

INNOVATION • INFORMATION • INTERACTION

MATERIALS INNOVATIONS IN AN EMERGING HYDROGEN ECONOMY

FEBRUARY 24-27, 2008 • HILTON OCEANFRONT • COCOA BEACH, FLORIDA USA

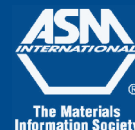
MEETING GUIDE



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www.ceramics.org/hydrogen2008



Welcome

On behalf of the American Ceramic Society (ACerS) and ASM International, we would like to welcome all members, visitors and guests to the first Inter-Society conference on “Materials Innovations in an Emerging Hydrogen Economy.” We also want to thank our many colleagues and volunteers, along with sponsoring companies and endorsing organizations, including the National Hydrogen Association (NHA) and the Society for Advancement of Material and Process Engineering (SAMPE), for all their efforts in supporting this new interaction and for the exciting program that has been developed.

Among the most important challenges facing our nation and the international community is the ability to develop and implement dependable new sources of clean energy for the future. This is a critical objective for national and international security and to assure high environmental standards on a global scale. While important scientific and engineering progress has been made in meeting this challenge, in replacing the current fossil fuel-based economy with a new hydrogen-based structure, significant technical barriers still exist. An important component of achieving success involves development of new materials and systems. This conference, “Materials Innovations in an Emerging Hydrogen Economy,” represents an interdisciplinary approach of assembling leading experts in the field to meet and discuss the technical challenges and means for addressing them, while also providing a forum for introducing and assisting new researchers to this field of existing, new and needed technologies, to make a hydrogen economy a reality in our lifetime.

Our H-conference team has assembled leaders in the field, including top researchers from the international community, federal and national US laboratories, academia, government organizations, and the important industrial sector to focus on hydrogen-related needs and challenges. The interest has been outstanding, with 112 presentations from 14 countries, in 17 sessions and one poster session, comprising a major part of the program. There are also many new and unique features that will be highlighted at the conference, along with a variety of networking events. Some of these interesting activities include a) tutorial presentations in areas of H-Production, H-Storage and H-Delivery/ Safety, b) very strong technical sessions, especially on new materials development in H-storage, as well as overviews of global hydrogen-related research (US, the EC, Japan, Canada, S. Korea, India, Argentina and China), c) dinner speaker and author, Addison Bain, discussing interesting aspects of the role of hydrogen in the Hindenburg disaster and d) a “ride-and-drive” event in which participants can drive new hydrogen-based vehicles provided by Toyota and Ford.

We very much appreciate everyone taking time out of their busy schedules to participate in this conference and wish all our colleagues a very interesting, enjoyable and worthwhile interaction.

Best regards,

George and Jack

George Wicks, H-Conference Co-Organizer/ ACerS BOD
Consulting Scientist
Savannah River National Laboratory
Aiken, SC 29808

Jack Simon, H-Conference Co-Organizer/ Past Pres. ASM, International
President, Technology Access
Roscommon, MI 48653

Table of Contents

Schedule At A Glance	2
Thank You to Our Sponsors	2
Presenting Author List	3
Final Program	
Monday Morning	4
Monday Afternoon	4
Tuesday Morning	5–7
Tuesday Afternoon	7–8
Wednesday Morning	8–9
Abstracts	10–26
Author Index	27–29

Sponsors



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Dr. Jack Simon, Technology Access, Aiken, SC

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Dr. John Turner, National Renewable Energy Lab, Golden, CO
Dr. E. Akiba, AIST, Tokyo, Japan
Dr. Maximilian Fichtner, FZK, Germany
Dr. Bjorn Hauback, IFE, Norway

Schedule At A Glance

Sunday, February 24, 2008

Conference Registration	3 PM – 7 PM	Grand Ballroom Foyer
Welcome Reception	5 PM – 7 PM	Pool Deck

Monday, February 25, 2008

Conference Registration	7 AM – 7:30 PM	Grand Ballroom Foyer
Welcome and Tutorial Lectures	8 AM – 9:45 AM	Sea Oats & Sawgrass
International Overviews 1	10 AM – 12 PM	Sea Oats & Sawgrass
Lunch	12 PM – 1 PM	Horizons
International Overviews 2	1 PM – 3:15 PM	Sea Oats & Sawgrass
Complexes 1 – Borohydrides	1 PM – 3:40 PM	Seahorse
Pre-Conference Dinner Reception	6:45 PM – 7:30 PM	Grand Ballroom Foyer
Dinner and Special Presentation by Dr. Addison Bain	7:30 PM – 10 PM	Grand Ballroom

Tuesday, February 26, 2008

Conference Registration	7 AM – 7:30 PM	Grand Ballroom Foyer
Adsorbents 1	8 AM – 10:20 AM	Sea Oats
Adsorbents and Chemical Hydrides	10:20 AM – 12PM	Sea Oats
Delivery 1	8 AM – 10 AM	Sawgrass
Delivery 2	10:20 AM – 12 PM	Sawgrass
H Storage/National & International Activities	8 AM – 10:20 AM	Dunes 1 & 2
Leakage/Safety 1	10:20 AM – 12 PM	Dunes 1 & 2
Complexes 2 – Alanates	8 AM – 10:20 AM	Seahorse
Water/Solar 1 – Nuclear	10:20 AM – 12 PM	Seahorse
Hollow Glass Microspheres (HGMs)	1 PM – 3:20 PM	Sea Oats
Leakage/Safety 2	1 PM – 3:20 PM	Dunes 1 & 2
Hydrocarbons	1 PM – 3:20 PM	Seahorse
Guest Tour	9 AM – 4 PM	Kennedy Space Center
Lunch	12 PM – 1 PM	Horizons
Ride and Drive Program	3:30 PM – 5:30 PM	Hilton Parking Lot
Poster Session Move-In	3:30 PM – 4:30 PM	Horizons
Poster Session	5:30 PM – 7:30 PM	Horizons

Wednesday, February 27, 2008

Conference Registration	8 AM – 10 AM	Grand Ballroom Foyer
Tanks and Systems	8 AM – 9:40 AM	Sea Oats
Water/Solar 2	8 AM – 9:40 AM	Seahorse

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Welcome Reception Co-Sponsor

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A Special Thanks to Toyota and Ford for providing H2 vehicles used in the Ride and Drive Program

Presenting Author List

Name	Date	Time	Room	Abstract Number	Name	Date	Time	Room	Abstract Number
A					M				
Adams, T.M.	26-Feb	10:20AM	Sawgrass	H2-DELV-06	Ma, Z.	25-Feb	1:00PM	Sea Oats	H2-OVER-04
Al-Batty, S.	27-Feb	9:20AM	Seahorse	H2-PROD-23	Macland, A.J.	25-Feb	3:20PM	Seahorse	H2-STOR-07
Anderson, E.B.	27-Feb	8:00AM	Seahorse	H2-PROD-19	Marrero-Alfonso, E.Y.	26-Feb	5:30PM	Horizons	H2-STOR-40
Andrukaitis, E.	25-Feb	11:30AM	Sea Oats	H2-OVER-03	Mintz, J.	26-Feb	2:00PM	Dunes 1 & 2	H2-LEAK-06
Au, M.	25-Feb	2:40PM	Seahorse	H2-STOR-05	Mohajeri, N.	26-Feb	5:30PM	Horizons	H2-STOR-34
Autrey, T.	26-Feb	11:00AM	Sea Oats	H2-STOR-16	Mohajeri, N.	26-Feb	5:30PM	Horizons	H2-STOR-38
B					N				
Balachandran, U.	26-Feb	1:00PM	Seahorse	H2-PROD-08	Mohajeri, N.	26-Feb	2:00PM	Sea Oats	H2-STOR-31
Beaird, A.M.	26-Feb	5:30PM	Horizons	H2-STOR-39	Molendowska, A.	26-Feb	5:30PM	Horizons	H2-STOR-41
Bonner, B.B.	26-Feb	8:00AM	Sawgrass	H2-DELV-01	Morgan, M.	26-Feb	2:40PM	Dunes 1 & 2	H2-LEAK-08
Bowman, R.C.	25-Feb	1:20PM	Seahorse	H2-STOR-02	Morreale, B.	26-Feb	5:30PM	Horizons	H2-PROD-16
Boyd, R.W.	27-Feb	8:20AM	Sea Oats	H2-STOR-49	Morreale, B.	26-Feb	5:30PM	Horizons	H2-PROD-17
C					P				
Chun, C.	26-Feb	1:40PM	Seahorse	H2-PROD-10	Morreale, B.	26-Feb	5:30PM	Horizons	H2-PROD-18
Clark, E.A.	26-Feb	2:20PM	Dunes 1 & 2	H2-LEAK-07	Motyka, T.	27-Feb	8:00AM	Sea Oats	H2-STOR-48
Cooper, A.	26-Feb	11:20AM	Sea Oats	H2-STOR-17	Muradov, N.	26-Feb	2:00PM	Seahorse	H2-PROD-11
D					R				
Day, D.E.	26-Feb	1:00PM	Sea Oats	H2-STOR-28	Newell, D.	26-Feb	5:30PM	Horizons	H2-OVER-12
Dillon, A.	26-Feb	10:20AM	Sea Oats	H2-STOR-14	Newkirk, J.W.	26-Feb	11:00AM	Seahorse	H2-PROD-03
E					S				
Edson, D.L.	26-Feb	2:40PM	Seahorse	H2-PROD-13	Nibur, K.	26-Feb	9:00AM	Sawgrass	H2-DELV-04
Elgowainy, A.	26-Feb	8:20AM	Sawgrass	H2-DELV-02	Price, T.C.	25-Feb	3:00PM	Seahorse	H2-STOR-06
Erck, R.	26-Feb	9:20AM	Sawgrass	H2-DELV-05	T				
Eryilmaz, O.L.	26-Feb	11:40AM	Sawgrass	H2-DELV-10	Rahimian, M.	26-Feb	5:30PM	Horizons	H2-STOR-43
F					U				
Fang, Z.Z.	26-Feb	8:20AM	Seahorse	H2-STOR-23	Ramaprabhu, S.	26-Feb	9:20AM	Dunes 1 & 2	H2-OVER-11
Feng, Z.	26-Feb	11:00AM	Sawgrass	H2-DELV-08	Raszwski, F.C.	26-Feb	3:00PM	Sea Oats	H2-STOR-32
Fichtner, M.	25-Feb	1:00PM	Seahorse	H2-STOR-01	Raszwski, F.C.	26-Feb	5:30PM	Horizons	H2-STOR-44
Filiou, C.	25-Feb	10:30AM	Sea Oats	H2-OVER-02	Rawls, G.B.	26-Feb	8:40AM	Sawgrass	H2-DELV-03
G					V				
Galindo, J.I.	25-Feb	1:30PM	Sea Oats	H2-OVER-05	Rich, J.	26-Feb	2:40PM	Sea Oats	H2-PROD-07
Galindo, J.I.	26-Feb	8:00AM	Dunes 1 & 2	H2-OVER-08	Ricker, R.E.	26-Feb	10:40AM	Sawgrass	H2-DELV-07
Gallego, N.C.	26-Feb	9:00AM	Sea Oats	H2-STOR-11	Ricker, R.E.	26-Feb	5:30PM	Horizons	H2-DELV-12
Gopalan, S.	27-Feb	8:20AM	Seahorse	H2-PROD-20	Ronnebro, E.	25-Feb	2:20PM	Seahorse	H2-STOR-04
Graetz, J.	26-Feb	8:40AM	Seahorse	H2-STOR-24	Ross, D.K.	26-Feb	9:40AM	Sea Oats	H2-STOR-13
H					W				
Hannum, T.J.	27-Feb	9:00AM	Sea Oats	H2-STOR-51	Schroder, M.	26-Feb	9:20AM	Sea Oats	H2-STOR-12
Hansen, E.K.	26-Feb	5:30PM	Horizons	H2-STOR-45	Schubert, P.J.	26-Feb	5:30PM	Horizons	H2-STOR-33
Hathcock, D.	26-Feb	3:00PM	Dunes 1 & 2	H2-LEAK-09	Shewchun, J.	26-Feb	11:00AM	Dunes 1 & 2	H2-LEAK-02
Herring, J.	26-Feb	10:40AM	Seahorse	H2-PROD-02	Shmayda, W.T.	26-Feb	8:40AM	Dunes 1 & 2	H2-OVER-10
Heung, L.K.	26-Feb	2:20PM	Sea Oats	H2-PROD-06	Sisson, R.D.	26-Feb	10:20AM	Dunes 1 & 2	H2-LEAK-01
Hirscher, M.	26-Feb	8:00AM	Sea Oats	H2-STOR-08	Sofronis, P.	26-Feb	11:40AM	Dunes 1 & 2	H2-DELV-11
Huang, C.	27-Feb	9:00AM	Seahorse	H2-PROD-22	Speaker, R.	26-Feb	11:20AM	Dunes 1 & 2	H2-STOR-21
I					X				
Jena, P.	26-Feb	9:40AM	Seahorse	H2-STOR-27	Spielvogel, B.	26-Feb	5:30PM	Horizons	H2-PROD-15
Jensen, C.	26-Feb	9:00AM	Seahorse	H2-STOR-25	Srinivasan, S.S.	26-Feb	5:30PM	Horizons	H2-STOR-37
Jones, T.M.	26-Feb	1:20PM	Dunes 1 & 2	H2-LEAK-04	Stanescu, M.	26-Feb	1:40PM	Dunes 1 & 2	H2-LEAK-05
J					Y				
Kapoun, K.	26-Feb	1:20PM	Seahorse	H2-PROD-09	Steriotis, T.	26-Feb	9:40AM	Dunes 1 & 2	H2-STOR-19
Kherani, N.P.	26-Feb	8:20AM	Dunes 1 & 2	H2-OVER-09	Stetson, N.	25-Feb	10:00AM	Sea Oats	H2-OVER-01
Kim, J.	25-Feb	2:45PM	Sea Oats	H2-OVER-07	Stokes, E.H.	26-Feb	5:30PM	Horizons	H2-STOR-46
Kim, Y.	26-Feb	2:20PM	Seahorse	H2-PROD-12	Summers, W.	26-Feb	10:20AM	Seahorse	H2-PROD-01
Korinko, P.S.	26-Feb	3:00PM	Seahorse	H2-PROD-14	Sundaram, S.K.	26-Feb	3:20PM	Seahorse	H2-OVER-06
K					Z				
Lasseigne, A.N.	26-Feb	11:20AM	Sawgrass	H2-DELV-09	Sundaresan, R.	25-Feb	2:15PM	Sea Oats	H2-PROD-24
Latroche, M.J.	26-Feb	10:40AM	Sea Oats	H2-STOR-15	Talu, O.	26-Feb	5:30PM	Horizons	H2-STOR-36
Lee, J.A.	26-Feb	5:30PM	Horizons	H2-STOR-47	Tange, K.	27-Feb	8:40AM	Sea Oats	H2-STOR-50
Li, Y.	26-Feb	9:00AM	Dunes 1 & 2	H2-STOR-18	Thrun, L.B.	26-Feb	1:00PM	Dunes 1 & 2	H2-LEAK-03
Linares-Solano, A.	26-Feb	8:40AM	Sea Oats	H2-STOR-10	Towata, S.	26-Feb	9:20AM	Seahorse	H2-STOR-26
Linares-Solano, A.	26-Feb	5:30PM	Horizons	H2-STOR-35	W				
Linkous, C.A.	27-Feb	8:40AM	Seahorse	H2-PROD-21	Wachtel, P.F.	26-Feb	1:20PM	Sea Oats	H2-STOR-29
Long, J.R.	26-Feb	8:20AM	Sea Oats	H2-STOR-09	Walters, R.T.	26-Feb	5:30PM	Horizons	H2-DELV-13
Louthan, M.R.	26-Feb	10:40AM	Dunes 1 & 2	H2-STOR-20	Wicks, G.G.	26-Feb	1:40PM	Sea Oats	H2-STOR-30
Lvov, S.	26-Feb	11:20AM	Seahorse	H2-PROD-04	X				
L					Y				
Zhang, D.	26-Feb	5:30PM	Horizons	H2-STOR-42	Z				
Zhao, J.	25-Feb	1:40PM	Seahorse	H2-STOR-03	Zhang, D.	26-Feb	5:30PM	Horizons	H2-STOR-42
Zidan, R.	26-Feb	8:00AM	Seahorse	H2-STOR-22	Zhao, J.	25-Feb	1:40PM	Seahorse	H2-STOR-03
Ziebarth, J.	26-Feb	11:40AM	Seahorse	H2-PROD-05	Zidan, R.	26-Feb	8:00AM	Seahorse	H2-STOR-22
M					Z				
N					Z				

Monday, February 25, 2008**Welcome and Tutorial Lectures**

Room: Sea Oats

Session Chairs: George Wicks, Jack Simon

8:00 AM**Opening Remarks**

Jack Simon and George Wicks

8:15 AM**Hydrogen Production Tutorial:**

Gerald Voecks*, Jet Propulsion Laboratory (ret.) and General Motors Research

8:45 AM**Hydrogen Storage Tutorial:**

George Thomas*, Sandia-Livermore (ret.)

9:15 AM**Hydrogen Delivery/Safety Tutorial:**

Thomas Joseph*, Air Products & Chemicals, Inc.

9:45 AM**Break****Global Hydrogen Activities****International Overviews 1**

Room: Sea Oats

Session Chairs: Michael Hirscher, Max-Planck Institute; Ashraf Imam, Naval Research Laboratory

10:00 AM**(H2-OVER-01) Review of Materials Development Programs for Hydrogen Storage (Invited)**

N. Stetson*, U.S. Department of Energy, USA; J. Petrovic, Los Alamos National Laboratory (retired), USA; C. Read, G. Ordaz, M. Gardiner, U.S. Department of Energy, USA; G. Thomas, Sandia National Laboratories (retired), USA; S. Satyapal, U.S. Department of Energy, USA

10:30 AM**(H2-OVER-02) Research Priorities and Progress in Hydrogen Energy Research in the European Union (Invited)**

C. Filiou*, P. Moretto, European Commission, Netherlands; J. Martin-Bermejo, European Commission, Directorate-General Research, Belgium

11:00 AM**(H2-OVER-03) An Overview of Hydrogen-related Materials Research Activities in Japan (Invited)**

Naotsugu Itoh*, Utsunomiya University, Japan

11:30 AM**(H2-OVER-04) Materials Issues for H2 R&D in Canada (Invited)**

E. Andrukaitis*, Defence R&D Canada, Canada

International Overviews 2

Room: Sea Oats

Session Chairs: Theodore Steriotis, NCSR "Demokritos"; Ned Stetson, U.S. Dept. of Energy

1:00 PM**(H2-OVER-05) Energy Materials Research and Development to the Power System for Fuel Cell Electric Vehicle in China (Invited)**

Z. Ma*, Institute of Electrochemical & Energy Technology, China

1:30 PM**(H2-OVER-06) Introduction of the Hydrogen Economy in Emerging Markets (Invited)**

J. I. Galindo*, Alset Technology LLC, Argentina

2:00 PM**Break****2:15 PM****(H2-OVER-07) Taking India to Hydrogen Economy (Invited)**

R. Sundaresan*, Nonferrous Materials Technology Development Centre (NFTDC), India

2:45 PM**(H2-OVER-08) Current Status of R&D on Hydrogen Production and Storage in Korea (Invited)**

J. Kim*, Hydrogen Energy R&D Center, South Korea

Storage**Complexes 1 - Borohydrides**

Room: Seahorse

Session Chairs: Ragai Zidan, Savannah River National Laboratory; Ted Motyka, Savannah River National Laboratory

1:00 PM**(H2-STOR-01) Challenges in the Development of Complex Hydride Based Systems for Reversible Hydrogen Storage (Invited)**

M. Fichtner*, Research Center Karlsruhe, Germany

1:20 PM**(H2-STOR-02) Evaluations of Formation and Reversibility of Metal Borohydrides via Volumetric and Nuclear Magnetic Resonance Methods (Invited)**

R. C. Bowman*, Jet Propulsion Laboratory, USA; S. Hwang, California Institute of Technology, USA; J. W. Reiter, Jet Propulsion Laboratory, USA; C. Kim, H. Kabbour, J. J. Purewal, C. C. Ahn, California Institute of Technology, USA

1:40 PM**(H2-STOR-03) Exploration of Magnesium-Containing Borohydrides and Their Complexes for On-board Hydrogen Storage (Invited)**

G. Soloveichik, S. Kniajanski, J. Rijssenbeek, Y. Gao, GE Global Research, USA; J. Zhao*, The Ohio State University, USA

2:00 PM**Break****2:20 PM****(H2-STOR-04) Development of New Metal Hydrides and Borohydrides (Invited)**

E. Ronnebro*, Sandia National Laboratories, USA; E. H. Majzoub, University of Missouri, USA

2:40 PM**(H2-STOR-05) The Stability and Reversibility of Metallic Borohydrides**

M. Au*, Savannah River National Laboratory, USA

3:00 PM**(H2-STOR-06) Synergistic Effect of LiBH₄ + MgH₂ as a Potential Reversible High Capacity Hydrogen Storage Material**

T. C. Price*, G. Walker, D. Grant, The University Of Nottingham, United Kingdom

3:20 PM**(H2-STOR-07) Destabilization of Complex Hydrides by Halide Ion Substitutions on the Hydride Sub-Lattice (Invited)**

A. J. Maeland*, H. W. Brinks, A. Fossdal, M. H. Sorby, H. Grove, B. C. Hauback, Institute for Energy Technology, Norway

*Denotes Presenter

Tuesday, February 26, 2008

Storage

Adsorbents 1

Room: Sea Oats

Session Chairs: Anne Dillon, National Renewable Energy Laboratory; Alan Cooper, Air Products

8:00 AM

(H2-STOR-08) Physisorption of Hydrogen on Novel Porous Materials (Invited)

M. Hirscher*, B. Panella, B. Schmitz, Max Planck Institute for Metals Research, Germany

8:20 AM

(H2-STOR-09) High-Throughput Methodology for Discovery of Metal-Organic Frameworks with a High Hydrogen Binding Enthalpy (Invited)

S. S. Kaye, S. Horike, J. R. Long*, University of California, Berkeley, USA

8:40 AM

(H2-STOR-10) High Density Carbon Materials for Hydrogen Storage (Invited)

A. Linares-Solano*, M. Jordá-Beneyto, D. Lozano-Castello, F. Suárez-García, D. Cazorla-Amorós, Universidad de Alicante, Spain

9:00 AM

(H2-STOR-11) Palladium-doped Nanoporous Carbon Fibers for Hydrogen Storage (Invited)

N. C. Gallego*, C. I. Contescu, V. V. Bhat, Oak Ridge National Laboratory, USA; H. L. Tekinalp, D. D. Edie, Clemson University, USA

9:20 AM

(H2-STOR-12) High Hydrogen Adsorption by Porous Coordination Framework Materials

M. Schroder*, University of Nottingham, United Kingdom

9:40 AM

(H2-STOR-13) Identification of H₂ Trapping Sites on Single-Walled Carbon Nanotubes Using Neutron Scattering, Ab Initio Calculations, and Langmuir Fits to Adsorption Isotherms (Invited)

D. K. Ross*, M. Seifi, P. A. Georgiev, D. Reilly, I. Morrison, University of Salford, United Kingdom

10:00 AM

Break

Adsorbents and Chemical Hydrides

Room: Sea Oats

Session Chairs: Nidia Gallego, Oak Ridge National Laboratory; D. Ross, University of Salford

10:20 AM

(H2-STOR-14) Novel Organometallic Fullerene Complexes for Vehicular Hydrogen Storage (Invited)

A. Dillon*, E. Whitney, C. Engrakul, C. Curtis, P. Parilla, K. O'Neill, L. Simpson, M. Heben, National Renewable Energy Laboratory, USA

10:40 AM

(H2-STOR-15) Highly Porous Compounds with Very Large Surface Area for Hydrogen Storage (Invited)

M. J. Latroche*, CNRS, France; C. Serre, T. Loiseau, G. Férey, CNRS-Université de Versailles, France

11:00 AM

(H2-STOR-16) Solid State Chemical Hydrogen Storage (Invited)

T. Autrey, D. Camaioni*, Pacific Northwest National Laboratory, USA

11:20 AM

(H2-STOR-17) An Integrated Hydrogen Storage and Delivery Approach Using Organic Liquid-phase Carriers (Invited)

A. Cooper*, A. Scott, D. Fowler, M. Ford, B. Toseland, H. Cheng, G. Pez, Air Products and Chemicals, Inc., USA

Distribution

Delivery 1

Room: Sawgrass

Session Chairs: Tim Armstrong, Oak Ridge National Laboratory; Dave McColskey, NIST

8:00 AM

(H2-DELV-01) A Stakeholders Perspective on Material Challenges of Developing Hydrogen Delivery Infrastructure

B. B. Bonner*, Air Products and Chemicals, Inc., USA

8:20 AM

(H2-DELV-02) Hydrogen Delivery Analysis: Enhanced Model and New Results

A. Elgawainy*, M. Mintz, J. Gillette, Argonne National Laboratory, USA

8:40 AM

(H2-DELV-03) Codes and Standards for a Hydrogen Economy Infrastructure (Invited)

G. B. Rawls*, Savannah River National Lab, USA; L. Hayden, Louis Hayden Consultants, USA; M. Rana, Praxair Inc., USA

9:00 AM

(H2-DELV-04) Hydrogen-Assisted Fracture in Steels for Hydrogen Delivery and Storage (Invited)

B. Somerday, K. Nibur*, C. San Marchi, Sandia National Laboratories, USA

9:20 AM

(H2-DELV-05) Friction and Wear Properties of Materials used in Hydrogen Service

R. Erck*, G. Fenske, O. Eryilmaz, Argonne National Laboratory, USA

9:40 AM

Break

Delivery 2

Room: Sawgrass

Session Chairs: Brian Bonner, Air Products; Petros Sofronis, University of Illinois - Urbana/Champaign

10:20 AM

(H2-DELV-06) Affect of Microstructure on Hydrogen Permeation and Embrittlement in Pipeline Materials

P. S. Korinko, T. M. Adams*, A. J. Duncan, Savannah River National Laboratory, USA

10:40 AM

(H2-DELV-07) Evaluation of the Susceptibility of Simulated Welds in HSLA-100 and HY-100 Steels to Hydrogen Induced Cracking

M. R. Stoudt, D. J. Pitchure, R. E. Ricker*, NIST, USA

11:00 AM

(H2-DELV-08) High-Pressure Hydrogen Permeation, Diffusion and Transport in Pipeline Steels (Invited)

Z. Feng*, L. M. Anovitz, T. R. Armstrong, Oak Ridge National Laboratory, USA

11:20 AM

(H2-DELV-09) Advanced Non-Destructive Hydrogen Content Sensors (Invited)

A. N. Lasseigne*, National Institute of Standards and Technology, USA; K. Koenig, Colorado School of Mines, USA; D. McColskey, T. Siewert, National Institute of Standards and Technology, USA

11:40 AM

(H2-DELV-10) An Imaging TOF-SIMS Study of Hydrogen-free to Highly Hydrogenated DLC Films Subjected to Tribological Tests in Hydrogen Gas Environment

O. L. Eryilmaz*, A. Erdemir, R. Erck, Argonne National Laboratory, USA

Global Hydrogen Activities**H Storage/National and International H Activities**

Room: Dunes 1 & 2

Session Chairs: Kyoichi Tange, Toyota Motor Corporation; Thomas Hannum, HyPerComp Engineering

8:00 AM**(H2-OVER-09) Global Perspective Towards the Establishment of the Hydrogen Economy (Invited)**

J. I. Galindo*, Alset Technology LLC, Argentina

8:20 AM**(H2-OVER-10) Tritium: A Micropower Source for On-Chip Applications (Invited)**

N. P. Kherani*, University of Toronto, Canada; B. Liu, K. P. Chen, University of Pittsburgh, USA; S. Zukotynski, University of Toronto, Canada

8:40 AM**(H2-OVER-11) Fusion and Hydrogen-Economy Materials Issues (Invited)**

W. T. Shmayda*, University of Rochester, USA

9:00 AM**(H2-STOR-18) Progress of Hydrogen Storage and Container Materials (Invited)**

Y. Li*, Chinese Academy of Sciences, China

9:20 AM**(H2-OVER-12) Hydrogen Economy in India: Materials Issues and Challenges (Invited)**

S. Ramaprabhu*, Indian Institute of Technology - Madras, India

9:40 AM**(H2-STOR-19) European Integrated Project NESSHY: Overview and Promising Results (Invited)**

T. Steriotis*, A. Bourlinos, G. Charalambopoulou, A. Stubos, NCSR "Demokritos", Greece

10:00 AM

Break

Leakage Detection/Safety**Leakage/Safety 1**

Room: Dunes 1 & 2

Session Chairs: Robert Oesterreich, Airliquide; Thomas Mebrahtu, AirProducts

10:20 AM**(H2-LEAK-01) The Fundamental Aspects of Hydrogen Effects on Steels and Other Alloys: A Review**

R. D. Sisson*, Worcester Polytechnic Institute, USA

10:40 AM**(H2-STOR-20) Testing for Hydrogen Embrittlement: A Tutorial**

M. R. Louthan*, Savannah River National Laboratory, USA

11:00 AM**(H2-LEAK-02) Review of Codes and Standards for Hydrogen Refueling Stations**

S. Mahajana, D. Edwards, J. Shewchun*, Wayne State University, USA

11:20 AM**(H2-STOR-21) Hydrogen Safety Standards: Storage, Handling, Usage and Distribution (Invited)**

R. Speaker*, Air Liquide Industrial LP, USA; J. Hayes, C. Laffin, Project Engineering, USA

11:40 AM**(H2-DELV-11) Fracture Toughness Assessment of Hydrogen Pipelines (Invited)**

P. Sofronis*, M. Dadfarnia, I. M. Roberston, M. Martin, University of Illinois at Urbana-Champaign, USA

Storage**Complexes 2 - Alanates**

Room: Seahorse

Session Chairs: Ji-Cheng Zhao, Ohio State University; Maximilian Fichtner, Research Center Karlsruhe

8:00 AM**(H2-STOR-22) Neutron Scattering Studies of the Structure and Dynamics of NaMgH₃ (Invited)**

R. Zidan*, A. C. Stowe, Savannah River National Lab, USA; A. I. Acatrinci, M. A. Hartl, L. L. Daemen, Los Alamos National Laboratory, USA

8:20 AM**(H2-STOR-23) Hydrogen Storage Materials Based on Li-Al-Mg-N-H Systems (Invited)**

Z. Z. Fang*, J. Lu, H. Sohn, University of Utah, USA

8:40 AM**(H2-STOR-24) Direct Alane Formation under Mild Conditions (Invited)**

J. Graetz*, Brookhaven National Lab, USA; S. Chaudhari, Washington State University, USA; J. Wegryzn, J. R. Johnson, Y. Celebi, W. Zhou, J. Reilly, Brookhaven National Lab, USA

9:00 AM**(H2-STOR-25) Exploration of the Direct Synthesis of Alane through Hydrogenation of Aluminum in Supercritical Fluid Media**

C. Jensen*, University of Hawaii at Manoa, USA; R. Ayabe, G. McGrady, T. Humphries, University of New Brunswick, Canada

9:20 AM**(H2-STOR-26) Recent progress in materials designing for inorganic hydrogen storage medium (Invited)**

S. Towata*, K. Miwa, T. Noritake, N. Ohba, M. Matsumoto, M. Aoki, TOYOTA Central R&D Labs., Japan; H. Li, Y. Nakamori, S. Orimo, Tohoku univ., Japan

9:40 AM**(H2-STOR-27) Understanding Dehydrogenation Mechanisms: From Complex Hydrides to Carbon based Nanostructures**

P. Jena*, Virginia Commonwealth University, USA

10:00 AM

Break

Production**Water/Solar 1 - Nuclear**

Room: Seahorse

Session Chairs: Charlie Chun, ExxonMobil; Balu Balachandran, Argonne National Laboratory

10:20 AM**(H2-PROD-01) Materials Considerations for High Temperature Thermochemical Hydrogen Production (Invited)**

W. Summers*, Savannah River National Laboratory, USA

10:40 AM**(H2-PROD-02) High Temperature Electrolysis for Hydrogen Production**

J. Herring*, C. M. Stoots, J. E. O'Brien, Idaho National Laboratory, USA; J. J. Hartvigsen, Ceramatec, Inc., USA

11:00 AM**(H2-PROD-03) Nickel-Silicon Alloys for Hydrogen Generation by the Sulfur-Iodine Cycle**

J. W. Newkirk*, R. K. Brow, U. of Missouri-Rolla, USA; T. M. Lillo, Idaho National Laboratory, USA

11:20 AM**(H2-PROD-04) K-Bi Thermochemical Cycle for Hydrogen Production**

S. Lvov*, V. Rodriguez-Santiago, M. Fedkin, Penn State University, USA

11:40 AM**(H2-PROD-05) Recent Results on Splitting Water with Al Alloys**

J. Woodall, C. R. Allen, J. Ziebarth*, Purdue University, USA

Storage

Hollow Glass Microspheres (HGMs)

Room: Sea Oats

Session Chairs: Robert Miller, Air Products; Rana Mahtadi, Toyota Motor Corp.

1:00 PM

(H2-STOR-28) The Manufacturing and Characterization of Hollow Glass Spheres Designed for Storing Hydrogen

D. E. Day*, MO-SCI Corporation, USA; J. E. Shelby, Alfred University, USA

1:20 PM

(H2-STOR-29) High Pressure Hydrogen Storage in Hollow Glass Microspheres

P. F. Wachtel*, J. E. Shelby, Alfred University, USA; M. J. Snyder, Corning, Inc, USA

1:40 PM

(H2-STOR-30) Unique Porous Wall, Hollow Glass Microspheres for Hydrogen Storage, Separations and Other Related Applications

G. G. Wicks*, K. L. Heung, R. F. Schumacher, Savannah River National Laboratory, USA

2:00 PM

(H2-STOR-31) New Concept for Storing Reactive Complex Hydrides On-board of Automobiles

R. Mohtadi*, Toyota Motor Engineering and Manufacturing North America, USA; K. Tange, T. Matsunaga, Toyota Motor Corporation, Japan; G. Wicks, K. Heung, R. Schumacher, Savannah River National Lab, USA

2:20 PM

(H2-PROD-06) Encapsulation of Palladium in Porous Wall Hollow Glass Microspheres

L. K. Heung*, G. G. Wicks, R. F. Schumacher, Savannah River National Laboratory, USA

2:40 PM

(H2-PROD-07) Separation of Hydrogen from Mixed Gases Using Hollow Glass Microspheres

J. Rich*, J. E. Shelby, Alfred University, USA

3:00 PM

(H2-STOR-32) Impacts of Composition and Heat Treatment on Pore Size in Borosilicate Glass Microspheres

F. C. Raszewski*, E. K. Hansen, D. K. Peeler, R. F. Schumacher, Savannah River National Laboratory, USA; S. W. Gaylord, N. A. Carlie, L. Petit, K. A. Richardson, Clemson University, USA

Leakage Detection/Safety

Leakage/Safety 2

Room: Dunes 1 & 2

Session Chairs: Richard Sisson, Worcester Polytechnic Institute; Mircea-Stefan Stanescu, Linde Group

1:00 PM

(H2-LEAK-03) Ceramic Hydrogen Safety Sensor for the Emerging Hydrogen Economy

L. B. Thrun*, S. L. Swartz, S. R. Cummings, NexTech Materials, Ltd., USA

1:20 PM

(H2-LEAK-04) Explosive Nature of Hydrogen in a Partial Pressure Vacuum (Invited)

T. M. Jones*, W. R. Jones, Solar Atmospheres Inc., USA

1:40 PM

(H2-LEAK-05) Safety Aspects of Hydrogen at Low and High Velocity (Invited)

R. W. Boyd, The Linde Group, USA; M. Stanescu*, P. Stratton, The Linde Group, Germany

2:00 PM

(H2-LEAK-06) Closing the Loop: The Recovery and Recycle of Tritium From Commercial Devices (Invited)

J. Mintz*, Lawrence Berkeley National Lab, USA

2:20 PM

(H2-LEAK-07) Tritium Effects on Polymeric Materials

E. A. Clark*, Savannah River National Laboratory, USA

2:40 PM

(H2-LEAK-08) Tritium Aging Effects on Forged Stainless Steel

M. Morgan*, Savannah River National Laboratory, USA

3:00 PM

(H2-LEAK-09) Standards and New Practices for Physical Hazards Assessment of Nanomaterials

D. Hathcock*, Savannah River National Laboratory, USA

Production

Hydrocarbons

Room: Seahorse

Session Chairs: Craig Jensen, University of Hawaii; Jason Graetz, Brookhaven National Laboratory

1:00 PM

(H2-PROD-08) Development of Dense Membranes for Hydrogen Production and Purification (Invited)

U. Balachandran*, T. H. Lee, L. Chen, J. J. Picciolo, J. E. Emerson, S. E. Dorris, Argonne National Laboratory, USA

1:20 PM

(H2-PROD-09) Gasification-Route to Hydrogen: Can Membranes Make a Difference? (Invited)

C. Guo, K. Kapoun*, Shell Hydrogen, USA

1:40 PM

(H2-PROD-10) Materials Challenges in Hydrogen Production from Hydrocarbons

C. Chun*, F. Hershkowitz, ExxonMobil Research and Engineering Company, USA; T. A. Ramanarayanan, Princeton University, USA

2:00 PM

(H2-PROD-11) Production of Hydrogen and Synthetic Hydrocarbon Fuels from Biomass-based Feedstocks

N. Muradov*, A. T-Raissi, F. Smith, K. Kallupalayam, Florida Solar Energy Center, USA

2:20 PM

(H2-PROD-12) SiC Nanoporous Membrane for Hydrogen Separation at High Temperature

Y. Kim*, W. Kwon, S. Kim, E. Kim, Korea Institute of Ceramic Engineering and Technology, South Korea; D. Choi, Yonsei University, South Korea

2:40 PM

(H2-PROD-13) Porous Alumina Tubular Substrates for Hydrogen/Gas Separation

D. L. Edson*, J. R. Schorr, S. Sengupta, R. Revur, T. Pyles, MetaMateria Partners, USA; H. Verweij, K. Shqau, The Ohio State University, USA

3:00 PM

(H2-PROD-14) Alternative Materials to Pd Membranes for Hydrogen Purification

P. S. Korinko*, T. M. Adams, Savannah River National Laboratory, USA

3:20 PM

(H2-PROD-24) Materials Discovery for Hydrogen Production by Coal Gasification

S.K. Sundaram*, Pacific Northwest National Laboratory, USA

Posters 5:30 PM**Room: Horizons****Poster Session**

(H2-DELV-12) Analysis of Electrochemical Experiments for Evaluation of Susceptibility to Embrittlement by Hydrogen Gas
R. E. Ricker*, D. J. Pitchure, NIST, USA

(H2-DELV-13) Inexpensive, Off-The-Shelf Hybrid Microwave TPD System

R. T. Walters*, Savannah River National Laboratory, USA; G. G. Wicks, P. R. Burket, Savannah River National Laboratory, USA

(H2-STOR-33) Thermodynamic Analysis of a Novel Hydrogen Storage Material: Nanoporous Silicon

P. J. Schubert*, A. D. Wilks, Packer Engineering, Inc., USA

(H2-STOR-34) First Generation High Throughput Combinatorial Hydrogen Storage Materials Screening System

N. Mohajeri*, A. T-Raissi, K. K. Ramasamy, J. Baik, N. Muradov, UCF-Florida Solar Energy Center, USA

(H2-STOR-35) Synthesis of Activated Carbon Fibres for High-Pressure Hydrogen Storage

A. Linares-Solano*, M. Kunowsky, Universidad de Alicante, Spain; B. Weinberger, F. D. Lamari, Université Paris 13, France; F. Suárez-García, D. Cazorla-Amorós, Universidad de Alicante, Spain

(H2-STOR-36) Palladium Nanowires for Hydrogen Storage: Equilibrium and Kinetics

O. Talu*, A. Ertan, S. N. Tewari, Cleveland State Univ., USA

(H2-STOR-37) Nanocrystalline Effects on the Reversible Hydrogen Storage of Complex Hydrides

S. S. Srinivasan*, M. U. Jurczyk, Y. D. Goswami, E. K. Stefanakos, University of South Florida, USA

(H2-STOR-38) Ammonia Borane Thermolysis- Borazine and Diborane Capture

N. Mohajeri*, K. K. Ramasamy, A. T-Raissi, UCF-Florida Solar Energy Center, USA

(H2-STOR-39) Mechanisms of the Steam Hydrolysis of Sodium Borohydride

A. M. Beaird*, E. Y. Marrero-Alfonso, T. A. Davis, M. A. Matthews, University of South Carolina, USA

(H2-STOR-40) Water Utilization in the Hydrolysis of Sodium Borohydride

E. Y. Marrero-Alfonso*, A. M. Beaird, T. A. Davis, M. A. Matthews, University of South Carolina, USA

(H2-STOR-41) Investigating Hydrogen Storage Behaviour of Pt and Pd Decorated Transition Metal Oxides

A. Molendowska*, P. J. Hall, University of Strathclyde, United Kingdom; S. Donet, Commissariat à l'Énergie Atomique (CEA), France

(H2-STOR-42) Carbon Nanotubes' Diameter Influence on Performance of Pt/CNTs for PEM Fuel Cell

D. Zhang*, University of Michigan, USA; L. Shen, X. Wu, Shanghai Jiaotong University, China

(H2-STOR-43) Effect of Alumina Particle Content on Properties of Al-Al₂O₃ Matrix Composite

M. Rahimian*, N. Ehsani, H. Baharvandi, N. Parvin, Melek Ashtar University of Technology, Iran

(H2-STOR-44) Review of U.S. Patents for the Production of Hollow Glass Microspheres

F. C. Raszewski*, E. K. Hansen, R. F. Schumacher, Savannah River National Laboratory, USA

(H2-STOR-45) Impact of Glass Composition on the Production of Borosilicate Hollow Glass Microspheres

F. C. Raszewski, E. K. Hansen*, D. K. Peeler, R. F. Schumacher, Savannah River National Laboratory, USA

(H2-OVER-13) Using Porous Microspheres as Additives in Lead-Acid Batteries

D. Newell*, D. B. Edwards, S. N. Patankar, University of Idaho, USA

(H2-STOR-46) Hydrogen Permeability of Various Tank Wall Materials under Tetra-axial Strain and Gas Pressures

E. H. Stokes*, Southern Research Institute, USA

(H2-PROD-15) Facile Generation of Hydrogen from an Ammonium/Borohydride Mix

B. Spielvogel*, BoroScience International Inc, USA

(H2-STOR-47) Trade Study for Cost Effective, Safe and Lightweight Metallic Material Pressure Vessels for Hydrogen Storage

J. A. Lee*, NASA-Marshall Space Flight Center, USA

(H2-PROD-16) Fossil Fuel Based Gasification: Materials for Hydrogen and Liquid Fuel Production

B. Morreale*, A. Cugini, U.S. D.O.E. National Energy Technology Laboratory, USA

(H2-PROD-17) Fossil Fuel Based Gasification: Materials for Hydrogen and Liquid Fuel Production, Part 2

B. Morreale*, A. Cugini, U.S. D.O.E. National Energy Technology Laboratory, USA

(H2-PROD-18) Fossil Fuel Based Gasification: Materials for Hydrogen and Liquid Fuel Production, Part 3

B. Morreale*, A. Cugini, U.S. D.O.E. National Energy Technology Laboratory, USA

Wednesday, February 27, 2008**Storage****Tanks and Systems**

Room: Sea Oats

Session Chairs: Robert Bowman, Jet Propulsion Laboratory; Leung Heung, Savannah River National Laboratory

8:00 AM

(H2-STOR-48) Reversible and Complex Metal Hydrides

T. Motyka*, Savannah River National Laboratory, USA

8:20 AM

(H2-STOR-49) Carbon Fiber Fully Over-Wrapped Composite Cylinders for Storage of Hydrogen at Pressures of up to 100 MPa (Invited)

R. W. Boyd*, The Linde Group, USA

8:40 AM

(H2-STOR-50) New Evaluation Tool Allowing for Hydrogen Storage Tank System Volume and Weight Estimation

K. Tange*, M. Ishikiriyama, Toyota Motor Corporation, Japan; R. Mohtadi, Toyota Motor Engineering and Manufacturing North America, USA; K. Hirose, Toyota Motor Corporation, Japan

9:00 AM

(H2-STOR-51) Development and Verification of Type 2 Composite High Pressure Hydrogen Bulk Storage Vessels (Invited)

T. J. Hannum*, HyPerComp Engineering, USA

Production**Water/Solar 2**

Room: Seahorse

Session Chair: William Summers, Savannah River National Laboratory

8:00 AM

(H2-PROD-19) Development of Advanced Catalysts for PEM Water Electrolysis

E. B. Anderson*, K. E. Ayers, J. Manco, E. Styche, Distributed Energy Systems, USA

8:20 AM

(H2-PROD-20) Parametric Modeling of Heat Recuperative Solid Oxide Electrolysis System

S. Gopalan*, Howard University, USA; J. Hartvigsen, Ceramatec Inc, USA; R. McConnell, National Renewable Energy Laboratory, USA; M. Mosleh, Howard University, USA

8:40 AM

(H2-PROD-21) X-Ray Photoelectron Investigation of Phosphotungstic Acid as a Proton-Conducting Medium in Solid Polymer Electrolytes

C. A. Linkous*, S. L. Rhoden, Florida Solar Energy Center, USA; K. M. Scammon, University of Central Florida, USA

9:00 AM

(H2-PROD-22) Hydrogen Production via Photooxidation of Aqueous Sodium Sulfite Solutions

C. Huang*, C. A. Linkous, O. Adebijiyi, A. T-Raissi, University of Central Florida, USA

9:20 AM

(H2-PROD-23) 1-Step Fabrication of Nanoscale Zero Valent Iron Particles from Steel-Mill Waste for the Generation of PEMFC-grade Green Hydrogen

S. K. Kesavan, S. Al-Batty*, A. Azad, The University of Toledo, USA

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Monday, February 25, 2008

Global Hydrogen Activities

International Overviews 1

Room: Sea Oats

Session Chairs: Michael Hirscher, Max-Planck Institute; Ashraf Imam, Naval Research Laboratory

10:00 AM

(H2-OVER-01) Review of Materials Development Programs for Hydrogen Storage (Invited)

N. Stetson¹, U.S. Department of Energy, USA; J. Petrovic, Los Alamos National Laboratory (retired), USA; C. Read, G. Ordaz, M. Gardiner, U.S. Department of Energy, USA; G. Thomas, Sandia National Laboratories (retired), USA; S. Satyapal, U.S. Department of Energy, USA

Commercially viable on-board storage of hydrogen for hydrogen-fueled vehicles is a technical challenge that requires significant breakthroughs in materials development. Advanced hydrogen storage options under investigation include physical storage of hydrogen in high-pressure composite tanks and materials-based storage where hydrogen is "bonded" or contained within a solid or liquid. Extensive research is being carried out throughout the world on new concepts and materials to meet the challenge of hydrogen storage for transportation as well as for stationary and portable applications. An overview of key materials development programs for hydrogen storage, including the U.S. Department of Energy's National Hydrogen Storage Project as well as other U.S. and international activities, will be summarized. Issues associated with hydrogen storage in materials, including metal hydrides, sorbents and chemical hydrides, will be presented and the current status of hydrogen storage systems will be discussed. Important recent research avenues and results will be highlighted. Examples of international collaborations on hydrogen storage and future plans will also be outlined.

10:30 AM

(H2-OVER-02) Research Priorities and Progress in Hydrogen Energy Research in the European Union (Invited)

C. Filiou¹, P. Moretto, European Commission, Netherlands; J. Martin-Bermejo, European Commission, Directorate-General Research, Belgium

The European Commission (EC) fosters and funds under its multi-annual work programme – currently the Seventh Framework Programme (2007-2013) – research, development and demonstration activities on hydrogen and fuel cells. It has also successfully mobilised key European stakeholders via the establishment and operation of the industry-led European Hydrogen and Fuel Cell Technology Platform and most recently with the launching of its follow-up, the Fuel Cells and Hydrogen Joint Technology Initiative (JTI), a long-term public-private Joint Undertaking to be funded by the European community and an Industry Grouping. The aim of this joint undertaking is through integrated, focused actions to explore the potential and accelerate the development and deployment of these key technologies at European level, with a vision of clean, affordable and secure energy systems based on hydrogen as an energy carrier and fuel cells as energy converters.

11:30 AM

(H2-OVER-04) Materials Issues for H2 R&D in Canada (Invited)

E. Andrukaitis¹, Defence R&D Canada, Canada

Several materials issues exist for H2 R&D in Canada. Similar issues exist for both domestic and defence applications, but with some differences. For the military, the overall system must have highest energy density possible to compete with other options. The more H2 per unit weight that can be generated, stored or carried, the better. Volume constraints also exist for mobile/portable applications. The safety of H2 on or near soldiers is also important. Both reversible H2

storage, single use and alternative H2 producing fuels with high energy densities have a large materials challenge. Known reversible metal hydrides that store large specific masses of H2 also have high enthalpies of formation and require high temperatures to release the strongly bound H2. A reversible H2 storage capacity of at least 6 wt% is needed. But no metal alloy has been found which provides a winning combination of adequate capacity for reversible H2 storage, low cost and the requirements in reversibility, thermodynamics, capacity and kinetics are achieved.

International Overviews 2

Room: Sea Oats

Session Chairs: Theodore Steriotis, NCSR "Demokritos"; Ned Stetson, U.S. Dept. of Energy

1:00 PM

(H2-OVER-05) Energy Materials Research and Development to the Power System for Fuel Cell Electric Vehicle in China (Invited)

Z. Ma¹, Institute of Electrochemical & Energy Technology, China

Fuel cell electric vehicle (FCEV) is the most important zero emission electric vehicle. The obstacle to the commercialization for FCEV is hydrogen storage with high density and safety. According to the expertise from the demonstration of the FCEV in the world, hybrid FCEV which integrated with advanced battery or supercapacitor will become new power system for FCEV. Energy materials innovation and production process development to the energy storage system, such as hydrogen storage and batteries, are needed to reduce cost. The progress on the energy materials to the energy storage system in China will be introduced in detail. How to optimize the energy storage system and integrate the power system with fuel cell? The effect of the hydrogen storage manner and energy storage system is discussed and explained.

1:30 PM

(H2-OVER-06) Introduction of the Hydrogen Economy in Emerging Markets (Invited)

J. I. Galindo¹, Alset Technology LLC, Argentina

The Argentinean Case: Lessons and critical aspects in the implementation of CNG as an alternative fuel. Industrial evolution and key elements of success. Currently over 1,500,000 cars running on CNG. The Chilean Case: A new model for the establishment of hydrogen as an alternative fuel. Strategic and Technical implications in the transportation and energy sector.

2:15 PM

(H2-OVER-07) Taking India to Hydrogen Economy (Invited)

R. Sundaresan¹, Nonferrous Materials Technology Development Centre (NFTDC), India

The necessity of taking India into hydrogen energy economy has been recognised, and a roadmap to hydrogen economy was drawn up in 2006. With the production of 2-, 3- and 4-wheelers having gone up by over 100% during the period 2001-07, the primary attention to hydrogen usage is in the transport sector. While there is some effort to bring down the cost of PEM fuel cells to promote their use in cars, particularly in the form of electric cars with the battery backed up by a fuel cell, the initial thrust is towards introduction of hydrogen in the present IC engines. India had earlier introduced, on environmental concerns, extensive use of compressed natural gas (CNG) in IC engines in public transport vehicles. Currently the development is towards introduction of hydrogen as a 5-10% mixture with CNG in IC engines and work towards increasing the admixture, named Hithane, to as high a hydrogen content as possible, probably 30%. The Indian automobile producers Tata Motors, Bajaj Auto, Mahindra & Mahindra, Ashok Leyland and Eicher Motors have come together in developing and optimising such mixture. It is expected that fuel cell powered vehicles will be taken up only as a long term strategy. There have

been several concerns voiced on the proposed roadmap. One major issue is on sourcing hydrogen. The proposed roadmap includes setting up production of up to a million vehicles running on hydrogen or hithane, but no serious work has been proposed on developing cost effective hydrogen production in such large quantity. Reforming of fossil fuels and coal med methane for hydrogen is no real solution since carbon fixation costs would be prohibitive. Storage issues also need to be sorted out. Although it is planned that hithane would be provided from dispensing stations, considerable transportation of hydrogen would be involved and safe and economic transport mechanisms enabled by hydrogen storage materials will need to be drawn up. A third consideration is on energy equations of hydrogen usage in IC engine. With the cost of hydrogen being necessarily much greater than fossil fuels in the foreseeable future, use of hydrogen in generating and running an electric motor would be far more energy efficient than the mere replacement of fossil fuels in a low efficiency IC engine. The continuing work towards taking India to hydrogen economy in several centres across India is discussed in the light of India's fast growing energy needs.

2:45 PM

(H2-OVER-08) Current Status of R&D on Hydrogen Production and Storage in Korea (Invited)

J. Kim¹, Hydrogen Energy R&D Center, South Korea

In order to overcome the barriers to hydrogen economy, hydrogen production technology based on renewable energy sources is important and an affordable and stable hydrogen storage technology must be preceded. The Hydrogen Energy R&D Center (HERC) was launched in October 2003, in order to develop the key technologies for the production, storage, and use of hydrogen energy for expediting realization of hydrogen economy. The current status of hydrogen production and storage R&D program in the Republic of Korea will be reviewed and specific achievements in each research program will be presented. Especially and the efforts for development of photochemical/photo electrochemical hydrogen production from water and hydrogen storage materials with nanostructure will be covered in this presentation.

Storage

Complexes 1 - Borohydrides

Room: Seahorse

Session Chairs: Ragai Zidan, Savannah River National Laboratory; Ted Motyka, Savannah River National Laboratory

1:00 PM

(H2-STOR-01) Challenges in the Development of Complex Hydride Based Systems for Reversible Hydrogen Storage (Invited)

M. Fichtner¹, Research Center Karlsruhe, Germany

An overview will be given on complex hydride systems which are currently investigated for reversible hydrogen storage. The state-of-the art will be presented as well as setbacks in the development, challenges and opportunities for the future.

1:20 PM

(H2-STOR-02) Evaluations of Formation and Reversibility of Metal Borohydrides via Volumetric and Nuclear Magnetic Resonance Methods (Invited)

R. C. Bowman¹, Jet Propulsion Laboratory, USA; S. Hwang, California Institute of Technology, USA; J. W. Reiter, Jet Propulsion Laboratory, USA; C. Kim, H. Kabbour, J. J. Purewal, C. C. Ahn, California Institute of Technology, USA

The phases in the Li-Mg-B-H and Li-Sc-B-H systems have been assessed via nuclear magnetic resonance (NMR) studies. By implementing solid-state NMR techniques such as Magic Angle Spinning (MAS) and cross-polarization (CP) MAS; NMR provides detailed in-

formation on the processes responsible for the formation of hydride phases along with their transformations during desorption. Volumetric measurements yield composition changes during H₂ absorption and desorption where MAS-NMR spectra give clear indications of the phases formed whether they are crystalline or amorphous. In particular, ¹¹B MAS and CPMAS measurements establish the creation of stable intermediate polyborane "B_nH_m" species in the amorphous decomposition products that severely impact the ability to reform the initial borohydride phases following desorption at high temperatures. These polyborane species limit reversibility for most borohydrides unless means are developed to enhance their reactivity.

1:40 PM

(H2-STOR-03) Exploration of Magnesium-Containing Borohydrides and Their Complexes for On-board Hydrogen Storage (Invited)

G. Soloveichik, S. Kniajanski, J. Rijssenbeek, Y. Gao, GE Global Research, USA; J. Zhao¹, The Ohio State University, USA

Magnesium-containing borohydrides and their complexes are promising materials for on-board hydrogen storage. They have very high weight percent hydrogen capacities and are made up of abundant elements (thus potentially low cost). The study on Mg(BH₄)₂, Mg(BH₄)₂(NH₃)₂ and other materials will be reported. An amorphous, intermediate phase formation during decomposition of the Mg(BH₄)₂ gives hope for reversibility, especially when combined with dopants and catalysts. Attempts to synthesize other borohydrides and their complexes will also be discussed.

2:20 PM

(H2-STOR-04) Development of New Metal Hydrides and Borohydrides (Invited)

E. Ronnebro¹, Sandia National Laboratories, USA; E. H. Majzoub, University of Missouri, USA

Anticipating a future hydrogen economy, we need to discover new light-weight, high-capacity reversible hydrogen storage materials which meet the US Department of Energy (DOE) targets. We will here present our work on screening for new complex anionic hydrides by using the hot-sintering technique under high-hydrogen pressures (<3000bar, <500C). In the past, there were no theories available for predicting potential metal hydrides. Thus, in a close collaboration between experimentalists and theorists, we used our newly synthesized bialkali alanate, K₂LiAlH₆, as a role model, to explore the possibilities of using theoretical modelling as a guidance for predicting new materials. Moreover, the potential to utilize catalyzed calcium borohydride, Ca(BH₄)₂, as a reversible hydrogen storage material will be discussed, as well as a recently predicted and synthesized bialkali borohydrides.

2:40 PM

(H2-STOR-05) The Stability and Reversibility of Metallic Borohydrides

M. Au¹, Savannah River National Laboratory, USA

With 18.4 wt% of hydrogen content, LiBH₄ is ideal material for hydrogen storage. However, heating up to 400oC is required to liberate hydrogen. It is difficult to re-absorbed hydrogen after dehydrogenation. It is found that mixing metal halides will reduce stability resulting in dehydrogenation at very low temperature. The XRD investigation found that the halides will react with LiBH₄ to form other unstable borohydrides through ion exchange reaction. However, the stability reduction was often accompanied with increase of irreversibility. The halide modified LiBH₄ did not absorb hydrogen after dehydrogenation even at elevated temperature and pressure. TGA-RGA analyses indicated that some metal halide modified lithium borohydrides evolved diborane during dehydrogenation. The formation of diborane causes unrecoverable capacity loss and irreversibility. In most case of our investigation, more unstable borohydrides

seem to be less reversible. The detail experiment data and discussion will be presented in this paper.

3:00 PM

(H2-STOR-06) Synergistic Effect of LiBH₄ + MgH₂ as a Potential Reversible High Capacity Hydrogen Storage Material

T. C. Price^{*}, G. Walker, D. Grant, The University Of Nottingham, United Kingdom

LiBH₄+MgH₂ is a high capacity destabilised multicomponent system and therefore very attractive for hydrogen storage. In situ neutron diffraction experiments were undertaken to characterise the mechanism of decomposition of the LiBD₄ - MgD₂ system, with an emphasis on investigating the synergistic effects of the components on cyclability and reduction of decomposition temperatures, in both vacuum and partial pressures of deuterium. Results from non-stoichiometric 0.3LiBD₃-MgD₂ under vacuum showed Mg aided decomposition of LiBD₄ forming LiD, B and D₂. The presence of Mg also destabilised the LiD forming Mg_{0.3}Li_{0.7} and Mg_{0.18}Li_{0.82} alloys, it was also found that the reaction could be fully reversed using much milder conditions than required for LiBH₄. It can be concluded that the Mg acts as a catalyst for the decomposition of LiBD₄ forming LiD and that the presence of Mg, leading to the formation of Li_xMg_y alloys, destabilises the LiD enabling release of all the potential D₂.

3:20 PM

(H2-STOR-07) Destabilization of Complex Hydrides by Halide Ion Substitutions on the Hydride Sub-Lattice (Invited)

A. J. Maeland^{*}, H. W. Brinks, A. Fossdal, M. H. Sorby, H. Grove, B. C. Hauback, Institute for Energy Technology, Norway

The ability to manipulate the dissociation pressure is an important feature of hydrogen storage materials. In classical metal hydrides, e.g. LaNi₅H₆, this is done by modifying the electronic structure through substitutions on the metal sub-lattice (La or Ni sites or both). Substitutions on the metal sites in complex hydrides to alter the stability is also possible. Vajo et al. took a different approach for strongly bound complex hydrides, e.g. LiBH₄. In his scheme the desorbed state is stabilized: $\text{LiBH}_4 + \frac{1}{2}\text{MgH}_2 \rightleftharpoons \text{LiH} + \frac{1}{2}\text{MgB}_2 + 2\text{H}_2$. This effectively reduces the enthalpy of desorption and increases the H₂ equilibrium pressure; the stability of the complex hydride, however, is not changed. In the present talk a new and alternative approach to alter the stabilities is presented. The changes in stabilities of complex hydrides are brought about by substitutions by halide anions (fluoride) on the hydride sub-lattice.

Tuesday, February 26, 2008

Storage

Adsorbents 1

Room: Sea Oats

Session Chairs: Anne Dillon, National Renewable Energy

Laboratory; Alan Cooper, Air Products

8:00 AM

(H2-STOR-08) Physisorption of Hydrogen on Novel Porous Materials (Invited)

M. Hirscher^{*}, B. Panella, B. Schmitz, Max Planck Institute for Metals Research, Germany

Besides high hydrogen storage density, one important prerequisite for automotive application is short refuelling time without evolving a large amount of heat. Owing to the low heat of adsorption involved in physisorption of hydrogen molecules, cryo-adsorption systems based on materials with high specific surface area fulfil these requirements. The presentation will give an overview on hydrogen adsorption measurements of different microporous materials, e.g., carbon

nanostructures, zeolites, MOFs etc. For the maximum hydrogen uptake at high pressure and 77 K an almost linear correlation with the specific surface area is found, whereas, the adsorption at low pressure depends on the pore size or the metal ions. The results indicate that nanostructures with high specific surface area and micropore density are very promising materials for hydrogen storage by physisorption at lower temperatures. Partial funding by the European Commission DG Research (contract SES6-2006-518271/NESSHY) is gratefully acknowledged by the authors.

8:20 AM

(H2-STOR-09) High-Throughput Methodology for Discovery of Metal-Organic Frameworks with a High Hydrogen Binding Enthalpy (Invited)

S. S. Kaye, S. Horike, J. R. Long^{*}, University of California, Berkeley, USA

Automated procedures are being developed in collaboration with Symyx Technologies for the generation of microporous metal-organic frameworks with exposed metal sites. Robotic instrumentation is used to dispense reactants and solvents into an array of reaction vessels, which can then be sealed and heated to the desired temperature. Methods for isolating, weighing, and photographing the solid products are under development, as are parallel means of characterization by x-ray powder diffraction and Raman spectroscopy. In addition, rapid methods for performing crude thermogravimetric analyses and estimating adsorption capacities are being devised. The reliability of these techniques are tested through comparisons with selected bulk-scale experiments performed using traditional laboratory methods. As these new automated procedures become available, the methodology is being applied in the search for new metal-organic frameworks exhibiting high-enthalpy hydrogen adsorption.

8:40 AM

(H2-STOR-10) High Density Carbon Materials for Hydrogen Storage (Invited)

A. Linares-Solano^{*}, M. Jordá-Beneyto, D. Lozano-Castello, F. Suárez-García, D. Cazorla-Amorós, Universidad de Alicante, Spain

This work remarks the importance of preparing high density carbon materials and the need of reporting H₂ storage in volumetric basis (not in gravimetric, as usual). Therefore, packing density, including inter-particle and pore volume, has to be reported. This is relevant for H₂ vehicle use where tank volume is a key point. For reliable applications, we have also prepared advanced activated carbon monoliths (AACM) with high porosity and density. H₂ storage capacity of our best AACM, at 77 K and 4 MPa, are the highest reported one (excess adsorbed H₂ and total H₂ stored of 29.7 and 39.3 g L⁻¹, respectively). Although higher values have been reported for MOFs, these are unrealistic because crystal density (which does not include inter-particle space) has been used. In conclusion, 1) high density carbon materials are needed for H₂ storage 2) our AACM are very promising adsorbents and 3) the claimed MOFs's H₂ uptakes need confirmation using, for volumetric calculations, other density (i.e. packing) than crystal density.

9:00 AM

(H2-STOR-11) Palladium-doped Nanoporous Carbon Fibers for Hydrogen Storage (Invited)

N. C. Gallego^{*}, C. I. Contescu, V. V. Bhat, Oak Ridge National Laboratory, USA; H. L. Tekinalp, D. D. Edie, Clemson University, USA

Pd-free and Pd-containing activated carbon fibers (Pd-ACF) were synthesized from isotropic pitch. Hydrogen adsorption was analyzed at temperatures between 5 and 80 °C and moderate pressures (up to 2 MPa). It was found that adsorption on Pd-ACF is always higher than that of the corresponding ACF, and in excess of what it would be expected based on formation of Pd hydride, supporting the mechanism of hydrogen spillover. It was also found that temperature and pressure have opposing effects on physisorption and spillover. It is hypothesized that a narrow temperature range exists, where the kinetic

advantage of H₂ spillover in Pd-ACF overlaps synergistically with the thermodynamic advantage of physisorption, contributing to highly enhanced uptakes compared with the Pd-free carbons. Research sponsored by the Division of Materials Sciences and Engineering, U.S. Department of Energy under contract with UT-Battelle, LLC.

9:20 AM

(H2-STOR-12) High Hydrogen Adsorption by Porous Coordination Framework Materials

M. Schroder^{*}, University of Nottingham, United Kingdom

The storage of hydrogen in a safe and compact form represents a significant current challenge, and there is wide-ranging interest in the development of stable materials that can store and release hydrogen with fast kinetics and high reversibility over multiple cycles. Porous co-ordination framework compounds have enormous potential in this regard. We report the synthesis, structural characterisation and gas adsorption studies of a range of metal-organic materials including stable carboxylate-linked complexes that exhibit high porosity and surface area coupled with high hydrogen capacities. Of particular interest is a family of isotopological porous framework materials based upon tetracarboxylate complexes of Cu(II). Our results indicate that it is not simply pore volume but guest-pore fit that determines the affinity of hydrogen molecules within the framework structure. Our materials afford a maximum hydrogen uptake of over 7 wt.% at 77K, exceeding the DoE target of 6.5 wt%.

9:40 AM

(H2-STOR-13) Identification of H₂ Trapping Sites on Single-Walled Carbon Nanotubes Using Neutron Scattering, Ab Initio Calculations, and Langmuir Fits to Adsorption Isotherms (Invited)

D. K. Ross^{*}, M. Seifi, P. A. Georgiev, D. Reilly, I. Morrison, University of Salford, United Kingdom

Neutron Inelastic Scattering measurements of the para-ortho transition in H₂ trapped on the surface of single-walled carbon nanotubes shows two distinct spectra, characteristic of two different sites, which we presume to be the groove sites between two tangentially touching nanotubes and sites on the convex surface of a single tube. Adsorption isotherm measurements give excellent fits using two Langmuirs yielding the adsorption energy at the two different sites to be around 40 meV and 60 meV for different samples of nanotubes. Ab initio calculations yield trapping energies of around 50 meV and 100meV for SWNTs for convex and groove sites respectively (less zero point energies), the latter increasing significantly with increasing tube radius. The results suggest that 2-Langmuir fits to H₂ adsorption isotherms provide a means of estimating the mean SWNT radii in a given sample.

Adsorbents and Chemical Hydrides

Room: Sea Oats

Session Chairs: Nidia Gallego, Oak Ridge National Laboratory; D. Ross, University of Salford

10:20 AM

(H2-STOR-14) Novel Organometallic Fullerene Complexes for Vehicular Hydrogen Storage (Invited)

A. Dillon^{*}, E. Whitney, C. Engrakul, C. Curtis, P. Parilla, K. O'Neill, L. Simpson, M. Heben, National Renewable Energy Laboratory, USA

We have probed new techniques in order to coordinate C₆₀ with either Fe, Sc, Cr, Co or Li. The new compounds were characterized with multiple techniques. All of the structures were found to have unique binding sites for hydrogen with temperature programmed desorption. Furthermore, the Fe(C₆₀) complex has a reversible hydrogen storage capacity of 0.5 wt% at 77 K with an H₂ overpressure of 2 bar. The extensive characterization techniques indicate that C₆₀-Fe-C₆₀-Fe-C₆₀-chain structures of an undetermined length

are formed. The specific surface area of the Fe(C₆₀) compound is only ~ 50 m²/g indicating a porous network that H₂ but not N₂ may access. A Li₁₂C₆₀ compound has also been synthesized. In good agreement with theoretical studies, hydrogen binding energy for the compound is approximately 7 kJ/mol, but the capacity at 77 K and 2 bar is ~ 0.3 wt%. The difference between the experimental and theoretical capacity is attributed to significant differences in structure.

10:40 AM

(H2-STOR-15) Highly Porous Compounds with Very Large Surface Area for Hydrogen Storage (Invited)

M. J. Latroche^{*}, CNRS, France; C. Serre, T. Loiseau, G. Férey, CNRS-Université de Versailles, France

Different means can be used to store hydrogen and solid state storage is one of the most promising. Different approaches can be chosen to reach high gravimetric and volumetric capacities. On one hand, one can use physisorption by developing materials with very high surface area though weak interactions between hydrogen molecules and the framework imply low temperature working range. On the other hand, metallic or complex materials allow chemisorption at room temperature but hydrogen dissociation and strong bonding induce high thermal effects and limited kinetic. In the present paper, different microporous materials able to reversibly store hydrogen will be presented. Different porous metal terephthalates and carboxylates have been obtained showing very large pore sizes and giant surface areas. Beside the usual properties of these porous compounds, these structures have potential capabilities for hydrogen storage and their gas sorption properties will be described.

11:00 AM

(H2-STOR-16) Solid State Chemical Hydrogen Storage (Invited)

T. Autrey^{*}, Pacific Northwest National Laboratory, USA

Our group has been working on developing an in-depth understanding of the chemical and physical properties of amine borane materials for solid state on-board hydrogen storage. These materials, (NH_xBH_x) provide both high gravimetric and volumetric densities of hydrogen. Hydrogen is released at low temperatures through a series of moderate exothermic reactions. In this work we present experimental studies designed to elucidate more details about the potential mechanism for H₂ formation from NH_xBH_x compounds in the solid state and in solution. This work supported in part by DOE EERE CoECHS. Battelle operates PNNL for DOE.

11:20 AM

(H2-STOR-17) An Integrated Hydrogen Storage and Delivery Approach Using Organic Liquid-phase Carriers (Invited)

A. Cooper^{*}, A. Scott, D. Fowler, M. Ford, B. Toseland, H. Cheng, G. Pez, Air Products and Chemicals, Inc., USA

Cost-effective, reliable, and energy-efficient hydrogen storage is a key requirement to realize the potential of H₂ powered vehicles. Organic liquids with high hydrogen storage capacities and low volatility have been developed for use as hydrogen carriers for an integrated production, delivery, and storage of hydrogen. Liquid carrier prototypes, such as alkylated carbazoles and other aromatic heterocyclic compounds, can be dehydrogenated at 1 atm. hydrogen pressure and temperatures of 150-225 C to yield high-purity H₂. The reversible capacities of the liquid carriers are 5.5-7.2 wt. % H₂ and 50-70 g H₂/liter. A recent extension of this concept is the use of organic liquid hydrogen carriers that can provide hydrogen by dehydrogenation and, via a selective oxidation reaction using unpressurized air, provide heat sufficient to balance the endothermic dehydrogenation reaction. Preliminary examples of this "autothermal" hydrogen storage concept will be discussed.

Distribution

Delivery 1

Room: Sawgrass

Session Chairs: Tim Armstrong, Oak Ridge National Laboratory;
Dave McColskey, NIST

8:00 AM

(H2-DELV-01) A Stakeholders Perspective on Material Challenges of Developing Hydrogen Delivery Infrastructure

B. B. Bonner^{*}, Air Products and Chemicals, Inc., USA

Successful development and deployment of hydrogen and fuel cell vehicle technologies will have tremendous energy security and environmental benefit. Hydrogen delivery is a critical contributor to the cost, energy use and emissions associated with hydrogen supply pathways. Air Products is working on developing hydrogen delivery technologies that enable the introduction and long term viability of hydrogen as an energy carrier for transportation and other markets. This encompasses full integration of hydrogen delivery from production to and including the dispenser at a refueling station or energy site. This presentation will explore areas where progress is being made in hydrogen delivery today that expands hydrogen delivery infrastructure and supports the use of hydrogen as a major energy carrier. The presentation will also outline areas where further advancements in lower cost, lighter weight, and stronger materials are required to further support the transition to hydrogen.

8:20 AM

(H2-DELV-02) Hydrogen Delivery Analysis: Enhanced Model and New Results

A. Elgowainy^{*}, M. Mintz, J. Gillette, Argonne National Laboratory, USA

As part of the DOE hydrogen analysis (H2A) program, the Hydrogen Delivery Scenario Analysis Model (HDSAM) was developed to provide a user-friendly tool to estimate the cost of hydrogen delivery for a range of markets, demand levels, and infrastructure configurations. Hydrogen delivery includes a series of packaging and storage stages as the hydrogen fuel is being transported from a production facility to a refueling station. The most recent version of the model, Version 2.0, incorporates calculations of delivery infrastructure storage requirements, as well as energy use and greenhouse gas emissions associated with hydrogen delivery. HDSAM focuses on hydrogen delivery analysis using currently available technologies. HDSAM was built to provide a platform for comparing (a) the total cost contribution per kg of delivered hydrogen, (b) the component-level breakdown of delivery cost, and (c) the energy use and greenhouse gas emissions for various delivery options, and market types, and market sizes and penetrations.

8:40 AM

(H2-DELV-03) Codes and Standards for a Hydrogen Economy Infrastructure (Invited)

G. B. Rawls^{*}, Savannah River National Lab, USA; L. Hayden, Louis Hayden Consultants, USA; M. Rana, Praxair Inc., USA

The development of new codes and standards to support hydrogen delivery systems and components are needed for a national hydrogen economy with widespread interstate use. In an attempt to support the ongoing effort on hydrogen fuel infrastructure in USA, a need has been identified for Code rules for 15,000 psi gaseous hydrogen vessels for stationary storage as well as transport applications. In addition a new piping Code, ASME B31.12, is under development to provide rules for pipelines and industrial and residential pipe systems in hydrogen service. This paper presents a review of existing rules which are being used in the design and manufacture of hydrogen piping and vessels and presents the new rules which are in various stages of development. Alternate material such as fiber reinforced piping and vessels are also being inves-

tigated to reduce cost of hydrogen systems. Additional research needs to support the technical basis for codes and standards are discussed.

9:00 AM

(H2-DELV-04) Hydrogen-Assisted Fracture in Steels for Hydrogen Delivery and Storage (Invited)

B. Somerday, K. Nibur^{*}, C. San Marchi, Sandia National Laboratories, USA

The objective of this study is to measure the hydrogen-assisted fracture resistance of candidate steels for components in the hydrogen energy infrastructure, e.g., stainless steels for manifold hardware, low-alloy steels for pressure vessels, and carbon steels for pipelines. Hydrogen-assisted fracture is measured using two different methods, i.e., tensile specimens thermally precharged in hydrogen gas or fracture mechanics specimens concurrently loaded and exposed to hydrogen gas. Tensile fracture results demonstrate that type 316 stainless steels can be resistant to hydrogen-assisted fracture, however this resistance depends on alloy content, temperature, and the presence of stress concentrators. Fracture mechanics measurements of sustained-load cracking thresholds reveal that low-alloy and carbon steels can be very susceptible to hydrogen-assisted fracture. Despite such susceptibility, measurements of fracture mechanics properties enable structural analysis to quantitatively demonstrate design margins.

9:20 AM

(H2-DELV-05) Friction and Wear Properties of Materials used in Hydrogen Service

R. Erck^{*}, G. Fenske, O. Eryilmaz, Argonne National Laboratory, USA

Mechanical components used in the production and delivery of hydrogen, such as in compressors used for pipeline or point-of-delivery applications, can be subject to excessive wear, have poor reliability, or may require the use of lubricants that can contaminate the hydrogen. In order to understand these potential problems affecting the economics and reliability of components, experiments were undertaken to assess the friction and wear properties of candidate materials, such as stainless steel or nickel alloys. Coatings, based on graphite, amorphous carbon or MoS₂ were also examined. Tribological test results are presented for sliding at low speeds in sub-ambient hydrogen gas, as well as high-speed tests of materials in pure hydrogen gas at ambient pressure.

Delivery 2

Room: Sawgrass

Session Chairs: Brian Bonner, Air Products; Petros Sofronis, University of Illinois - Urbana/Champaign

10:20 AM

(H2-DELV-06) Affect of Microstructure on Hydrogen Permeation and Embrittlement in Pipeline Materials

P. S. Korinko, T. M. Adams^{*}, A. J. Duncan, Savannah River National Laboratory, USA

As H₂ fuel to a consumer commodity many transportation and transmission issues must be addressed. A significant one is transportation of the fuel from the production site to the consumer refueling station. Several scenarios are possible, such as, liquid transport, gaseous trucking, or pipelines. While H₂ has been used industrially for decades, the introduction as a consumer product will result in a significantly higher volume of gas being transported than is currently used. In order to meet this increased demand, new transport methods and materials may be required. Studies are underway to measure the amount of H₂ that permeates typical pipeline steels and the influence of microstructure on the permeation rate and the affect of microstructure on the hydrogen embrittlement susceptibility. These data will be shared in this presentation and the future plans for the project will be described. U.S. Department of Energy: Contract DE-AC09-96SR185

10:40 AM

(H2-DELV-07) Evaluation of the Susceptibility of Simulated Welds in HSLA-100 and HY-100 Steels to Hydrogen Induced CrackingM. R. Stoudt, D. J. Pitchure, R. E. Ricker^{*}, NIST, USA

The cracking susceptibility of a HSLA-100 steel was examined and compared to that of a HY-100 steel in the as-received condition and after heat treatment to simulate the thermal history of a single pass weld. Slow strain rate tensile tests were conducted on samples of these alloys with these thermal histories in an inert environment and in an aqueous solution during continuous cathodic charging at different potentials with respect to a reference electrode. Both alloys exhibited reduced ductilities at cathodic potentials indicating susceptibility to hydrogen embrittlement. The results of these experiments will be presented and discussed in relation to the observed microstructures and fractography.

11:00 AM

(H2-DELV-08) High-Pressure Hydrogen Permeation, Diffusion and Transport in Pipeline Steels (Invited)Z. Feng^{*}, L. M. Anovitz, T. R. Armstrong, Oak Ridge National Laboratory, USA

Hydrogen induced mechanical property degradation is a primary concern for the safe operation of hydrogen delivery and storage systems made of ferritic steels. The degree of degradation is related to the concentration of hydrogen in the metal. Under high-pressure the amount of hydrogen entering the metal depends on both processes at the surface and those inside metal. As part of a DOE program, we investigated hydrogen permeation, solubility, diffusion, and transport processes in pure iron and ferritic steels by means of high-pressure gaseous hydrogen permeation experiment. The effects of hydrogen pressure, temperature and steel microstructure will be presented. The surface effects and their implications in controlling hydrogen into metal will be discussed. Issues related to hydrogen transport phenomena in high-pressure hydrogen and on-going research to address these issues to ensure cost-effective operation and long-term reliability of the hydrogen delivery infrastructure will also be considered.

11:20 AM

(H2-DELV-09) Advanced Non-Destructive Hydrogen Content Sensors (Invited)A. N. Lasseigne^{*}, National Institute of Standards and Technology, USA; K. Koenig, Colorado School of Mines, USA; D. McColsky, T. Siewert, National Institute of Standards and Technology, USA

Demanding integrity problems, such as hydrogen, material aging, higher-strength materials, and materials with complex engineered structures, require new solutions. Advanced integration of physical phenomena measurements will result in new opportunities for the non-destructive community and the development of new analytical measurement equipment and practices. For example, novel electronic tools are being expanded to meet the needs of our industry's demands for pipeline integrity by relating quantitative hydrogen content measurements to physical properties. The development of advanced hydrogen sensors will allow the pipe integrity to be frequently or continuously monitored by utilizing real-time hydrogen sensors to assure pipeline safety and environmental protection. A non-contact induced current low-frequency impedance technique has been developed to cost-effectively assess hydrogen content in pipeline steel and its weldments will be discussed.

11:40 AM

(H2-DELV-10) An Imaging TOF-SIMS Study of Hydrogen-free to Highly Hydrogenated DLC Films Subjected to Tribological Tests in Hydrogen Gas EnvironmentO. L. Eryilmaz^{*}, A. Erdemir, R. Erck, Argonne National Laboratory, USA

Diamondlike carbon (DLC) coatings can be good candidates for use in a wide range of mechanical systems used in the production, delivery, and uses of hydrogen. Research to date shows that these films are

very compatible with hydrogen environments and capable of providing very low friction and wear. In this study, we explored the effect of hydrogen on the tribological behavior of wide range of DLC films. DLC films are grown in gas discharge plasmas containing 1 to 10 H/C ratios. Ball on disk tests were run on coated samples in hydrogen environments. Surface analytical studies and depth profiles of the friction-tested and un-tested areas are carried out using an imaging time of flight secondary Ion Mass Spectroscopy. Three dimensional TOF-SIMS images are reconstructed from selected masses, and depths to elucidate the extent of tribochemical interactions. Finally we have correlated these findings with in friction and wear behaviors of those DLC films.

Global Hydrogen Activities**H Storage/National and International H Activities**

Room: Dunes 1 & 2

Session Chairs: Kyoichi Tange, Toyota Motor Corporation; Thomas Hannum, HyPerComp Engineering

8:00 AM

(H2-OVER-09) Global Perspective Towards the Establishment of the Hydrogen Economy (Invited)J. I. Galindo^{*}, Alset Technology LLC, Argentina

Public perception before and after Global warming awareness. Economic issues – Financing the hydrogen economy through private entities. Return on investment for investors. Key technologies for the establishment of the hydrogen economy. Implementation models.

8:20 AM

(H2-OVER-10) Tritium: A Micropower Source for On-Chip Applications (Invited)N. P. Kherani^{*}, University of Toronto, Canada; B. Liu, K. P. Chen, University of Pittsburgh, USA; S. Zukotynski, University of Toronto, Canada

With the continual miniaturization of microelectronics and its corresponding reduction in power requirements, there is growing research interest in the development of on-chip radioisotope micropower sources. Tritium, a radioisotope of hydrogen, is one of the promising candidates for such applications given its benign radiation characteristic, maximum electron energy of 18.6 keV, and its relatively long half-life of 12.3 years. Further, tritium decay beta particles pose little radiation damage concern given that the threshold energy for silicon lattice disruption due to knock-on collisions is 20 keV. However, stable incorporation of tritium into semiconductor materials at sufficiently high watt density is challenging. We present recent development of versatile techniques of occluding relatively high-density of tritium into various forms of semiconductor materials for on-chip device applications. Candidate tritiated materials include hydrogenated amorphous silicon, crystalline silicon, silicon dioxide and carbon nanotubes.

8:40 AM

(H2-OVER-11) Fusion and Hydrogen-Economy Materials Issues (Invited)W. T. Shmayda^{*}, University of Rochester, USA

The fusion-power and the hydrogen-economy communities face common materials issues. Both hydrogen isotopes, deuterium and tritium, will be used to fuel fusion power reactors. Processes for gas storage, purification, handling, delivery and recovery, represent major materials challenges. The gases must be handled over broad temperature and pressure regimes. Since tritium is radioactive, the processes need to incorporate ultrahigh leak tightness requirements. Tritium decay can induce helium embrittlement, enhance corrosion, or degrade the mechanical properties. These effects have analogs in high-

pressure hydrogen systems. This presentation will highlight the two main avenues towards fusion power: magnetic and inertial confinement fusion, discuss the materials' requirements issues and summarize the international research and development efforts aimed at addressing the requirements. The issues facing the both communities will be compared and contrasted.

9:00 AM

(H2-STOR-18) Progress of Hydrogen Storage and Container Materials (Invited)

Y. Li^{*}, Chinese Academy of Sciences, China

The hydrogen economy is being promoted as a solution to the world's energy and environmental problems arising upon the use of fossil fuels, and Chinese government has also put the hydrogen economy as one of its priority areas. However, implementing hydrogen economy requires solutions to a series of grand challenges, among which safe and efficient hydrogen storage and transportation have been widely recognized as the most technically challenging ones. Commercialization of hydrogen-powered vehicles requires an onboard hydrogen storage system that can store both high gravimetric (≥ 90 gH₂ kg⁻¹) and volumetric (≥ 82 gH₂ L⁻¹) density of deliverable hydrogen at a moderate temperature range. In this talk, the energy and environment challenges will be briefly discussed, the progress of various H-storage and its container materials in China, in particular, at the Institute of Metal Research, will be summarized.

9:20 AM

(H2-OVER-12) Hydrogen Economy in India: Materials Issues and Challenges (Invited)

S. Ramaprabhu^{*}, Indian Institute of Technology - Madras, India

Due to the increase in the oil and gas prices and greenhouse gas emissions, many research groups in India are working on hydrogen production and storage technologies to identify alternate and self-sustaining sources of energy to achieve commercialization. At present, hydrogen is produced by reforming natural gas due to cost advantages over electrolysis and other renewable technologies. However, many scientific groups are exploring the possibility of using renewable technologies that use solar, biogas and biomass to produce hydrogen in large quantities. Research on hydrogen storage technologies is focused on the development of newer complex hydrides and nano-material-composites based storage. Both production and storage technologies face many challenges that must be overcome before the hydrogen economy becomes an achievable reality. Reforming technique is less expensive and therefore will be continued to produce hydrogen till one gets cost effective renewable technologies for mass production of hydrogen. Similarly, the new materials will be investigated for hydrogen storage, but it will take some time before they are used in commercial applications. The present talk provides an overview of developments in hydrogen technologies- hydrogen production and storage technologies- such as electrolysis, biomass, complex hydrides and carbon nanotube technologies in India.

9:40 AM

(H2-STOR-19) European Integrated Project NESSHY: Overview and Promising Results (Invited)

T. Steriotis^{*}, A. Bourlinos, G. Charalambopoulou, A. Stubos, NCSR "Demokritos", Greece

Integrated Project NESSHY (Novel Efficient Solid Storage for Hydrogen) comprises the major ongoing European initiative in H₂ Solid Storage. NESSHY objectives cover porous systems, regenerative hydrogen stores and solid hydrides. Efforts include innovative experimental and modeling methodologies, upscale of material production, development of demonstration storage tanks as well as prototype testing. The presentation will give a brief overview on the scientific objectives of NESSHY and it will further focus on encouraging results pertaining to metal doped carbon foams. The starting carbon foams are lightweight have high surface areas and porosities,

and contain oxygen in the concentration range of conventional graphite oxide. Doping with Pd or Pd alloys lead to composites that reveal enhanced H₂ sorption capacities, most likely based on the spillover mechanism. Partial funding by the European Commission (FP6 contract SES6-2006-518271) is gratefully acknowledged by the authors.

Leakage Detection/Safety

Leakage/Safety 1

Room: Dunes 1 & 2

Session Chairs: Robert Oesterreich, Airliquide; Thomas Mebrahtu, AirProducts

10:20 AM

(H2-LEAK-01) The Fundamental Aspects of Hydrogen Effects on Steels and Other Alloys: A Review

R. D. Sisson^{*}, Worcester Polytechnic Institute, USA

In this tutorial presentation the fundamental aspects of hydrogen effects on the mechanical behavior of steels and other alloys will be presented with a focus on the materials of construction for hydrogen production, delivery and storage. The topics to be presented include: hydrogen embrittlement, hydrogen sulfide stress corrosion cracking, hydrogen attack, hydrogen blistering, and hydrogen effects on fatigue. The fundamentals of the kinetics of hydrogen interactions with alloys and the physical metallurgy of hydrogen in a solid solution will be discussed. This presentation will set the stage for discussions for hydrogen compatibility testing of materials to be used in the emerging hydrogen economy.

10:40 AM

(H2-STOR-20) Testing for Hydrogen Embrittlement: A Tutorial

M. R. Louthan^{*}, Savannah River National Laboratory, USA

Hydrogen has deleterious effects on the mechanical properties of numerous alloys and, unfortunately, the variables that influence the timing and magnitude of these effects are also numerous. The susceptibility to hydrogen embrittlement, as measured in a tensile test, depends on the microstructure and chemistry of the alloy, the temperature of the test, the surface finish of the specimen, the test strain rate, the pressure and purity of the hydrogen environment and the hydrogen content and distribution in the alloy. Tensile data alone cannot be used to predict the performance of a component. The effects of stress state, cyclic loading, thermal gradients and time under load must also be determined. A component that contains no hydrogen when placed in service may absorb hydrogen during service because of exposure to moisture, acids, hydrogen sulfide and other hydrogen containing environments. The presence of hydrogen either in or on the alloy typically lowers ductility, increases fatigue crack growth rates, decreases fracture

11:00 AM

(H2-LEAK-02) Review of Codes and Standards for Hydrogen Refueling Stations

S. Mahajana, D. Edwards, J. Shewchun^{*}, Wayne State University, USA

Hydrogen has been promoted as an energy carrier to replace fossil fuels such as oil in transportation systems. It is claimed to be a very clean form of energy. Fuel cell technology for utilizing hydrogen is still in an embryonic stage and most of the future development of the so-called Hydrogen Economy will depend on a suitable hydrogen refueling infrastructure. The lack of suitable, properly agreed upon Codes and Standards is a major barrier for such infrastructural development. While DOE has conducted research, development and demonstration efforts in order to obtain data needed to establish a scientific basis for requirements incorporated into existing codes and standards, the impact has largely been marginal. Essentially, this is

due to the fact that there is no standardization and each hydrogen re-fueling station is individually designed. This paper focuses on procedures and precautions that need to be standardized so that safe, user-friendly operations will emerge.

11:20 AM

(H2-STOR-21) Hydrogen Safety Standards: Storage, Handling, Usage and Distribution (Invited)

R. Speaker^{*}, Air Liquide Industrial LP, USA; J. Hayes, C. Laffin, Project Engineering, USA

With the interest and use of hydrogen increasing in most industrial business sectors, it is important that we better understand the various safety considerations as they relate to hydrogen. This presentation provides basic information on the characteristics and properties of the element Hydrogen, along with hydrogen's associated hazards. It includes a short summary of how hydrogen is currently produced, transported, and a detailed discussion of the practices required to deal safely with this material in production, storage, and transportation. Finally, this presentation will also provide an overview relative to the safety standards governing the safe storage, handling, distribution and usage of hydrogen.

11:40 AM

(H2-DELV-11) Fracture Toughness Assessment of Hydrogen Pipelines (Invited)

P. Sofronis^{*}, M. Dadfarnia, I. M. Roberston, M. Martin, University of Illinois at Urbana-Champaign, USA

Hydrogen embrittlement of steels is a serious issue in the implementation of the hydrogen pipeline transmission technology. To understand and mitigate the problem of embrittlement, our approach integrates mechanical property testing, microstructural characterization, and finite element modeling. First, the hydrogen trapping characteristics of typical steels from pipelines in service and new micro-alloyed microstructures are identified through Electron Microscopy, Thermal Desorption Spectroscopy, and Permeation Measurements. A hydrogen transport methodology for the calculation of hydrogen accumulation ahead of an axial crack on the internal surface of a pipeline is outlined. The numerical results demonstrate that constraint fracture mechanics based on the T-stress concept can be used to describe the hydrogen distribution and the stress field ahead of the crack. The results are used to discuss a lifetime prediction methodology for failure of materials used for pipelines and welds exposed to high-pressure hydrogen.

Storage

Complexes 2 - Alanates

Room: Seahorse

Session Chairs: Ji-Cheng Zhao, Ohio State University; Maximilian Fichtner, Research Center Karlsruhe

8:00 AM

(H2-STOR-22) Neutron Scattering Studies of the Structure and Dynamics of NaMgH₃ (Invited)

R. Zidan^{*}, A. C. Stowe, Savannah River National Lab, USA; A. I. Acatrinci, M. A. Hartl, L. L. Daemen, Los Alamos National Laboratory, USA

Sodium magnesium tri-hydride (NaMgH₃) was used as a model compound in an attempt to understand the mechanistic of formation of novel complex hydrides, formed by ball milling or molten state processing technique. NaMgH₃ is formed by the reaction of NaH with MgH₂ and found to exhibit intermediate thermodynamics characteristics of hydrogen sorption. The neutron vibrational spectrum of both reagents NaH and MgH₂ have been compared to NaMgH₃ at 10 K on a Filter Difference Spectrometer (FDS) in order to understand the nature of hydrogen bonding in the ternary material. Although the structure of NaMgH₃ was reported IINS studies revealed that a

rhombohedral structure was only 0.9 kcal/mol above the published ground state orthorhombic structure. Calculation of the electronic structure and neutron vibrational spectrum of NaMgH₃ based on both structures suggests possible structural disorder or the coexistence of the rhombohedral phase with an orthorhombic phase.

8:20 AM

(H2-STOR-23) Hydrogen Storage Materials Based on Li-Al-Mg-N-H Systems (Invited)

Z. Z. Fang^{*}, J. Lu, H. Sohn, University of Utah, USA

In recent years, several categories of materials have been studied for hydrogen storage including simple metal hydrides such as MgH₂, complex metal hydrides such as alanates including NaAlH₄ and LiAlH₄, and amides such LiNH₂. Although all these materials have good prospects, all of them have some attributes that prevent their use for practical hydrogen storage applications. It was discovered recently that when these materials are combined the reaction of these materials can be used for reversible hydrogen storage. The combined material systems possess more promising properties than when they are used alone. For example, lithium amide material was found to destabilize lithium alanates. Lithium amide can be used to react with magnesium hydride which forms a binary lithium magnesium nitride – LiMgN. LiMgN can be rehydrogenated and reversibly store up to 8wt% of hydrogen. This presentation will review some of the experimental findings as well as fundamental understandings regarding this category of materials.

8:40 AM

(H2-STOR-24) Direct Alane Formation under Mild Conditions (Invited)

J. Graetz^{*}, Brookhaven National Lab, USA; S. Chaudhari, Washington State University, USA; J. Węgrzyn, J. R. Johnson, Y. Celebi, W. Zhou, J. Reilly, Brookhaven National Lab, USA

Aluminum hydride (AlH₃) is a metastable hydride (298K) with a high H content (10.1 %) and rapid H₂ evolution rates at low temperature (<100°C). Direct hydrogenation of Al requires pressures >7 kbar at 298K and is therefore impractical. We demonstrate that alanates can be formed under mild conditions by utilizing an electron donor as a stabilizing agent. In these experiments Ti-doped Al is reacted directly with H₂ in various solvents. The surface Ti seems to act as a spillover catalyst, disassociating H₂ through electron transfer from Ti 3d orbitals to the antibonding (σ*) orbital of H₂. Atomic hydrogen then reacts with nearby Al to form molecular alane (Al_xH_{3x}). Ultimately, the transient alane is harvested and stabilized by an electron donor (e.g. amine) to form an alane adduct. The alane adducts investigated exhibit reversible H cycling with practical H capacities >2 wt. %. In addition, we demonstrate that it may be possible to break-up some of the less stable alane adducts to remove the stabilizing molecule and recover pure AlH₃.

9:00 AM

(H2-STOR-25) Exploration of the Direct Synthesis of Alane through Hydrogenation of Aluminum in Supercritical Fluid Media

C. Jensen^{*}, University of Hawaii at Manoa, USA; R. Ayabe, G. McGrady, T. Humphries, University of New Brunswick, Canada

Alane, AlH₃ has recently received considerable attention as a potential hydrogen storage material for onboard applications. In view of its high, 10 wt % hydrogen content and its demonstrated ability to evolve hydrogen at practical rates at temperatures below 100°C upon balling milling or the addition of additives, it would appear to have a very high practical potential. However, because of the very low, ~6 kJ/mol enthalpy of dehydrogenation of alane, its synthesis through direct dehydrogenation can be accomplished only at extreme pressures. In attempt to circumvent this constraint, we are exploring the hydrogenation of aluminum in supercritical fluid media. The remarkably high solubility of hydrogen gas in supercritical fluids (SCFs) has previously been exploited to effect the hydrogenation of organic substrates

under much lower pressures than those employed in the corresponding conventional hydrogenations. Our initial studies using supercritical CO₂ and resulted in the uptake of 0.5 wt % H₂ by the Al metal. We are currently exploring the utility of alternative SCF media. The characterization of the materials that were obtained in these studies by MAS 27Al NMR and X-ray diffraction will be presented.

9:20 AM

(H2-STOR-26) Recent progress in materials designing for inorganic hydrogen storage medium (Invited)

S. Towata^{*}, K. Miwa, T. Noritake, N. Ohba, M. Matsumoto, M. Aoki, TOYOTA Central R&D Labs., Japan; H. Li, Y. Nakamori, S. Orimo, Tohoku univ., Japan

Hydrogen storage technology is one of the most important issues for practical and global application of fuel cell vehicles. Current FC vehicles usually equip compressed hydrogen tank system; however, the tank system in the limited space lacks the necessary amount of hydrogen for practical driving range, 500 km. To design a compact, light-weight hydrogen tank system, solid hydrogen absorption materials (i.e. metal hydrides and chemical hydrides) draw much attention due to their high volumetric and gravimetric hydrogen density. We have been working on solid hydrogen storage materials such as, magnesium amide/lithium hydride mixtures, lithium borohydride/lithium amide mixtures, and metal borohydrides. Our collaboration of theoretical and experimental approach has brought two concepts to improve hydrogen storage materials: (1) anion or cation substituted metal borohydrides, (2) reaction enthalpy-maintained composites. Our recent progress in designing new hydrogen storage materials will be presented.

9:40 AM

(H2-STOR-27) Understanding Dehydrogenation Mechanisms: From Complex Hydrides to Carbon based Nanostructures

P. Jena^{*}, Virginia Commonwealth University, USA

Ideal hydrogen storage materials for mobile applications must meet some stringent requirements: high gravimetric and volumetric densities, fast kinetics, and favorable thermodynamics for applications under ambient temperature and pressure. The high gravimetric density can only be met if the storage materials consist of light elements from Li to Al. Unfortunately, in these materials hydrogen is either bound too weakly or too strongly, thus its desorption suffers from poor kinetics and thermodynamics. Catalysts and nanostructuring are the only two ways to overcome this problem. This talk will deal with the role of transition metal atoms (Sc to Cu) and carbon nanostructures (graphene, fullerenes, and nanotubes of varying curvature) on the dehydrogen thermodynamics of NaAlH₄. I will also discuss the capacity of carbon based nanostructures functionalized with metal atoms to store hydrogen for room temperature applications.

Production

Water/Solar 1 - Nuclear

Room: Seahorse

Session Chairs: Charlie Chun, ExxonMobil; Balu Balachandran, Argonne National Laboratory

10:20 AM

(H2-PROD-01) Materials Considerations for High Temperature Thermochemical Hydrogen Production (Invited)

W. Summers^{*}, Savannah River National Laboratory, USA

Thermochemical water-splitting cycles use heat as the primary energy input to drive a series of linked chemical reactions that result in the separation of water into hydrogen and oxygen. All intermediate chemicals are recycled. The input heat can be produced by advanced high temperature nuclear reactors or solar receivers, thus providing a clean, sustainable means for large-scale hydrogen production. Research has identified a small number of leading cycles, most notably

the Sulfur Iodine and Hybrid Sulfur Process. There are also numerous alternative cycles that are in earlier stages of development. A common feature of all cycles is the need to deal with corrosive chemicals under severe operating conditions of high temperature (>900 °C) and high pressure (9 MPa). This presentation will discuss the materials challenges for this application and the current state of the art.

10:40 AM

(H2-PROD-02) High Temperature Electrolysis for Hydrogen Production

J. Herring^{*}, C. M. Stoots, J. E. O'Brien, Idaho National Laboratory, USA; J. J. Hartvigsen, Ceramatec, Inc., USA

We are developing solid-oxide cells for the efficient High Temperature Electrolytic (HTE) production of hydrogen using the heat and electricity of advanced nuclear reactors. By operating at temperatures of 800-850° C, the cell voltage can be reduced by 40% compared to conventional electrolysis. The planar cells are electrolyte-supported and consist of 0.150 mm-thick yttria- or scandia-stabilized zirconia. The inlet to the cells is 90 v/o steam, 10 v/o hydrogen, while the outlet is about 25 v/o steam and 75 v/o hydrogen. During the summer of 2007 we constructed the initial configuration of the HTE Integrated Laboratory Scale (ILS) experiment at the INL. The ILS was tested with a single module containing four stacks of 60 cells each beginning in September 2007. This module initially produced 1.32 normal m³/hr of hydrogen. During early FY-08 we will examine the components for the single full module, as well as the half-module tested for 2040 hours during the summer of 2006.

11:00 AM

(H2-PROD-03) Nickel-Silicon Alloys for Hydrogen Generation by the Sulfur-Iodine Cycle

J. W. Newkirk^{*}, R. K. Brow, U. of Missouri-Rolla, USA; T. M. Lillo, Idaho National Laboratory, USA

The Sulfur-Iodine Thermochemical Cycle coupled to a high temperature nuclear reactor is one efficient means for producing hydrogen. Currently, there are few materials for the pressurized sulfuric acid decomposition loop that possess both the requisite corrosion resistance and reasonable ductility for fabricating components and to reduce the likelihood of catastrophic component failure. Nickel-silicon intermetallic alloys show promise as an affordable, corrosion-resistant material. Certain Ni-Si alloys are easily joined by traditional methods such as welding and preliminary corrosion studies indicate excellent corrosion resistance to sulfuric acid. We will review the effects of Ni-Si alloy modifications on the mechanical properties and the corrosion resistance. The creation of a passive film in oxidizing acids will also be described and strategies for improving film performance will be discussed. In addition, the use of these alloys for components critical for the S-I cycle will be described.

11:20 AM

(H2-PROD-04) K-Bi Thermochemical Cycle for Hydrogen Production

S. Lvov^{*}, V. Rodriguez-Santiago, M. Fedkin, Penn State University, USA

Alternative thermochemical cycles are considered promising technologies for hydrogen production. Active metal alloy thermochemical cycles offer the possibility of simpler process design and lower operation temperatures and, therefore, the possibility of lower capital costs. An example of these active metal alloy thermochemical cycles is the K-Bi cycle, which is particularly attractive due to simplicity and possibility to implement the process in a single-reactor setup. Proof-of-principle studies have been performed, at 580 degrees Celsius, to evaluate the viability of the electrolysis step of the K-Bi cycle. The electrochemical step is considered the main factor in the cycle assessment since it requires an energy input (electric current), which, if too high, could render the cycle impractical. Our preliminary experiments yielded promising results, indicating the process occurring at relatively low electrolysis potentials, close to theoretical value of 1.5 V.

11:40 AM

(H2-PROD-05) Recent Results on Splitting Water with Al AlloysJ. Woodall, C. R. Allen, J. Ziebarth^{*}, Purdue University, USA

Recently, we reported that solid alloys containing Al compositions that included 28 wt%, 50 wt%, and 80 wt% Al when placed in contact with water at or near room temperature would react to generate hydrogen gas, heat, and alumina. The hydrogen mass yield of the reaction was 100%. The Ga was found to be completely inert, recoverable, and hence recyclable. The Ga can be of low purity and when coupled with a current electrolysis efficiency of reducing alumina to Al of 50% makes this an economically viable process for creating hydrogen on demand. In this presentation we will discuss the results of some recent experiments to further elucidate the properties of the Al-Ga-water process. We have measured reaction rates of water with the alloys versus reaction temperature, pH of the solution, etc. We have investigated using other solvents including Ga-In, and Ga-In-Sn mixtures. We have also performed experiments where the Ga is reused up to 50 cycles. The results of these experiments will be reported at the conference.

Storage**Hollow Glass Microspheres (HGMs)**

Room: Sea Oats

Session Chairs: Robert Miller, Air Products; Rana Mahtadi, Toyota Motor Corp.

1:00 PM

(H2-STOR-28) The Manufacturing and Characterization of Hollow Glass Spheres Designed for Storing HydrogenD. E. Day^{*}, MO-SCI Corporation, USA; J. E. Shelby, Alfred University, USA

This paper focuses on the procedures used to manufacture and characterize hollow glass spheres (HGS) which have been specifically designed for storing hydrogen at high pressure. The general techniques used to produce HGS from melts of different composition are described. The HGS were evaluated by several techniques including examination by scanning electron microscopy combined with image analysis software that yielded the size distribution of the HGS. Wall thickness was measured from images of broken HGS while the true and bulk densities were determined using helium and volume pycnometers. Other properties were determined from spectroscopic measurements made on melts of the same composition as the HGS. The release kinetics of hydrogen from the HGS were highly dependent upon the presence of transition elements such as Ni, Co, and Fe and each of these elements greatly accelerated the release of hydrogen from the HGS.

1:20 PM

(H2-STOR-29) High Pressure Hydrogen Storage in Hollow Glass MicrospheresP. F. Wachtel^{*}, J. E. Shelby, Alfred University, USA; M. J. Snyder, Corning, Inc, USA

The possibility of storing high pressure in hollow glass microspheres was first proposed more than 30 years ago. Until recently, the stored hydrogen could only be released on demand by either destroying the microspheres, e.g. crushing, or by heating them to several hundred degrees. The former process allows only a single use, while the second is very slow. The discovery of photo-induced hydrogen diffusion, which results in highly controlled, rapid hydrogen release has led to dramatically improved potential for use of hollow glass microspheres for this application. Results of recent studies involving hydrogen pressures ranging from subatmospheric to 70 MPa will be presented. The storage density of hydrogen in the material will be discussed. Hydrogen release kinetics by photo-induced outgassing as a function of stored pressure will be presented. Hydrogen losses during storage will

also be discussed. Other information regarding the photo-induced process will also be presented

1:40 PM

(H2-STOR-30) Unique Porous Wall, Hollow Glass Microspheres for Hydrogen Storage, Separations and Other Related ApplicationsG. G. Wicks^{*}, K. L. Heung, R. F. Schumacher, Savannah River National Laboratory, USA

The Savannah River National Laboratory (SRNL) has developed a new medium for storage of hydrogen and other gases. This involves fabrication of thin, Porous Walled, Hollow Glass Microspheres (PW-HGMs), with diameters in the range of 1 to several hundred microns. What is unique about the glass microballons is that porosity has been induced and controlled within the thin, one micron thick walls, on the scale of 10 to several thousand Angstroms. This porosity results in interesting properties including the ability to use these channels to fill the microballons with special absorbents and other materials, thus providing a contained environment even for reactive species. Gases can now enter the microspheres and be retained on the absorbents. SRNL is involved in about a half dozen different programs involving the PWHGMs and an overview of some of these activities and results emerging will be presented.

2:00 PM

(H2-STOR-31) New Concept for Storing Reactive Complex Hydrides On-board of AutomobilesR. Mohtadi^{*}, Toyota Motor Engineering and Manufacturing North America, USA; K. Tange, T. Matsunaga, Toyota Motor Corporation, Japan; G. Wicks, K. Heung, R. Schumacher, Savannah River National Lab, USA

Currently, hydrogen is stored on-board automobiles either under high pressure or under cryogenic conditions. These systems suffer from hydrogen low volumetric density making them unpractical for onboard storage. Storage of chemically bonded hydrogen in materials like complex metal hydrides considerably enhances the hydrogen volumetric density. Currently, global research efforts are focused on improving the hydrogen storage properties in these materials including enhancing the gravimetric density, the dehydrogenation thermodynamics, kinetics, and reversibility. Another major challenge which would be an obstacle to their utilization; even if the storage densities are met, is achieving a safe onboard storage as these materials are highly reactive in ambient air. In the work we will present, we will show a new innovative way which improves the safety of handling and storing these materials. We are able to achieve this by encapsulating complex metal hydrides in hollow glass microspheres.

2:20 PM

(H2-PROD-06) Encapsulation of Palladium in Porous Wall Hollow Glass MicrospheresL. K. Heung^{*}, G. G. Wicks, R. F. Schumacher, Savannah River National Laboratory, USA

Porous wall hollow glass microspheres (PWHGM) were produced by a hot flame process followed by heat treating and acid leaching steps. The PWHGM size ranged from about 1 to 200 micron with pore size between 10 to 1000 Angstrom. The interior of the microspheres were filled with palladium in an attempt to generate an advanced packing material for hydrogen and hydrogen isotopes separation. A soak-and-dry method was used to introduce palladium into the hollow microspheres. Repeating the soak-and-dry steps can fill the microspheres with palladium to near capacity. The method and the results will be discussed.

2:40 PM

(H2-PROD-07) Separation of Hydrogen from Mixed Gases Using Hollow Glass MicrospheresJ. Rich^{*}, J. E. Shelby, Alfred University, USA

The hydrogen economy will require an extensive expansion of our ability to produce high purity hydrogen. Many of the methods pro-

posed for producing hydrogen result in gas mixtures. The hydrogen must be separated from these mixtures before use in fuel cells. Our work proposes to use hollow glass microspheres to separate hydrogen from mixed gas streams. Hydrogen will permeate the walls of the glass microspheres, while most other gases will not. After removal from the presence of the other gases, the microsphere can then be outgassed to release the high purity hydrogen. Results of studies of hydrogen separation from helium, nitrogen, argon, and carbon dioxide will be presented. Results indicate that this is a highly efficient process capable of producing high purity hydrogen using a cheap, non-toxic, recyclable glass product.

3:00 PM

(H2-STOR-32) Impacts of Composition and Heat Treatment on Pore Size in Borosilicate Glass Microspheres

F. C. Raszewski^{*}, E. K. Hansen, D. K. Peeler, R. F. Schumacher, Savannah River National Laboratory, USA; S. W. Gaylor, N. A. Carlie, L. Petit, K. A. Richardson, Clemson University, USA

A series of phase separated alkali-alkaline earth-borosilicate glasses was formed into hollow glass microspheres by a flame forming process. The resulting hollow glass microspheres were then subjected to various heat treatment conditions and leached with strong mineral acids to remove the more soluble alkali borate rich phase in order to form a porous wall, hollow glass microsphere composed primarily of silica. Some of the relationships between glass composition, heat treatment, and porosity will be discussed.

Leakage Detection/Safety

Leakage/Safety 2

Room: Dunes 1 & 2

Session Chairs: Richard Sisson, Worcester Polytechnic Institute; Mircea-Stefan Stanescu, Linde Group

1:00 PM

(H2-LEAK-03) Ceramic Hydrogen Safety Sensor for the Emerging Hydrogen Economy

L. B. Thrun^{*}, S. L. Swartz, S. R. Cummings, NexTech Materials, Ltd., USA

Hydrogen safety sensors are essential to the safe implementation of hydrogen as our fuel of the future and thus, to the commercial acceptance of fuel cell technology. No commercially available hydrogen sensor, however, meets both the cost and functionality requirements of these applications. Through extensive materials evaluation, NexTech Materials has developed a new ceramic sensor coating for detecting hydrogen over a wide range of 500 to 10,000 ppm. These sensors exhibit fast response and recovery times, low cross-sensitivities to interferants such as carbon monoxide, methane, and humidity, and long term performance stability, enabling use of these sensors for area monitors, switch-activated alarm mechanisms, and hand-held hydrogen leak detectors. In this paper, NexTech's hydrogen sensor materials technology will be described. The selection and role of the key components of the sensor formulation will be discussed, as well as the impact of each of these materials on sensor performance characteristics.

1:20 PM

(H2-LEAK-04) Explosive Nature of Hydrogen in a Partial Pressure Vacuum (Invited)

T. M. Jones^{*}, W. R. Jones, Solar Atmospheres Inc., USA

The explosive nature of hydrogen is well reported at atmospheric conditions. However, the explosive properties of hydrogen in sub-atmospheric pressures are not well known. Hydrogen has desirable characteristics for many processes however, using hydrogen in an atmosphere that is primed for an explosion must have several safeguards and an understanding of its explosive limits, vacuum or otherwise. A laboratory vessel was constructed to withstand hydrogen explosions to test these principals. Topics of discussion will in-

clude mixtures of hydrogen and air in partial pressure vacuum, and determination of the explosive ranges. Sources of ignition will be discussed and how the ignition source and location can affect the explosive characteristics. Other topics of discussion will be what types of safeguards could be used, more specifically an oxygen probe, and how these safeguards can be employed to prevent a catastrophic explosion.

1:40 PM

(H2-LEAK-05) Safety Aspects of Hydrogen at Low and High Velocity (Invited)

R. W. Boyd, The Linde Group, USA; M. Stanescu^{*}, P. Stratton, The Linde Group, Germany

Using hydrogen as a transportation fuel for vehicles requires storage at much higher pressures than the traditional use of hydrogen in industrial applications. The history of using hydrogen for material processing applications goes back over 100 years, however recent research has shown that very low velocity conditions in a controlled environment could change a uniform gas mixture to a condition of stratification of two gases of different molecular weights, without contradicting the second law of thermodynamics. On the other end of the extreme, the new emerging hydrogen fuel applications require hydrogen to be delivered and stored at very high pressures of up to 100 bar and again we are seeing fluid behavior that might defy our expectations. This presentation contains information related to the safety problems encountered in low and high velocity hydrogen applications and recommendations for safe use of hydrogen in both traditional and emerging energy applications.

2:00 PM

(H2-LEAK-06) Closing the Loop: The Recovery and Recycle of Tritium From Commercial Devices (Invited)

J. Mintz^{*}, Lawrence Berkeley National Lab, USA

Uncertainty concerning the ultimate disposition of used devices is a significant impediment to the expanded use of tritium in industrial products. Adding to these concerns is evidence of tritium contamination from growing numbers of municipal landfills. Fortunately, over the past seven years the LLNL Tritium Facility has developed a strong program of tritium recovery and recycle from such tritium bearing products. Beginning with US Army tritium powered illumination devices, the program now encompasses several commercial clients in addition to the Department of Defense. Product forms, recovery techniques, waste packaging and disposition and approximate cost are described. A major upgrade of capability, now under construction, will greatly increase capacity and reduce cost for the most common forms. This upgrade will also be discussed in some detail.

2:20 PM

(H2-LEAK-07) Tritium Effects on Polymeric Materials

E. A. Clark^{*}, Savannah River National Laboratory, USA

The radioactive decay of the hydrogen isotope tritium causes radiation damage of polymers. Although the low-energy beta decay extends only a few microns in polymers, the permeation of hydrogen isotope molecules through polymers ensures that the entire bulk is exposed to the beta radiation. Polymers are commonly employed in gas handling systems, mainly for sealing applications (valve stem tips, packing, O-rings) and cable insulation. Many commercially available components employ polymers, and it is impractical to design tritium handling systems without some polymer parts. Thus, the degradation of polymer components in tritium handling systems must be managed, through materials selection, inspection, and regular replacement. This talk will describe the methods used to characterize tritium exposure effects on several thermoplastics and an elastomer, including dynamic mechanical analysis of viscoelastic properties and radiolytic gas production.

2:40 PM

(H2-LEAK-08) Tritium Aging Effects on Forged Stainless SteelM. Morgan^{*}, Savannah River National Laboratory, USA

The fracture toughness properties of Type 21-6-9 stainless steel were measured for forgings in the unexposed, hydrogen-exposed, and tritium-exposed conditions. Fracture toughness samples were cut from conventionally-forged and high-energy-rate-forged forward-extruded cylinders and tested at room temperature using ASTM fracture-toughness procedures. Some of the samples were exposed to either hydrogen or tritium gas (340 MPa, 350C) prior to testing. Tritium-exposed samples were aged for up to seven years and tested periodically in order to measure the effect on fracture toughness of ³He from radioactive tritium decay. The results show that hydrogen-exposed and tritium-exposed samples had lower fracture-toughness values than unexposed samples and that fracture toughness decreased with increasing decay ³He content. Forged steels were more resistant to embrittlement from tritium and ³He than annealed steels although their fracture-toughness properties depended on the degree of sensitization that occurred during processing.

3:00 PM

(H2-LEAK-09) Standards and New Practices for Physical Hazards Assessment of NanomaterialsD. Hathcock^{*}, Savannah River National Laboratory, USA

The Savannah River National Laboratory has undertaken a review of U.S. and international standards for determining pyrophoricity and other physical hazards associated with the use of nanomaterials in R&D and production environments. The task includes an evaluation of how current standards can be applied to materials on the nano-scale, and identification of areas that are lacking a clear method for identifying the unique hazards involved with nanomaterials. A collection of case study information from institutions involved with nanomaterials has begun in support of this effort. Work is also underway to develop test methodologies for nanomaterials hazards screening using common laboratory instrumentation. The goal of this work is the development of a Standard Practice in cooperation with ASTM Committee E56 for developing a safe handling and processing envelope for nanomaterials.

Production**Hydrocarbons**

Room: Seahorse

Session Chairs: Craig Jensen, University of Hawaii; Jason Graetz, Brookhaven National Laboratory

1:00 PM

(H2-PROD-08) Development of Dense Membranes for Hydrogen Production and Purification (Invited)U. Balachandran^{*}, T. H. Lee, L. Chen, J. J. Picciolo, J. E. Emerson, S. E. Dorris, Argonne National Laboratory, USA

We are developing dense cermet (i.e., ceramic-metal composite) membranes for separating hydrogen from product streams generated during coal gasification. Hydrogen separation with these membranes is nongalvanic, and hydrogen separated from the feed stream is of high purity, so post-separation purification steps are unnecessary. Using several feed gas mixtures, we measured the hydrogen flux in the temperature range of 500-900°C. This rate varied linearly with the inverse of membrane thickness and reached $\approx 33 \text{ cm}^3[\text{STP}]/\text{min}\cdot\text{cm}^2$ at 900°C for an $\approx 15\text{-}\mu\text{m}$ -thick membrane when 100% H₂ at ambient pressure was used as feed gas. When membranes were tested in a gas mixture that contained CH₄, CO, and CO₂ for times that approached ≈ 500 h, performance did not degrade. We also tested the membranes in gas mixtures containing H₂S. The present status of membrane development will be presented in this talk. Work supported by the U.S.

Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory.

1:20 PM

(H2-PROD-09) Gasification-Route to Hydrogen: Can Membranes Make a Difference? (Invited)C. Guo, K. Kapoun^{*}, Shell Hydrogen, USA

From a resource and economic perspective, coal gasification is again starting to look viable given the rising oil and gas prices along with increasing energy security concerns. Shell's proven Shell coal gasification process (SCGP) is helping customers around the globe capitalize on their coal and biomass resources. In addition, Integrated gasification combined cycle (IGCC) is gaining further momentum due to its high efficiency, low emission advantages. Much effort has been initiated in intensification and/or simplification of gasification processes to reduce cost and improve efficiency; one popular approach has been through the use of high temperature membranes. This paper will focus on the assessment of membrane-based technologies in treating raw syngas streams with a strong orientation towards high-purity H₂ production. Pros and cons of membrane technology and requirements for membranes to be competitive with benchmark technologies will be discussed based on techno-economical evaluations.

1:40 PM

(H2-PROD-10) Materials Challenges in Hydrogen Production from HydrocarbonsC. Chun^{*}, F. Hershkowitz, ExxonMobil Research and Engineering Company, USA; T. A. Ramanarayanan, Princeton University, USA

About 80% of H₂ is produced from natural gas alone by steam reforming, partial oxidation and autothermal reforming and is used in chemicals and refining industries. Gasification of coal and other heavies is also a viable option for syngas and H₂ production. Fossil fuels would continue to play a key role in the H₂ economy of the future especially if CO₂ control technologies were to become a commercial reality. There are, however, many materials and corrosion challenges in industrial processes for H₂ production from fossil fuels. This presentation examines these challenges with particular emphasis on a high temperature material degradation phenomenon termed "metal dusting" and its control strategies. Also presented are materials challenges related to ExxonMobil's advanced steam reforming process known as pressure swing reforming. This technology is a new way to make syngas and H₂ from hydrocarbons and can be utilized in different process scenarios ranging from on-board reforming to industrial syngas production.

2:00 PM

(H2-PROD-11) Production of Hydrogen and Synthetic Hydrocarbon Fuels from Biomass-based FeedstocksN. Muradov^{*}, A. T-Raissi, F. Smith, K. Kallupalayam, Florida Solar Energy Center, USA

In this presentation, we describe a novel and versatile process for thermocatalytic conversion of biomass and biogas to hydrogen and/or synthetic hydrocarbon fuels (SHF). Florida specific citrus waste (CW) was used as feedstock. CW is pyrolyzed in the presence of steam to a pyrolysis gas at 600-750°C. The pyrolysis gas is further steam-reformed at 850°C to a gaseous mixture containing H₂, CO and CO₂. At this point, adding biogas to the reformer increases the yield and H₂:CO ratio of the syngas. The syngas is further processed in a water gas shift reactor to H₂-CO₂ and finally to H₂ with purity of 99.9%. The process can be modified to allow SHF production, which is done by feeding the syngas to Fischer-Tropsch (F-T) reactor to produce liquid hydrocarbons. The F-T synthesis was conducted at 210°C and 10 atm using cobalt catalyst generating liquid hydrocarbons (C₈-C₂₀) as well as a waxy hydrocarbon by-product.

2:20 PM

(H2-PROD-12) SiC Nanoporous Membrane for Hydrogen Separation at High Temperature

Y. Kim^{*}, W. Kwon, S. Kim, E. Kim, Korea Institute of Ceramic Engineering and Technology, South Korea; D. Choi, Yonsei University, South Korea

Ceramic membranes possessing nano sized pores have great potential for gas separation at high temperature since they have a good stability at high temperatures. Moreover, nanoporous silicon carbide membrane can be expected to use under hydrothermal condition at high temperature as membrane reactors for conversion enhancement in steam reforming reaction of natural gas. In this research, nanoporous SiC membrane has been developed for the hydrogen separation via spin coating technique using preceramic polymers such as polycarbosilane, polyphenylcarbosilane and CVD technique using methyltrichlorosilane as a precursor. The prepared SiC membrane was characterized with SEM, TEM, FT-IR and thin film XRD and so on. H₂ permeance was about 10⁻⁷ mol m⁻²s⁻¹Pa⁻¹ and selectivity of H₂ to N₂ was about 40~160. The nanoporous hydrogen selective SiC membranes show promise for application in membrane reactor for steam reforming reaction of natural gas and IGCC reactions.

2:40 PM

(H2-PROD-13) Porous Alumina Tubular Substrates for Hydrogen/Gas Separation

D. L. Edson^{*}, J. R. Schorr, S. Sengupta, R. Revur, T. Pyles, MetaMateria Partners, USA; H. Verweij, K. Shqau, The Ohio State University, USA

MetaMateria Partners has developed methods for making graded porous substrates for thin separation membranes. Through the use of these strong porous supports, the thickness of the active membrane can be reduced which increases the flux while reducing the cost. Alumina tubes with lengths of 30 cm and controlled interconnecting porosities of 1.4 or 4 microns are routinely produced using a low pressure, water-based injection molding process. Methods for reducing surface porosities to ~100 nm provides a base for the deposition of nanostructured membranes with thicknesses of less than 100 nm. Current development programs are ongoing to apply membrane layers for hydrogen separation from reformed gases and nanofiltration for water purification.

3:00 PM

(H2-PROD-14) Alternative Materials to Pd Membranes for Hydrogen Purification

P. S. Korinko^{*}, T. M. Adams, Savannah River National Laboratory, USA

Cost effective production of high purity H₂ is required for H₂ fuel cells to be more widely accepted. Current H₂ purification methods may use high value precious metal membranes; e.g., H₂ is often purified using Pd-Ag membranes in systems referred to as diffusers. These diffusers are often expensive and may be of variable reliability. Consequently, alternative materials for the Pd-Ag membranes are of interest. To address this niche market, SRNL has been developing a "common metallic alloy" for use as a replacement membrane material for H₂ diffusers. The alloys of interest contain nickel, vanadium and titanium. Like the Pd alloys they are susceptible to hydriding under certain temperature conditions and experience brittle fracture if cooled in the presence of H₂. This presentation will describe the attributes of the alloys that have been tested and will show relative permeation rates using both electrochemical cell measurement and gas permeation techniques. U.S. Department of Energy Contract DE-AC09-96SR185

3:20 PM

(H2-PROD-24) Materials Discovery for Hydrogen Production by Coal Gasification

S.K. Sundaram^{*}, Pacific Northwest National Laboratory, USA

Integrated gasification combined-cycle (IGCC) technology consists of partial oxidation or gasification of coal for the production of hydrogen and power. Partial oxidation or gasification combines coal, oxygen and steam to produce synthesis gas which is further processed to in-

crease hydrogen and convert carbon monoxide to carbon dioxide and the hydrogen is then separated. Several advancements are needed for the success of IGCC, e.g., novel catalysts, membranes, and materials for advanced, lower cost separations of hydrogen from carbon dioxide and other contaminants. In addition, improvements in many technological areas will be needed, e.g., gasifier design, materials and feed systems, and advancements in carbon dioxide capture and sequestration technology. An overview of materials needs and challenges of coal gasification will be presented. Additionally, progress made on materials for gasification under the Energy Conversion Initiative (ECI) at Pacific Northwest National Laboratory (PNNL) will be presented.

Poster Session

Room: Horizons

(H2-DELV-12) Analysis of Electrochemical Experiments for Evaluation of Susceptibility to Embrittlement by Hydrogen Gas

R. E. Ricker^{*}, D. J. Pitchure, NIST, USA

Cathodic charging is a convenient method for introducing hydrogen into samples for studying the influence of this interstitial element on the properties of metals and alloys. Relatively inexpensive equipment can be used to cathodically charge samples with atomic hydrogen for experiments designed to measure solubility, diffusion, ductility, or crack propagation. However, there is some concern about the relevance of experiments conducted using cathodic charging to embrittlement by hydrogen gas at the pressures that will be used to contain, compress, deliver, and use hydrogen fuels. This paper presents the theoretical basis and the scientific principles underlying the use of cathodic charging in these experiments and evaluates different experimental techniques. The results of experiments conducted in our laboratory using controlled electrochemical charging conditions are reported and compared to experiments on samples charged by exposure to gas phase hydrogen.

(H2-DELV-13) Inexpensive, Off-The-Shelf Hybrid Microwave TPD System

R. T. Walters^{*}, Savannah River National Laboratory, USA; G. G. Wicks, P. R. Burket, Savannah River National Laboratory, USA

Savannah River National Laboratory (SRNL) is developing a modern gas assay method for spent tritium storage beds. A complete characterization of the storage bed is not obtained from analysis of the desorbed gases. A technique has been developed that releases the helium content in a way that allows quantitative measurement with the same accuracy as that measured for other absorbed species. SRNL had successfully identified the right materials of construction to heat small samples of tritium storage bed material in a commercial "hybrid" microwave oven in a controlled manner (TPD) to cause the desired effect of releasing the helium. A cold test for the unit consisted of producing a non-condensable gas and measuring it in the unit at temperature (1200oC). CaCO₃ was decomposed and the moles of gas produced were measured. The measured amounts of gas were within 2.6% of that predicted by stoichiometry. A plant configured hybrid microwave oven assembly is scheduled to be deployed in the Tritium Facility by early 2008.

(H2-STOR-33) Thermodynamic Analysis of a Novel Hydrogen Storage Material: Nanoporous Silicon

P. J. Schubert^{*}, A. D. Wilks, Packer Engineering, Inc., USA

Bulk silicon can be made nanoporous by suitable electrochemical etch techniques. Hydrogen storage and evolution from as-synthesized nanoporous silicon has been demonstrated, ranging from 4.9 to 6.6% w/w. To assess this media as a viable engineering solution for hydrogen storage, a detailed analysis of the process thermodynamics are required. Based in part on lab data, and partly on theory, a complete thermodynamic analysis of porous silicon is presented. Available data indicates a near-neutral hydrogen release energy (0.6 kJ/mol) with silicon bond reformation. Hydrogen uptake data is not available because the porous silicon reforms upon hydrogen evolution. The use

of a catalytic agent, covered under a patent pending, is shown herein to prevent reforming, and provide a low-temperature chemical pathway for hydrogen recharge. These studies are applied to an electric airplane to assess their viability as a hydrogen storage material.

(H2-STOR-34) First Generation High Throughput Combinatorial Hydrogen Storage Materials Screening System

N. Mohajeri¹, A. T-Raissi, K. K. Ramasamy, J. Baik, N. Muradov, UCF-Florida Solar Energy Center, USA

Hydrogen storage still presents the main obstacle to implementation of a hydrogen economy, especially in the portable and transportation applications. As part of DOE's "Grand Challenge for Basic and Applied Research in Hydrogen Storage", various hydrogen storage materials such as metal hydrides, metal organic frameworks, and chemical hydrides are under wide investigation and exploration. Therefore, in order to speed up the process of down selecting promising hydrogen storage materials, we believe that a high throughput combinatorial screening approach can be extremely beneficial and helpful. In this paper, we present the design, fabrication, and test results of our first generation high throughput combinatorial material screening system (HTCMSS). Furthermore, the development of chemochromic hydrogen sensing membrane used in HTCMSS will be discussed.

(H2-STOR-35) Synthesis of Activated Carbon Fibres for High-Pressure Hydrogen Storage

A. Linares-Solano¹, M. Kunowsky, Universidad de Alicante, Spain; B. Weinberger, F. D. Lamari, Université Paris 13, France; F. Suárez-García, D. Cazorla-Amorós, Universidad de Alicante, Spain

Chemical activation of carbon fibres (ACF) for H₂ storage is presented. Two kinds of precursors were activated using KOH and NaOH. Porosity of the ACF was determined by N₂ and CO₂ adsorption isotherms at 77K and 273K, respectively. H₂ adsorption at room temperature was measured by an automated volumetric device for pressures up to 20 MPa and a gravimetric-volumetric device for pressures up to 70 MPa. To obtain the total storage capacities the packing densities of the synthesised fibres were determined, and their true densities were measured by helium expansion. Carbonisation temperature of the precursor, activation agent and mixing ratio have a high impact on the porosity development. The results obtained from both H₂ equipments are compared and reveal that the porous structure and densities have a high influence on the total storage capacity. ACF have a high potential as H₂ storage materials. Research in this area has to continue in order to further optimise microporosity and H₂ capacities.

(H2-STOR-36) Palladium Nanowires for Hydrogen Storage: Equilibrium and Kinetics

O. Talu¹, A. Ertan, S. N. Tewari, Cleveland State Univ., USA

Storage of hydrogen is a major issue for hydrogen power systems. Hydrogen storage materials must have high volumetric and gravimetric capacity with fast kinetics at relatively low temperature and high tolerance to cycling. Metal hydrides are the most promising materials. Nanoparticles have different physical and chemical properties from conventional bulk materials. Our ultimate goal is to produce large specific surface area nanostructured metals. The large surface area is expected to help kinetics and may increase equilibrium capacity. Among various nano-fabrication techniques, electrodeposition has clear advantages of fast growth and simple set-up. Palladium is chosen because of its well characterized bulk hydride properties. Palladium nanowires are grown in the pores of anodized aluminum oxide. Electrodeposited palladium is characterized by microscopy, SEM, XRD, and EDX. In addition, P-T behavior and kinetics are measured with the volumetric differential pressure hydrogen apparatus.

(H2-STOR-37) Nanocrystalline Effects on the Reversible Hydrogen Storage of Complex Hydrides

S. S. Srinivasan¹, M. U. Jurczyk, Y. D. Goswami, E. K. Stefanakos, University of South Florida, USA

Metal/complex hydrides for on-board hydrogen storage applications are in great demand to develop holy grail storage systems that

can meet the 2010 DOE and FreedomCAR targets. Some of the well known complex hydride families such as alanates, amides, borohydrides and combination mixtures are mainly based on light weight alkali or alkaline elements (Li, Na, Mg etc.) and possesses high theoretical hydrogen storage capacity. Since the complex borohydrides (e.g. NaBH₄, LiBH₄ etc.) are highly stable systems, it is necessary to explore less stable materials or develop destabilization mechanism for hydrogen storage in complex hydrides. The present study aims on developing the new transition metal based complex borohydrides which are having promising capacities at low decomposition temperatures. The destabilization of these complex structures by either nanocrystalline form of alkaline hydride ad-mixing or nanocatalysts doping found to enhance the reversible hydrogen storage behavior.

(H2-STOR-38) Ammonia Borane Thermolysis- Borazine and Diborane Capture

N. Mohajeri¹, K. K. Ramasamy, A. T-Raissi, UCF-Florida Solar Energy Center, USA

Thermolysis has been employed by many to generate hydrogen from ammonia borane (AB) complex. The overall process is exothermic, but requires heat to be added to activate the AB complex. One of the main drawbacks of AB thermolytic process is the involvement of competing reactions leading to the formation of certain by-products such as borazine, diborane and polymeric aminoboranes that are harmful to the operation of proton exchange (PEM) fuel cells. Borazine and diborane introduction to PEM fuel cell may limit the lifetime and performance of the fuel cell's catalysts and electrodes. Hence, it is important to purify hydrogen gas from all impurities. In this paper, borazine and diborane scrubbing capability and efficiency of different solid sorbents will be presented and discussed.

(H2-STOR-39) Mechanisms of the Steam Hydrolysis of Sodium Borohydride

A. M. Beaird¹, E. Y. Marrero-Alfonso, T. A. Davis, M. A. Matthews, University of South Carolina, USA

The purpose of this study is to elucidate the mechanism and physical phenomena involved in the steam hydrolysis of NaBH₄, an alternative pathway that may improve hydrogen storage. In-situ visual observation of the reaction and its phase behavior was accomplished with a quartz reactor and borescope camera. Reaction products were analyzed by ¹¹B NMR from both the steam and aqueous hydrolysis reactions for comparison. The reaction rate and conversion appear to rely on the ability of the hydride to absorb water from the atmosphere and then dissolve in it, a phenomenon called deliquescence that depends on the reaction temperature, pressure and mol fraction of water. Based on this study, deliquescence is necessary for reaction, but only occurs above 30% humidity at 110°C and requires higher humidity as reaction temperature is increased. Analysis of the reaction products indicates that a BH₃ containing intermediate found in the aqueous reaction is not present in the steam pathway, indicating a different reaction mechanism.

(H2-STOR-40) Water Utilization in the Hydrolysis of Sodium Borohydride

E. Y. Marrero-Alfonso¹, A. M. Beaird, T. A. Davis, M. A. Matthews, University of South Carolina, USA

Chemical hydrides are potentially useful as a medium for hydrogen storage at ambient temperature and pressure. Hydrogen is produced when a chemical hydride, in this case NaBH₄ reacts with water. (NaBH₄ + (2+x)H₂O → 4H₂ + NaBO₂·xH₂O) The purpose of our study is to minimize the amount of water required in the reaction by exposing solid chemical hydrides to steam, in contrast to the catalyzed aqueous reaction. A smaller quantity of water will lead to a lightweight, low volume storage system. Characterization of the hydrated byproducts is performed to optimize reaction conditions for rates and minimum water. Thermogravimetric analysis and x-ray diffraction studies revealed that the favored product of the reaction at 110°C is NaBO₂·2H₂O. Preliminary experiments showed that the product of the reaction is independent of

the hydride/water ratio. This complicates the process design, because calculations show that a hydration factor less than $x=0.84$ is necessary to meet the FreedomCar specifications for weight and volume efficiency.

(H2-STOR-41) Investigating Hydrogen Storage Behaviour of Pt and Pd Decorated Transition Metal Oxides

A. Molendowska¹, P. J. Hall, University of Strathclyde, United Kingdom; S. Donet, Commissariat l'Energie Atomique (CEA), France

Transition metal oxides are proposed to be used as material for hydrogen storage. Based on references it was proposed to decorate powders by Pt and Pd nanoparticles to enhance kinetics and amount of gas stored. System used was Fluidised Bed Metal-Organic Chemical Vapour Deposition. Apparatus allow deposit pure metal particles without any further treatment. Materials were analyzed by various techniques: BET method, SEM, XRD, EDX in order to have full description of deposited metals and changes of material topology. Hydrogen adsorption measurements were performed using Sievert apparatus in 8Bar hydrogen pressure and 77K. XRD and SEM have confirmed presence of nanoparticles in the powder, the mean size was between 300-700 nm, amount was estimated by EDX between 1-5%wt and surface area does not exceed 100m²/g. Adsorption measurements have shown that undoped TiO₂ store 2.4%wt. of H₂ at 80min. Presence of metals increase kinetics of 35% and amount of gas stored of 20% for Pd and 60% for Pt.

(H2-STOR-42) Carbon Nanotubes' Diameter Influence on Performance of Pt/CNTs for PEM Fuel Cell

D. Zhang¹, University of Michigan, USA; L. Shen, X. Wu, Shanghai Jiaotong University, China

Carbon nanotube (CNT) is one of promising alternative support materials for catalysts used in fuel cell. Some works have been done on both single-wall carbon nanotube (SWCNT) and multi-wall carbon nanotube (MWCNT). The CNTs supported catalysts shows better performance than active carbon supported catalysts. Few works has been done on comparing the effect of varied CNT diameters on their characteristic and catalysis. In our work, different diameters' CNTs have been used as support for anode catalysts. The characteristics have been measured by BET, XRD, TEM, EDX methods. Their electrochemical properties were tested in three-electrodes system by CHI instruments. The BET surface area increases with the nanotube diameter decrease. But current density increases with the diameter decrease.

(H2-STOR-43) Effect of Alumina Particle Content on Properties of Al-Al₂O₃ Matrix Composite

M. Rahimian¹, N. Ehsani, H. Baharvandi, N. Parvin, Melek Ashtar University of Technology, Iran

In present study, the effect of amount of alumina particles on the properties of Al-Al₂O₃ composite was investigated. For this purpose, alumina particle average size 12 μ m, in 5,10 and 20 wt%, and aluminum powder with average size of 30 μ m were used. Single action presse with 440 MPa compacting pressure was used to prepare cylindrical samples. Then as-pressed samples sintered for 45 min at 550 °C. It was found that, alumina (0-20 wt%) increasing, led to the hardness and wear resistant increasing; but relative density decreasing. Also yield stress and compression strength were increased and then they were decreased; as the amount of aluminum increases. Grain size and reinforcement distribution homogeneity were decrease with the alumina increasing.

(H2-STOR-44) Review of U.S. Patents for the Production of Hollow Glass Microspheres

F. C. Raszewski¹, E. K. Hansen, R. F. Schumacher, Savannah River National Laboratory, USA

The patent literature contains a wealth of varying concepts dealing with the manufacture of hollow glass microspheres. A review of this literature beginning with very early hollow glass microspheres derived from special clay particles (1954) and sodium silicate mixtures (1961) up to the more recent technologies involving glass frit particles and sol-gel solutions will be reviewed and compared. Some of the advantages and limita-

tions of the various manufacturing methods will be suggested. While the primary requirement of the earliest manufacturing methods was to produce low density-low cost fillers for plastic materials, more recent developments have been aimed as gas storage and other non-traditional uses.

(H2-STOR-45) Impact of Glass Composition on the Production of Borosilicate Hollow Glass Microspheres

F. C. Raszewski¹, E. K. Hansen¹, D. K. Peeler, R. F. Schumacher, Savannah River National Laboratory, USA

A series of phase separated alkali-alkaline earth-borosilicate glasses was formed into hollow glass microspheres by a flame forming process. The location of the glass compositions within the immiscibility dome was found to have a profound effect on the formation of hollow glass microspheres. Characterization of the hollow glass microspheres will also be presented.

(H2-OVER-13) Using Porous Microspheres as Additives in Lead-Acid Batteries

D. Newell¹, D. B. Edwards, S. N. Patankar, University of Idaho, USA

The lead-acid battery has a high volumetric energy density, high specific power performance, and high power density. This coupled with the low cost of materials makes it an excellent power source for use in electric and hybrid electric vehicles. Improving the specific energy performance would help both vehicles achieve a longer electric driving range. We have been able to produce porous hollow glass microspheres that would provide structure and electrolyte storage in the active material of both electrodes. The pore sizes created were typically from 1-20 microns in diameter. We have also investigated the use of porous titania beads to improve utilization when conductivity limits the reaction. Because of the limited quantity of additives produced, we were not able to adequately test either the titania conductive beads or the PGHMs in battery plates. However, in the paper we do use models to provide an estimate of how these additives can improve the specific energy performance of lead-acid batteries.

(H2-STOR-46) Hydrogen Permeability of Various Tank Wall Materials under Tetra-axial Strain and Gas Pressures

E. H. Stokes¹, Southern Research Institute, USA

The H₂ permeability of a variety of polymeric based materials were measured at various gas pressures ranging up to 5000 psi with tetra-axial strains out to the failure point the materials. The gas perm facility was calibrated using NIST SRM 1470 as described in ASTM D 1434. For those materials with no as-processed macro-porosity the permeability of the materials were found to obey the Solution-Diffusion model, where flow rates are a linear direct function of material cross-sectional area and gas pressure differential across the material and an inverse function of the thickness of the material in the direction of flow. In general, the effects of in-plane tetra-axial strain were a steady rise in permeability with strain until the material reached its yield point when the permeability rose precipitously with strain out to the failure point. In general the initial phase was reversible and the latter not. However, in some cases the reversible phase extended past the yield point.

(H2-PROD-15) Facile Generation of Hydrogen from an Ammonium/Borohydride Mix

B. Spielvogel¹, BoroScience International Inc, USA

The reaction of borohydride salts with ammonium salts in nonaqueous media was investigated to determine the feasibility as a method of hydrogen generation. Intimate mixes of ammonium and borohydride salts were contacted with limited quantities of high molecular weight glymes and hydrogen evolution measured using a gas burette. Useful rates of hydrogen evolution were obtained without any catalyst. Up to three moles of hydrogen/mole of borohydride can be obtained at 80 °C in several hours. A significant advantage of this method over aqueous hydrolysis is the ease of regeneration of spent material to borohydride by simple reaction with an alcohol to form a borate ester for reduction back to borohydride. Although the reaction proceeds with

formation of some ammonia borane, other intermediates are undoubtedly present resulting in facile decomposition and hydrogen evolution.

(H2-STOR-47) Trade Study for Cost Effective, Safe and Lightweight Metallic Material Pressure Vessels for Hydrogen Storage

J. A. Lee*, NASA-Marshall Space Flight Center, USA

A trade study is presented for cost effective, safe and lightweight metallic pressure vessels for hydrogen storage. Depending on the storage application, some metallic materials are suitable for storing hydrogen gas up to 10,000 psi in the temperature range from -150 F to +150 F. The study shows that high performance aerospace aluminum alloys such as aluminum-lithium are highly effective for lightweight, no-welding pressure vessels in transportation applications, surprising with minimal weight increase in comparison with similar sized Composite Overwrapped Pressure Vessels (COPV), which can cost several times more than metallic pressure vessels. Pressure vessels made from NASA's advanced aluminum alloys can also be used to store liquid hydrogen at -423 F, with good fracture toughness properties at cryogenic temperature.

(H2-PROD-16) Fossil Fuel Based Gasification: Materials for Hydrogen and Liquid Fuel Production

B. Morreale*, A. Cugini, U.S. D.O.E. National Energy Technology Laboratory, USA

The United States Department of Energy's National Energy Technology Laboratory is aggressively investigating technologies to address global climate change, to secure fuel independence, and to ultimately move towards clean and inexpensive power generation. The gasification of carbonaceous feedstocks (such as coal, biomass or natural gas) has been identified as a means of addressing the near-term impact of the aforementioned concerns. The synthesis gas or syngas produced from the gasification process possesses the flexibility to be converted to electricity, hydrocarbon based fuels or hydrogen, while eliminating greenhouse gas emissions through carbon dioxide sequestration and utilization technologies.

(H2-PROD-17) Fossil Fuel Based Gasification: Materials for Hydrogen and Liquid Fuel Production, Part 2

B. Morreale*, A. Cugini, U.S. D.O.E. National Energy Technology Laboratory, USA

NETL is currently utilizing a wide scale of computational and experimental techniques in an effort to advance the technologies associated with the production of flexible, inexpensive, clean energy from nationally indigenous fossil fuel resources. Some of NETL's specific research interests include: the development of new gasifier refractories, chemically and mechanically robust catalysts for syngas production and conversion, advanced combustion and fuel cell materials, sorbents and membranes for gas separations, and advanced materials and concepts for managing carbon emissions.

(H2-PROD-18) Fossil Fuel Based Gasification: Materials for Hydrogen and Liquid Fuel Production, Part 3

B. Morreale*, A. Cugini, U.S. D.O.E. National Energy Technology Laboratory, USA

The United States Department of Energy's National Energy Technology Laboratory is aggressively investigating technologies to address global climate change, to secure fuel independence, and to ultimately move towards clean and inexpensive power generation. The gasification of carbonaceous feedstocks (such as coal, biomass or natural gas) has been identified as a means of addressing the near-term impact of the aforementioned concerns. The synthesis gas or syngas produced from the gasification process possesses the flexibility to be converted to electricity, hydrocarbon based fuels or hydrogen, while eliminating greenhouse gas emissions through carbon dioxide sequestration and utilization technologies.

Wednesday, February 27, 2008

Storage

Tanks and Systems

Room: Sea Oats

Session Chairs: Robert Bowman, Jet Propulsion Laboratory; Leung Heung, Savannah River National Laboratory

8:00 AM

(H2-STOR-48) Reversible and Complex Metal Hydrides

T. Motyka*, Savannah River National Laboratory, USA

The development of a viable hydrogen storage system is one of the key challenges that must be met prior to the establishment of a true hydrogen economy. Current hydrogen storage options, such as compressed gas and liquid hydrogen, fall short of meeting vehicle manufacturers' goals for safe and efficient energy storage. The most viable long-term alternative to these options is solid-state storage, which has been proven both safe and efficient. This paper will describe the current hydrogen storage challenges and also review the approach that SRNL, its new laboratory and its partners will follow to help solve these challenges.

8:20 AM

(H2-STOR-49) Carbon Fiber Fully Over-Wrapped Composite Cylinders for Storage of Hydrogen at Pressures of up to 100 MPa (Invited)

R. W. Boyd*, The Linde Group, USA

The emerging applications for alternate fuels include PEM fuel cells that are being developed for handheld devices, small utility vehicles, personal transportation products (cars) and heavy duty city buses. One major challenge for the vehicle integrator is the low density of hydrogen. The only storage container technology applicable at 40 to 100 MPa is carbon fibre fully over-wrapped composite cylinders. Steel cylinders technology that has been used at 16 to 20 MPa for hydrogen distribution and storage is severely challenged when trying to support the new hydrogen fuel applications. This presentation will address some recent Compressed Gas Association (CGA) recommendations on the use of carbon fibre fully over-wrapped composite cylinders in non-vehicular applications and present some examples of the application of composite tanks in stationary and mobile applications.

8:40 AM

(H2-STOR-50) New Evaluation Tool Allowing for Hydrogen Storage Tank System Volume and Weight Estimation

K. Tange*, M. Ishikiriya, Toyota Motor Corporation, Japan; R. Mohtadi, Toyota Motor Engineering and Manufacturing North America, USA; K. Hirose, Toyota Motor Corporation, Japan

Hydrogen storage presents a main obstacle for large scale commercialization of fuel cell vehicles. Presently, most of hydrogen storage research has been focused on enhancing the hydrogen materials content without paying much consideration to the overall system capacity. In order to evaluate materials potential and figure out the issues related to on board storage systems, we have developed a new evaluation tool allowing for tank volume and weight estimation. In the model, we classified the tank systems into 6 types depending on the hydrogen storage material properties. Each component weight and volume is calculated based on adsorbing and desorbing condition and the design parameters such as the auxiliary power and its efficiency. As a result, the system volume and weight can be roughly estimated and judged for each material using by 4 factors, mass%, bulk density, enthalpy change and desorption temperature. At the meeting, we plan to show and discuss the results of our model.

9:00 AM

(H2-STOR-51) Development and Verification of Type 2 Composite High Pressure Hydrogen Bulk Storage Vessels (Invited)

T. J. Hannum^{*}, HyPerComp Engineering, USA

1) Develop safe, reliable 15,000 psi H₂ bulk storage 2) Use metallurgical, composite, & regulatory expertise to validate DOE's goals of cost, volume & weight efficiency 3) Validate Type 2 vessel cost effectiveness thru hardware fabrication & testing thus identifying proper materials, design, processing, & end product capability 4) Validate & mature relevant ASME codes The team includes HEI (prototype), ASME (codes/stds), SRNL (metallurgy/govt codes) & CP Industries (liners). Air Products will advise as end user. Scope includes identifying pressure vessel geometry, material selection, testing & qualification options followed by design & analysis to produce preliminary design package followed by subscale fabrication of steel liners by CPI for process development. Subscale vessels will validate design concept & establish statistically relevant data for extrapolation to full scale design, fabrication/testing to demonstrate required hardware qualification & validation performance.

Production

Water/Solar 2

Room: Seahorse

Session Chair: William Summers, Savannah River National Laboratory

8:00 AM

(H2-PROD-19) Development of Advanced Catalysts for PEM Water Electrolysis

E. B. Anderson^{*}, K. E. Ayers, J. Manco, E. Styche, Distributed Energy Systems, USA

PEM water electrolysis for on site hydrogen generation is an attractive option for many industrial applications, but there is a need to reduce the cost of the membrane-electrode assembly (MEA) in order to provide a viable near-term solution for an emerging hydrogen economy. To address this need, recent efforts to identify new membrane and catalyst materials to optimize the MEA cost-performance ratio have been initiated. The anode for water oxidation contributes significant overpotential to the cell and thus is a primary target for optimization. Catalyst research focused on noble metals, as pure oxides or binary blends of metal oxides made by a high temperature fusion method. Alternate materials were synthesized in house or obtained from suppliers and were evaluated electrochemically, using a combination of bench tests and performance in operating electrolysis stacks. Preliminary results indicate that performance improvements are achievable vs. the current baseline and provide direction for future designs.

8:20 AM

(H2-PROD-20) Parametric Modeling of Heat Recuperative Solid Oxide Electrolysis System

S. Gopalan^{*}, Howard University, USA; J. Hartvigsen, Ceramtec Inc, USA; R. McConnell, National Renewable Energy Laboratory, USA; M. Mosleh, Howard University, USA

Solid oxide electrolysis is a viable way of producing hydrogen. The efficiency of electrolysis increases with increased operating temperature as a result of reduction in Gibbs free energy. The main goal of this paper is to demonstrate the effectiveness of using a heat exchanger to recuperate the thermal energy from the exhaust streams of the solid oxide electrolysis cell which is currently wasted. The recovered heat can be used to achieve the desired operating temperature. A parametric model describing the heat recuperative solid oxide electrolysis system is developed. The exit temperature of the gas streams, size of the heat exchanger, efficiency of hydrogen production are determined as a function of operating voltage, steam utilization, stack size, area specific resistance and insulation properties of the system. The optimum operating conditions are subse-

quently identified. A comparison between the efficiency of conventional solid oxide electrolysis and recuperative solid oxide electrolysis is made

8:40 AM

(H2-PROD-21) X-Ray Photoelectron Investigation of Phosphotungstic Acid as a Proton-Conducting Medium in Solid Polymer Electrolytes

C. A. Linkous^{*}, S. L. Rhoden, Florida Solar Energy Center, USA; K. M. Scammon, University of Central Florida, USA

Phosphotungstic Acid (PTA) is a cluster compound consisting of 12 tungsten trioxide units interlocked in a shield around a phosphate ion center. The oxygen atoms bound in the cluster are thought to define a surface across which hydrogen ions may be transported. This process is thought to occur largely without the assistance of surrounding molecular species such as water, so that PTA has been incorporated into polymer electrolytes with the intent of enhancing proton conductivity at low relative humidity. We have been using X-ray photoelectron spectroscopy to monitor changes in the PTA complex as a function of chemical treatment. Shifts in the W4f transition were found after exposure to sodium and cesium salts. These shifts are thought to be related to changes in the oxygen coordination shell around each tungsten atom. The structural changes associated with these chemical treatments and their impact on proton conductivity will be discussed.

9:00 AM

(H2-PROD-22) Hydrogen Production via Photooxidation of Aqueous Sodium Sulfite Solutions

C. Huang^{*}, C. A. Linkous, O. Adebisi, A. T-Raissi, University of Central Florida, USA

This paper presents a novel process for the production of hydrogen by radiating aqueous Na₂SO₃ solutions with ultraviolet (UV) light (wavelength $\lambda = 254$ nm). Hydrogen was generated at a quantum efficiency of 14.42% using 0.05 M Na₂SO₃ solution at pH of 7.59. Experimental data show that the mechanism of photooxidation of Na₂SO₃ follows two reaction pathways: 1) SO₃²⁻ ions directly oxidize to form SO₄²⁻, and 2) SO₃²⁻ ions oxidize to dithionate (S₂O₆²⁻), which then convert into SO₄²⁻ ions. It was also found that the mechanism of photolytic oxidation of Na₂SO₃ in water is affected by the solutions' initial pH. Photooxidation of aqueous Na₂SO₃ at an initial solution pH of 9.80 resulted in total oxidation of the sulfite to Na₂SO₄ via formation of sodium dithionate (Na₂S₂O₆) as a reaction intermediate. When the initial pH was lowered to 7.55, hydrogen formation rate increased and reached a maximum value. Further reduction of pH to 5.93 resulted in the formation of elemental sulfur.

9:20 AM

(H2-PROD-23) 1-Step Fabrication of Nanoscale Zero Valent Iron Particles from Steel-Mill Waste for the Generation of PEMFC-grade Green Hydrogen

S. K. Kesavan, S. Al-Batty^{*}, A. Azad, The University of Toledo, USA

Active nanoscale zero valent iron powder was obtained via solvothermal reduction process from steel industry's mill-scale waste, using hydrazine as an inexpensive reductant. It was found that the slurry pH, pressure and the reaction time played important role in the conversion of the waste into nano Fe. The metal so obtained was crystalline with body centered cubic structure and edge dimension ~5 nm. The powder also showed improved kinetics and greater propensity for the hydrogen generation than the coarser microscale iron obtained through traditional reduction techniques. To initiate and sustain the somewhat endothermic MSR process, a solar concentrator consisting of a convex polyacrylic bowl with aluminum reflective coating was fabricated. A combination of mill-scale waste, hydrazine for nanometal generation and solar energy for actuating MSR, obviates several drawbacks plaguing the grand scheme of producing pure and humidified H₂ to a PEMFC stack.

Author Index

A		Cooper, A.*10	Gillette, J.11	
Acatrinci, A.I.14	Cugini, A.22	Gopalan, S.*23	Goswami, Y.D.20	
Adams, T.M.19	Cummings, S.R.17	Graetz, J.*14	Grant, D.9	
Adams, T.M.*11	Curtis, C.10	Grove, H.9	Guo, C.18	
Adebiyi, O.23	D		H	
Ahn, C.C.8	Dadfarnia, M.14	Hall, P.J.20	Hannum, T.J.*22	
Al-Batty, S.*23	Daemen, L.L.14	Hansen, E.K.17, 21	Hansen, E.K.*21	
Allen, C.R.16	Davis, T.A.20	Hartl, M.A.14	Hartvigsen, J.23	
Anderson, E.B.*23	Day, D.E.*16	Hartvigsen, J.J.15	Hathcock, D.*18	
Andrukaitis, E.*7	Dillon, A.*10	Hauback, B.C.9	Hayden, L.11	
Anovitz, L.M.12	Donet, S.20	Hayes, J.14	Heben, M.10	
Aoki, M.15	Dorris, S.E.18	Herring, J.*15	Hershkowitz, F.18	
Armstrong, T.R.12	Duncan, A.J.11	Heung, K.16	Heung, K.L.16	
Au, M.*8	E		Heung, L.K.*16	
Autrey, T.*10	Edie, D.D.9	Hirose, K.22	Hirschler, M.*9	
Ayabe, R.14	Edson, D.L.*19	Horike, S.9	Huang, C.*23	
Ayers, K.E.23	Edwards, D.13	Humphries, T.14	Hwang, S.8	
Azad, A.23	Edwards, D.B.21	I		
B		J		
Baharvandi, H.21	Ehsani, N.21	Jena, P.*15	Jensen, C.*14	
Baik, J.19	Elgowainy, A.*11	Johnson, J.R.14	Jones, T.M.*17	
Balachandran, U.*18	Emerson, J.E.18	Jones, W.R.17	Jordá-Beneyto, M.9	
Beaird, A.M.20	Engrakul, C.10	Jurczyk, M.U.20	K	
Beaird, A.M.*20	Erck, R.12	Kabbour, H.8	Kallupalayam, K.18	
Bhat, V.V.9	Erck, R.*11	Kapoun, K.*18	Kaye, S.S.9	
Bonner, B.B.*11	Erdemir, A.12	F		
Bourlinos, A.13	Ertan, A.20	Fang, Z.Z.*14	G	
Bowman, R.C.*8	Eryilmaz, O.11	Fedkin, M.15	Galindo, J.I.*7, 12	
Boyd, R.W.17	Eryilmaz, O.L.*12	Feng, Z.*12	Gallego, N.C.*9	
Boyd, R.W.*22	F		Gao, Y.8	
Brinks, H.W.9	Fang, Z.Z.*14	Fenske, G.11	Gardiner, M.7	
Brow, R.K.15	Fedkin, M.15	Fichtner, M.*8	Gaylord, S.W.17	
Burket, P.R.19	Feng, Z.*12	Filiou, C.*7	Georgiev, P.A.10	
C		Ford, M.10		
Carlie, N.A.17	Fossdal, A.9			
Cazorla-Amorós, D.9, 20	Fowler, D.10			
Celebi, Y.14	Férey, G.10			
Charalambopoulou, G.13	G			
Chaudhari, S.14	Galindo, J.I.*7, 12			
Chen, K.P.12	Gallego, N.C.*9			
Chen, L.18	Gao, Y.8			
Cheng, H.10	Gardiner, M.7			
Choi, D.19	Gaylord, S.W.17			
Chun, C.*18	Georgiev, P.A.10			
Clark, E.A.*17				
Contescu, C.I.9				

Author Index

Kesavan, S.K.	23	Miwa, K.	15	Reilly, D.	10	
Kherani, N.P.*	12	Mohajeri, N.*	19, 20	Reilly, J.	14	
Kim, C.	8	Mohtadi, R.	22	Reiter, J.W.	8	
Kim, E.	19	Mohtadi, R.*	16	Revur, R.	19	
Kim, J.*	8	Molendowska, A.*	20	Rhoden, S.L.	23	
Kim, S.	19	Moretto, P.	7	Rich, J.*	16	
Kim, Y.*	19	Morgan, M.*	18	Richardson, K.A.	17	
Knijajanski, S.	8	Morreale, B.*	22	Ricker, R.E.*	12, 19	
Koenig, K.	12	Morrison, I.	10	Rijssenbeek, J.	8	
Korinko, P.S.	11	Mosleh, M.	23	Roberston, I.M.	14	
Korinko, P.S.*	19	Motyka, T.*	22	Rodriguez-Santiago, V.	15	
Kunowsky, M.	20	Muradov, N.	19	Ronnebro, E.*	8	
Kwon, W.	19	Muradov, N.*	18	Ross, D.K.*	10	
L			N			
Laflin, C.	14	Nakamori, Y.	15	S		
Lamari, F.D.	20	Newell, D.*	21	San Marchi, C.	11	
Lasseigne, A.N.*	12	Newkirk, J.W.*	15	Satyapal, S.	7	
Latroche, M.J.*	10	Nibur, K.*	11	Scammon, K.M.	23	
Lee, J.A.*	21	Noritake, T.	15	Schmitz, B.	9	
Lee, T.H.	18	O			Schorr, J.R.	19
Li, H.	15	Ohba, N.	15	Schroder, M.*	10	
Li, Y.*	13	Ordaz, G.	7	Schubert, P.J.*	19	
Lillo, T.M.	15	Orimo, S.	15	Schumacher, R.	16	
Linares-Solano, A.*	9, 20	O'Brien, J.E.	15	Schumacher, R.F.	16, 17, 21	
Linkous, C.A.	23	O'Neill, K.	10	Scott, A.	10	
Linkous, C.A.*	23	P			Seifi, M.	10
Liu, B.	12	Panella, B.	9	Sengupta, S.	19	
Loiseau, T.	10	Parilla, P.	10	Serre, C.	10	
Long, J.R.*	9	Parvin, N.	21	Shelby, J.E.	16	
Louthan, M.R.*	13	Patankar, S.N.	21	Shen, L.	21	
Lozano-Castello, D.	9	Peeler, D.K.	17, 21	Shewchun, J.*	13	
Lu, J.	14	Petit, L.	17	Shmayda, W.T.*	12	
Lvov, S.*	15	Petrovic, J.	7	Shqau, K.	19	
M			R			
Ma, Z.*	7	Pez, G.	10	Siewert, T.	12	
Maeland, A.J.*	9	Picciolo, J.J.	18	Simpson, L.	10	
Mahajana, S.	13	Pitchure, D.J.	12, 19	Sisson, R.D.*	13	
Majzoub, E.H.	8	Price, T.C.*	9	Smith, F.	18	
Manco, J.	23	Purewal, J.J.	8	Snyder, M.J.	16	
Marrero-Alfonso, E.Y.	20	Pyles, T.	19	Sofronis, P.*	14	
Marrero-Alfonso, E.Y.*	20	R			Sohn, H.	14
Martin, M.	14	Rahimian, M.*	21	Soloveichik, G.	8	
Martin-Bermejo, J.	7	Ramanarayanan, T.A.	18	Somerday, B.	11	
Matsumoto, M.	15	Ramaprabhu, S.*	13	Sorby, M.H.	9	
Matsunaga, T.	16	Ramasamy, K.K.	19, 20	Speaker, R.*	14	
Matthews, M.A.	20	Rana, M.	11	Spielvogel, B.*	21	
McColsky, D.	12	Raszewski, F.C.	21	Srinivasan, S.S.*	20	
McConnell, R.	23	Raszewski, F.C.*	17, 21	Stanescu, M.*	17	
McGrady, G.	14	Rawls, G.B.*	11	Stefanakos, E.K.	20	
Mintz, J.*	17	Read, C.	7	Steriotis, T.*	13	
Mintz, M.	11			Stetson, N.*	7	
				Stokes, E.H.*	21	
				Stoots, C.M.	15	
				Stoudt, M.R.	12	

Stowe, A.C.14	Tewari, S.N.20	Wicks, G.16
Stratton, P.17	Thomas, G.7	Wicks, G.G.16, 19
Stubos, A.13	Thrun, L.B.*17	Wicks, G.G.*16
Styche, E.23	Toseland, B.10	Wilks, A.D.19
Summers, W.*15	Towata, S.*15	Woodall, J.16
Sundaram*, S.K.22		Wu, X.21
Sundaesan, R.*7	V	
Suárez-García, F.9, 20	Verweij, H.19	Z
Swartz, S.L.17		Zhang, D.*21
T	W	Zhao, J.*8
T-Raissi, A.18, 19, 20, 23	Wachtel, P.F.*16	Zhou, W.14
Talu, O.*20	Walker, G.9	Zidan, R.*14
Tange, K.16	Walters, R.T.*19	Ziebarth, J.*16
Tange, K.*22	Wegrzyn, J.14	Zukotynski, S.12
Tekinalp, H.L.9	Weinberger, B.20	
	Whitney, E.10	

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