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# From R&D to products: Innovation with Fraunhofer

Prof. Dr. Alexander Michaelis

Energy and environmental technology at IKTS.



**Membranes**



**PV / Batteries**



**Fuel Cells**



# Fraunhofer is the largest organization for **applied** research in Europe → **your partner for Innovation**

## 7 alliances

- microelectronics
- production
- information and communication
- **materials and components**
- life sciences
- surface technology and photonics
- defence research and technology



59 Institutes  
at 40 Locations



18.000 staff



1,7 Bill. € Budget



**Joseph von Fraunhofer**  
(1787-1826)

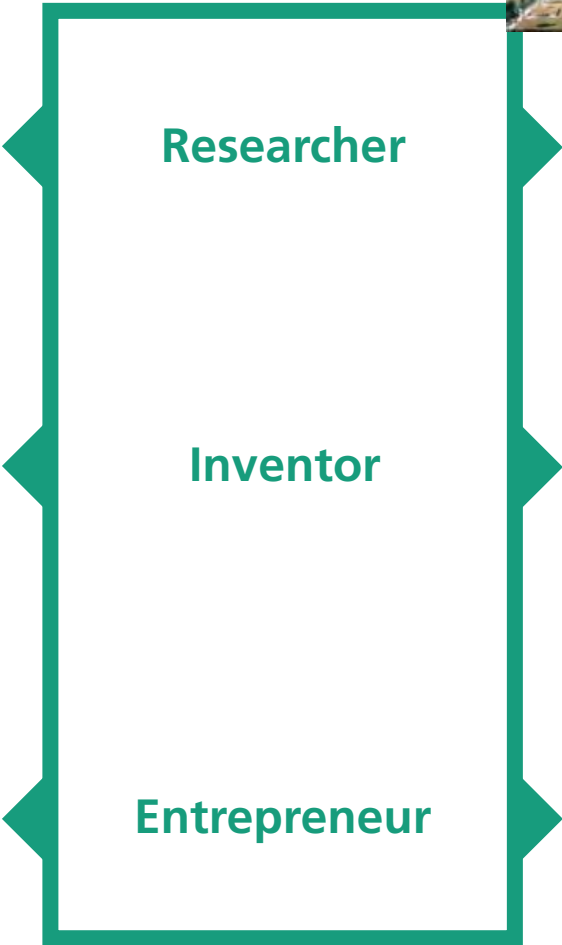


**The Fraunhofer-Gesellschaft ,  
Headquarter Munich**

Discovery of the "Fraunhofer lines" in the solar spectrum

New methods for processing lenses

Director and partner in a glassworks

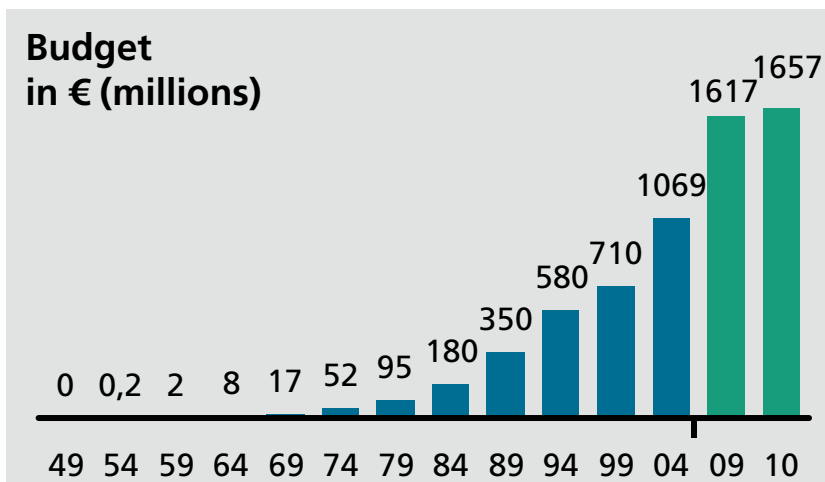
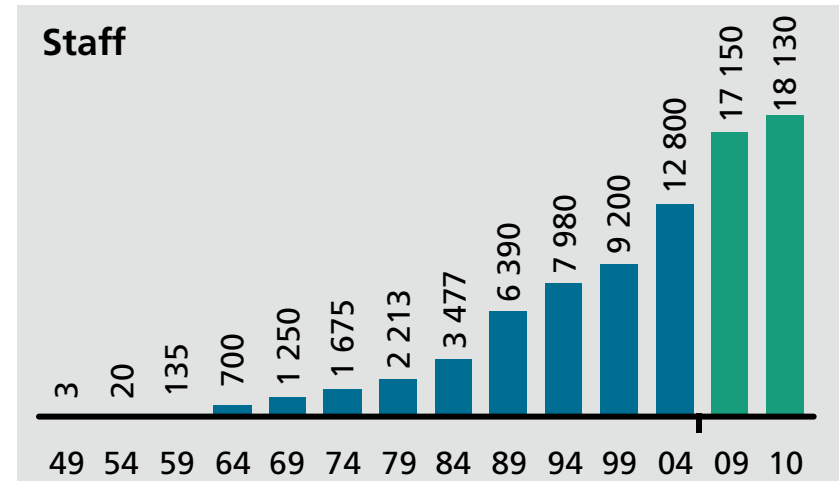
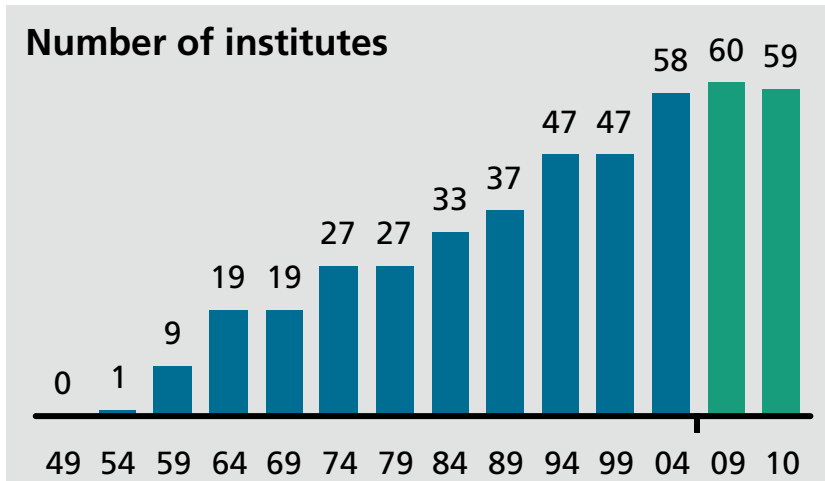


Research and development on behalf of industry and state

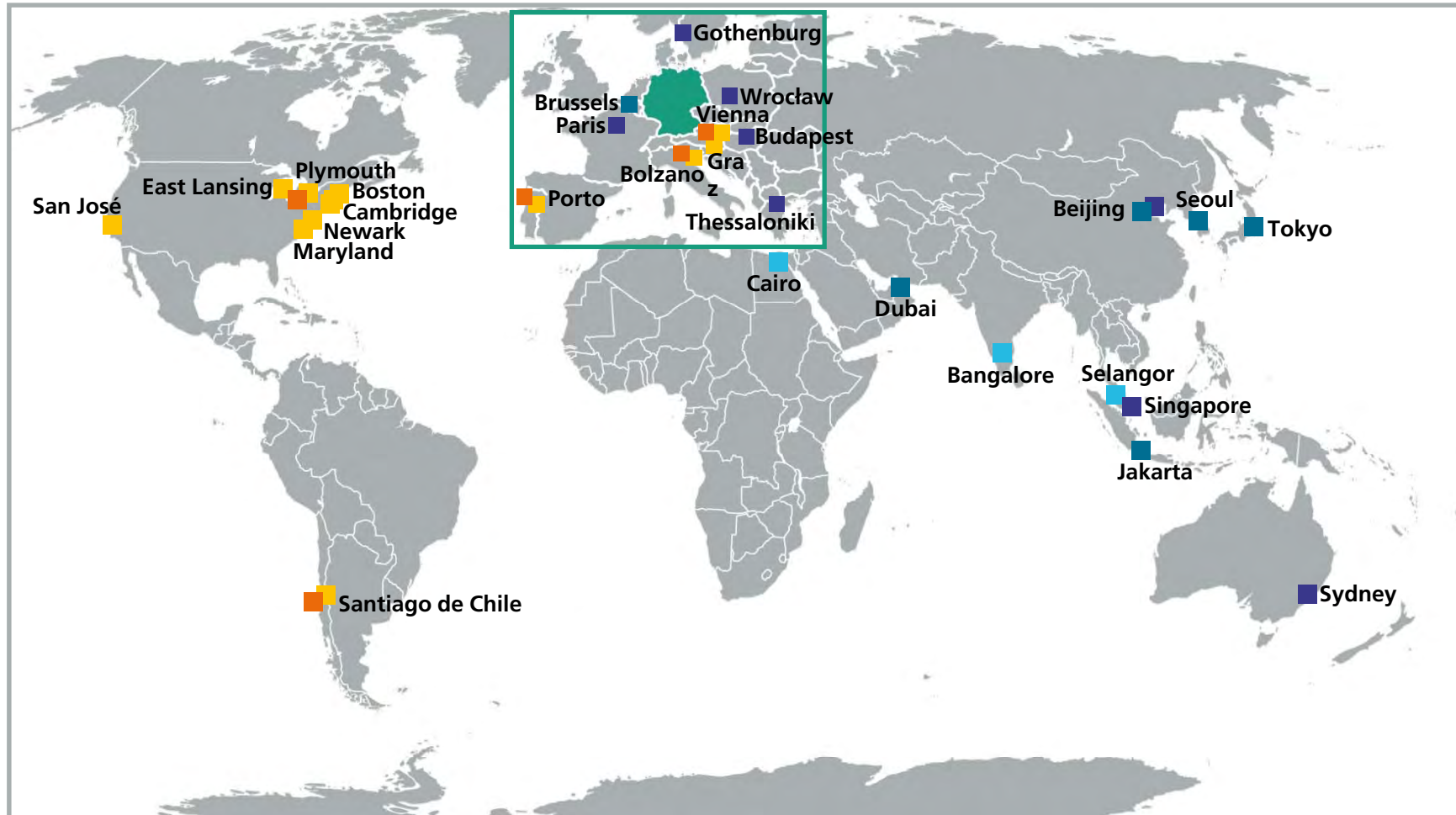
mp3 music format, white LED, high-resolution thermal camera

Research volume: approx. 1.7 billion € annually **of which 1.4 billion € is generated through contract research**

# From a small association to the leading organization for applied research in Europe

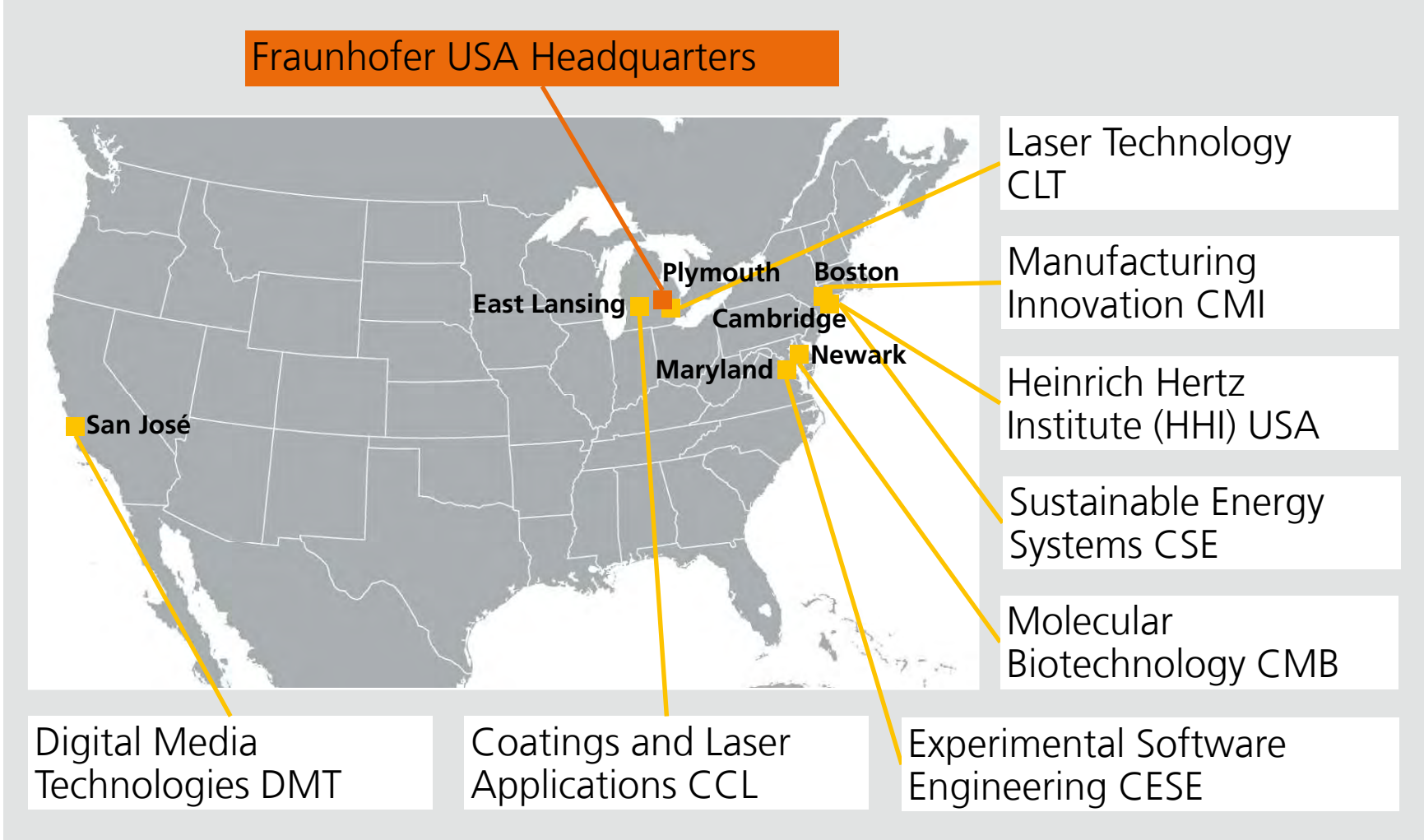


# Fraunhofer worldwide



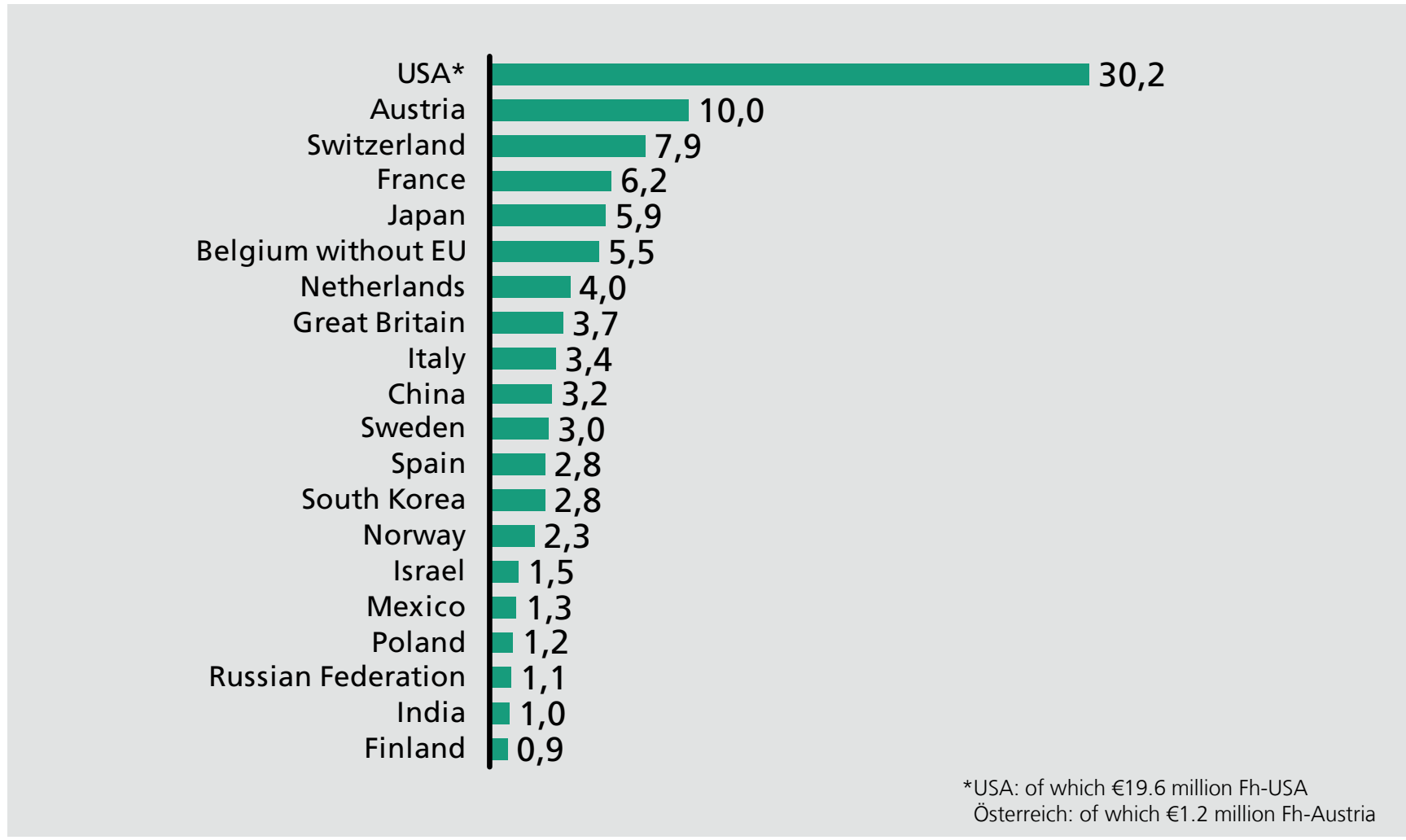
- Subsidiary
- Center
- Project Center / Strategic Cooperation
- Representative Office
- Senior Advisor

# Fraunhofer USA, Inc. first overseas subsidiary, est. 1994



# International Revenues 2010 by Countries – Top 20

(without EU-Commission) in million €



# Fraunhofer Institute of Ceramic Technologies and Systems, IKTS

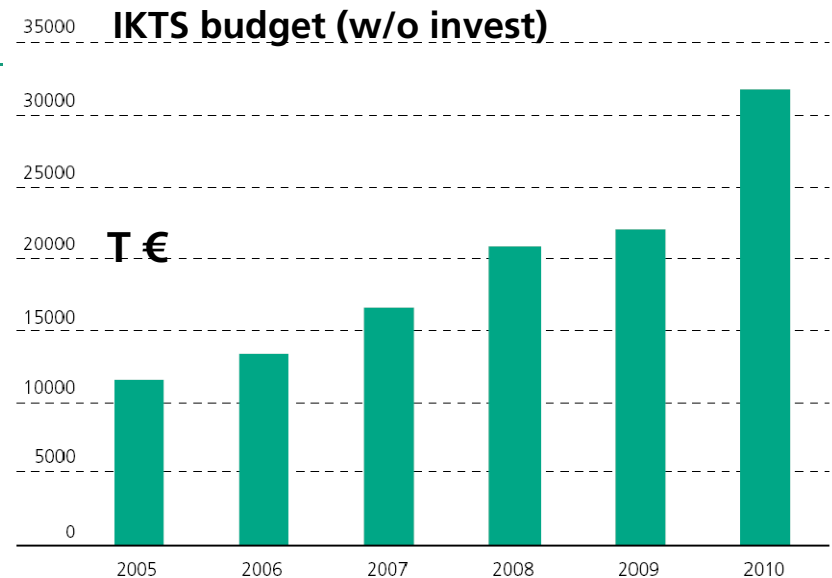
- IKTS belongs to the top 5 Fraunhofer Institutes
- Main market of IKTS: Energy and environmental technology

Sites Dresden and Hermsdorf

Staff: 420

Budget: 32 Mio € w/o invest

ca 80 % revenue from contract research  
(50 % directly from industry)





# Environmental Engineering and Bioenergy at IKTS

1. CO<sub>2</sub>-reduction in combustion plants / CCS gas filtration (O<sub>2</sub>-production)
2. Water technology (waste water, potable water)
3. Bioenergy (Biogas, Bioethanol, Biobuthanol, Biodiesel)
4. Diesel particle filter
5. Catalysis and membrane reactors

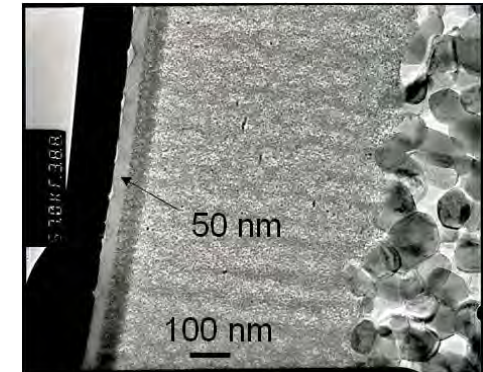


## Examples for membrane-materials used at IKTS

1. Nano-porous membranes (Zeolite, carbon, CNTs, MOFs, amorphous oxides, ...)
2. Dense mixed conducting membranes (Perovskites,  $ZrO_2$ , Tungstenates, ...)
3. Metallic membranes (Pd, Ag/Pd, Cu/Pd, ...)
4. Composite membranes (Zeolite/Polymer, CNT/Polymer, ...)
5. Catalysts on ceramic porous substrates (mixed oxides, precious metals, ...)

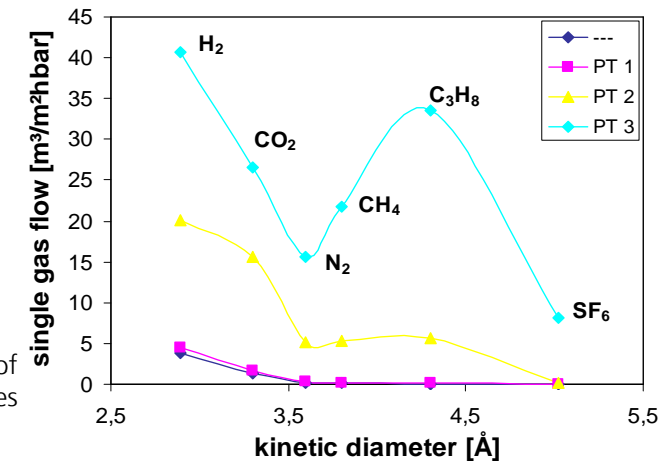


Ceramic substrate tubes



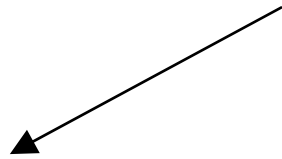
Nano-porous  $TiO_2$ -membrane layer

Separation performance of carbon membranes

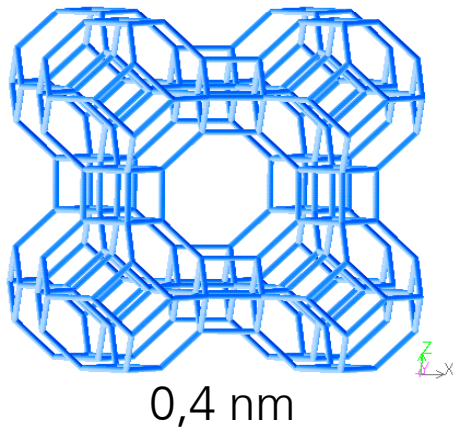


**IKTS develops membranes and catalysts, produces and tests components at application conditions**

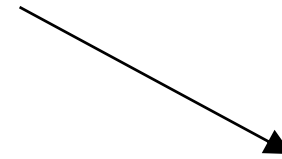
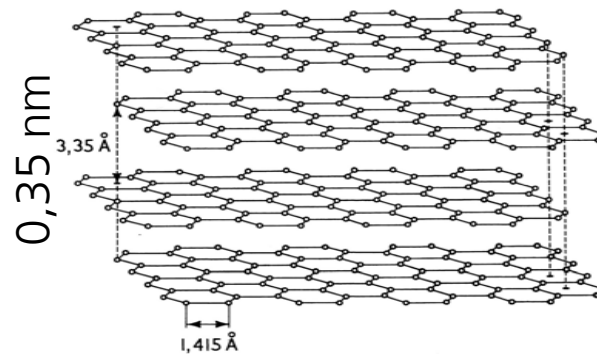
# Formation of structural pores < 1 nm



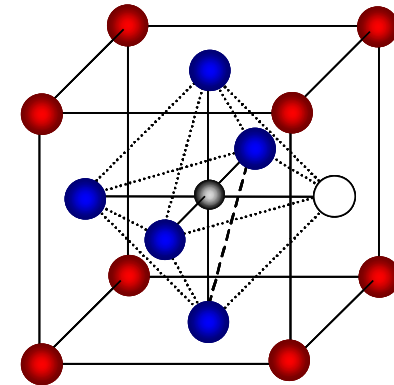
Crystallographic cages/channels



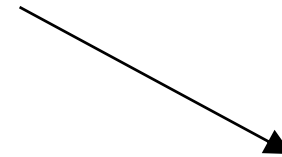
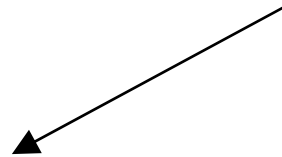
Lattice plane distances



Crystallographic defects (vacancies)



# Formation of structural pores < 1 nm



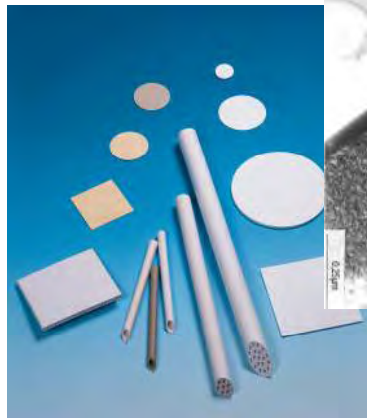
Crystallographic cages/channels

Lattice plane distances

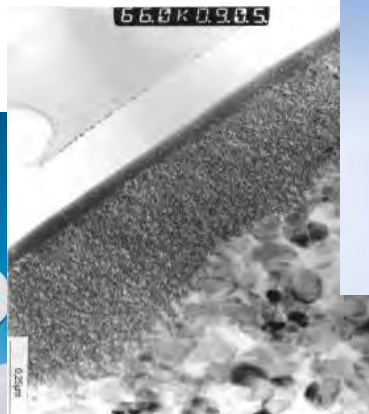
Crystallographic defects (vacancies)



# From materials up to the systems / products



support



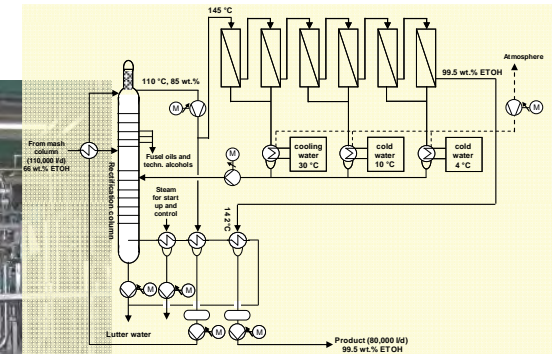
membrane



module



system / product



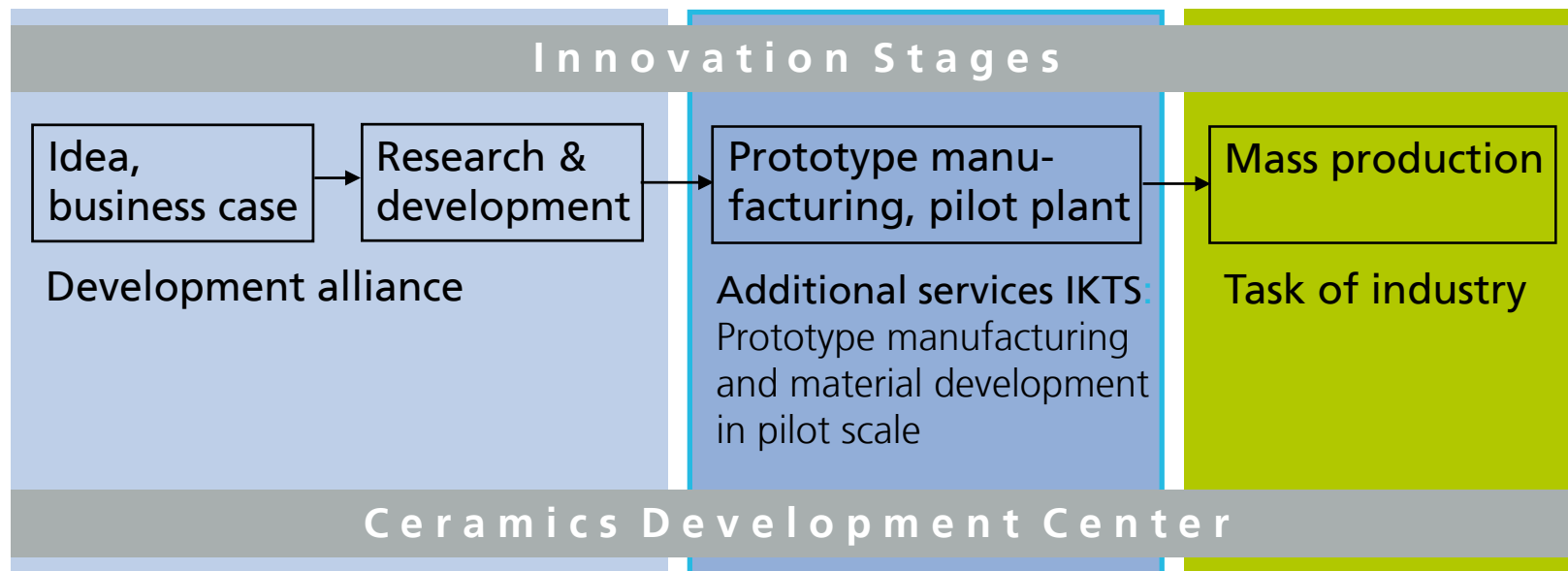
process

# Profile of the Fraunhofer IKTS

## Range of Services

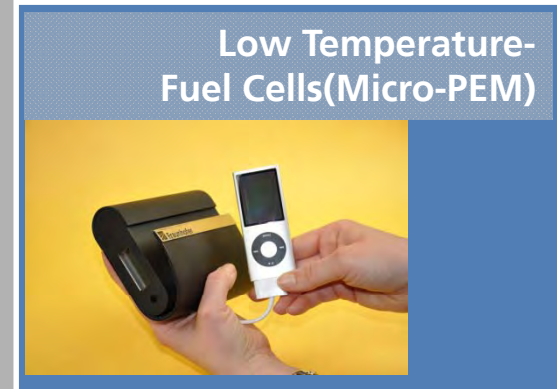
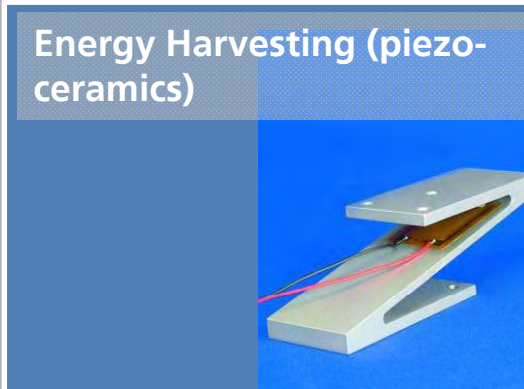
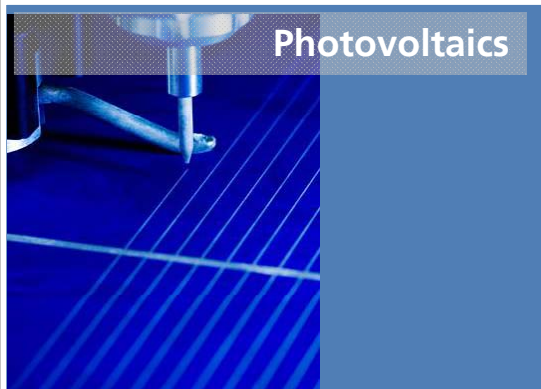
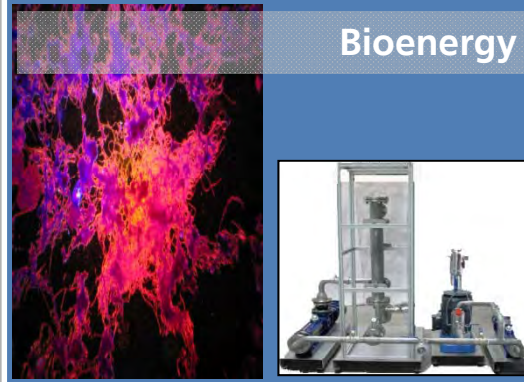
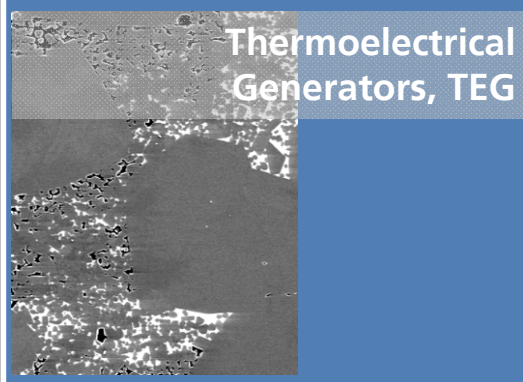
Realization of R&D projects

Transfer to pilot scale



# Energy R&D at IKTS: Highlights

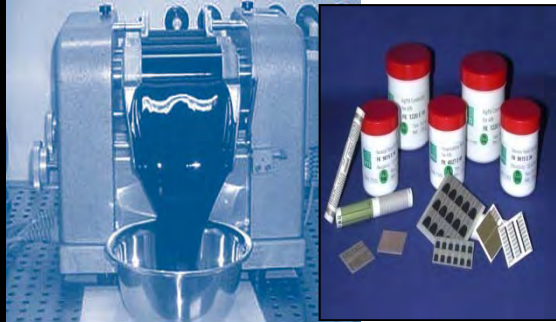
**eneramic®** Energy with ceramics



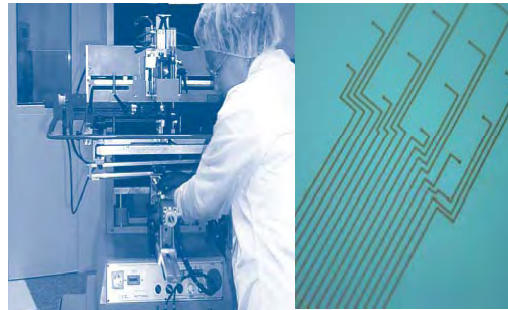
# technology platform functional ceramics / thick film (slurry) deposition



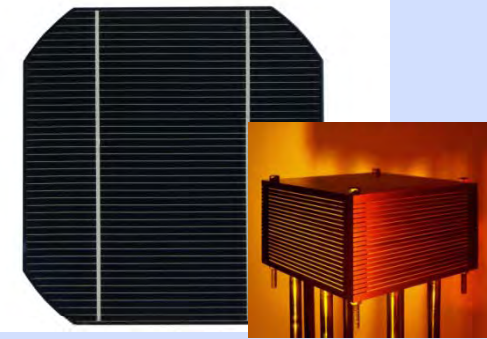
## 1 pastes / slurry



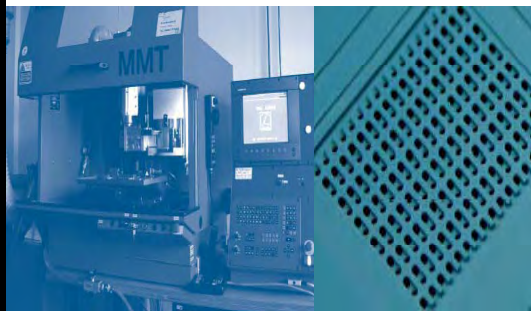
## 2 tape casting, printing



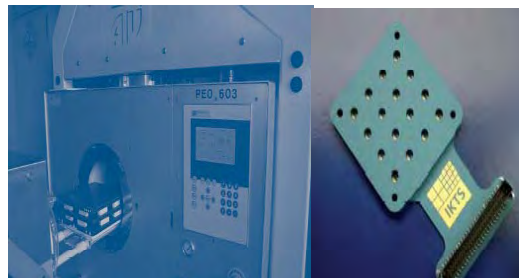
## Micro- and Energy systems



## 3 stacking



## 4 lamination, co-fire

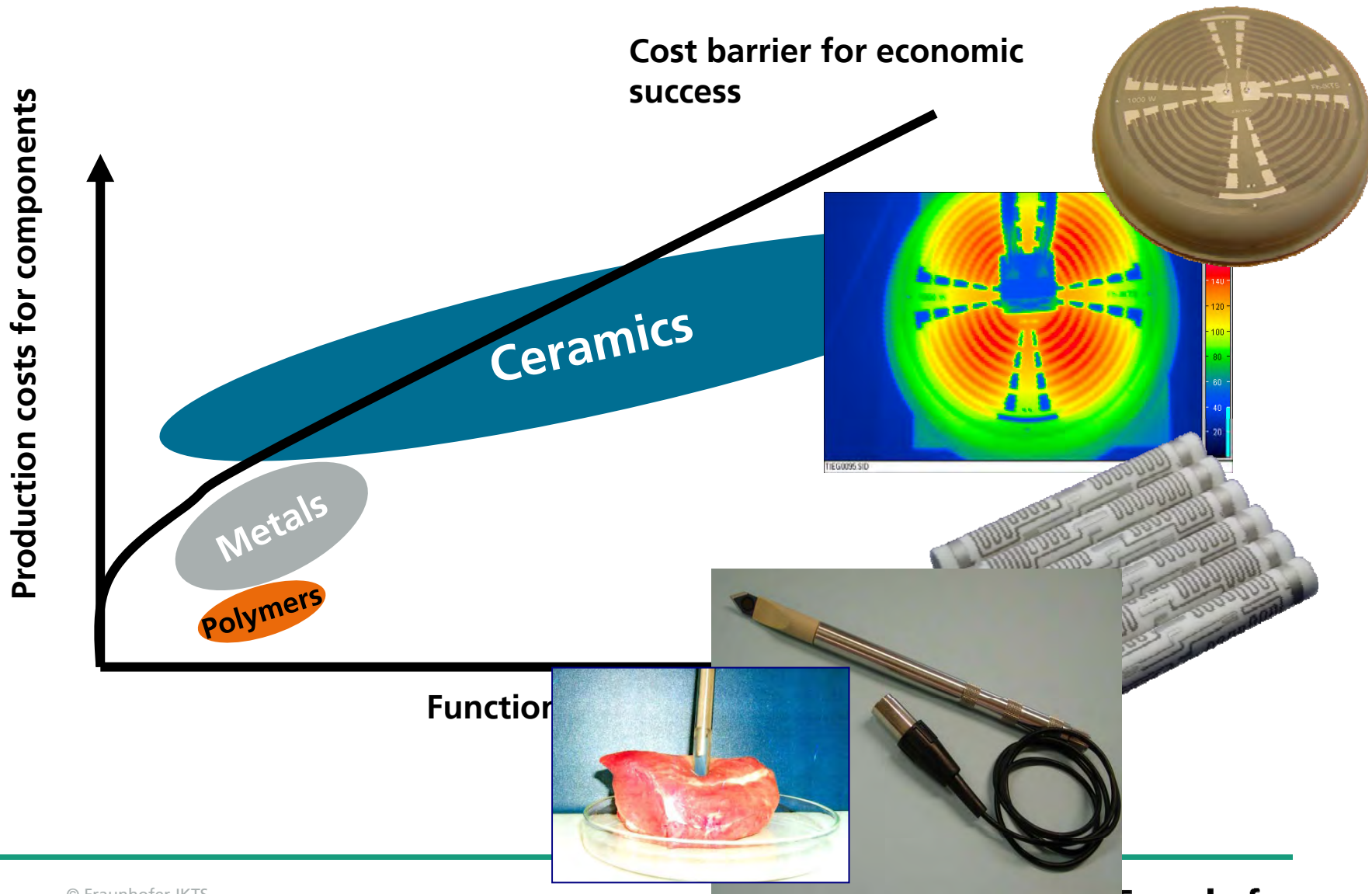


## Micro-Fuel Cells

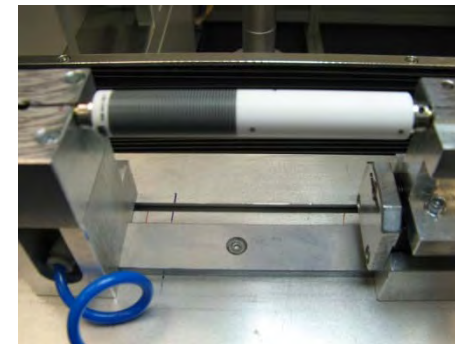




# Thick film technology for function integration



# Screen Printing at IKTS



- Screen Printing of planar and tubular structures
- Automatic positioning
- Clean Room facilities

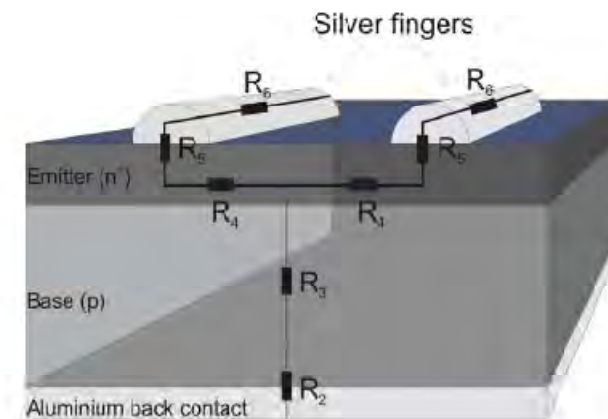
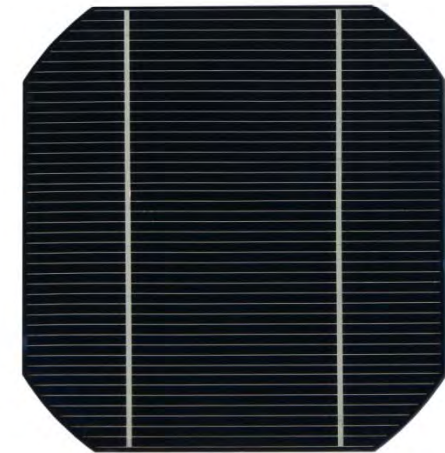
# Photovoltaics with Focus on BEOL (Contacting)

## Materials for Thick Film Contacting / Issues

1. Cost Reduction, less Ag
2. Environmental friendly materials (Pb-free)
3. Higher lateral resolution
4. Better Yield

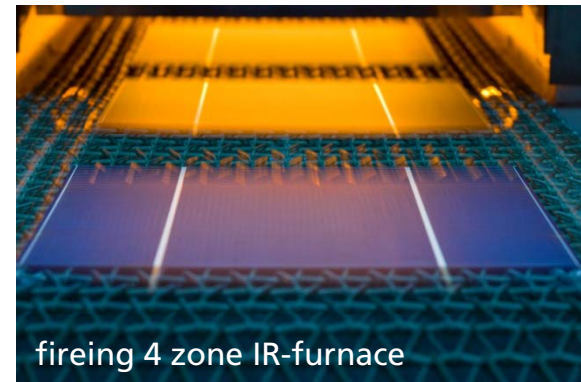
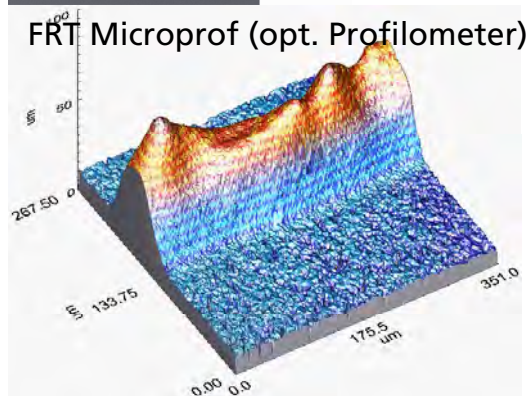
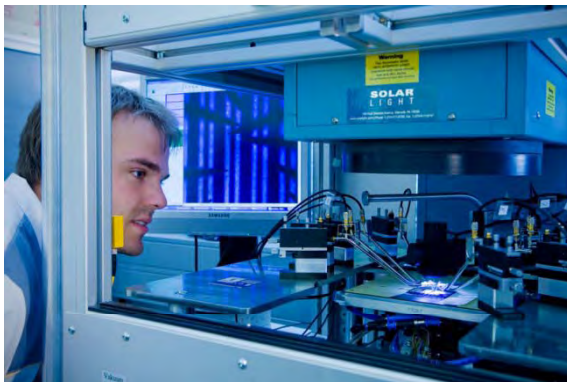
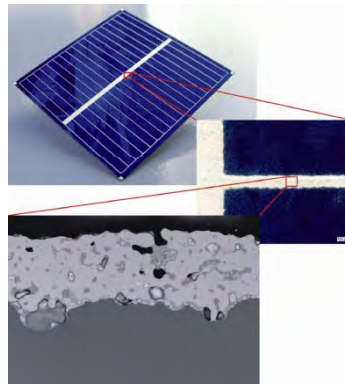
## Production Processes

1. Higher throughput
2. Non contact to improve yield
3. Automatization



# Thick Film Technology for Contacting of Solar-cells

Screen printing



Electrical characterization

# IKTS — Printing Technologies



Screen Printing



Inkjet- Printing



Aerosol Printing

# Joint IKTS / Roth & Rau AG 10 MW PV pilot line

## Closing the gap: From lab to fab

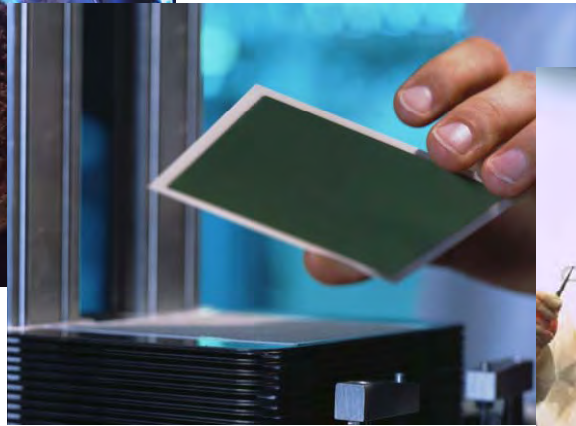


# Solid Oxide Fuel Cell (SOFC) value chain

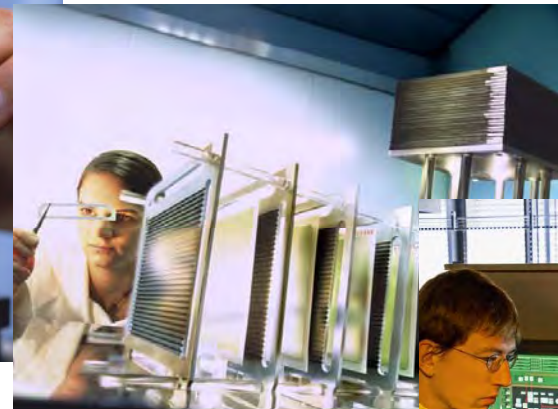
## Material



## MEA



## Stack



## System



- **Take over of Siemens AG planar SOFC Technology including IP and some assets in 1998**

# Fuel cell systems at IKTS



Hydrogen  
PEFC



Tubular  
SOFC



LPG  
SOFC



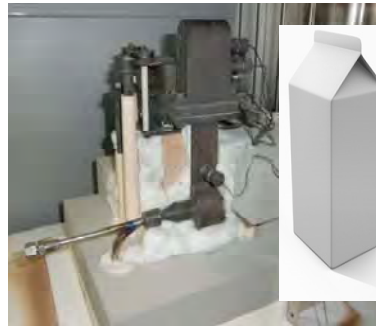
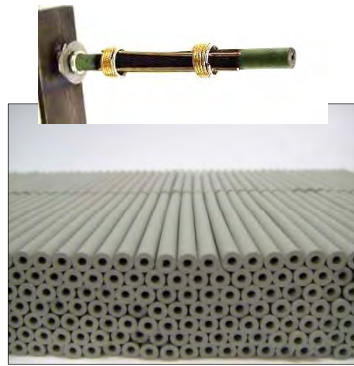
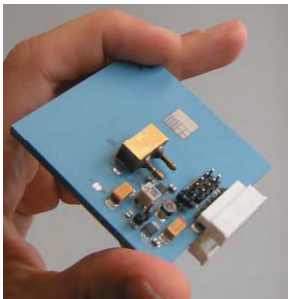
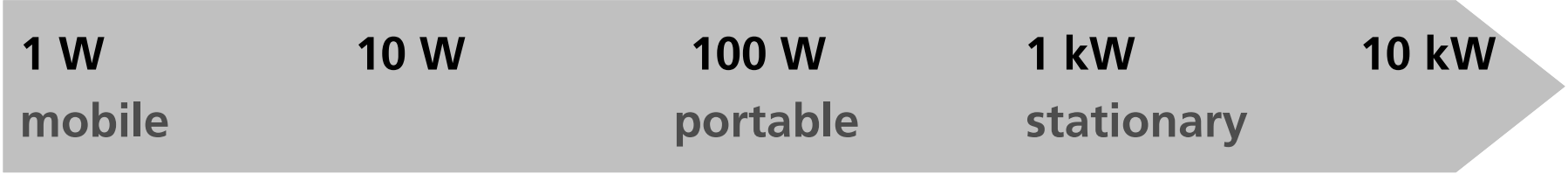
Natural gas  
SOFC



Biogas  
SOFC



# Fuel cell systems at IKTS



Hydrogen  
PEFC

Tubular  
SOFC



LPG  
SOFC



Natural gas  
SOFC

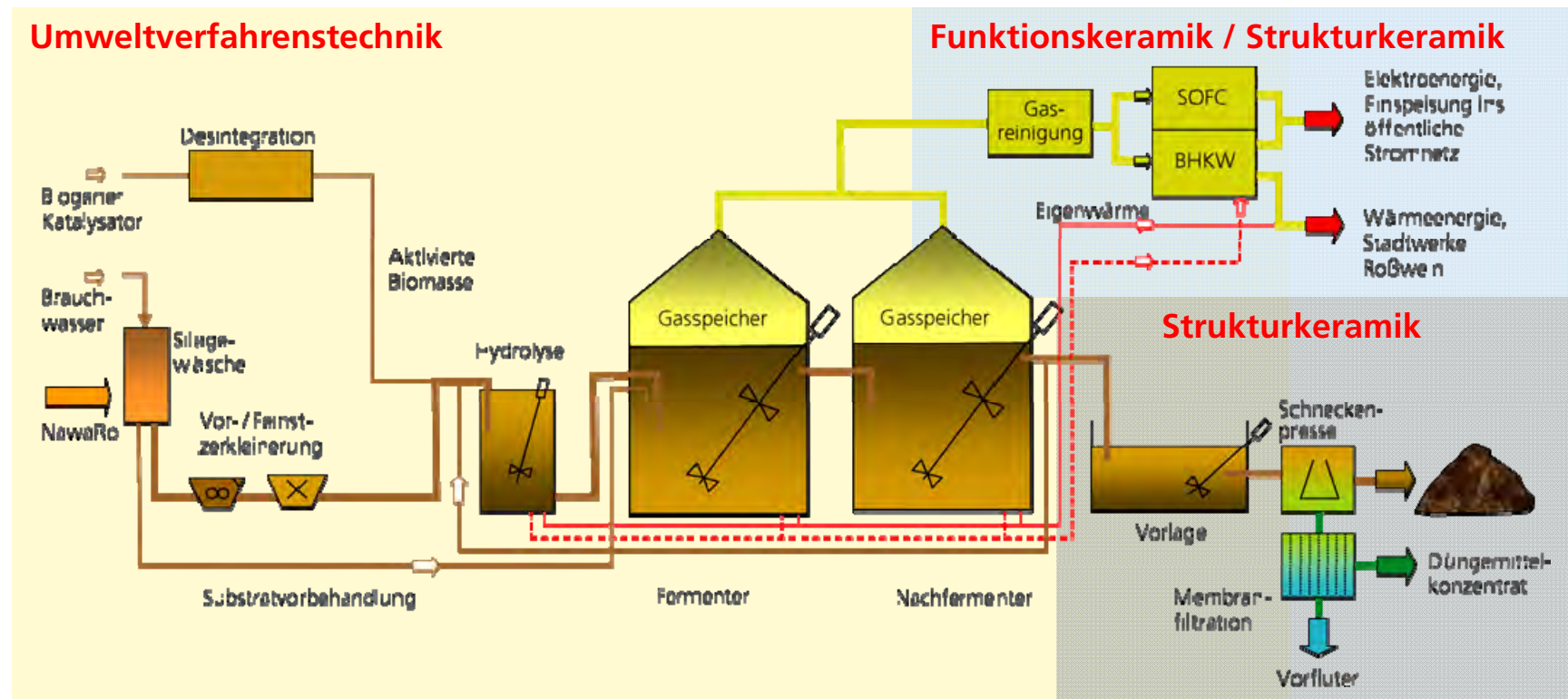
Biogas  
SOFC

# Bioenergy Application Center at „Pöhl“ in Saxony

Synergy between structural + functional ceramics

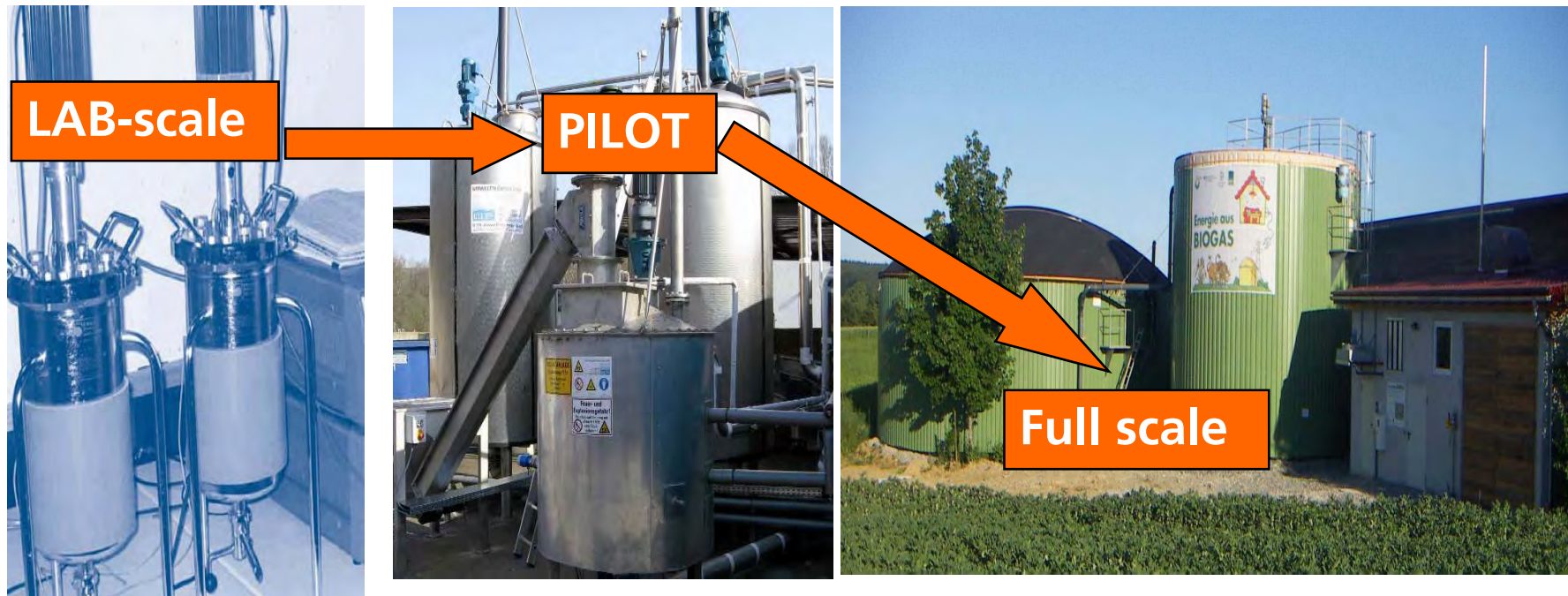
## Energy Storage:

Redox - Flow Battery  
NaS Battery

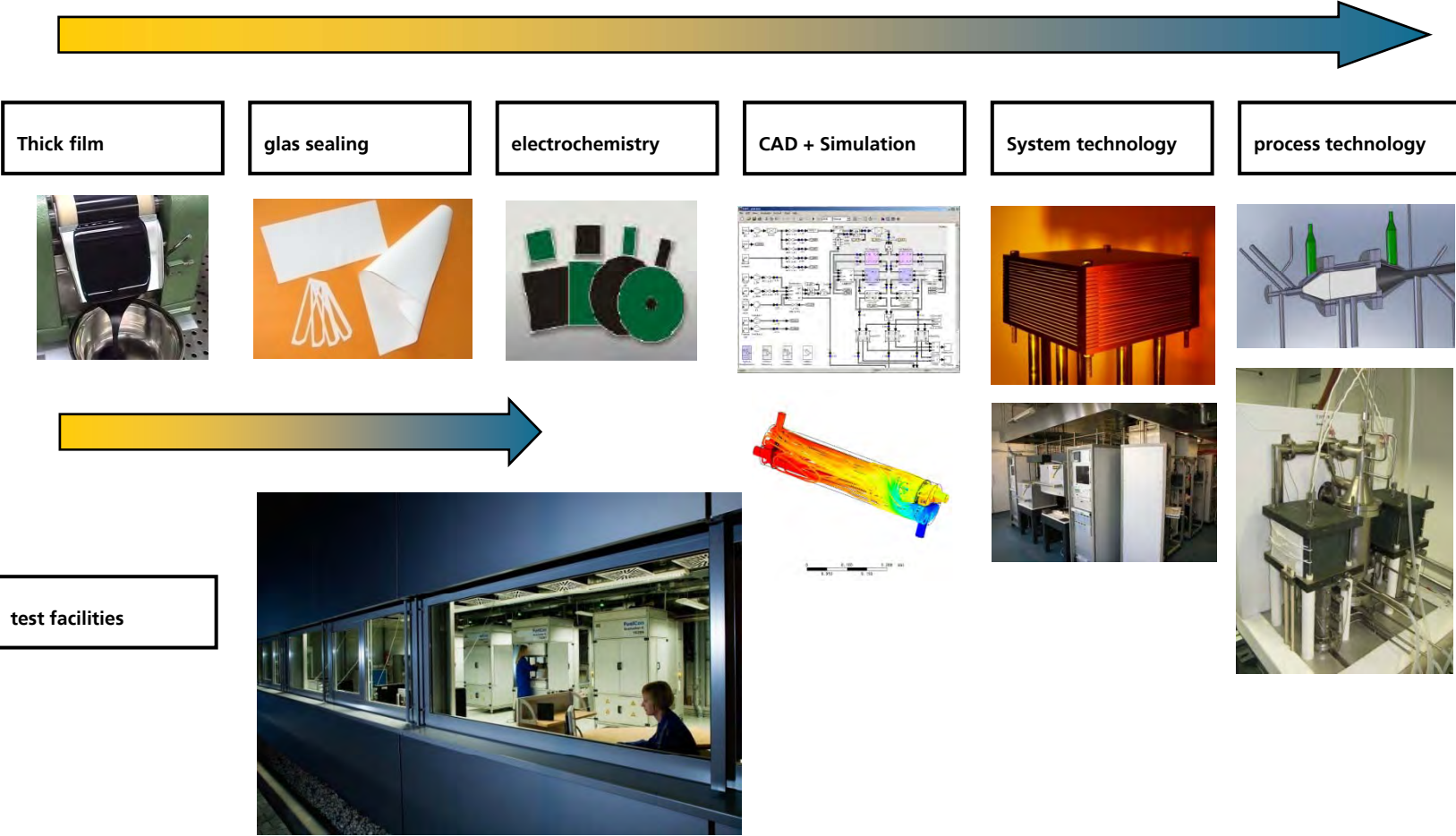


# Environmental Processing Technology at Fraunhofer IKTS

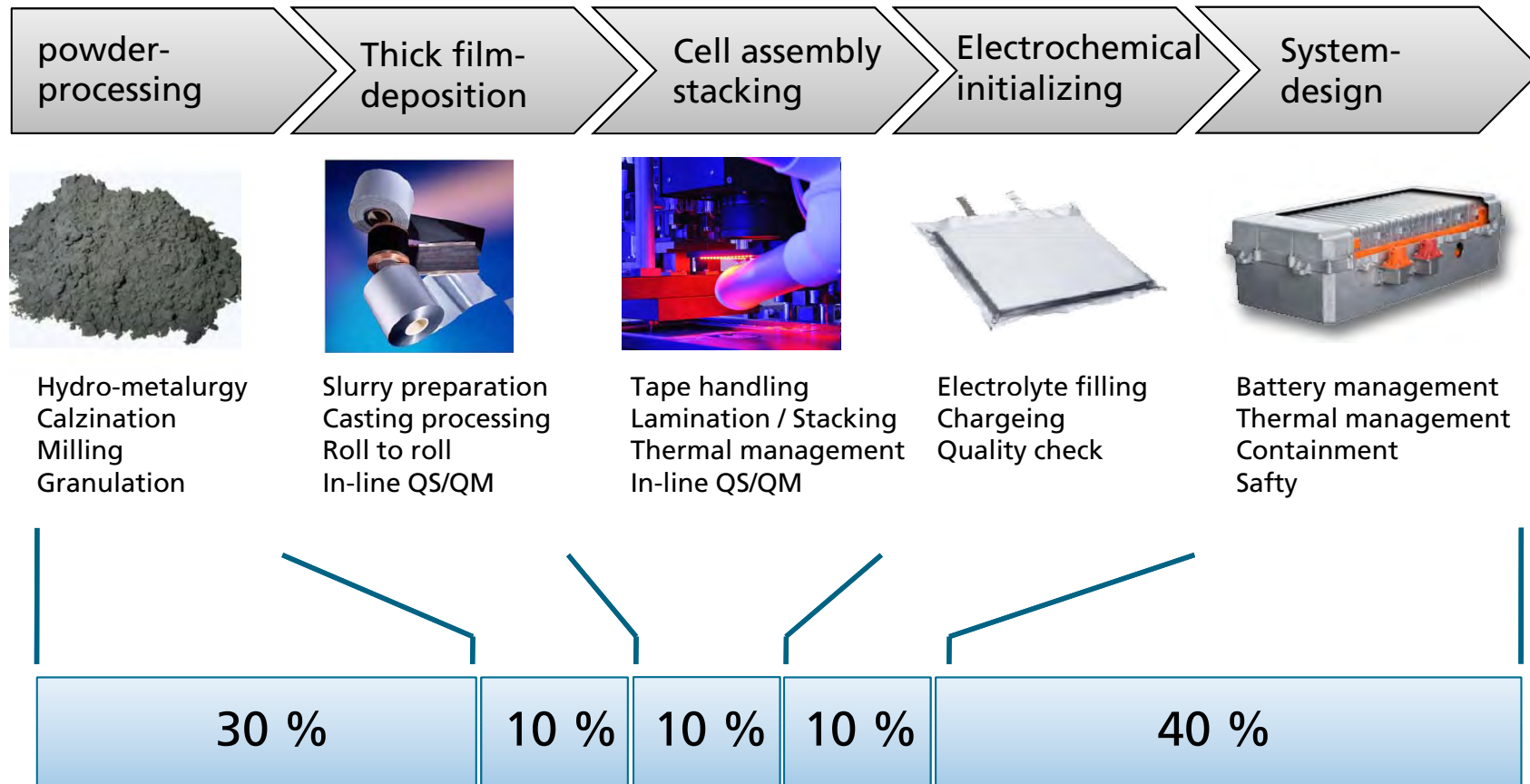
ENERGY/ENVIRONMENT/AGRICULTURE => Project „ More biogas at higher energy level –way to efficient power production“



# IKTS integrated technology line along complete value chain

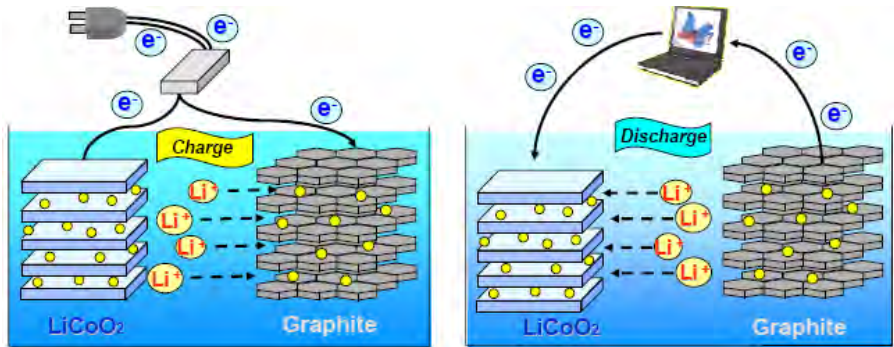


# Storage technology: Li-Ion Battery → value chain / technology line



# Technology platform for battery systems

powder-processing



Material	Average discharge voltage, V	Theor. max. capacity, mAh/g	Reversible capacity, mAh/h	Energy density, mWh/g	Safety	Cost
LiCoO <sub>2</sub> (LC)	3,9	274	150 - 160	580 - 620		
LiNi <sub>0,8</sub> Co <sub>0,15</sub> Al <sub>0,05</sub> O <sub>2</sub> (NCA)	3,8	271,5	180 - 220	680 - 830		
LiNi <sub>1/3</sub> Co <sub>1/3</sub> Mn <sub>1/3</sub> O <sub>2</sub> (NCM)	3,5	278	170	595		
LiMn <sub>2</sub> O <sub>4</sub> (LM)	4,05	148	100 - 120	405 - 485		
LiFePO <sub>4</sub>	3,4	170	150 - 160	510 - 540		

- chemical synthesis
- calcination
- milling, granulation
- electrochemistry

# Powder Processing

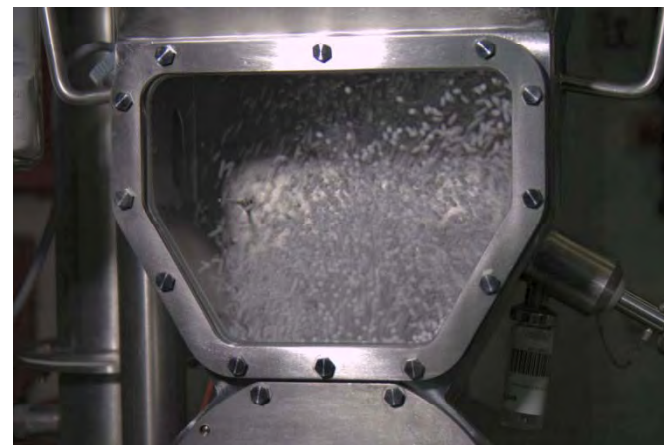
- **Objective:** refining and shaping of precursors and product powders
- **Approach:** using pilot-plant scale processing technology at IKTS
- **IKTS scope:**
  - Milling, granulation, shaping and coating using spray dryer / fluidized bed reactors
  - Developing cost effective, eco-friendly, proprietary processing methods
- **Advantage:**
  - Tight interface to production process, no end-of-pipe innovation
  - Systematic approach to complete powder production process



Large scale pilot spray drier/coater



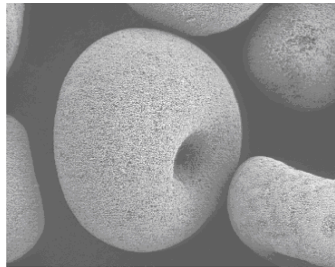
Fluid bed reactor



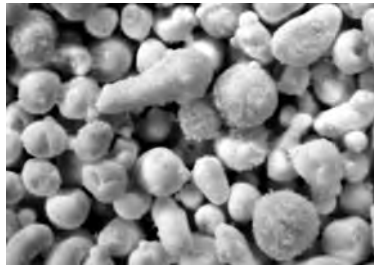
In-process control and measurement

# Powder Processing – Shape control

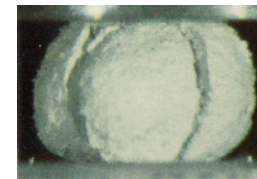
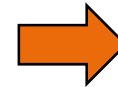
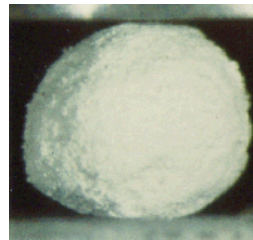
- **Objective:** generate controlled-shape powders, characterisation of powders
- **Approach:** using IKTS know-how from other powders
- **IKTS scope:**
  - Developing process windows for controlled shapes using state-of-the-art machinery
  - Using IKTS high-end characterisation methods
- **Advantage:**
  - Tight link between powder shaping, characterisation and electrochemistry



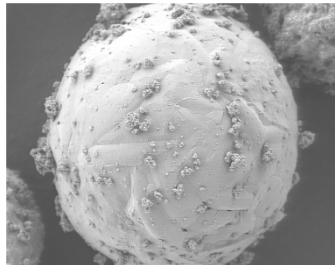
Donut shaped



Potato shaped



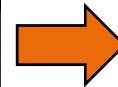
Single granule mechanics




Nano coatings



Hollow and graded



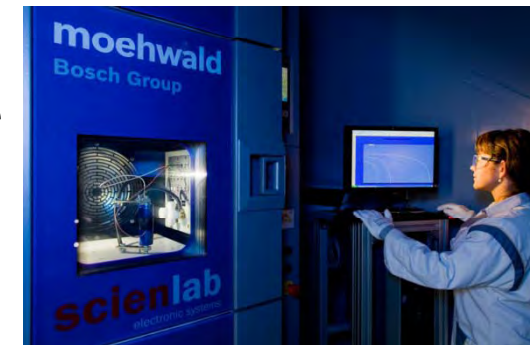
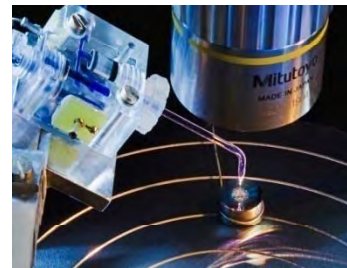
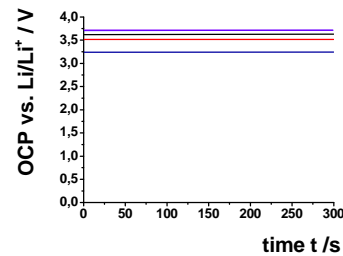
Precise granule shape measurement

	
EQPC	187.955 $\mu\text{m}$
Sphericity	0.889
Aspect ratio	0.892
Convexity	0.937
Image Number	706



# Electrochemistry at IKTS

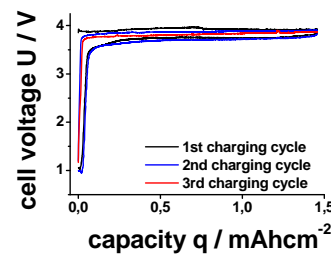
- **Objective:** electrochemical performance of cathode powders and electrodes
- **Approach:** using high-end electrochemical and battery research methods
- **IKTS scope:**
  - Electrochemical assessment of performance in short iteration loops
  - Understanding of structure-performance relationships
  - degradation mechanisms, post-mortem-analysis
- **Advantage:**
  - First hand, independent information on powder performance



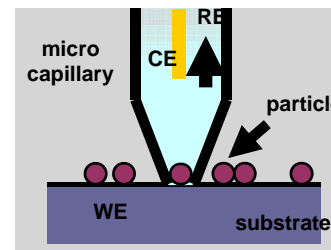
Large scale battery testers



Quick-check cell setup



Standard tests



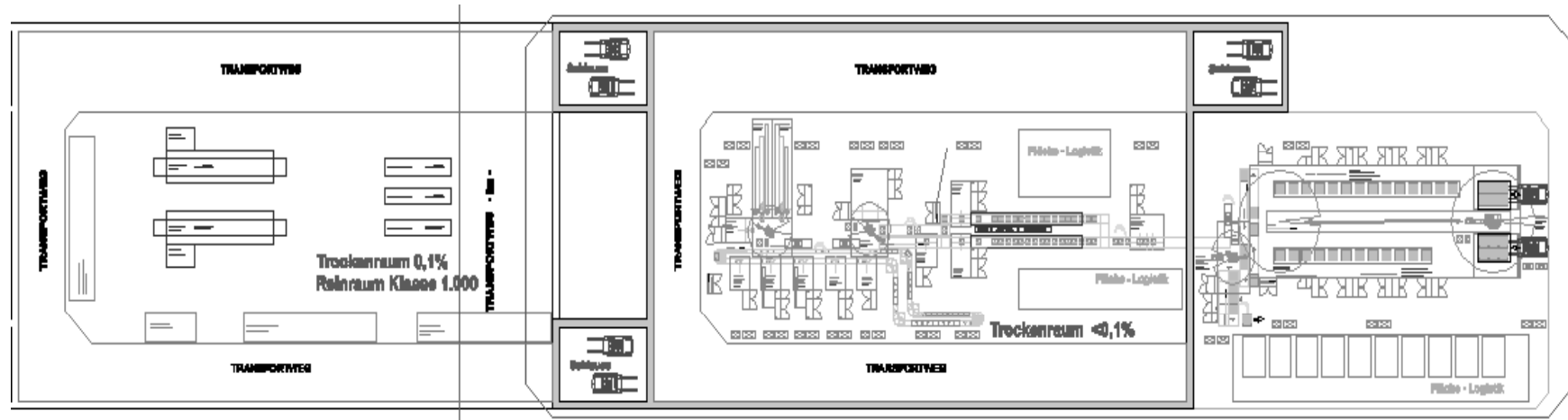
High end micro equipment



# partnerships

## Project LiFab

- Pilot scale production of Li-Ion-Batteries
- Process- and technology development



**ThyssenKrupp System Engineering**  
ThyssenKrupp Drauz Nothelfer



# Save the date !

10th CMCEE



## International Symposium on Ceramic Materials and Components for Energy and Environmental Applications

May 20-23, 2012

Dresden, Germany



About the conference

Topics

Important dates

Call for papers and posters

Schedule

Registration

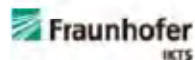
Sponsorship

Accommodation and  
Accompanying person program

Contact

Hosted by

Fraunhofer Institute for  
Ceramic Technologies and  
Systems IKTS



Deutsche Keramische  
Gesellschaft e.V.



CERAMITEC 2012 fair



### Welcome to the 10th CMCEE

With your participation we look forward once again to discussing the most important questions in the field of 'ceramic components and materials for energy and environmental technology', to gaining new knowledge and to identifying future trends in advanced ceramics science and technology.

We cordially invite you to visit Dresden. Besides its landscape beauty, Dresden currently is one of the most important hot spots of research in Germany and Europe with an enormous density of research institutes and scientists. Dresden offers a very pleasant environment for a successful symposium in 2012.

Right after the symposium you also will have the opportunity to visit the CERAMITEC 2012 fair in Munich. We are proud that we were able to win GERAMITEC, one of the most important exhibition fairs on technical ceramics, as co organizer of CMCEE allowing us to offer you a combined program in Dresden in Munich. With a special symposium package we offer organized transfer to Munich, one of the most beautiful cities of Germany.

We look forward to seeing you in Dresden and Munich.

The organizing committee of the 10th CMCEE:



Chair  
Prof. Dr. Alexander Michaelis

Institute Director  
Fraunhofer Institute for Ceramic  
Technologies and Systems  
IKTS  
Dresden, Germany



Co-chair  
Dr. Mrityunjay Singh

Chief Scientist  
Ohio Aerospace Institute,  
NASA Glenn Research Center  
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Co-chair  
Prof. Dr. Tatsuki Ohji

Prime Senior Research Scientist  
National Institute of Advanced  
Industrial Science and  
Technology (AIST)  
Nagoya, Japan



May 23-24, 2012

Munich, Germany