Novel Sintering Processes I**

Room: Ballroom E

**2:40 PM**

#### **(SINTER-030-2008) Microwave Sintering of Various Materials and Its Advantages (Invited)**

D. Agrawal\*, Penn State University, USA

Application of microwave energy for materials processing is emerging as a novel technology with many advantages over conventional processing, such as reduction in processing cycle time, providing finer microstructures and improved mechanical properties. The microwave energy is highly versatile in its application to numerous diverse fields such as communication, chemical reactions, rubber vulcanization, drying, food processing, etc. However, its application in ceramics and metallic materials has developed only in the last two decades. Many specialty ceramics, composites, and metal powders have been successfully processed in microwave with improved properties. The selective heating feature of microwaves has led to effective brazing and joining of metal parts. Even bulk metals can be heated and melted in microwave field. This presentation will give an overview of the current status and new developments in this field and will discuss possible explanation of microwave enhancements during sintering of various materials.

3:20 PM

**(SINTER-031-2008) Direct and Hybrid Microwave Sintering of Yttria-Zirconia Ceramics in an Instrumented Single-mode Cavity**

S. Charmond, C. Carry\*, D. Bouvard, INPG-UJF, France

The use of microwave energy to sinter ceramics is a promising technology for improving the microstructure and reducing the processing time and energy. The microstructural development of 3 and 8 mol% yttria-stabilized zirconia nanopowders during direct and hybrid microwave sintering was studied for various heating rates. A removable cylindrical SiC susceptor was used for hybrid heating experiments. Microwave heating was achieved in a 2.45 GHz single-mode cavity. The sliding short-circuit piston controls the impedance of the resonant cavity and the microwave power available to yield the desired temperature-time profile. Asymmetrical temperature gradient on the upper sample surface was evidenced using a thermal imaging camera. After sintering, the microstructures were observed by SEM and compared to conventionally sintered materials in terms of grain size. Meanwhile the mechanical properties were characterized by Vickers indentation tests.

3:40 PM

**(SINTER-032-2008) Finite Element Modelling of Microwave Sintering**

D. Bouvard\*, S. Charmond, C. P. Carry, Grenoble INP, France

Microwave sintering involves several phenomena strongly coupled to each other: electromagnetism, heat transfer and sintering. For a better control of this complex process the simulation of microwave sintering is carried out with COMSOL finite element code. At a given time a stationary calculation provides the electromagnetic field in the cavity and in the compact when an incident power is assumed. From the electric field in the compact the value of the generated heat is deduced. A transient thermal calculation is thus run with this value as a heat source and with radiative losses at the boundaries of the compact. The density of the compact is updated through a prescribed densification law. Dielectric permittivity and thermal parameters are supposed to depend on relative density and temperature. Finally temperature and density kinetics are obtained. A critical issue in this simulation is getting relevant permittivity values for ceramic powders. Experimental and modelling approaches are suggested for this purpose.

4:00 PM

**(SINTER-033-2008) Microwave Sintering Explored by X-Ray Microtomography**

K. Ishizaki\*, M. Battabyal, Y. Yamada Pittini, R. Nicula, S. Vaucher, EMPA, Switzerland

At present, 3D X-ray microtomography is one powerful instrument or way to observe diamond composite powders for which it is not possible to obtain cross section pictures. This 3D observation of microstructures opens up new opportunities for analyses. Diamond and metal powder mixtures microwave irradiated were analyzed using synchrotron-based X-ray tomographic microscopy. From the results it is recognized that the sample obtained by microwave irradiation is completely different in each level depending upon the way it was irradiated. To obtain a uniform and good sintered sample, the microwave irradiation time and the power are of critical value.

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**(SINTER-034-2008) Sintering of Combustion Synthesized TiB<sub>2</sub>-ZrO<sub>2</sub> Composite Powders in Conventional and Microwave Furnaces**

H. Khachatryan, Yerevan State University, Armenia; A. Vats\*, Z. Doornbos, SDSM&amp;T, USA; S. Kharatyan, Yerevan State University, Armenia; J. A. Puszynski, SDSM&amp;T, USA

Comparative pressureless sintering studies of TiB<sub>2</sub>-ZrO<sub>2</sub> composite powders with different compositions of Y<sub>2</sub>O<sub>3</sub> stabilized ZrO<sub>2</sub> were conducted using conventional and microwave sintering furnaces in an inert atmosphere. Composite powders were prepared in one step combustion synthesis (CS) process using two different initial reactant compositions: i) Ti-2B-0.2ZrO<sub>2</sub> (unstabilized) and ii) Zr-TiO<sub>2</sub>-2B. In this paper, the effect of all processing steps in preparation of green samples, morphology of initial composite powders, sin-

tering conditions in both conventional and microwave furnaces on the density of sintered articles and their phase compositions and microstructure will be discussed in details. The effect of operating conditions and internal arrangement of SiC susceptors and an insulation box on microwave furnace stability will be discussed as well.

5:00 PM

**(SINTER-035-2008) Microwave Rapid Debinding and Sintering of MIM/CIM Parts**

P. Veronesi\*, C. Leonelli, G. Poli, L. Denti, A. Gatto, University of Modena and Reggio Emilia, Italy

Microwave assisted thermal debinding of parts obtained by Metal Injection Moulding (MIM) or Ceramic Injection Moulding (CIM) could benefit from the heating selectivity, having the organic binder to preferentially absorb microwaves, thus accelerating the conventional process, which has to rely on heating by conduction. This is particularly useful when dealing with ceramic powders having low thermal conductivity, but also more conductive materials can be treated faster if the maximum temperature difference inside each part is kept low. Once the organic binder is removed, microwaves at 2.45 GHz can be used to rapidly sinter the obtained brown parts, minimizing grain growth. In this work, microwave assisted debinding and sintering of MIM/CIM parts, made of stainless steel, alumina and titania is studied, using numerical simulation to investigate the presence of localised effects ascribable to the electromagnetic field distribution in the powder compacts.

5:20 PM

**(SINTER-036-2008) Rapid Hot Pressing of Diamond based Composites**

T. Schubert\*, FhG-IFAM, Germany; E. Neubauer, ARCS, Austria; T. Weissgärber, B. Kieback, FhG-IFAM, Germany

For electronic circuits, the main type of failure is thermal fatigue, owing to the different thermal expansion coefficients (CTE) of semiconductor chips and packaging materials. Therefore, the search for matched CTE of packaging materials in combination with a high thermal conductivity is the major task. Metal-diamond composites, e.g. copper composites are promising solutions. For the manufacturing of these copper diamond composites rapid hot pressing techniques were used. These techniques take advantages of both the control of interfacial reactions between the metal and the diamond and the relatively short cycle time of the process. Different to the conventional hot pressing, the rapid hot presses heat the samples by using a direct flow of electrical current. The thermal properties of these composites will be presented. In addition, the homogeneity of the properties across the diameter of the sintered samples were investigated and correlated with in-situ measurements of the temperature distribution within the sample.

## **Modeling of Sintering at Multiple Scales**

### **Modeling II**

Room: Scripts I

2:40 PM

**(SINTER-037-2008) Sintering Powder Compact Densification and Deformation: Effects of Constitutive Behaviors and Macroscopic Conditions**

H. Camacho\*, P. E. Garcia-Casillas, C. A. Martinez-Perez, J. T. Elizalde-Galindo, IIT-UACJ, Mexico; A. Garcia-Reyes, Interceramic, Mexico; R. K. Bordia, University of Washington, USA

The densification and deformation during sintering using the standard continuum formulation based on the VE analogy is simulated. Several macroscopic conditions and constitutive behaviors are considered. The Scherer cell, the Mackenzie-Shuttleworth and the Riedel models are used. A modified Riedel model to consider interface properties is included. Finally, a glass-ceramic constitutive behavior is considered using the Mooney equation. Best sintering conditions are obtained for a ceramic layer under no density and temperature gradient. Gradients induce constraints that affect densification

and deformation. Amorphous ceramics exhibit the simplest densification and deformation response. For crystalline materials, the coupling between densification and grain growth complicates the analysis but provides a practical way of controlling the viscosity. Glass ceramics start as amorphous materials but, at some point, densification is inhibited due to crystallization.

**3:00 PM**

### **(SINTER-038-2008) Analysis of Four Different Approaches to Predict and Control Sintering**

M. W. Reiterer\*, Medtronic, Inc., USA; K. G. Ewsuk, Sandia National Laboratories, USA

Understanding and predicting sintering, which has been a goal since the first attempts to mathematically describe the sintering process in the 1950s, is necessary to eliminate machining after sintering, and to reliably predict and control sintered microstructure and the resultant mechanical and electrical properties. We have compared, experimentally validated and even improved the Riedel Svoboda solid state sintering model, the Skorohod-Olevsky viscous sintering model, a Kinetic Monte Carlo model provided by Tikare, and the Master Sintering Curve approach introduced by Johnson et al. An assessment of the ability of these models to predict densification and microstructure evolution, and to contribute to the fundamental understanding and control of sintering is presented. This work was supported by the U. S. Department of Energy (DOE) under contract DE-AC04-94AL85000 to Sandia National Laboratories. Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed-Martin company, for the USDOE.

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### **(SINTER-039-2008) Atomistic Scale Study on Effect of Crystalline Misalignment on Densification during Sintering Nano Scale Tungsten Powder**

A. Moitra, S. Kim, S. Kim, S. Park\*, R. M. German, M. M. Horstemeyer, Mississippi State University, USA

An atomistic simulation is used in this research to probe the sintering process of crystalline tungsten and tungsten alloys at the sub-microscopic level. We have performed an atomistic simulation with nanoscale tungsten particles. Of primary interest is the application and development of classical and quantum mechanical methodologies to gain insight into the fundamental characteristics of atomic movement during sintering and how various additives influence the sintering processing. Since both neck growth and shrinkage result, it is possible to extend these calculations to the physical properties of the material. Also, this paper focuses on densification and grain growth during sintering as a function of the crystalline misalignment between particles. These findings can provide a foundation for a new virtual approach to nanoscale processing and material design.

**3:40 PM**

### **(SINTER-040-2008) Numerical Simulation of Densification and Deformation of Porous Bodies in a Granular Pressure-Transmitting Medium**

J. Ma\*, Southeastern Louisiana University, USA; E. Olevsky, San Diego State University, USA

In the attempt to achieve maximum densification and least distortion for near-net-shaped manufacturing, quasi-isostatic pressing (QIP) is studied. In QIP, self-propagating high-temperature synthesis (SHS) and subsequent consolidation are conducted in a rigid die where the SHS body is located at the center of the surrounding granular pressure-transmitting medium (PTM). Following the SHS, a uniaxial load is applied to the PTM, which builds up a quasi-isostatic stress in the die. The constitutive behaviors of both the post-SHS body and the PTM are determined based on theoretical and experimental studies. By incorporating them into a finite element model, the densification and deformation behaviors of the post-SHS body are simulated and the results are compared to the experimental data with satisfactory agreement. To obtain desired final shape, the optimized initial shape of the pre-QIP porous body is also designed based on a special iterative simulation approach.

**4:00 PM**

### **(SINTER-041-2008) Influence of External Constraints on the Stability of Sintering of Biporous Materials**

M. Shtern\*, A. Kuzmov, V. Skorokhod, E. Olevsky, Institute for Problems of Materials Sciences, Ukraine

The sintering of materials with bimodal porous structure under constraints is considered. The theoretical analysis is based on the continuum model of the sintering for a biporous body. The most representative cases of constraining - from uniaxial strengthening up to the (iso-directional) boundary constraints are analysed. Both the general shrinkage kinetics and the evolution of each kinds of pores were examined. The non - uniform distributions of large and small pores within a porous specimen contacting a deformation-restricting surface are studied. Using the FEM analysis it was found that in opposite to a nonomodal porous body, the material flow within the matrix material is possible for a biporous body even for the all-round constraint of the porous billet. For cases closed to the all- round restriction, the sintering is accompanied by the growth of large pores and reduction of the small ones when the difference between initial small and large pore sizes is negligibly small.

**4:40 PM**

### **(SINTER-042-2008) Evolution of Approaches to HIP Modeling and HIP Consolidation**

V. N. Samarov\*, V. Goloveshkin, D. Seliverstov, V. Neponyatschy, LNT P/M, USA

The general task of HIP modeling is in designing the initial shape of the HIP tooling providing the final part after the solid phase HIP consolidation of powder in a shaped capsule. The core of modeling is the description of the mutual deformation of the compressible (powder) and non-compressible (HIP tooling) materials. There are no precise mechanical models of material behavior far beyond the yield level typical for HIP. Therefore in most of the cases the initial adequacy of the constitutive equations does not enable to provide the necessary precision of modeling and corrections must be installed into the models. HIP Consolidation process itself is also evolving towards providing controlled microstructure and properties including those of the "net surfaces" via the optimization of the powder size and the HIP cycle for the complex shapes. The paper presents the evolution of the models providing adequate description of HIP for the parts of different geometrical complexity.

**5:00 PM**

### **(SINTER-043-2008) Sintering of Copper Nanoparticles: A Molecular Dynamics Study**

S. S. Indrakanti\*, R. Jayanarasimha, NIT, India

Molecular dynamics simulation was employed to study the consolidation of copper nanoparticles and investigate the various processes of sintering. Simulations were carried out under diverse thermodynamics of time and temperature. Nanoparticles have been the area of active research in recent years as they have novel and unique properties, which distinguish them from the bulk phase. Given the difficulties associated with experimental analysis at the nanoscale, nanoparticles are good candidates for study using molecular modeling methods, particularly computer simulation. The local shear stresses in the necking region exceed the local strength of copper, due to ultra fine size of the particles. This causes deformations and gives rise to a new mechanism for initial stages of sintering. The Lennard-Jones potential function was used by GROMACS (software for molecular dynamics simulation) for trajectory calculations. We were able to see physically how the sintering progresses which wouldn't have been possible otherwise.

## Sintering of Nano-Structured Materials

### Nano-Structured Materials II

Room: Scripts II

**2:40 PM**

#### (SINTER-044-2008) Two-step Sintering of Molybdenum Nanopowder (Invited)

Y. Kim\*, D. Kim, S. Kim, M. Park, Hanyang University, South Korea

Molybdenum is a potential material for use at elevated temperatures since it shows excellent mechanical properties at high temperatures. Conventionally, Mo powder is sintered at temperature over 1800°C in order to fabricate dense parts due to its high melting point of 2610°C. In this study, the nano-sized Mo powder was fabricated by high energy ball-milling and subsequent hydrogen reduction. Two-step process was employed for the sintering of Mo nanopowder to obtain fine grain size in bulk part. The densification over 94% could be obtained by the pressureless sintering of Mo nanopowder at 1200°C for 1 h with 1.4 μm in grain size and the 2.34 GPa in hardness. The two-step sintering process led to restrain grain growth to 0.5 μm and to consequently improve hardness up to 3.15 GPa even though the density was 90% of theoretical value.

**3:20 PM**

#### (SINTER-045-2008) Spark Plasma Sintering of Nanocrystalline WC-12Co Cermets

V. Bonache, M. Salvador, V. Amigo, Universidad Politecnica de Valencia, Spain; M. Hungria, Centro Nacional de Investigaciones Metalúrgicas (CSIC), Spain; D. Busquets\*, Universidad Politecnica de Valencia, Spain

In this work the densification, microstructural development and mechanical properties of ultrafine and nanocrystalline WC-12Co mixtures, consolidated by spark plasma sintering (SPS) has been studied. Also, this process is compared to hot isostatic pressing (HIP) and conventional sintering in vacuum. Ultrafine and nanocrystalline mixtures obtained by both high energy milling and commercial nanopowders have been used. The sintered materials have been evaluated by measuring density, hardness and indentation fracture toughness, and microstructurally characterized by optical microscopy, electron microscopy (SEM and TEM), and X ray Diffraction. The results show that spark plasma sintering allows consolidating full density materials at low temperatures and short time, thereby minimizing grain growth with respect to the conventional sintering. The materials obtained with nanocrystalline mixtures have similar properties to the obtained by HIP, reaching hardness values above 1800 HV and fracture toughness higher than 9 MPa √m.

**3:40 PM**

#### (SINTER-046-2008) Nano-scaled Si<sub>3</sub>N<sub>4</sub>/SiC Materials based on Pre-ceramic Polymers and Ceramic Powder

U. Degenhardt\*, G. Motz, University of Bayreuth, Germany; F. Stegner, K. Berroth, FCT Ingenieurkeramik GmbH, Germany; W. Harrer, R. Danzer, University of Mining Leoben, Austria

Silicon nitride ceramics exhibits high mechanical strength and excellent fracture toughness. A further improvement of the fracture toughness is anticipated on Si<sub>3</sub>N<sub>4</sub>-materials with nano-scaled silicon carbide segregations. However, the common processes for the fabrication of these materials are complex and expensive. A new way for manufacturing is the combination of pre-ceramic polymers and ceramic powder. Polycarbosilazane precursors can be used as an alternative binder which offer a high chemical purity, an homogeneous element distribution, flexible processing methods and a high ceramic yield. The procedure starts with the coating of silicon nitride powder with the pre-ceramic polymer and subsequent uniaxial pressing. Subsequent heat treatment converts the pre-ceramic precursor into an amorphous SiCN-ceramic. At higher temperatures the SiCN-ceramic generates fine distributed SiC-segregations and subsequent gas pressure sintering leads to a dense nano-scaled Si<sub>3</sub>N<sub>4</sub>/SiC ceramic.

**4:00 PM**

#### (SINTER-047-2008) Study of Sintering and Grain Growth of Nanocrystalline Tungsten Powder

H. Wang\*, Z. Z. Fang, University of Utah, USA

A detailed study of sintering and grain growth kinetics of nanocrystalline tungsten powder was carried out. The nanocrystalline tungsten powder was produced by high energy planetary ball milling and subject to sintering in a dilatometer under hydrogen atmosphere with a temperature range from 1000°C to 1400°C. Submicron sized tungsten powder was also employed for studying the size effects on sintering. The results show that the sintering temperature of nanocrystalline tungsten powder decrease dramatically compared to that of sintering conventional micron-sized powders (≥2000°C). Over 95% relative density can be achieved at a temperature as low as 1100°C. Dilatometric data and analysis were used for studying the densification kinetics of nanocrystalline tungsten powder. The relationship between grain growth and densification will be studied. The paper will also discuss the mechanisms of densification and grain growth during sintering of nanocrystalline tungsten.

**4:40 PM**

#### (SINTER-048-2008) Control of Transformation and Sintering Paths in Nanostructured Transition Alumina

M. Azar\*, J. Chevalier, V. Garnier, INSA-Lyon, France

Production of fully dense nanostructured alumina ceramics from transition alumina nanopowders is hardly obtained, especially via natural sintering. The transformation into the stable α phase is indeed accompanied by vermicular microstructures entrapping a high proportion of intragranular pores. The present study allows a complete description of transformations and sintering paths. A correlation between densification behaviour, microstructural evolution and mechanical properties in compacts is established using dilatometry, Scanning Electron Microscopy, X-Ray diffraction and vickers indentation method. We show that a careful control of the transformation sequences, from γ to Θ and from Θ to α polymorphs may be achieved at lower temperature, insuring an especially high compacity before sintering. Sintering may then be conducted at lower temperature, insuring ultrafine dense alumina.

**5:00 PM**

#### (SINTER-049-2008) Grain Growth during Sintering of Nanosized Powders

Z. Z. Fang\*, H. Wang, V. Kumar, X. Wang, University of Utah, USA

To manufacture nanocrystalline bulk materials, the goal of nanosintering is to achieve not only full densification but also retaining of nanoscale grain sizes. Research has shown that the grain growth during nano sintering can be treated as consisting of two parts: the dynamic grain growth that occurs during heating up and the normal grain growth that occurs primarily after the compact reaches greater than 90% relative density. The normal grain growth is well studied and documented. The initial dynamic grain growth, however, is not well understood. For nanosized powders, the contribution of the initial grain growth cannot be ignored because that the contribution of the initial grain growth is sufficient to cause the material to lose its nanocrystalline characteristics. This paper examines the fundamental issues of the initial grain growth during nano sintering. Experimental investigations of the sintering of nanosized WC-Co and W powders are presented.

**5:20 PM**

#### (SINTER-050-2008) Comparison of Pressureless and Spark Plasma Sintering of Bulk Nanoceramics

K. Maca\*, M. Trunec, Brno University of Technology, Czech Republic; Z. Shen, Stockholm University, Sweden

Spark plasma sintering (SPS) is a promising method for rapid densification of ceramic nanopowders at relatively low temperatures. The reasons why SPS is so effective in densifying nanoceramics are still not fully understood. In this presentation we report the sintering behaviours of nanopowder zirconia compacts during SPS and conventional pressureless sintering. By following the evolution of the relative density and pore size distribution during sintering it was found that during SPS the increase of pore size that is often observed in the intermediate stage of pressureless sintering was avoided. This observation

reveals and highlights the importance of particle rearrangement as well as the pore size control for the densification of nanoceramics.

**Tuesday, November 18, 2008**

### Plenary Session 2

Room: Ballroom C

**8:20 AM**

#### **(SINTER-051-2008) Sintering of Constrained Films (Invited)**

A. Cocks\*, University of Oxford, United Kingdom

A general strategy will be presented for modeling sintering that can take into account the effect of different thermodynamic driving forces and dissipative processes that occur at different scales. This will be applied to the sintering of thin films, including the sintering of particulate based systems, for which sintering is desirable, and the sintering of air plasma sprayed (APS) and electromagnetically enhanced physical vapor deposited (ePVD) coatings, for which sintering is undesirable. The effect of initial imperfections will be described. Depending on the exact sintering conditions, the imperfections can either be benign, and effectively sinter in the same way as the bulk material, or they can trigger instabilities in the sintering process which can lead to desintering and eventually the initiation of cracks at the sites of the imperfections, which can grow leading to 'mud-cracking' of the coating. The conditions under which this occurs will be identified and equations will be presented for the characteristic spacing of the mud-cracks.

## **Evolution and Control of Microstructure during Sintering Processes**

### Microstructure III

Room: Ballroom D

**9:20 AM**

#### **(SINTER-052-2008) Gravitational Role in Liquid Phase Sintering**

R. M. German\*, S. Park, P. Suri, Mississippi State University, USA; J. L. John, ATI Alldyne, USA; L. G. Campbell, Eaton Corp., USA

Seventy seven experiments were performed in microgravity with thousands of parallel ground-based experiments to identify critical conditions for the microgravity trials. Tungsten heavy alloys were selected for these experiments to accentuate solid-liquid density difference in a small sample. Included in the experiments were controlled variations in several independent parameters. This presentation summarizes key findings from these experiments, showing significant challenges to both folklore and previously accepted models. The summarization will show conceptual changes in models for densification, distortion, microstructure evolution (especially grain size and its distribution), in situ strength evolution, grain agglomeration and bonding, and relations between the independent parameters listed above.

**9:40 AM**

#### **(SINTER-053-2008) Effect of Cu on Sintering Behaviour of Nanostructured Fe Powder**

D. Sivaprahasam\*, ARC-International, India; S. Bysak, Central Glass and Ceramic Research Institute, India; A. M. Sriramamurthy, G. Sundararajan, ARC-International, India; K. Chattopadhyay, Indian Institute of Science, India

Nanostructured Fe and Fe-4 wt.% Cu powders (35 nm) with about 4 nm passive oxide layer were synthesized by levitational gas condensation process. The as synthesized powders were compacted and sintered under hydrogen atmosphere in the temperature range of 500-1100°C. The densification and microstructure of the sintered samples were evaluated using optical as well as scanning and transmission electron microscopy. At all sintering temperatures, the density of nano Fe-4 wt.% Cu was found to be higher when compared with nano Fe in spite of a lower green density of the former. The difference in the densities was significant particularly at lower sintering temperature. Such observation could be correlated to the microstructure. The microstructure of

nano Fe sintered at or below 900°C revealed high amount of Fe-oxides viz. Fe<sub>3</sub>O<sub>4</sub> entrapped between the Fe grains, where as in nano Fe-4 wt.% Cu, the microstructure was free from such Fe-oxides and showed Cu particles/precipitates of 50-70nm both at the grain boundary and inside the BCC Fe grains. The difference in the microstructure was attributed to the presence of Cu as a uniformly distributed separate phase in the nano Fe-4 wt.% Cu powder, which enhanced the reduction rate of surface passive Fe-oxide layer significantly so that even before sintering predominate all the oxides are removed.

**10:00 AM**

#### **(SINTER-054-2008) Sintering of Functionally Graded Cemented Tungsten Carbide**

Z. Z. Fang\*, P. Fan, J. Guo, University of Utah, USA; P. Prichard, Kennametal Inc., USA

Cemented tungsten carbide WC-Co is usually sintered using the liquid phase sintering process. To manufacture functionally graded WC-Co with internal cobalt gradient, the migration of liquid phase during sintering must be controlled. Research has shown that the migration of cobalt is controlled by the driving force of minimizing the interfacial energies between Co and WC particles. The interfacial energies depend on cobalt content, grain size, and carbon content. By understanding the influence of these factors, one can custom design the powder compositions and sintering atmosphere to manipulate the distribution of the cobalt phase in the microstructure, thus create WC-Co with cobalt gradient. Both experimental and modeling results of the liquid phase migration phenomena are presented in this paper. A key finding of the research is that WC-Co composite with a significant surface to interior cobalt gradient (>3%) can be produced in one sintering one by controlling the carbon potentials.

**10:40 AM**

#### **(SINTER-055-2008) Experimental Determination of Sintering Parameters for Second Stage Sintered of Silicon Nitride**

C. Theron\*, Saint-Gobain HPM, USA; W. Cannon, Rutgers University, USA

The sintering parameters of silicon nitride are determined during the second stage of liquid phase sintering via interrupted sinter forging tests under compressive uniaxial load. The silicon nitride with an yttria-alumina rich secondary phase was submitted to seven levels of stress (from 0.2MPa to 9.4MPa) at three different temperatures (1500C, 1550C and 1600C) with continuous monitoring of the axial and longitudinal shrinkage during all experiments to directly obtain the sintering stress, viscous Poisson's ratio and bulk viscosity. The sintering stress increases from 7.5MPa to 21.5MPa and then decreases to 11.5MPa at respectively 60%, 70% and 80% of theoretical density. This variation is largely attributed to the noticeable changes of microstructure during the second stage of liquid phase sintering, especially the overall pore size distribution, as well as, the degree to which the liquid phase is fully melted and partially or fully fills the smallest pores.

**11:00 AM**

#### **(SINTER-056-2008) Effect of Particle Size Distribution on the Microstructure and the Mechanical Properties of Reaction Bonded Boron Carbide**

N. Frage\*, A. Weizmann, S. Hayun, M. P. Dariel, Ben-Gurion University of the Negev, Israel

The high fraction of residual silicon is the major drawback of boron carbide-based reaction bonded composites. Residual silicon fraction depends on the initial porosity of the preforms and the amount of free carbon. Various approaches such as the addition of silicon compound forming or carbon releasing elements have been put forward in order to reduce the residual silicon fraction. It was also established that the higher the green density of the preforms, the lower the residual fraction of silicon. Green preforms with at least 75% of TD were obtained by using optimized multimodal mixtures of boron carbide powders. This allowed reducing the residual Si volume fraction in the final composites to less than 10Vol.%. Such composites displayed elevated stiffness values (380-390GPa), hardness (2100-2300 HV) and flexure strength (300-320MPa).



11:20 AM

**(SINTER-057-2008) Pressureless Sintering of Boron Carbide**

M. Mashhadi\*, Department of Metallurgy and Materials Engineering, Faculty of Engineering, Tarbiat Modares University, Iran; V. M. Sglavo, Department of Materials Engineering and Industrial Technologies, University of Trento, Italy

The effect of Al addition on pressureless sintering of B<sub>4</sub>C ceramic and its mechanical properties was analyzed in the present work. Different amounts of Al, from 0% to 5wt% were added to the base material and sintering was conducted at 2050°C and 2150°C under Ar atmosphere. Microstructure, crystal phases, density and mechanical properties evolution were studied and correlated to Al additions and sintering temperature. The density and the grain size of the sintered samples, increased significantly with Al load while less evidence is the effect of sintering temperature; 94% dense material was obtained by adding 4wt% Al regardless of the maximum firing temperature. By adding about 3wt% Al, the fracture strength, elastic modulus, hardness and fracture toughness of the sintered B<sub>4</sub>C samples were measured 270MPa, 320GPa, 53GPa and 5.5MPa.m<sup>1/2</sup>, respectively.

11:40 AM

**(SINTER-058-2008) Effect of the Carbon Source on the Microstructure and Mechanical Properties of Reaction Bonded Boron Carbide**

S. Hayun\*, M. P. Dariel, N. Frage, Ben Gurion University, Israel

Reaction bonded boron carbide composites were fabricated by molten Si infiltration of partially sintered B<sub>4</sub>C preforms with and without free carbon addition. During the infiltration process, liquid silicon reacts with free carbon and/or with carbon that originated in the B<sub>4</sub>C phase. This reaction results in the formation of SiC and, by the dissolution precipitation process, in the formation of ternary carbide B<sub>12</sub>(B,C,Si)<sub>3</sub>. The fraction of SiC in the final composite depends on the green porosity and its morphology on the carbon source. Silicon reacting with excess free carbon gives rise to a polygonal morphology, its reaction with the gradually released carbon from the carbide yields plate-like SiC particles. The Young modulus and the hardness increase, while the flexural strength and K<sub>1C</sub> decrease with decreasing fraction of residual silicon. The correlation between the mechanical properties and the microstructure of the infiltrated composites will be discussed.

**Novel Sintering Processes; Field-Assisted Sintering Techniques****Novel Sintering Processes II**

Room: Ballroom E

9:20 AM

**(SINTER-059-2008) Synthesis of Bulk Fully Dense Nanocrystalline Functional Oxides with Grain Size Approaching 10 nm (Invited)**

U. Anselmi-Tamburini\*, University of Pavia, Italy

Significant modification in the defect structure and in the functional properties of bulk oxides are expected when the grain size approaches 10 nm. The synthesis of these materials, however, resulted to be particularly challenging. We recently developed a new approach to the densification of nanocrystalline ceramic powders based on a high pressure modification of the Field Assisted Sintering technique. In the FAST technique the densification of the nanopowders is performed in a graphite die heated through a flux of high density electric current. Very high heating rates (up to 500°C/min) can be obtained by this mean. In the high pressure modification, pressures up to 1 GPa are applied during the densification process. This approach allows to reduce drastically sintering times and temperatures and to obtain fully dense materials with grain size approaching 10 nm.

10:00 AM

**(SINTER-060-2008) Spark Plasma Sintering of Fe-Based Structural Amorphous Metals (SAM) with Yttria Nanoparticle Additions**

O. A. Graeve\*, R. Kanakala, K. Sinha, University of Nevada, Reno, USA; L. Kaufman, CALPHAD, Inc., USA; E. Wang, B. Pearson, G. Rojas-George, University of Nevada, Reno, USA; J. C. Farmer, Lawrence Livermore National Laboratory, USA

The objective of this study was the fast preparation, via spark plasma sintering, of fully-dense SAM7 specimens with and without yttria nanoparticle additions. From SEM it was determined that the densification process was effective in producing fully-dense specimens. Experimental density measurements resulted in 7.77 g/cc for the pure SAM7 and 7.30 g/cc for the SAM7 with 2.5wt% yttria. The agreement between the experimental density of the SAM7 specimen and the theoretical value is quite remarkable (theoretical density = 7.75 g/cc). However, the specimen with yttria has an error of 4.8% between the experimental density and the theoretical calculations (theoretical density = 7.67 g/cc). X-ray diffraction results exhibit a typical amorphous broad peak for all specimens. Hence, the presence of yttria during milling and consolidation does not promote devitrification of the SAM7 powder.

10:40 AM

**(SINTER-061-2008) Fundamental Aspects of Spark-Plasma Sintering**

E. Olevsky\*, San Diego State University, USA

Spark-plasma sintering (SPS) carries a potential for the efficient consolidation of powder materials. Possible mechanisms of the enhancement of consolidation in SPS versus conventional techniques of powder processing are categorized with respect to their thermal and non-thermal nature. A model for spark-plasma sintering taking into consideration various mechanisms of thermally and non-thermally-activated material transport is developed. The interplay of three mechanisms of material transport during SPS is considered: surface tension-, electromigration- and external stress-driven grain-boundary diffusion, surface tension- and external stress-driven power-law creep, and temperature gradient-driven thermal diffusion. The obtained results are applicable to the ample range of powder consolidation techniques which involve high local temperature gradients and high heating rates. The results of modeling agree well with the experimental data on SPS of a metal (aluminum) and ceramic (alumina) powders in terms of SPS shrinkage kinetics.

11:00 AM

**(SINTER-062-2008) Field Activated Sintering Technique: Recent Developments (Invited)**

J. R. Groza\*, UCD, USA

The interest in FAST is due to the specific phenomena upon electrical field/current exposure. They result in distinctive processing effects such as enhanced powder sintering (in minutes as compared with hours in conventional sintering), synthesis of ceramic compounds (e.g., FeCr<sub>2</sub>S<sub>4</sub> synthesized in <1h at 950 C as compared to 5 days for conventional reaction sintering) or achieving some unique properties (e. g, transparency in usually opaque optical materials). Our recent work has been focused on FAST fundamentals and applications, with emphasis on sintering atmosphere, reaction and diffusion, pulsing effects, and near net shaping.

11:40 AM

**(SINTER-063-2008) Direct Comparison between Hot Pressing and Field Assisted Sintering of Oxide Powders**

J. Langer\*, TU Darmstadt, Germany; M. J. Hoffmann, Institute of Ceramics in Mechanical Engineering, Germany; O. Guillon, TU Darmstadt, Germany

This study aims at comparing of hot pressing and electric field assisted sintering of oxides nanopowders with different electrical properties and grain sizes. An alumina powder is used as an electrically insulating, zinc oxide as a semi-conducting and yttrium stabilized zirconia as an ion conducting nanopowder. Processing parameters are kept identical for both methods: heating rate, dwell time, applied pressure, atmosphere and sample geometry. Temperature is measured locally to assess temperature homogeneity in the sample. Densifica-

tion behavior is investigated by determining shrinkage rates as a function of temperature and mechanical load, densification mechanisms and their activation energy. Microstructure evolution is characterized by measuring pore size/orientation, grain size/shape as a function of density and location in the specimens.

**12:00 PM**

**(SINTER-064-2008) Experimental Evidence for the Current Effect during Pulsed Electric Current Sintering**

O. Van der Biest\*, K. Vanmeensel, K.U.Leuven, Belgium; A. Laptev, Donbass State Engineering Academy, Ukraine; S. Huang, L. Staverescu, J. Vleugels, K.U.Leuven, Belgium

Pulsed electric current sintering (PECS), also known as Field Assisted Sintering Technology (FAST) or Spark Plasma Sintering (SPS), employs a high pulsed DC current to intensify sintering. The use of a high electrical current provides, besides technological advantages such as high heating rates and shorter processing times, additional benefits such as the intensification of diffusion and enhanced chemical reactivity. This contribution will highlight the advantages of using a pulsed current with respect to powder compact densification behaviour and material synthesis, resulting in often new materials with improved properties, especially in case of electrically conductive materials. Practical examples of the sintering behaviour of Y-ZrO<sub>2</sub> based electrically conductive composites and carbide composites will be shown. The observed phenomena will be related to the temperature and current density distributions during the PECS process.

## Modeling of Sintering at Multiple Scales

### Modeling III

Room: Scripts I

**9:20 AM**

**(SINTER-065-2008) Simulation of Sintering: From Grain Dimensions to Complex Parts (Invited)**

T. Kraft\*, A. Wonisch, I. Schmidt, H. Riedel, Fraunhofer IWM, Germany

First possibilities of the discrete element method are presented. This method is especially suited to study the initial stage of sintering where rearrangement is active. The simulation scheme is based on a random aggregate of particles and takes mesoscopic properties like particle sizes, particle distribution, rotation and rearrangement into account. Appropriate pair forces between particles have been derived to simulate sintering. Secondly, current developments in modeling geometrically complex structures are presented. One application deals with sintering of ceramic multilayer circuits based on LTCCs. It is demonstrated that with modern computers the sintering process can be simulated with resolutions down to the individual circuit path width for a singularized circuit. However, many of these circuits are usually sintered together before singulation. Since the simulation of these multi circuit systems with the necessary resolution is beyond current possibilities, a homogenization method has been developed.

**10:00 AM**

**(SINTER-066-2008) Verification, Performance, and Validation of a Modified SOVS Continuum Constitutive Model in a Nonlinear Large-Deformation Finite Element Code**

J. G. Arguello\*, Sandia National Laboratories, USA

The continuum theory of sintering embodied in the constitutive description of Skorohod & Olevsky can be combined with results from mesostructure evolution simulations to model shrinkage and deformation of ceramics. The continuum portion is based on a finite element formulation that allows 3D components to be modeled using SNL's nonlinear large-deformation FE code, JAS3D. This tool provides a capability to model sintering of complex 3D components. Recent modifications to the model which incorporated a more physics-based Arrhenius-type viscosity function than the function in the original model, dictated that the suite of V&V problems, previously developed, be exercised anew on the modified model. The verification and performance of

the most-current version of the implemented continuum sintering constitutive model will be presented and discussed, as will the validation of the model using experimental results from laboratory experiments.

**10:40 AM**

**(SINTER-067-2008) Effect of a Substrate on the Microstructure of Thick Films**

C. L. Martin\*, INP Grenoble, France; R. K. Bordia, University of Washington, USA

Sintering of thick films on a dense substrate is an important process for a variety of applications: electronic packaging, sensors, and protective coatings. The presence of a substrate is of great consequence on the microstructure of the constrained sintered films. It has been experimentally observed that they develop an anisotropic microstructure with the pores oriented along the axis normal to the substrate during sintering. We use Discrete Element Method (DEM) simulations to study quantitatively such anisotropy. We model particles as spheres interacting through sintering forces both with other particles and with the substrate. Additionally, tangential viscous forces account for the drag of the substrate on the particles. Our simulations show that anisotropy develops along the thickness of the film. Using different thicknesses, we confirm that the microstructure is more porous close to the substrate. Also, pores that are close to the substrate have their long axis mostly oriented parallel to the substrate.

**11:00 AM**

**(SINTER-068-2008) Modelling Constrained Sintering and Cracking**

J. Pan\*, R. Huang, Leicester University, United Kingdom

Constrained sintering is used to fabricate multi-layered ceramics, micro-electronic films and protective coatings. Powder materials are applied to a substrate using techniques such as inkjet printing, sol-gel processing or dip coating. During heating the porous layers attempt to shrink, which is however constrained by the substrate and adjacent layers, giving rise to stresses and causing cracking. There are two major challenges in modeling the constrained shrinking and cracking: (a) the experimental difficulty in obtaining the constitutive data for the porous materials and (b) the numerical difficulty in dealing with multiple cracking. In this talk a modeling strategy to overcome these difficulties will be presented. A so called Material Point Method is combined with a reduced formulation for the finite element method which has the advantage of not requiring the full constitutive law and can deal with multiple cracks conveniently. A series of numerical case studies will be presented.

**11:20 AM**

**(SINTER-069-2008) Direct Multiscale Modeling of Sintering**

A. Maximenko\*, A. Kuzmov, Institute for Problems of Materials Science, Ukraine; E. A. Olevsky, San Diego State University, USA

Traditional continuum modeling of sintering considers porosity as the only structural parameter of material. In that case porosity evolution equation follows from the matter conservation law. In some important cases the only structural parameter is not enough for the prediction of macroscopic shrinkage. Introduction of additional structural parameters necessitates formulation of a priori unknown evolution equations for them. A new multiscale numerical approach for the modeling of sintering based on the parallel monitoring of micro- and macro-scale evolutions has been proposed. The internal structure of the porous material is described by the set of unit cells defined in the special control points of specimens. Numerical examples demonstrate a high level of macroscopic inhomogeneity of porous structure evolution during constrained sintering of porous bars and multilayer specimens. Results of the modeling have been compared with prediction of the Skorokhod-Olevsky continuum sintering model.

11:40 AM

**(SINTER-070-2008) Variations in Sintering Stress and Viscosity with Mixing Ratio of Metal/Ceramic Powders**

K. Shinagawa\*, Faculty of Engineering, Kagawa University, Japan

Distortions or cracking in metal/ceramic graded powder compacts during sintering may be caused by the variation in densification behavior of the layers with different mixing ratios. Considering the analysis of macroscopic internal stresses in the layered structures, the sintering behavior should be characterized by the driving force and the viscous resistance. In the present study, the sintering stress as well as the viscosity of the powder mixtures with metal/ceramic ratio ranging from 0/100 to 100/0 is estimated by using a continuum model. The calculated results are compared with the experimental data obtained from sinter-forging tests for Ni/Al<sub>2</sub>O<sub>3</sub> system. The mean-field micromechanics model can explain the experimental data when the powder mixtures consist of agglomerates.

12:00 PM

**(SINTER-071-2008) Anticipating Shrinkage and Distortion during Sintering of Complex Ceramic Parts Manufactured by Stereolithography**

J. Erauw\*, C. Delmotte, F. Petit, F. Cambier, Belgian Ceramic Research Centre, Belgium

This paper evaluates finite element simulation as a potential retro-engineering tool at the green body design stage in the case of alumina parts manufactured by stereolithography. A finite element simulation code has been used, in which the behaviour of the material has been described by a classical two parameters constitutive model. The parameters of the model have been extracted from dilatometry experiments combined with MSC analysis. The prediction of the numerical simulation for model geometries produced by stereolithography has then been validated using in-situ video imaging of the parts dimensional changes during sintering. Good agreement between numerical simulation and experimental data is obtained although further improvements of the constitutive model appear necessary to encompass the anisotropic character of the observed shrinkage resulting from the layer-by-layer deposition process.

**Sintering of Nano-Structured Materials****Nano-Structured Materials III**

Room: Scripts II

9:20 AM

**(SINTER-072-2008) Densification and Deformation of Amorphous Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>-Y<sub>2</sub>O<sub>3</sub> Derived from Precursors (Invited)**

V. Jayaram\*, Indian Institute of Science, India

Powders of Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>-Y<sub>2</sub>O<sub>3</sub> can be synthesized in the amorphous state over a wide range of compositions by the decomposition of inorganic precursors derived from spray pyrolysis or co-precipitation. It is found that these materials can be densified in the amorphous state by hot pressing at moderate temperatures and pressures. The densification response is more akin to that of a metal with a well defined flow stress and exhibits little creep. Mechanical testing of densified pellets reveal that deformation at 600-700° C takes place by means of shear bands well below the crystallization temperature at stresses ~ few hundred MPa and results in plastic strains of ~ 10% or more. These results will be discussed in the context of the anomalously low density of the amorphous phase (~ 2/3rd of the crystalline phases) and its low elastic modulus and hardness (100 and 3 GPa vis-à-vis 300 and 18-20 GPa for the crystalline phases).

10:00 AM

**(SINTER-073-2008) MoSi<sub>2</sub> Formation Mechanisms during a Spark Plasma Synthesis from Mechanically Activated Powder Mixture**

F. Bernard\*, G. Cabouro, S. Chevalier, Institut Carnot de Bourgogne, France; E. Gaffet, NRG, UMR 5060 CNRS / Université de Technologie de Belfort-Montbéliard, France; Y. Grin, Max-Planck-Institut für Chemische Physik fester Stoffe, Germany

Dense MoSi<sub>2</sub> with a nano-organized microstructure was synthesized by mechanical activation. In order to determine the MoSi<sub>2</sub> formation mechanisms, it was essential to develop original experiments, such as the Time Resolved X-ray Diffraction coupled to infrared thermography to monitor "in-situ" structural and thermal evolutions during the current-activated reactive sintering process. Such investigations allow a new interpretation of MoSi<sub>2</sub> formation mechanisms. In addition, an investigation of the influence of SPS processing parameters (temperature, heating rate, mechanical pressure and holding time) on the chemical composition and the microstructure characteristics has been performed. The present work shows also that the so-obtained materials present better oxidation resistance in comparison to a dense microstructured MoSi<sub>2</sub>, due to the silica scale formation under high temperature oxidizing atmosphere. The most interesting results are obtained at "low" temperature (673-873 K).

10:40 AM

**(SINTER-074-2008) Tribological Performance of Nano Alumina Composites**

A. Sivanandam\*, IIT Delhi, India; R. Janakarajan, IIT Kanpur, India

This work primarily concerns with manufacturing of alumina and alumina-zirconia ceramic composite using nano powders and characterization of the manufactured specimens. The procured nano powders were analyzed for their shape and size through laser spectrometer and SEM. The compacts of nano alumina and nano alumina - zirconia composites were sintered. Sintered specimens were evaluated and studied through hardness testing, SEM and XRD analysis. Sub micron sized grains of sintered specimens of alumina and alumina-zirconia composites, revealed the importance of nano powders. Such nano alumina and nano alumina composites are finding wear resistance and cutting tool applications and hence the wear performances of alumina and alumina-zirconia composites were evaluated through pin on disc wear testing machine. It was found that alumina-zirconia composites exhibit lower wear resistance when compared with nano alumina.

11:00 AM

**(SINTER-075-2008) Thermal Stability Studies of Gold Nanoparticle Arrays**

R. Tiruvalam\*, P. Clasen, R. Ristau, C. J. Kiely, M. P. Harmer, Lehigh University, USA

In comparison to the sintering of micron-scale particles, little is known about the fundamentals of sintering ligand stabilized nanoparticles. This is a complex regime where nanoparticle melting points are size-dependant, diffusion length scales are much reduced and particle surfaces are coated. There are instances where the controllable solid-state sintering of self-assembled nanoparticle arrays is desirable (e.g. sintering of strings of particles into nanowires). In this study, in-situ TEM is used to elucidate how parameters such as particle size, ligand & substrate identity, and heating rate/time can affect the sintering mechanism (i.e. coarsening versus densification) and sintering kinetics of ligand stabilized Au nanoparticle arrays. We will demonstrate that Au particles below 3nm are prone to sintering even at room temperature over extended time periods, which has serious consequences for the envisioned shelf-life of any future self-assembled nanoscale devices constructed from Au nanoparticles of this scale.

11:20 AM

**(SINTER-076-2008) Thin Film Sintering of Zinc Oxide**

M. Koenig\*, Technische Universitaet Darmstadt, Germany

Zinc oxide as thin functional film has come into the focus of interest due to its low cost and competitive properties. As an alternative to complex vacuum methods, thin films in a thickness regime of 50 - 200 nm were prepared by

spin coating from suspensions of nanocrystalline zinc oxide powder and sintered at temperatures up to 1000 °C. Pore size was examined by nitrogen adsorption and Hg porosimetry, imaging was carried out using high resolution SEM and AFM and particle sizes were determined by XRD. Object of this research is the attainment of a high electrical conductivity at low sintering temperature. As the atomic and electronic structure of the grain boundary as well as the grain-boundary area has to be considered, an additional technique was applied. Thus, Young's modulus was determined by nanoindentation to quantify the grain boundary area and correlated to the electrical conductivity determined by four-point probe measurements.

**11:40 AM**

### **(SINTER-077-2008) In Situ Formation and Densification of TiNi Shape Memory Alloy by Spark Plasma Sintering (Invited)**

D. C. Linch\*, Metal Processing Systems, USA; J. Meen, University of Houston, USA; B. G. Eranezhuth, Clarkson Aerospace, USA

Equiatomic or near equiatomic TiNi phase has CsCl type (B2) structure and exhibits shape memory effect. The martensitic and reverse transformation temperatures of these alloys in nanocrystalline form are highly sensitive to the alloy stoichiometry, the presence of phases other than TiNi, and the grain size. In the present study nanocrystalline TiNi shape memory alloy has been produced by mechanical alloying of titanium hydride with nickel, followed by spark plasma sintering. During mechanical milling the pre-cursor components mix at nanoscale. Subsequent processing under the conditions of high pressure, temperature, and plasma formation at the interface of particles results in abnormal interdiffusion to form the intermetallic compound. Results of investigations on the alloy formation in terms of processing parameters, alloy chemistry, and grain size will be presented.

## Wednesday, November 19, 2008

### **Evolution and Control of Microstructure during Sintering Processes**

#### **Microstructure IV**

Room: Ballroom D

**8:20 AM**

#### **(SINTER-078-2008) Development of Anisotropy during Zero Shrinkage Experiments (Invited)**

O. Guillon\*, Technische Universität Darmstadt, Germany

During the cofiring of multilayered ceramics in particular in microelectronics, zero radial shrinkage is necessary to keep tight geometrical tolerances and facilitate the subsequent mounting of components. This can be achieved by applying a compressive mechanical load (sinter-forging) or by using a constraining layer (acting as a substrate). Role of material (alumina and LTCC glass ceramic composite), effect of film thickness will be highlighted in the presentation. In both cases, anisotropy develops with densification, as evidenced by microstructural characterization (pore/grain size and orientation). This may be the reason why isotropic continuum mechanical modelling relying on viscous properties (free strain rate, uniaxial viscosity and viscous Poisson's ratio) measured on bulk specimens is not able to predict quantitatively zero shrinkage experiments. Development of anisotropic models is thus required, but determination of anisotropic parameters is experimentally challenging.

**9:00 AM**

#### **(SINTER-079-2008) Microstructure Evolution in Zirconia Nanoparticle Compacts during Pressureless Sintering**

M. Trunec\*, K. Maca, Brno University of Technology, Czech Republic

The present work investigates the requirements on microstructure of powder compacts that are necessary to obtain dense zirconia bodies with nanocrystalline structure by pressureless sintering. Four nanometer-sized zirconia powders were used for the preparation of nanoparticle compacts by different compaction techniques. The size of pores in ceramic green bodies and their

evolution during sintering were correlated with the characteristics of individual nanopowders and with the sintering behavior of powder compacts. Dense zirconia ceramics (>99% t.d.) with a nanocrystalline structure could be prepared only with both small pores (<10 nm) and homogeneous structure in powder compacts. Inhomogeneous structure in a powder compact, even with small pores, prevented the low-temperature densification due to local shrinkage and subsequent pore growth. Pore size evolution during sintering was identified as a suitable tool for characterization of powder compacts homogeneity.

**9:20 AM**

#### **(SINTER-080-2008) Reduction of Intra Crystalline Porosity in Ba<sub>0.5</sub>Sr<sub>0.5</sub>Co<sub>0.8</sub>Fe<sub>0.2</sub>O<sub>3-x</sub> Perovskite Ceramic**

M. Zwick\*, E. M. Pfaff, Aachen University, Germany

Perovskite ceramics with mixed ionic/electronic conductivity are in focus as oxygen transport membranes. During sintering cubic structure shows an abnormal grain growth resulting in high intra crystalline porosity. In this work sintering methods were investigated to reduce porosity. Heating rate and dwelling time as well as atmosphere were varied. Resulting microstructures were analyzed by SEM. Because of high sintering activity > 1100°C the heating rate has to be limited. Dwelling time reduces the intra crystalline pores near grain boundaries. For this type of MIEC ceramic it is known that oxygen vacancies decrease with oxygen partial pressure and reduce the mobility and diffusion of oxygen ions. This was used to reduce grain growth rate. Additionally high oxygen partial pressure inside pores can eliminate these pores by a better bulk diffusion compared to nitrogen. Influence of pore size distributions on mechanical properties was characterized by 4-point bending tests.

**9:40 AM**

#### **(SINTER-081-2008) Improved Dye-Sensitized Solar Cell Components by Uniaxial Freeze Drying and Sintering**

E. Khaleghi\*, E. A. Olevsky, SDSU, USA; M. A. Meyers, UCSD, USA

Many methods are used to produce the titanium dioxide surface (a crucial component) of dye-sensitized solar cells (DSSC), including electrophoretic deposition (EPD), screen printing, and doctor blade deposition. Each of the methods has its advantages and disadvantages, but none is close to the "ideal" surface morphology, which has a large surface area for dye attachment, but does not impede electron flow. We use uniaxial freeze drying, and sintering, to create microstructures of unique porosity and pore structure. The pore structure created from this technique has many applications where a high porosity and controlled microstructure are necessary, such as improving the performance of DSSCs, or the creation of nanorods and nanowires inside the channels. A technique has been developed, utilizing freeze drying, to produce a superior surface morphology for DSSCs that increases surface area for dye attachment, and shows a significant performance increase over traditional deposition methods.

**10:20 AM**

#### **(SINTER-082-2008) Modification of Mass Transport during Sintering Induced by Thermal Gradient**

S. Saunier\*, F. Valdivieso, P. Goeuriot, Ecole des Mines de Saint-Etienne, France

Because of the new sintering processes developments, thermal cycles become shorter. But it has been noticed that the sintering cycle time decrease can conduct to thermal gradients in the sample. Until now, the effects of such gradients are not well known. Thus, the aim of this study is to contribute to understand phenomena induced by gradients applied during the initial stage of sintering. We will observe the consequences on this stage but also on the further densification. Two important results are brought out: - For pure alpha-alumina : the comparison between conventional treatments and treatments under thermal gradients has shown that a gradient modifies the specific surface area drop and then accelerates the further densification. - For alpha-alumina containing impurities : The experiments have shown that a gradient can modify the impurities' dissolution and change the mass transport. Finally the grain growth can be favoured at the expense of the densification.

## Novel Sintering Processes; Field-Assisted Sintering Techniques

### Novel Sintering Processes III

Room: Ballroom E

**8:20 AM**

#### **(SINTER-083-2008) Full Densification of SiC without any Additives by SPS**

M. Ohyanagi\*, N. Toyofuku, Y. Kodera, Ryukoku University, Japan; Z. Munir, University of California, Davis, USA

Silicon carbide with stacking disordered structure was synthesized by high energy ball milling under Ar gas atmosphere. The silicon carbide was fully consolidated without any additives by spark plasma sintering. Simultaneous stacking disordered-order transformation and the consolidation made the bulk density higher than 99%. The silicon carbide formation during the high energy ball milling was characterized by FT-IR, <sup>29</sup>Si-NMR and TEM. The role of stacking disordered-order transformation on the consolidation was discussed with structural analysis by X-ray diffraction, Raman spectroscopy and both of <sup>13</sup>C- and <sup>29</sup>Si-NMR. The electro conductivity and surface roughness of high dense silicon carbide bulk was described.

**8:40 AM**

#### **(SINTER-084-2008) Influence of Electric Fields During the Field Assisted Sintering Technique (FAST)**

M. Müller\*, R. Clasen, Saarland University, Germany

With the field assisted sintering technique it is possible to reduce sintering temperature and grain growth significantly. Therefore this method is of major interest for sintering compacts of nanopowders. Although this method was proven for a lot of materials, the mechanism is not yet completely understood. In the present study a modified experimental setup was used to separate the electric currents for heating and passing through the sample. The influence of temperature, heating rate, pressure, holding time and electric current was measured on pressed samples of nanosized titania powders. The microstructure of the specimens after sintering was analyzed by SEM. The heating rate and the electric field are the dominant factors on the emerging microstructure. They favoured neck formation and growth of single grains having a diameter more than 500 nm, which grew in a matrix having a mean diameter of 120 nm. It is concluded that the electric field activates the surface of powder particles.

**9:00 AM**

#### **(SINTER-085-2008) Influence of Electrical Fields on Grain Growth in Ceramics (Invited)**

S. Ghosh, A. Chokshi, R. Raj\*, University of Colorado, USA

Electrical fields have been shown to reduce the flow stress for creep in zirconia and alumina (Conrad, H, et al.), and conversely, the application of normal stress has been shown to produce an electrical potential at temperatures where interfacial diffusion is viable (Pannikatt et al.). A theoretical model on the influence of interfacial space charge on self-diffusion has been developed (Jannik et al.). Experiments that are likely to show a significant influence of electrical fields on sintering behavior are pending. In this paper we show that the application of electrical fields can significantly retard the rate of grain growth in zirconia. The extent of retardation appears to be nearly proportional to the applied field: electrical fields of approximately 100 V cm<sup>-1</sup> can reduce the grain growth by a factor or two. Possible mechanisms underlying this new phenomenon will be discussed. The retardation in grain growth is likely to have a strong influence on the sintering process.

**9:40 AM**

#### **(SINTER-086-2008) Simultaneous Synthesis and Densification of Magnesium Aluminate Spinel by SPS**

M. P. Dariel\*, S. Maier, N. Frage, Ben-Gurion University, Israel

Magnesium-aluminate spinel is a promising transparent armor material with excellent mechanical properties and a wide transparency range. Transparent

spinel is currently produced by hot pressing followed by hot isostatic pressing. Spark Plasma Sintering (SPS) is a relatively new consolidation technique that relies on the simultaneous application of elevated temperature, generated by a high current flow that passes through the compacted powder, and axial pressure. In an attempt to simplify the production route of spinel for various applications, polycrystalline magnesium-aluminate spinel was fabricated from mixture of magnesium oxide and aluminum oxide in a 1:1 molar ratio by means of the spark plasma sintering technique. Rapid heating rate of 100°C/min with holding at a maximum temperature (1600°C) for one hour allows obtaining a fully dense single phase composites with homogeneous structure. The effect of sintering additives on the densification and synthesis will be discussed.

**10:20 AM**

#### **(SINTER-087-2008) Sintering under Electrical Current: Micro and Macro Considerations (Invited)**

B. McWilliams, A. Zavaliangos\*, Drexel University, USA

Particle level and macroscopic level models for electric current assisted sintering techniques are presented. At the macroscopic level a fully coupled thermal-electric-sintering finite element model. With this model it is shown that changes in local resistance due to densification can greatly impact the distribution of thermoelectric gradients in the system, and the homogeneity of complex shape sintered parts. At the particle level, we offer a 2D multiparticle model that sheds light in the electrical current distribution at the contacts as well as the temperature distribution across a collection of particles. The implications of the results for the potential mechanisms active in electrical current assisted sintering will be reviewed.

**11:00 AM**

#### **(SINTER-088-2008) Spark Plasma Sintering of Conductive and Nonconductive Composites**

M. Herrmann\*, J. Räthel, W. Beckert, IKTS, Germany

The densification behavior of conducting and non conducting composites during spark plasma sintering was investigated. For the understanding of the densification shrinkage, curves, microstructure evaluations (electrical properties and phase transformation) and FEM modeling were used. Electrically conductive composites with a resistivity close to the percolation threshold show a complex sintering behavior and temperature distribution in the samples. The effect of direct current through the samples is evaluated using isolated and conducting punches. The differences in the formation of the microstructure are discussed.

**11:20 AM**

#### **(SINTER-089-2008) Fe/Cr-Al<sub>2</sub>O<sub>3</sub> Ceramic Matrix Nanocomposites Sintered by SPS**

G. Julien\*, CIRIMAT, France; E. Claude, CNRS, France; W. Alicia, P. Alain, CIRIMAT, France; C. Geoffroy, CNRS, France; U. Guralp, P. Jean-yves, B. Jean-denis, D. Jean, ENIT, France; F. Joel, P. Yann, SCT, France; L. Christophe, CIRIMAT, France

Fe/Cr-Al<sub>2</sub>O<sub>3</sub> ceramic matrix nanocomposites sintered by hot-pressing (HP) show both higher fracture strength and toughness than alumina [1]. This was attributed to the presence of Fe/Cr nanoparticles located within the Al<sub>2</sub>O<sub>3</sub> matrix grains [2]. To achieve this type of dense nanocomposites, it is imperative to use a starting composite powder already containing the Fe/Cr intragranular nanoparticles. Such powders [3-4] are obtained by selective reduction in pure H<sub>2</sub> (T>1050°C) of an oxide solid solution, α-Al<sub>2</sub>-2x-2yFe<sub>2</sub>xCr<sub>2</sub>yO<sub>3</sub>. Spark Plasma Sintering (SPS) allows to obtain highly densified materials with better control of their microstructure at lower temperatures and shorter dwell times than HP [5-6]. However, initial sintering revealed the formation of a FeAl<sub>2</sub>O<sub>4</sub>-type phase to the detriment of the metal nanoparticles. To obviate this, the effect of the SPS parameters (current, pulses) was investigated. The results on composition, microstructure, fracture strength and toughness of the materials will be reported.

11:40 AM

### (SINTER-090-2008) Sintering and Characterization of Telluride Materials Using Spark Plasma Sintering

J. E. Garay, J. Alaniz\*, UC Riverside, USA

Due to growing energy concerns, there has been a large increase in interest in the field of improving thermoelectric materials. Both Lanthanum Telluride and Lead Telluride have been recognized for their thermoelectric properties. We have used the Spark Plasma Sintering (SPS) technique as an efficient and effective method for densifying telluride powders/composites. We have explored different strategies for improving the thermoelectric figure of merit through second phase additions and varying processing parameters such as time, temperature, and pressure. Titania was used to decrease the thermal conductivity of the tellurides while carbon nanotubes (CNTs) were used as a way to maintain electrical conductivity and further decrease the thermal conductivity. The effect of processing parameters on the microstructure of these composites and their properties will be presented.

## Fundamental Aspects of Sintering

### Fundamentals I

Room: Scripts I

8:20 AM

### (SINTER-091-2008) Coarsening Laws in Sintering (Invited)

R. M. German\*, Mississippi State University, USA

Recent progress has shown good predictions for the grain size distribution in sintered material using standard statistical functions. If accurate time-dependent length scale laws are known, then reasonable microstructure predictions are possible. However, microstructure is not uniform and involves top-bottom gradients as well as evolving length scales. Many years ago reports showed differences in sintered compacts when examined for an effect of gravity. Even so, the majority of microstructure reports fail to disclose the image orientation with respect to gravity induced grain compression and pore buoyancy. Evidence shows there are statistically significant differences over relatively small distances in grain size, porosity, grain coordination number, neck size, and pore size. A few cases will be shown. Mathematical relations now exist to show how microstructure coarsening changes with respect to location inside a sintering body. Data from several parameters that change size during sintering will be used to illustrate the point.

9:00 AM

### (SINTER-092-2008) Critical Overview of Porosity Coarsening during Solid State Sintering

H. Exner\*, University of Technology, Darmstadt, Germany

Porosity is interconnected up to very high densities. The major feature during the densification stage is the coarsening of the continuous pore space. Coarsening of porosity during sintering has been observed in metals, ceramics and glasses. Thus, coarsening is an experimental fact, but the physical reasons are not entirely clear. On the other hand, monitoring and modelling of the growth of individual pores is relevant only at very high relative densities where the size of pores can be specified. Ways to characterize the geometry of the pore space in the lower range of densities are discussed with emphasis on stereological parameters. Recent and classical approaches, experimental findings with two dimensional model arrangements as well as computer simulations of formation and opening up of particle contacts, pore coarsening and particle re-arrangement are discussed.

9:20 AM

### (SINTER-093-2008) Anisotropy Shrinkage, Origin and Cure (Invited)

W. Cannon\*, Rutgers University, USA

Commercial powder particles are usually slightly anisotropic in shape. Under the shear conditions of tape casting particles align. For A16SG alumina the long axis aligns in the direction of casting and the plane of the platelet aligns parallel to the plane of the tape. The degree of alignment is dependent on the

shear strain rate. A lower shear rate is required to align the platelet in the tape plane than to align the long axis in the casting direction. Several image analysis methods were used to measure the alignment. Alignment was found to correlate with the anisotropy of sintering. The 2-D model based on alignment of elliptical particles was used to explain the anisotropy in both solid state and liquid phase sintering. These models also explain the decreasing anisotropy as the density increases. More importantly they predict that anisotropy in the solid state may be controlled by additives which change the ratio of grain boundary to surface diffusion and for liquid phase sintering by controlling the volume of liquid phase.

10:20 AM

### (SINTER-094-2008) Investigation of the Sintering of Heterogeneous Powder Systems by Synchrotron Microtomography and Discrete Element Simulation (Invited)

L. Olmos, T. Takahashi, C. L. Martin, Grenoble INP, France; M. Di Michiel, ESRF, France; D. Bouvard\*, D. Bellet, Grenoble INP, France

Collective particle behavior such as interparticle coordination and particle re-arrangement may play a significant role in the sintering of heterogeneous powder systems. Those phenomena have been investigated from both experiments – in situ X-ray microtomography – and modeling – discrete element simulation. In situ 3D images of sintering copper-based systems – copper particle with a size range up to 63  $\mu\text{m}$  including artificial pores or ceramic inclusions – have been obtained at the European Synchrotron Research Facilities with a resolution of 1.6  $\mu\text{m}$ . Quantitative analysis of these images provided valuable data on interparticle neck growth, coordination number variation and particle mobility. Meanwhile the sintering of the same systems has been simulated with dp3D discrete element code. From this experimental and modeling information the importance of collective behavior on densification and microstructural evolution is assessed.

11:00 AM

### (SINTER-095-2008) Experimental and Model Hot Pressing of Spherical Polycrystalline Zirconia Particles

W. Cannon\*, Rutgers University, USA; C. Auechalanukul, King Mongkut's University of Technology Thonburi, Thailand; A. Cuitino, Rutgers University, USA

Spherical polycrystalline SZP Y-ZrO<sub>2</sub> particles 10 to 100 microns in diameter were prepared by sintering TOSOH spray dried agglomerates to full density at 1400 C for 2 h. Sintered contacts between these particles were broken by light milling. These powders were ideal for studying kinetics of creep controlled hot pressing where densification is independent of particle size. Several models were compared to experimental results. Important variables to fit in a model are initial density, particle coordination number and stress distribution within the particle. A finite element method model was able to capture the stress distribution within a particle and the model results fit the experimental results for densification rate vs. density quite well. Alternatively, the analytical model by Helle, Easterling and Ashby which estimated changing coordination number during sintering and initial density but not stress distribution, fit the experimental results even better at high density.

11:20 AM

### (SINTER-096-2008) Sintering Kinetics of Materials Containing Large Pores (Invited)

J. Pan\*, Leicester University, United Kingdom; A. Cocks, University of Oxford, United Kingdom; J. Rödel, Darmstadt University of Technology, Germany

It is commonly believed that a large pore does not shrink during sintering. Here "large" is defined by the number of grains surrounding a pore, which is known as the co-ordination number. A classical textbook theory predicts that a pore would shrink only if its co-ordination number is less than a critical value. It follows that grain-growth can be used as a means to eliminate large pores. In this talk, we will argue that the critical coordination number theory is misleading. Firstly the critical coordination number theory will be briefly reviewed. Secondly experimental and computer simulation evidences against the theory will be collected from previous works and presented. Thirdly it will be shown that the characteristic diffusion distance for a large pore to shrink is

the average grain-size, rather than the distance between neighbouring pores. Grain-growth is therefore always harmful to the elimination of the pores. Finally the inherent problems of using the critical coordination number theory will be discussed.

## Sintering of Electronic Materials

### Electronics I

Room: Scripts II

8:20 AM

#### (SINTER-097-2008) Characterization of the Anisotropic Sintering Behavior of Textured Lead-Free Piezoceramics (Invited)

C. DiAntonio\*, Sandia National Laboratories, USA

The investigation of lead-free piezoelectric ceramic compositions, particularly textured materials, has recently gained an increased level of interest due to the efforts to reduce lead based components. Lead-free, texturally modified, oriented ceramic compositions, exhibit highly anisotropic properties and behavior. This work deals with the fabrication of a perovskite-type lead-free polycrystalline ceramic through a template-induced texturing process using morphologically controlled platelets. The focus vehicle lies with the bismuth based layer-structured perovskites. As a result of the induced texture to the resulting microstructure and the use of templated grain growth processing, unique and anisotropic sintering behavior results for the bulk ceramic component. Efforts on characterizing the connection between textured processing and sintering behavior for textured compositions in the lead-free (Na<sub>1/2</sub>Bi<sub>1/2</sub>)TiO<sub>3</sub>-Bi<sub>4</sub>Ti<sub>3</sub>O<sub>12</sub>-BaTiO<sub>3</sub> ternary system will be presented.

9:00 AM

#### (SINTER-098-2008) Influence of Rare-Earth Additives (Er and Ho) on Fractal Microstructure Characteristics and Dielectric Properties of BaTiO<sub>3</sub>

V. Mitic\*, L. Kocic, V. Paunovic, D. Mancic, L. Zivkovic, Univeristy of Nis, Serbia

Doped BaTiO<sub>3</sub> ceramics is very interesting for its application as resistors with PTCR, multilayer ceramics capacitors, thermal sensors etc. The specimens of BaTiO<sub>3</sub> doped with 0.1 and 0.5 wt% of Er<sub>2</sub>O<sub>3</sub> or Ho<sub>2</sub>O<sub>3</sub> used for this investigation were prepared by the conventional solid state reaction. The specimens were sintered in temperature interval from 1320°C to 1380°C in an air atmosphere for 4 hours. The grain size and microstructure characteristics for various samples and their phase composition was carried out using a scanning electron microscope SEM equipped with EDS system. SEM analysis of Er/BaTiO<sub>3</sub> and Ho/BaTiO<sub>3</sub> doped ceramics showed that in samples doped with a low level of rare-earth ions, the grain size ranged from 10-60µm, while with the higher dopant concentration the abnormal grain growth is inhibited and the grain size ranged between 2-10µm.

9:20 AM

#### (SINTER-099-2008) Influence of Milling Condition on Sintering Behavior and Electrical Properties of BaTiO<sub>3</sub> Ceramics

S. Sohn\*, K. Park, M. Hong, S. Song, Y. Yoon, J. Hong, Y. Kim, K. Hur, Samsung Electro-Mechanics Co., Ltd., South Korea

The influence of the milling condition on sintering behavior and electrical properties of BaTiO<sub>3</sub> ceramics was investigated in the BaTiO<sub>3</sub>(BT)-Dy-Mg system with borosilicate glass as a sintering agent. As milling time increased, specific surface area(SSA) of the powder increased linearly, while sinterability and dielectric property reached at a maximum and then decreased with an increasing SSA. TEM observation and EDS analysis on each specimens quenched at 800-1100 °C indicate that dispersibility of the additives is deteriorated with an increasing milling time, which causes a decrease in sinterability and dielectric property of BaTiO<sub>3</sub>. These results were assumed to be due to the decrease in fluidity of liquid phase with an increasing SSA (or shortage of the amount of effective liquid phase for sintering of BaTiO<sub>3</sub>).

9:40 AM

#### (SINTER-100-2008) Effect of Sintering Parameters of Nano-Structured BaTiO<sub>3</sub> on the Microstructure and Dielectric Properties

M. N. Siddique\*, M. T. Chowdhury, M. F. Islam, Bangladesh University of Engineering and Technology, Bangladesh

The effect of sintering temperature and holding time of nano-structured BaTiO<sub>3</sub> (100 nm) on the microstructure and dielectric property was investigated in this study. The samples were made by powder compaction technique (150 MPa). The sintering temperature was varied in the range of 1225°C to 1275°C and holding time in the range of 2 to 6 hours. Samples those sintered at 1225°C for 6 hours were found to possess better density (98% of theoretical density), smaller grain size and better dielectric properties. At higher temperature porosity is reduced but grain growth occurs. Sintering at lower temperature for a prolonged time causes the pores to be reduced keeping the grains smaller.

10:20 AM

#### (SINTER-101-2008) Low Temperature Sintering of Zinc Titanate (ZnTiO<sub>3</sub>) Ceramics Prepared by Modified Sol-Gel Method

S. S. Indrakanti\*, S. B. Vadlamani, NIT Warangal, India

Low temperature sintering of zinc titanate ceramics suitable for LTCC applications were studied using a combined effect of sintering additives and solution methods. Fine zinc titanate powders were synthesized using inorganic sol-gel process using zinc nitrate and titanium oxide. The prepared powders were calcined at different temperatures between 400 and 800°C for 2 hours to get phase pure ZnTiO<sub>3</sub> as evidenced by XRD. The powders were compacted and sintered at different temperatures between 900 and 1200°C for 2 hours. In addition, CuO was also added to enhance the kinetics of sintering. The combined effect of additives and chemical synthesis allowed to lower the sintering temperature and obtain 98% density at 1000°C as against 1200°C for mixed oxide powders. The dielectric constant of CuO doped ZnO-TiO<sub>2</sub> system was found to be higher than the undoped ZnO-TiO<sub>2</sub> system. The highest dielectric constant of 22~24 was observed for 1% CuO sintered at 1000°C.

10:40 AM

#### (SINTER-102-2008) Grain Boundary Structure and Dielectric Properties of Nonstoichiometric Strontium Titanate Ceramics

A. M. Senos\*, L. Amaral, P. M. Vilarinho, A. Tkach, University of Aveiro, Portugal; I. M. Reaney, University of Sheffield, United Kingdom

Microwave dielectrics are widely used as resonators and filters in microwave communications, elements in microwave ablation therapy and substrates for antennas/oscillators. Some applications require high dielectric permittivity ( $\epsilon_r$ ) coupled with high quality factor (Qf). For applications which require  $\epsilon_r > 200$ , material's choice is limited with only a handful of possibilities. One such material is SrTiO<sub>3</sub> (ST), particularly attractive because of its high Qf (>2500 GHz). However, Qf is dependent on a great many factors and varies with stoichiometry and processing. In this work, microstructure and structure of the grain boundaries of ST ceramics ( $0.997 \leq \text{Sr}/\text{Ti} \leq 1.02$ ), sintered in different conditions, were analysed by SEM and TEM. Rough grain boundaries are commonly observed, but, depending on stoichiometry, additional boundary faceting is present. Chemical analysis was performed by EELS. Grain boundaries contribution to the dielectric response was assessed by impedance spectroscopy.

11:00 AM

#### (SINTER-103-2008) Step-like Magnetic Behavior of Nanocrystalline Iron Oxides

J. R. Morales\*, J. E. Garay, UC Riverside, USA

The ability to control particle size in powders and crystal size in bulk materials within the nanometer realm has shown both experimentally and theoretically to exhibit properties fundamentally different than their conventional counterparts. Here we present work on the processing of nanocrystalline iron oxides using the Current Activated Pressure Assisted Densification (CAPAD). We have produced fully dense bulk solids of iron oxide with grain sizes between 20 – 500 nm. Remarkable magnetic behavior is evidenced in significant

'step-like' increases in magnetization with increases of temperature from 2K to 350K. Our processing allows us to control the height of these steps as well as temperature/field dependent onsets of sharp increases in magnetization.

**11:20 AM**

### **(SINTER-104-2008) Sintering of Electronic Ceramics Using Microwave Assist Technology**

S. M. Allan\*, H. S. Shulman, M. L. Fall, I. Baranova, Ceralink Inc, USA

Microwave Assist Technology (MAT) has been used to sinter electronic and magnetic ceramic materials. MAT processing, which combines electric heating with microwave energy, has been found to produce new microstructures and properties. New forms of grain and grain boundary engineering are possible due to the rapid heating and microwave effects. Using MAT to sinter electroceramics can result in finer and more uniform grain sizes, more control of dopant diffusion, and less volatilization from oxides such as bismuth and lead. The dielectric properties of these materials are measured at microwave frequencies to predict heating behavior and microwave absorption. Computational modeling of MAT assists sintering process development. Several electroceramic systems have been sintered using MAT including various perovskites, ferrites, and zirconia. New devices for applications including capacitors, sensors, actuators, thermoelectrics, fuel cells, and sputtering targets may be possible with ceramics sintered using MAT.

**11:40 AM**

### **(SINTER-105-2008) Dielectric Properties of Aluminium Nitride Sintered by SPS**

Z. Valdez-Nava\*, S. Guillemet-Fritsch, CIRIMAT/LCMIE - UMR CNRS 5085, France; M. Ferrato, Boostec, France; S. Dinculescu, T. Lebey, LAPLACE, France

Aluminium nitride is used as a dielectric material for power electronics applications. The development of new sintering techniques such as Spark Plasma Sintering has permitted the sintering of this material. High temperature dielectric properties of AlN are little explored, since applications are often limited to temperatures around 125°C. In this work a comparison of the dielectric properties of conventionally and SPS sintered AlN is made. FEG-SEM and X-ray diffraction analysis are performed. Dielectric properties are determined by impedance analysis in the range of 0.1 Hz to 10 MHz up to temperatures of 350°C. An analysis of the complex impedance and phase angle is realised to evaluate the insulating properties of the materials. For SPS sintered AlN, the dielectric properties exhibit broader temperature stability compared to the conventionally sintered AlN. These changes in dielectric properties could be related to the different microstructures obtained after conventional sintering and SPS sintering

## **Sintering of Multi-Material and Multi-Layered Systems**

### **Multi-Material I**

Room: Ballroom D

**3:10 PM**

### **(SINTER-106-2008) Preparation of SiC Composite with Hexagonal and Turbostratic BN by MA-SPS Method**

Y. Koderu\*, H. Yamasaki, A. Mori, N. Toyofuku, M. Ohyanagi, Ryukoku University, Japan; Z. A. Munir, University of California, Davis, USA

Nano-metric SiC/BN was prepared through Mechanical Alloying (MA) from Si+C+BN powder and then consolidated by Spark Plasma Sintering (SPS) without any sintering aids. Two different MA atmospheres, Air and a N<sub>2</sub> with an oxygen concentration less than 1 ppm, were selected. In both cases, XRD results after MA revealed the absence of sharp peaks corresponding to SiC and BN. However, BN structure became hexagonal through the structural transformation during SPS, but the sample prepared under the inert gas remained a turbostratic structure. In a 50/50 SiC/BN ratio, the Vickers hardness of the reference sample, prepared by the conventional method with sintering aids, could not be measured due to high porosity. The sample prepared in our re-

search with a hexagonal and a turbostratic structure showed same hardness of approximately 3 GPa. However, the composite with a turbostratic structure had a bending strength of 330 MPa, which was higher than the composite with a hexagonal and 277 MPa.

**3:30 PM**

### **(SINTER-107-2008) Sinterability of Unidirectionally Structure-Controlled Hydroxyapatite/Zirconia Composites by Hot-Pressing and Their Mechanical Properties**

K. Yoshida\*, Tokyo Institute of Technology, Japan; M. Ando, Chiba Institute of Technology, Japan; T. Yano, Tokyo Institute of Technology, Japan; K. Hashimoto, Y. Toda, Chiba Institute of Technology, Japan

The authors have developed unidirectionally structure-controlled hydroxyapatite/zirconia composite by following process; Cylindrical hydroxyapatite (HAp) was prepared by extrusion process, and zirconia was coated on the cylindrical HAp. Zirconia-coated cylindrical HAp was unidirectionally aligned, and then pressureless-sintered to form a composite. In our previous study, we have reported that the structure-controlled HAp/zirconia composite fractured in non-brittle manner, and showed higher fracture energy than monolithic HAp ceramics. However, the composite contained open porosity of ~20%. In order to densify the composite and enhance its mechanical properties, we have tried to optimize the fabrication process of the composite and apply the hot-pressing. In this study, uniaxially structure-controlled HAp/zirconia composites were fabricated by hot-pressing, and their sinterability and mechanical properties were investigated.

**3:50 PM**

### **(SINTER-108-2008) Mechanical Properties of Optimized Crack-free Joining of Si<sub>3</sub>N<sub>4</sub> and Al<sub>2</sub>O<sub>3</sub> Using Polytypoidal Functional Gradient**

S. Ryu\*, C. S. Lee, J. Park, Hanyang University, South Korea; D. Riu, Korea Institute of Ceramic Engineering and Technic, South Korea; S. Ahn, Seoul National University, South Korea

Crack-free joining of Si<sub>3</sub>N<sub>4</sub> and Al<sub>2</sub>O<sub>3</sub> using 15 layers has been achieved by using SiAlON polytypoids as a functionally graded materials (FGM) bonding layer. Polytypoids in the Si<sub>3</sub>N<sub>4</sub>-Al<sub>2</sub>O<sub>3</sub> system provide a path to compatibility for such heterogeneous ceramics. For fabrication, green body was hot pressed at 38MPa while heating up to 1650°C, and it was cooled at 2°C/min to minimize residual stress during sintering. Flexural testing was conducted at 25 and 1000°C to determine the effect of temperature on the flexural strength of the optimized joint. The fracture surfaces were examined using scanning electron microscope (SEM). It was found that strength at high temperature didn't degrade as much compared to that at low temperature. Finally, transmission electron microscopy (TEM) was used to identify the polytypoids at the interfaces of different areas of the optimized joint.

**4:30 PM**

### **(SINTER-109-2008) Optimization of Density, Microstructure and Interface Region in a Co-Sintered (Steel/Cemented Carbide) Bi-Layered Material**

A. Thomazic\*, C. Pascal, J. Chaix, CNRS UMR 5266-Grenoble INP-UJF, France

Sintering of multi-layered materials implies specific pressing and sintering parameters to achieve good microstructure and interface cohesion. In a previous study, the sintering of a two-layered material, consisting of a tough layer (iron based material) and a hard one (cemented tungsten carbide) had been achieved by co-compaction at 600MPa and co-sintering at 1300°C for 10 min. Such a treatment leads to the formation of η phase (M<sub>6</sub>C) at the layers' interface. Lowering the sintering temperature avoids formation of this brittle phase but prevents densification. Five process parameters (composition, co-compaction pressure, heating rate, sintering temperature and duration) have been considered in a design of experiments (DOE) approach. Results from dilatometric studies, microstructure observations (amount of η phase), hardness and porosity measurements give guidelines to optimize process parameters and to obtain good properties for the bi-layered material.



4:50 PM

**(SINTER-110-2008) Two-Component Metal Injection Moulding and Co-Sintering of Multi-Material Micro Parts**

P. Imgrund\*, Fraunhofer IFAM, Germany

Micro metal injection moulding ( $\mu$ -MIM) was developed in recent years in order to make metallic materials available for a range of micromechanical, functional and medical applications. In this paper, two-component  $\mu$ -MIM (2C- $\mu$ -MIM) was used to manufacture bimetallic parts, consisting of non-magnetic 316L and ferromagnetic 17-4PH or pure iron. The main challenge for processing was to retain an intact material interface throughout all processing steps from injection moulding to co-sintering. The sintering behaviour was adapted by variation of powder and feedstock characteristics to minimize mismatch strain and stress. Quality of the interfaces regarding crack occurrence was significantly improved by adjusting sintering conditions and reducing the interface area. An index describing the suitability of the materials for co-sintering was derived. The interfaces were investigated concerning microstructure, diffusion and mechanical properties by SEM, linescans, micro hardness and micro tensile tests.

5:10 PM

**(SINTER-111-2008) Coupling between Sintering and Liquid Migration to Process W-Cu Functionally Graded Materials**

J. Missiaen, J. Raharijaona\*, INP Grenoble, France; R. Mitteau, CEA, France

The aim of this study is to analyse the mechanisms of liquid migration in the course of liquid phase sintering of W-Cu composition-graded components, in order to control the final composition profile. W-Cu materials with 10 and 20wt%Cu and with different W-particle sizes were processed starting with attritor-milled W-CuO powder mixtures reduced at 350°C. Preliminary dilatometric tests have shown that sintering of the W-Cu composite is controlled by solid state sintering of the submicron particle size W-skeleton. Analysis of liquid phase migration for different composition/granulometry associations indicates that the phenomenon depends on the differences in sinterability, on the available liquid and on open porosity in the layers beyond the melting point of copper. From these analyses, a way to control the gradient profile of W-Cu structure is proposed. This work will be used to process W-Cu FGM for fusion material applications, in particular plasma facing components.

5:30 PM

**(SINTER-112-2008) Influence of the Aluminium Content on the Sintering Mechanisms of (Ni-Al) Alloys**

N. Halem\*, Université Mouloud Mammeri, Algeria; M. Grosbras, Université de Poitiers, France

The goal of this work was to study the influence of an increase in the aluminium content, in a range thermal between 0,5 to 13% mass in aluminium, on the sintering behaviour of Ni-Al mixtures. The description and the interpretation of the observed phenomena were carried out starting from differential thermal analyses, dilatometric measurements, observations in X-ray diffraction and scanning electron microscopy. When the aluminium content remains lower than 8% the densification takes place by a process of traditional transitory liquid phase sintering with an evolution tending towards the formation of a solid solution of aluminium in nickel. In the case of the mixture with 13% of Al, the process is an extremely fast reactive sintering of the autocombustion type. The reaction is complete with instantaneous formation of the Ni<sub>3</sub>Al phase. As it is often the case with reactive systems, the materials obtained are characterized by the presence of a considerable residual porosity which depends on the aluminium content.

**Novel Sintering Processes; Field-Assisted Sintering Techniques****Novel Sintering Processes IV**

Room: Ballroom E

3:10 PM

**(SINTER-113-2008) Sintering Polycrystalline Laser Host Materials with a Millimeter-wave Beam (Invited)**

A. W. Fliflet\*, M. K. Hornstein, S. H. Gold, M. A. Imam, Naval Research Laboratory, USA; R. W. Bruce, M. Kahn, Icarus Research Inc., USA

Millimeter-wave sintering of ceramic laser host materials has been under investigation at the Naval Research Laboratory (NRL) for high-energy laser (HEL) applications. Advantages of polycrystalline, compared to single-crystal laser host materials, include lower processing temperature, higher gain from higher dopant concentration, cheaper fabrication, and larger devices. The NRL materials processing facility features a 15 kW, CW, 83 GHz GYCOM gyrotron oscillator, which can generate a Gaussian beam between 1 W/cm<sup>2</sup> and 2 kW/cm<sup>2</sup> irradiance. The green compacts are placed in an open or closed crucible in a vacuum environment and are heated directly by the 83 GHz beam. Compacts of doped and undoped YAG and yttria, potential polycrystalline laser host materials, have been sintered at temperatures of 1600 to 1800°C. Up to 99% theoretical density has been achieved with grain sizes ranging from 20 to 100 microns. Translucency has been achieved and factors impacting optical quality are under investigation.

3:50 PM

**(SINTER-114-2008) Progress in Spark Plasma Sintering of Ceramic Nanocomposites**

A. V. Ragulya\*, Frantsevich Institute for Problems in Materials Science, Ukraine

Promising rapid rate consolidation technology is Spark Plasma Sintering. The SPS considered for nanocomposites in the system TiN-AlN, and reaction system TiN/TiB<sub>2</sub>. In both cases, the grain growth/densification competition depends on strength of current, pulses duration and porosity. If these parameters are optimal, the sintered nanocomposite demonstrates uniform microstructure and top level of properties. Some novel aspects of SPS in the nanosystems: electric percolation, undesirable coarsening of pores and grains, electric breakdown, local melting are considered in detail. The evidences of micro-discharging mechanism and local melting are provided. Theoretical explanations of these effects and competition between densification and grain growth are presented as well. Nanocomposites developed TiN/TiB<sub>2</sub>, TiN/Si<sub>3</sub>N<sub>4</sub>, TiN/AlN and other demonstrate competitive combination of mechanical properties. The prospective cutting tool material TiN/TiB<sub>2</sub> has hardness around 28 GPa and fracture toughness of 10.5 MPa m<sup>1/2</sup>.

4:30 PM

**(SINTER-115-2008) Densification Kinetics of Alumina Compacts Undergoing Field Assisted Sintering**

M. Demuyneck\*, Belgian Ceramic Research Centre, Belgium; K. Vanmeensel, KULeuven, Belgium; J. Erauw, Belgian Ceramic Research Centre, Belgium; O. Van der Biest, KULeuven, Belgium; F. Cambier, Belgian Ceramic Research Centre, Belgium

Field assisted sintering (FAST), also known as spark plasma sintering or pulsed electric current sintering has attracted a lot of interest in recent years owing to its ability to enable the densification of a broad range of materials in a very short processing time. In the present study, the densification kinetics of commercial alumina powders submitted to field assisted sintering has been investigated. In order to get an insight into the benefits of FAST, the observed kinetics has been compared with that obtained using "conventional" hot pressing. In both cases, the influence of the initial powder grain size and of sintering parameters such as heating rate, dwell temperature, holding time and applied pressure on the overall densification behaviour and resulting microstructure (homogeneity, grain size ...) of the compacts as assessed by SEM

will be reported together with the respective calculated sintering activation energy.

### 4:50 PM

#### (SINTER-116-2008) Synthesis and Characterization of ZrB<sub>2</sub>-SiC Composites Produced by Spark Plasma Sintering (SPS)

I. Akin\*, F. Cinar Sahin, O. Yucel, Istanbul Technical University, Turkey; T. Goto, Tohoku University, Japan; G. Goller, Istanbul Technical University, Turkey

The ZrB<sub>2</sub>-SiC composites were prepared by the spark plasma sintering (SPS) technique. The SPS process was carried out at different sintering temperatures (1800C-2100C) for 3-5 minutes with a heating rate of 100C/min in vacuum and a uniaxial pressure of about 20 MPa was applied during the entire process. Densities of the composites were determined by the Archimedes method and 99.99% relative density was obtained for the 50ZrB<sub>2</sub>-50SiC (wt%) composite that sintered at 2100C for 3 minutes. The hardness of the composites was calculated as 22 to 30 GPa at the loads of 0.8 to 1.96 N and the fracture toughness (KIC) was calculated from a half-length of crack formed around corners of indentation and the obtained results were in the range of 3.50 to 5.41 MPa.m<sup>1/2</sup> at the loads of 2.94 to 3.92 N.

### 5:10 PM

#### (SINTER-117-2008) Sintering of Nanoscale Tungsten Powder Produced by Electrical Explosion Process

J. Kim\*, University of Ulsan, South Korea; Y. Kim, Hanyang University, South Korea; S. Oh, Seoul National University of Technology, South Korea; Y. Kwon, J. Kim, J. Ryu, University of Ulsan, South Korea

Nanoscale tungsten powder was produced by Electrical Explosion Process. Oxide passivation layer was removed by a reduction treatment. Prepared nanoscale tungsten powder was sintered by pressureless sintering and spark-plasma sintering, respectively. Shrinkage, sintered density and densification rate were measured. Microstructure changes during densification process were observed. For comparison the same sintering experiments were carried out for the microscale tungsten powder. The effect of oxygen content on the sintering behavior was confirmed, showing a different mechanism. From the sintering results for the powder compacts with controlled oxygen content the possible sintering mechanisms were obtained and discussed. The effect of tungsten powder size on the sintering behavior was also given.

### 5:30 PM

#### (SINTER-118-2008) The Electro-Discharge Compaction of Powder Tungsten Carbide - Cobalt - Diamond Composite Material

E. G. Grigoryev\*, A. V. Rosliakov, Moscow Engineering Physics Institute, Russian Federation

The manufacturing of high strength structure of powder tungsten carbide - cobalt - diamond composite material is investigated and optimal operating parameters are defined. The structure of tungsten carbide - cobalt - diamond composite material reaches top strength at certain magnitudes of applied pressure and high voltage electrical discharge parameters. We studied densification process of powder material during electro-discharge compaction by means of high-velocity filming. Pulse current parameters were measured by Rogovsky coil. The temperature evolution during electro-discharge compaction process was measured by means of thermocouple method. We have installed that the powder densification process has wave nature in electro-discharge compaction. We defined wave front velocity of densification process and pressure amplitude in wave front subject to parameters of electro-discharge compaction.

## Fundamental Aspects of Sintering

### Fundamentals II

Room: Scripts I

### 3:10 PM

#### (SINTER-119-2008) Process Understanding and Control Using the Master Sintering Curve (Invited)

K. Ewsuk\*, T. Hinklin, C. DiAntonio, Sandia National Laboratories, USA; M. Reiterer, Medtronic, Inc., USA; I. Nettleship, University of Pittsburgh, USA

The Master Sintering Curve (MSC) is a powerful tool with practical application to improve process control and advance processing science. The MSC has been applied to predict and control sintered density in systems that density by solid-state, liquid phase, or viscous sintering, in compacts comprised of nano or micro-scale powders, and in single-phase or composite systems. It also has application as a materials/process quality control tool. The MSC also allows us to link powder processing, microstructure, and properties, and provides insight into microstructure evolution during sintering. We will review our work to apply the MSC to predict and control densification, microstructure, and microstructure evolution during sintering, and to better understand powder processing and sintering science. This work was supported by the US Dept. of Energy (DOE) under contract DE-AC04-94AL85000 to Sandia National Labs. Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed-Martin company, for the USDOE.

### 3:50 PM

#### (SINTER-120-2008) New Master Sintering Curve Theory for Multiple Stage-Sintering

D. Hiratsuka\*, J. Tatami, T. Wakihara, K. Komeya, T. Meguro, Yokohama National University, Japan

In order to design a property of ceramics, to control sintering behavior is important. We can control a sintering behavior by using of master sintering curve (MSC) theory, however, the theory consists of combined stage sintering model with a scaling factor  $\Gamma$ . To control sintering more precisely, it is important to reflect sintering stage. In this study, we proposed a new MSC theory for multiple stage-sintering. We chose viscous flow sintering as a model system. This system has two sintering stage, disappearing open and closed pores, respectively. A new theory was developed based on these models and verified by in-situ measurement of sintering shrinkage of a silica glass compact. From the experimental results, it was found that a new theory combined initial and final stage of sintering. Furthermore, a unique curve was also obtained by the result of the change of processing factor such as a green density and a particle size of starting powder.

### 4:30 PM

#### (SINTER-121-2008) Linearization of Master Sintering Curve (Invited)

D. C. Blaine\*, Stellenbosch University, South Africa; S. Park, R. M. German, Mississippi State University, USA

The master sintering curve (MSC) is a simple and functional sinter model that is used to describe the densification of a particulate material during sintering when one sintering mechanism is dominant. Usually the MSC is expressed mathematically by a sigmoid relationship between the natural logarithm of the work-of-sintering and the relative density. The work-of-sintering is an integral term that includes the time and temperature path followed by the material during sintering as well as the activation energy for densification of the material. In this work, the sigmoid form of the MSC is linearized by relating the natural logarithm of the work-of-sintering to the densification parameter. The efficacy of the linearized MSC is illustrated by using the model to easily classify sintering mechanisms that change due to phase transformations during sintering. We also show by example of different powder metal systems, how the model parameters that characterize the MSC can be easily determined through using a linearized form of the model.

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**(SINTER-122-2008) Master Sintering Curve Formulated from Constitutive Models**

S. Park\*, P. Suri, Mississippi State University, USA; E. Olevsky, San Diego State University, USA; R. M. German, Mississippi State University, USA

The classical master sintering curve (MSC) has been derived from empirical sintering model with densification data over a range of heating rates and temperatures. To improve the accuracy, a new generalized formulation was proposed based on several constitutive equations including both grain growth and densification. The developed MSC models were applied to several material systems such as molybdenum, stainless steels, and tungsten heavy alloys (WHA), in order to obtain material properties for the finite element method (FEM) simulation and evaluate the effect of compaction pressure, phase change, grain growth, and composition on densification, to classify regions having different sintering mechanism, and to help engineer design, optimize, and monitor sintering cycles.

5:30 PM

**(SINTER-123-2008) Extension of the Master Sintering Curve to Complex Systems**

T. R. Hinklin\*, Sandia National Laboratories, USA; M. Reiterer, Medtronic, Inc., USA; K. Ewsuk, Sandia National Laboratories, USA

Two important assumptions in applying the Master Sintering Curve (MSC) approach to predict and control sintering are that: 1) densification is controlled by a single mechanism (with a single activation energy); and 2) there is a master relationship between microstructure and density that is independent of the sintering time-temperature profile. These assumptions largely hold true for many different systems and sintering conditions. However, in more complex systems, and often for longer time sintering profiles, the failure of the MSC approach to accurately predict densification suggests there may be multiple sintering mechanisms, and/or the density-microstructure trajectory may be changing significantly during sintering. Using simple parallel and series resistance analogies, the MSC approach has been modified to account for these possibilities. This extension of the MSC approach to more complex sintering scenarios will be explained and demonstrated using several disparate materials systems.

5:50 PM

**(SINTER-124-2008) Examination of Particle Contact and Crystalline Axis as a Origin of Sintering Deformation**

K. Uematsu\*, S. Tanaka, K. Yamazaki, Nagaoka University of Technology, Japan

Effect of anisotropy on sintering deformation was studied in alumina compacts, where particles characteristically have elongated shape along a,b-axis. They are the aspects of shape and crystalline axis. The shape affects the number of contact point, the site for sintering. The combination of crystalline axis governs the characteristics of grain boundaries, and thus sintering. Two kinds of alumina particles were used; a regular high purity powder with the c-axis normal to the face of platelet particles and a special particle which has elongated shape along c-axis. The direction of c-axis was aligned in a magnetic field. Two novel analytical tools were applied to directly examine the packing structure of powder particles in green compacts; the polarized light microscopy coupled with the liquid immersion method and SEM microscopy. Detailed analysis showed that the shape factor governs the sintering deformation rather than the crystal factor.

**Sintering of Electronic Materials****Electronics II**

Room: Scripts II

3:10 PM

**(SINTER-125-2008) Sintering of Inkjet-Printed Conductive Inks for Organic Electronic Devices**

M. Klokkenburg\*, S. Rucareanu, E. Rubingh, M. Tjeldink, Holst Centre, Netherlands

To enhance the performance of organic electronic devices on foil, such as flexible display, lighting, and signage devices, conductive metallic connections are required. In this context, direct inkjet printing is a promising method for depositing conductive inks on polymer substrates. However, the printed lines first need to be sintered in order to get the desired conductivity. For this, 'low-temperature' sintering techniques are applied that do not result in deformation of the polymer substrate. The printed lines typically have a width in the range of 20-500  $\mu\text{m}$  and they can be sintered within seconds to minutes to obtain highly conductive patterns using fast sintering techniques as photonic curing, microwave curing, and electric curing. The combination of inkjet-printed ink lines and fast curing techniques is very promising when it comes to production processes of printed electronics on thin substrates such as foil.

3:30 PM

**(SINTER-126-2008) Influence of the Milling Environment on the Sintered Structure of a W-Cu Composite**

F. Alves da Costa, F. Ambrozio Filho\*, A. Giuseppe Pereira da Silva, U. Umbelino Gomes, S. Jackson Guedes de Lima, Universidade Federal do Rio Grande do Norte, Brazil

This work reports the influence of the milling environment on the characteristics of the powders and on the structure and density of sintered samples. Powders with composition W-30wt%Cu were milled for 51 hours in a high energy planetary mill in dry and wet (cyclohexane) conditions. In addition, another powder of the same composition was mechanically mixed to be used as reference. The milled powders have composite particles, while in the mixed powder the original W and Cu particles can be clearly discerned. The powders were pressed and sintered at 1200 C for 1 hour under flowing hydrogen. The samples of the milled powders reached around 95% of relative density against 72% of the sample prepared with the mixed powder. The powders were characterized by means of XRD and SEM. The sintered samples were characterized by means of SEM, optical microscopy and density measurement.

3:50 PM

**(SINTER-127-2008) Low-Temperature Sintering of Nanoscale Silver Paste for Attaching Semiconductor Chips**

G. Lu\*, J. N. Calata, T. G. Lei, Virginia Tech, USA

European electronics manufacturers are aggressively pursuing a silver sintering technology for attaching semiconductor chips. Sintered chips on substrate are shown to have 3x better performance, 5x higher reliability, and higher chip junction temperature. However, the European process uses thick-film silver pastes and requires a pressure of 40 MPa to lower the sintering temperature to 250°C. We describe a strategy of using silver nanoparticles to achieve low-temperature sintering without any applied pressure. We formulated a uniform silver paste containing 30-nm particles. The paste can be readily stencil-printed or dispensed on substrate and sintered in air below 270°C for chip attachment. The sintered attachment has excellent electrical, thermal, and thermo-mechanical properties. These results demonstrate that our low-temperature sintering technology using nanoscale silver paste is a simpler lead-free solution for chip interconnection than the European technology.

### Application of Sintering in Emerging Energy Applications

#### **Application of Sintering in Energy Applications**

Room: Scripts II

**4:30 PM**

##### **(SINTER-128-2008) Constrained Sintering of SOFC Electrolytes**

A. Atkinson\*, J. Kim, R. A. Rudkin, Imperial College, United Kingdom; J. Rödel, University of Darmstadt, Germany

In some planar solid oxide fuel cells (SOFCs) a thin film electrolyte is sintered onto a rigid substrate which constrains the film. Here we describe a study of the constrained sintering of zirconia films on fully dense zirconia substrates. 10  $\mu\text{m}$  thick 3YSZ and 8YSZ green layers were screen printed on 300  $\mu\text{m}$  YSZ substrates. The stress induced by sintering (to 1350°C) was deduced from monitoring the bending displacement of strips of bi-layers using a long-distance microscope. The sintering kinetics of the constrained films were measured, using a sensitive optical dilatometer, and compared with the sintering kinetics of a free-standing film (80  $\mu\text{m}$  thick). The effect of the constraint is to slow the sintering rate by an amount equivalent to a reduction of approximately 200 K in temperature and limit the final density. The sintering stress is sufficient to induce relatively large defects in the constrained film. The results are discussed in terms of current theories for constrained sintering of films.

**4:50 PM**

##### **(SINTER-129-2008) Sintering Behaviour of $\text{Ce}_{0.9}\text{Gd}_{0.1}\text{O}_{1.95-\delta}$ in Reducing Atmosphere**

A. F. Kaiser\*, M. Pihlatie, S. Ramousse, Z. He, Risø-DTU, Denmark

At low oxygen partial pressures and high temperatures Gd-doped ceria can be reduced and the material becomes electronic conducting (e.g. 0.08  $\text{Scm}^{-1}$  at 800°C at a  $\text{pO}_2$  of  $10^{-16}$  atm for  $\text{Ce}_{0.9}\text{Gd}_{0.1}\text{O}_{1.95-\delta}$  - CGO10). These properties make CGO attractive for use in oxygen membranes. For some applications, e.g. in metal supported structures, the sintering of thin CGO layers into multilayer structures has to be done under reducing atmosphere. In the present work, the densification behaviour of CGO10 was investigated in reducing atmosphere and in air. Samples were prepared by tape casting and lamination of the layers into multi-layers and by die pressing. A dilatometer was used to determine the sample shrinkages from room temperature to 1400°C with different constant heating rates. Based on the sintering results, the densification rate was evaluated, and the activation energy for densification was determined. The densification rate was significantly enhanced in reducing atmosphere ( $\text{H}_2/\text{Ar}$ ), compared to that in air.

**5:10 PM**

##### **(SINTER-130-2008) Sintering of Composite from Nanopowder Ceramics**

M. Campos\*, A. Molina, A. Rosales, Simón Bolívar University, Venezuela; J. Quiñonez, Universidad Central de Venezuela, Venezuela

Nanocrystalline powders of yttria stabilized zirconia (YSZ) and samaria doped ceria (SDC) are mixed in a proportion of 50% each, in order to produce a composite for intermediate temperature solid oxide fuel cell. Powders are prepared under optimal combustion synthesis conditions previously established. Then, they are mixed thoroughly in jar alumina and the mixture compacted under isostatic pressing in order to evaluate phase stability. Green pellets are sintered using temperatures ranging 1350°C and 1550°C and times between 5 and 10 hours. Sintered pellets are characterized by SEM, TEM and Arquimedes method. Results indicate that temperature and time increment promote phases growth and interaction between them.

**5:30 PM**

##### **(SINTER-131-2008) Three-Dimensional Solar Cell Finite Element Sintering Simulation**

G. R. Brown\*, E. A. Olevsky, R. A. Levine, San Diego State University, USA; A. Shaikh, J. Salami, Ferro Corporation, USA

The sintering process is ubiquitous in manufacturing, but until now the design-oriented modeling of sintering presents considerable challenges. This type of modeling is necessary to be able to predict deformation and thus design appropriate powder compacts so that after they are sintered, the desired dimensions will be achieved. Currently this is done through a costly and time consuming trial and error process. In our research, an application of the Skrohod-Olevsky Viscous Sintering constitutive equation in a finite element (FE) model is developed and used to model a solar cell manufacturing problem. Experimental measurements are used to determine the properties of the solar cell materials, and these are used to calculate the parameters for the FE model. Simulation results are compared to experimental results and analysis has been made to evaluate the adequacy and usefulness of this approach.

**5:50 PM**

##### **(SINTER-132-2008) Sintering of a MgO Substrate and Membrane with MgO/Li<sub>2</sub>O Functionalization for Methane Catalysis**

O. Goerke, M. Ziemann, D. Habel, M. Driess, H. Schubert\*, Berlin University of Science and Technology, Germany

The catalysis of hydrocarbon is an essential step in energy technology and requires ceramic support with specific functionalization. For methane coupling a MgO support had to be processed by sintering and further coating by a MgO/Li<sub>2</sub>O active compound. Due to a fundamental experiment, a dense body with a planar surface was needed. High purity MgO powder of larger grain size as well ground powders have been sintered at 1800°C resulting in densities of over 90 % t.D. The specimen showed a dense surface but spherical pores were found. Sinter kinetics and pore formation phenomena will be reported. The functionalization was carried out by a molecular synthesis, metal organic sol gel process and compared to salt precipitation. Hence a comparable process for a three layered membrane based on the same materials will be reported.

**Thursday, November 20, 2008**

### Sintering of Multi-Material and Multi-Layered Systems

#### **Multi-Material II**

Room: Ballroom D

**8:20 AM**

##### **(SINTER-133-2008) Effect of Constraining Layers on the Densification of Low-Temperature Co-Fired Ceramics (LTCC) (Invited)**

D. Green\*, Pennsylvania State University, USA; J. Ollagnier, J. Rödel, Technische Universität Darmstadt, Germany

Non-densifying layers are used to constrain the in-plane shrinkage of LTCC during sintering, thereby improving dimensional tolerances. This approach can lead to significant internal stresses that reduce shrinkage rates and change the sintering material microstructure. Two case studies have been studied: (a) asymmetrical bi-layers and (b) symmetrical sandwich structures. In the first, an asymmetric stress state arises, leading to camber. Current viscous analog models will be discussed and compared to experiments. A new model that describes the camber of a viscous layer on an elastic substrate will be outlined. In the second case, stress calculations usually assume isotropic viscous properties and zero in-plane shrinkage. Recent experimental work has, however, shown that the constraining stresses lead to microstructural anisotropy. A simple theoretical approach has been developed to account for the elastic deformation of the constraining layers, which reduces the transient stress.

9:00 AM

**(SINTER-134-2008) LIBS Micro-Analysis of Sintering Multilayer PM Composites**

V. Leshchynsky\*, University of Windsor, Canada; W. Scharff, M. Ignatjev, IfU GmbH, Germany

A liquid phase sintering multilayer structures allows for complex shape-making capability. Unique aspects of liquid phase sintering powder metallurgy (P/M) parts, relating to the substantial capillary force associated with interconnected pores, require a specific filler alloy composition and process conditions which have to be monitored and controlled carefully. The new monitoring technique has been developed that uses laser-induced breakdown spectroscopy (LIBS) to chemically analyze PM composites during sintering. The beam from a Nd:YAG laser is guided by a mirror system to a sample in the furnace. Light emitted from the induced plasma passes back through a fiber optic cable that carries the information over a certain distance back to an Echelle spectrometer located beside the laser. Calibrations were performed during system testing. A vacuum furnace was used to simulate the sintering process, wherein the compacted samples were sintered to a temperature of ~1200 °C.

9:20 AM

**(SINTER-135-2008) Laser Sintering of Nano Scaled Alumina Powder for Scratch Resistant Transparent Coatings**

C. Rivinius\*, R. Clasen, Saarland University, Germany

Scratch resistant transparent layers are demanded for many applications like displays and for architectural use. The industrial fabrication of thin layers has been carried out by sol-gel coating for many years. But the thickness of those layers is limited to about 500 nm. However, the application of powder coatings by a dip coating process with aqueous alumina suspensions allows the generation of even thicker coatings. Thus green coatings of a thickness of more than 25 µm are possible. The nanosized alumina particles are sintered by means of a CO<sub>2</sub>-laser. The choice of matching laser parameters also allows the manipulation of the surface structure. The resulting coatings are free of cracks, optically transparent and show a sufficient bonding to the glass substrate. The microstructure and the crystal phase of the alumina coatings were analyzed by SEM and XRD, respectively. Their wear resistance is determined and compared with the properties of the glass substrates by tribological tests.

9:40 AM

**(SINTER-136-2008) Co-Sintering Behaviours of Oxide based Bi-Materials**

C. Carry, E. Yalamac\*, INPG-UJF, France; S. Akkurt, Izmir Institute of Technology, Turkey

Bi-materials have attracted attention due to combination of properties that such structures can offer. A strong bond between two co-sintered oxide ceramics can provide novel properties. This study focused on the densification and the microstructural evolution during co-sintering of alumina (Al<sub>2</sub>O<sub>3</sub>)-zirconia (Y-ZrO<sub>2</sub>) and alumina-spinel (MgAl<sub>2</sub>O<sub>4</sub>) bi-materials, produced by co-pressing of powders. High purity submicron powders were uniaxially pressed or copressed (150 or 250 MPa). The sintering behaviors of mono and bi-material bodies were investigated using a vertical dilatometer under constant heating rate conditions (from 1 to 10 °C/min up to 1580°C). Microstructural characterizations focused on the interface and diffusion layers of bonded bi-materials. Best bonding without cracks were observed on alumina-spinel bi-materials. Macroscopic and microscopic observations are analyzed, interpreted and discussed considering shrinkage and thermal expansion mismatches, residual stresses, diffusion kinetics and oxide phase diagrams.

10:20 AM

**(SINTER-137-2008) Superplastic Functional Gradient Al<sub>2</sub>O<sub>3</sub>-CNT-ZrO<sub>2</sub> Thin Film Composites**

H. Sarraf\*, Tokyo Institute of Technology, Japan

This paper will present fabrication of a new type of superplastic functional gradient thin film Al<sub>2</sub>O<sub>3</sub>-carbon nanotube (CNT)-ZrO<sub>2</sub> ceramic composites by using colloidal processing and superplastic diffusion bonding methods. Colloidal properties of concentrated suspensions of Al<sub>2</sub>O<sub>3</sub>-CNT-ZrO<sub>2</sub> mixtures with variable composition are optimized and selected suspensions used

for shaping of Al<sub>2</sub>O<sub>3</sub>-CNT-ZrO<sub>2</sub> mono-layers by utilizing a precise slip casting method. Nearly full dense and defect-free thin films will be prepared by spark plasma sintering. Superplastic diffusion bonding will be applied for joining of mono-layers by hot isostatic pressing method under optimal sintering conditions. Microstructure and mechanical properties of final materials will be discussed. Effect of CNTs as the interface bonding agents between different mono-layers during of superplastic deformation will be discussed. Influence of carbon nanotubes in such multi-layer thin film composites will be discussed in view of potential applications.

10:40 AM

**(SINTER-138-2008) Property-Oriented Sintering Approach for State-of-the-Art Multilayer Ceramic Capacitors**

A. V. Polotai\*, G. Yang, D. P. Shay, E. C. Dickey, C. A. Randall, The Pennsylvania State University, USA

Currently, one of the main problems arising in the processing of ultra-thin BME-MLCCs is the microstructural evolution of the electrode layers during co-sintering which leads electrode discontinuities. The two main factors contributing the internal electrode stability are sintering stresses and the formation of a high-temperature interfacial liquid (Ni,Ba,Ti) alloy layer at the interfaces between Ni electrodes and BaTiO<sub>3</sub> dielectrics. The careful control over the interfacial alloy layer and stress formation is required and possible solutions are discussed. The first approach is based on the modification-doping of Ni electrodes with one or several refractory metals. The second one utilizes a kinetic window between densification and degradation processes using a multiple stages sintering with variable heating rates. The advantages and disadvantages of each of these approaches are discussed in respect to the microstructural stability and electrical properties.

**Novel Sintering Processes; Field-Assisted Sintering Techniques****Novel Sintering Processes V**

Room: Ballroom E

8:20 AM

**(SINTER-139-2008) Pulse Plasma Sintering Technique: Fundamentals and Applications**

A. J. Michalski, M. Rosinski\*, Warsaw University of Technology, Poland

The presentation will present a new Pulse Plasma Sintering method (PPS), developed at WUT. Unlike other electric-field assisted sintering methods, the PPS method employs pulse high-current electric discharges for heating and activating the material to be sintered. The phenomena, taking place during the high-current pulses, which heat the powder during the PPS treatment and activate the sintering process, are similar to those occurring in other new techniques, but, in PPS, thanks to the much higher energy of the pulse discharge, these phenomena run much more intensively. The presentation will also contain some examples of application of PPS technique for producing sinters from a wide variety of materials.

8:40 AM

**(SINTER-140-2008) Consolidation of Bulk Nano-ceramics Using Current Activated Densification**

J. E. Garay\*, UC Riverside, USA

Nanocrystalline ceramics display significantly different properties and behaviors than their microcrystalline counterparts, yet they have been difficult to produce in bulk sizes. The versatile material processing technique of current-activated pressure assisted densification has proven effective in densifying nano-ceramic powders into bulk materials. Materials produced by this technique including functional and structural ceramics as well as possible applications of these materials are presented. The effectiveness of the electric currents as a processing parameter are demonstrated by increased processing efficiency as well as manifested in the enhanced properties of the materials produced. Results on large-sized, fully dense oxide ceramics with crystal sizes much less than 100nm are presented. Properties discussed include improved visible light

transmittance, enhanced toughness and altered thermal and electrical conductivity.

**9:00 AM**

### **(SINTER-141-2008) Correlation between Current Distribution and Microstructure Evolution during a Spark Plasma Sintering**

L. Minier\*, S. Le Gallet, Institut Carnot de Bourgogne, France; Y. Grin, Max-Planck-Institut für Chemische Physik fester Stoffe, Germany; F. Bernard, Institut Carnot de Bourgogne, France

The potential of the SPS process has been largely demonstrated, whereas the physicochemical mechanisms are not clear. The understanding of the sintering mechanisms is essential to produce compounds with a perfectly controlled microstructure. In this process, the current flowing is strongly dependent on the powder and die electrical properties. That is why, to evaluate the impact of the SPS sintering on the sample microstructure whatever the powder nature, the sintering of two materials, which differ mainly by their electrical and thermal properties, has been investigated. The sintering parameters were identified for each powder to obtain full dense materials. From these conditions, the sintering of the powders was performed by varying the current distribution in the sample/die system. To correlate microstructure evolutions with current distributions in the system, the samples were characterised by density measurements and SEM or metallography.

**9:20 AM**

### **(SINTER-142-2008) Influence of Minor Additives on Densification and Microstructure of Submicrometre Alumina Ceramics Prepared by SPS and HIP**

M. Mikocyzova, IIC SAS, Slovakia; J. Sedlacek, TU Karlsruhe, Germany; D. Galusek\*, IIC SAS, Slovakia

Refinement of microstructure and elimination of residual porosity are prerequisite for achievement of transparency of polycrystalline alumina for visible light. The two requirements are in obvious contradiction, as complete elimination of porosity requires high temperatures/long sintering times, accompanied with grain growth in the final stage of sintering. Pressure assisted methods e.g. spark plasma sintering (SPS), or hot isostatic pressing (HIP), facilitate faster densification at lower temperatures with reported microstructure refinement. The present work studies the influence of minor additives (500 ppm) of MgO, ZrO<sub>2</sub> and Y<sub>2</sub>O<sub>3</sub> on microstructure development and densification of a submicrometre alumina powder during SPS, with special attention paid to grain growth retarding action of ZrO<sub>2</sub> and Y<sub>2</sub>O<sub>3</sub>. Post-sinter HIP under various conditions is applied for complete elimination of residual porosity from the SPS specimens.

**9:40 AM**

### **(SINTER-143-2008) Spark Plasma Sintering of TiN: The Role of AlN Addition**

Z. Valdez-Nava, S. Guillemet-Fritsch\*, CIRIMAT/LCMIE - UMR CNRS 5085, France; M. Ferrato, Boostec, France; S. Dinculescu, T. Lebey, LAPLACE, France

Spark Plasma Sintering allows the sintering of refractory ceramics, such as titanium nitride. TiN is an interesting material because it presents good mechanical properties and exceptional electrical conductivity. In this work we sinter pure TiN and a mixture of TiN and small amounts (< 10%) of aluminium nitride (AlN). TiN and AlN used have an average particle size of 1.5 and 1.4 μm respectively. The SPS sintering, performed at 1800°C, leads to ceramics of densities higher than 95%. Results show that it is possible to obtain high electrical conductivity for pure TiN. Microstructural analysis performed by FEG-SEM shows that small AlN additions modify the grain size of TiN. The mean grain size of pure TiN after sintering is 10.6 μm, while AlN additions allow for a TiN grain size of 1.9 μm. Grain growth modification of TiN by AlN addition has not been shown elsewhere. Since grain size can have a large impact on mechanical properties, ongoing work is being performed to determine the mechanical properties of these materials.

**10:20 AM**

### **(SINTER-144-2008) Mechanisms Involved during Spark Plasma Sintering of Ceramic Powders**

G. Bernard-Granger\*, Saint-Gobain CREE, France

The densification and grain growth mechanisms during Spark Plasma Sintering of ceramic powders are discussed. The investigated materials are pure oxides (zirconia, spinel and alumina) and non oxide materials containing sintering additives (SiC and Si<sub>3</sub>N<sub>4</sub>). The invoked densification mechanisms are then compared to what is currently observed for more standard sintering techniques, as hot pressing.

**10:40 AM**

### **(SINTER-145-2008) Production and Characterization of WC-Co Cemented Carbides by Field Assisted Sintering**

F. C. Sahin\*, R. E. Ozudogru, O. Yucel, Istanbul Technical University, Turkey

WC-Co is the most widespread used cemented carbide with its WC particles bonded together by cobalt. In this study, cemented WC-Co bulk material is obtained from mixed WC-Co powder by using pressurized sintering technology (Field Assisted Sintering). Powder mixtures were sintered at 1300°C, 1350°C and 1375°C under 50MPa pressure in order to determine effects of sintering temperatures. Sintering behavior and mechanical properties such as density, hardness, bending strength and modulus of elasticity of fine-grained WC-5 wt% Co and WC-10 wt% Co hard metal were investigated. Microstructural observations were carried out by Scanning Electron Microscopy technique. Test results show that densities of bulk materials are close to theoretical density. Mechanical test results point out that hardness, bending strength and modulus of elasticity are more dependent on composition of cobalt content.

## **Fundamental Aspects of Sintering**

### **Fundamentals III**

Room: Scripts I

**8:20 AM**

### **(SINTER-146-2008) Role of Interface Complexions in Sintering (Invited)**

M. P. Harmer\*, S. J. Dillon, Lehigh University, USA; G. S. Rohrer, Carnegie Mellon University, USA

Recent theoretical and experimental work has revealed the existence of grain boundary “complexions” in a wide range of ceramic and metal systems. Complexions are equilibrium interface ‘phases’ that have associated thermodynamic properties such as excess volume, entropy and adsorption. Through control of the complexions, the grain boundary transport rate and hence the microstructure and material performance can be engineered towards a given application requirement. This presentation will summarize the current understanding and future prospects in this exciting new field of interface science and engineering. Grain boundary complexions are shown to offer an attractive alternative for explaining complex and previously poorly understood phenomenon in sintering science, such as abnormal grain growth.

**9:00 AM**

### **(SINTER-147-2008) Exploring the Role of Interface Complexions in the Sintering of Y<sub>2</sub>O<sub>3</sub>**

S. Ma\*, C. Kiely, M. Harmer, H. Caram, Lehigh University, USA

A new concept of interface complexion has been proposed. It recognizes grain boundaries as distinct “phases” which have complex and important three-dimensional structure at the atomic level. We have performed a fundamental grain growth kinetic study of the sintering of Yb/Er-doped yttrium oxide nanoparticles with the aim of understanding the factors that favor the formation of a dense, nanograined, optically transparent ceramic material. Over a narrow temperature range an abrupt increase in grain growth rate and a significant discontinuity in grain boundary mobility have been identified. Chemical analysis and preliminary transmission electron microscopy indicates that such a grain growth transition is correlated with a grain boundary structural (complexion) transition which is associated with silica impurities

segregated to the grain boundary. High density nanograined materials can be obtained by sintering below the critical temperature associated with the grain boundary complexion transition.

**9:20 AM**

**(SINTER-148-2008) Atmosphere as an Active Component in the Sintering of Aluminium**

G. Schaffer\*, The University of Queensland, Australia

Sintering of metals is typically conducted in a controlled atmosphere, which is used to sweep away volatile compounds, to reduce surface oxides or prevent further oxidation. However, the oxide on aluminium is thermodynamically very stable and cannot be reduced in conventional furnaces. Consequently, the role of the atmosphere in the sintering of aluminium is often seen as simply limiting further oxidation. However, it has recently been shown that the atmosphere is not inert and can either strongly activate or severely inhibit sintering. The effect of the atmosphere is also linked to the presence of trace amounts of certain elements such as tin. Some atmospheres can also induce multiple shrinkage events during sintering and the sintering rate increases over time. These effects may be linked to the wetting conditions, which change over time and are dependant on the alloy composition. The shrinkage mechanism which dominates at a particular stage of sintering may also be dependant on the atmosphere.

**9:40 AM**

**(SINTER-149-2008) Dissolution of Alumina in Silicate Glasses and the Glass Formation Boundary**

K. J. DeCarlo\*, T. F. Lam, K. Strong, W. M. Carty, Alfred University, USA

It is well known that chemical impurities segregate to the grain boundary in oxide ceramics and it is proposed that the grain boundary chemistry is dictated by the glass formation boundary in the system. For this to be possible it is necessary that the matrix grains readily dissolve into the grain boundary glass during sintering. Alumina is a model material for this study because the impurities are typical alkali and alkaline earth oxides plus silica and the glass formation ability of silicates is well known. This study examined the dissolution of alumina into a silicate glass through the use of glass-alumina diffusion couples and chemical mapping via WDS. The diffusion couples were heat treated to different temperatures and held for various times then quenched. Samples were sectioned and polished for WDS analysis. The data shows alumina dissolution rate is rapid and that resulting chemistry of the diffusion couple interface was consistent with the glass formation boundary in the system.

**10:20 AM**

**(SINTER-150-2008) Discussion of Non-Conventional Effects in Solid-State Sintering of Cemented Carbides (Invited)**

J. Missiaen\*, V. Bounhoure, S. Lay, INP Grenoble, France; E. Pauty, Sandvik Hard Materials, France

WC-Co materials are usually processed through a powder metallurgy route, including a liquid phase sintering step in the 1350-1450°C temperature range. However, it is for a long time established that a large part of sintering already occurs in the solid state for micronic or submicronic WC particles. Solid-state spreading of the Co-rich binder phase and local rearrangement of WC particles would be responsible for the compact densification. But non-conventional effects are still unexplained. First, shrinkage is essentially a function of temperature. Sintering time (or heating rate) has little effect, as far as slow heating is considered. Second, there is a strong influence of the C/W ratio on the spreading and sintering kinetics. Both these effects are discussed in this paper, based on experimental dilatometric and thermogravimetric results, microstructural investigations by SEM and TEM and considerations about interfacial energies in the system.

**11:00 AM**

**(SINTER-151-2008) Effect of Volume Fraction on Grain Growth during Liquid Phase Sintering of Tungsten Heavy Alloys**

J. L. Johnson\*, ATI Alldyne, USA; L. G. Campbell, Eaton Corporation, USA; S. Park, R. M. German, Mississippi State University, USA

Tungsten heavy alloys with compositions ranging from 35 to 93 wt.% tungsten were liquid phase sintered at 1500°C under microgravity conditions for isothermal hold times ranging from 1 to 600 minutes. These unique samples provide a means of experimentally testing grain growth models for solid volume fractions ranging from 0.048 to 0.858. Grain growth rate constants are determined and their dependence on the solid volume fraction is compared to the predictions of several grain coarsening models. Grain size distributions are shown to be self-similar and are fit to a Weibull distribution. Three-dimensional grain size distributions from several coarsening models are transformed into grain size distributions for two-dimensional cross-sections for comparison with the experimental data. Chi-squared tests and G-tests show that a coalescence model for grain growth fits the experimental observations better than solution-precipitation models even for dilute tungsten heavy alloys.

**11:20 AM**

**(SINTER-152-2008) Microstructure Relations and Input Knowledge Required in Liquid Phase Sintering**

R. M. German\*, Mississippi State University, USA

Attention on quantification of the liquid phase sintered microstructure has gained traction, bringing about the ability to predict a microstructure from a matrix of material parameters. For isotropic microstructures these include average surface energies (or the ratio of surface energies), solid volume fraction, and length scale parameters. For anisotropic microstructures more crystallographic information is required, but similar rules follow. Residual porosity and its placement in the microstructure is also possible; however, pore coarsening during sintering creates a need for additional parameters. Indeed, the closer we look at liquid phase sintered microstructures the greater the number of parameters. A tradeoff between amount of information required and the impact of the refinements shows that for typical applications a relatively small body of material parameters are required.

## Sintering of Bio-Materials

### **Sintering of Bio-Materials**

Room: Scripts II

**8:20 AM**

**(SINTER-153-2008) Sintering of Bioceramics (Invited)**

M. N. Rahaman\*, Missouri University of Science & Technology, USA

This article discusses sintering issues in the preparation of bioinert and bioactive ceramics and glasses for bone repair and regeneration. Because of their low friction and wear, dense bioinert ceramics are being used increasingly as bearings in total hip and knee replacement. However, catastrophic brittle failure in vivo remains a concern. Porous scaffolds of bioactive ceramics and glasses are being developed for the repair and regeneration of diseased or damaged bone. In addition to having the desired microstructure to support tissue ingrowth into the pores, the scaffold must also be capable of supporting physiologic loads. Sintering principles and techniques for the development of bioceramics with the desired microstructure and properties are discussed.

**9:00 AM**

**(SINTER-154-2008) Sintering Zirconia for Dental CAD/CAM Technology**

K. Sujirote\*, K. Sitthiseripratip, J. Jitsaard, K. Dateraksa, National Metal & Materials Technology Center, Thailand

Zirconia has been recently introduced in prosthetic dentistry for the fabrication of crowns and fixed partial dentures, in combination with CAD/CAM techniques. In this study, series of zirconia blanks with systematically controlled pre-sintering stage were milled using a 4 axes CNC milling machine. The pre-sintering heating rate and temperature of the blanks affect the in-

versely dependent hardness and machinability. Elliptical-rod geometry, major diameter 20-mm and minor diameter 12-mm, was designed to simplify the geometrical assessment and validation. Cutting condition, surface roughness, geometric accuracy and machining time were then optimized by varying depth of cut (mm), cutting feed (m/min), spindle speed (RPM) and step offset (mm). Compensation for shrinkage during sintering the pre-sintered zirconia was analyzed. Phase stability and mechanical properties of the products were re-assessed to understand the effect of machining damage.

**9:20 AM**

**(SINTER-155-2008) Sintering and Crystallisation of Bioactive Glasses for Tissue Engineering Scaffolds (Invited)**

A. Boccaccini\*, Imperial College London, United Kingdom; O. Bretcanu, Politecnico di Torino, Italy; D. Mohamad Yunus, Imperial College London, United Kingdom; L. Lefebvre, INSA Lyon, France; E. Verne, C. Vitale Brovarone, Politecnico di Torino, Italy; L. Gremillard, J. Chevalier, INSA Lyon, France

Sintering and crystallisation phenomena in powders of a typical bioactive glass composition (45S5 Bioglass®) have been investigated using a range of techniques in order to gain understanding of the processes involved in the fabrication of Bioglass® based glass-ceramic scaffolds for tissue engineering applications. From the knowledge of the interaction of viscous flow densification and crystallisation in dependence of heating rate and sintering temperature, the optimal processing parameters for the manufacture of robust 3D highly porous Bioglass® based scaffolds by the foam-replica technique were determined. Results will show also the link between the sintering parameters and the bioreactivity of the scaffolds in simulated body fluid. The relevance of understanding the sintering kinetics in the manufacture of such highly porous structures will be highlighted, with emphasis on shape distortion and anisotropy effects.

**10:20 AM**

**(SINTER-156-2008) Spark Plasma Sintering of Biomimetic Nanocrystalline Apatites at Very Low Temperature**

D. Grossin\*, C. Drouet, CIRIMAT UPS-INPT-CNRS, France; C. Estournes, E. Champion, R. Fabrice, SPCTS, France; C. Combes, C. Rey, CIRIMAT UPS-INPT-CNRS, France

Nanocrystalline apatites constitute biomimetic nanomaterials analogous to bone mineral. Their high surface reactivity is related to the presence of a metastable hydrated layer on the nanocrystals surface. However, sintering of such phases by conventional techniques at high temperature strongly alters their physico-chemical and biological properties. Therefore, a "soft" sintering process is needed to limit such alterations. In the present work, the SPS technique was used due to its specific advantage (sintering kinetics) in order to consolidate at low temperatures ( $T < 350^\circ$ ). The nano-bioceramics consolidated by SPS were thoroughly characterized. The related microstructure and texture were determined, and their mechanical properties were evaluated. The low-temperature consolidation mechanism was investigated, which is thought to involve the high ion mobility of the hydrated layer. This work should be helpful in particular for the preparation of a new generation of resorbable bioceramics.

**10:40 AM**

**(SINTER-157-2008) Effect of Sintering Temperature and Time on Microstructure and Properties of Zirconia Toughened Alumina (ZTA)**

M. M. Hasan\*, M. F. Islam, Bangladesh University of Engineering and Technology, Bangladesh

In this work, the effect of sintering temperature and time on density, hardness and microstructure of ZTA made with 85% vol  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> (150nm) and 15% vol monoclinic ZrO<sub>2</sub> (30-60nm) was investigated. The samples were made by conventional powder mixing and slip casting procedure. The sintering temperature was varied between 1400-1525°C for 2-6 hours. Without using any sintering aid and pressure about 93% of theoretical density and hardness of about 14 GPa were achieved. It was found that the density increased with sintering temperature but decreased at higher holding time. It is believed that this was occurred due to grain growth and phase transformation of Zirconia at prolonged holding time. The hardness also increased with density (and sintering temperature) but at higher sintering temperature it decreased due to grain coarsening. The increase of grain size with sintering temperature and time was also observed in this work.



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# 2009-2010 Meetings & Expositions of The American Ceramic Society

**January 18-23, 2009**

***33rd International Conference & Exposition on Advanced Ceramics & Composites***  
Hilton Daytona Beach Resort & Ocean Center  
Daytona Beach, Florida, USA

**May 11-13, 2009**

***Structural Clay Products Division Meeting***

**May 31-June 5, 2009**

***8th Pacific Rim Conference on Ceramic and Glass Technology***  
***Includes 2009 Annual Meeting of the***  
***International Commission on Glass (ICG)***  
Hyatt Regency Vancouver  
Vancouver, British Columbia, Canada

**October 25-29, 2009**

***Materials Science & Technology Conference and Exhibition –***  
***MS&T'09 combined with The ACerS 111th Annual Meeting***  
David L. Lawrence Convention Center  
Pittsburgh, Pennsylvania, USA

**January 24-29, 2010**

***34th International Conference & Exposition on Advanced Ceramics & Composites***  
Hilton Daytona Beach Resort & Ocean Center  
Daytona Beach, Florida, USA

**February 21-24, 2010**

***Materials Innovation in an Emerging Hydrogen Economy***  
Hilton Cocoa Beach Oceanfront  
Cocoa Beach, FL, USA

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***Materials Science & Technology Conference and Exhibition –***  
***MS&T'10 combined with The ACerS 112th Annual Meeting***  
George R. Brown Convention Center  
Houston, TX, USA

