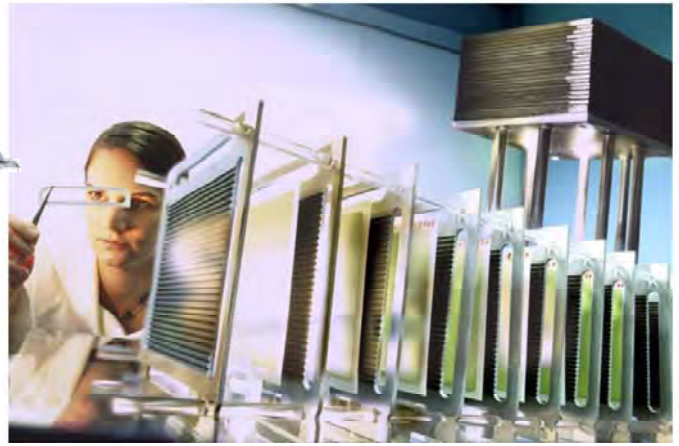
From R&D to products: Innovation with Fraunhofer

Prof. Dr. Alexander Michaelis

Energy and environmental technology at IKTS.

Membranes

PV / Batteries



Fuel Cells

Fraunhofer IKTS

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

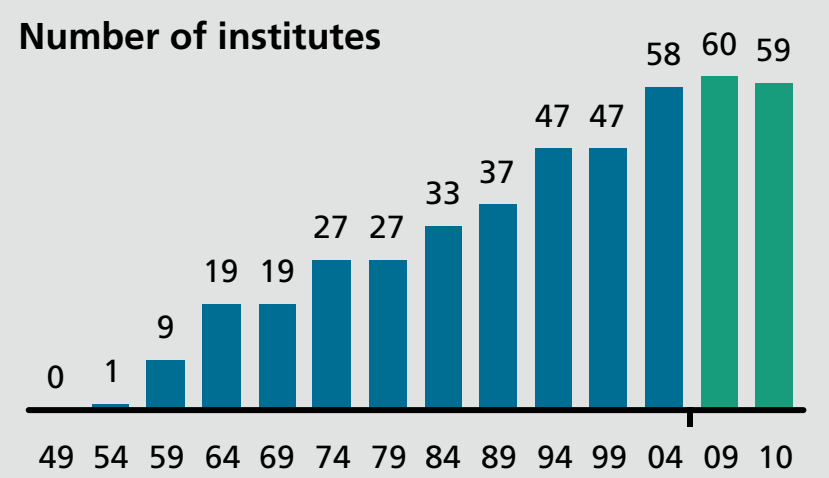
1,7 Bill. € Budget

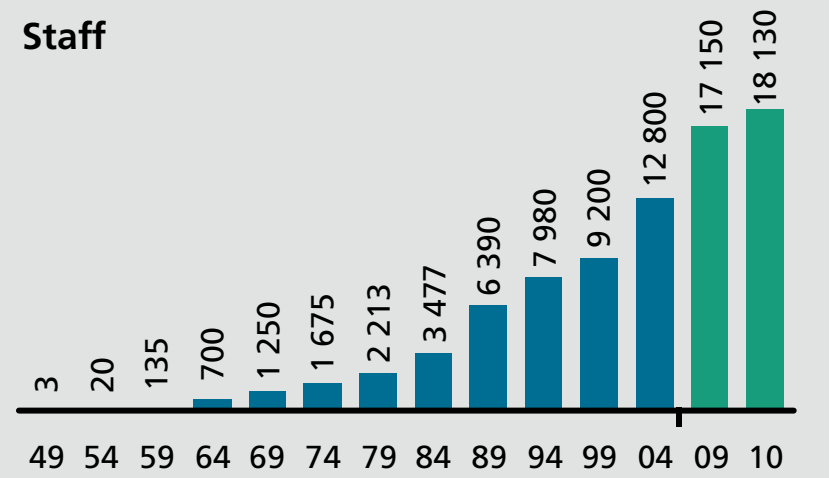
Joseph von Fraunhofer
(1787-1826)

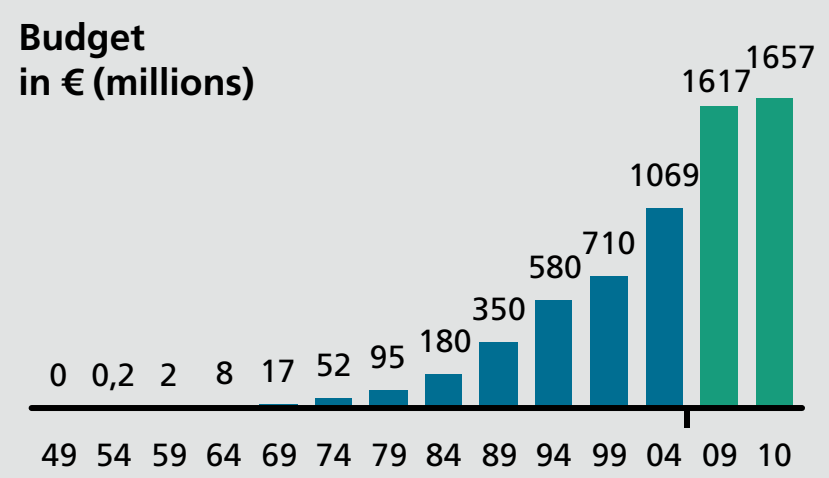
The Fraunhofer-Gesellschaft , Headquarter Munich

Discovery of the “Fraunhofer lines” in the solar spectrum	Researcher	Research and development on behalf of industry and state
New methods for processing lenses	Inventor	mp3 music format, white LED, high-resolution thermal camera
Director and partner in a glassworks	Entrepreneur	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

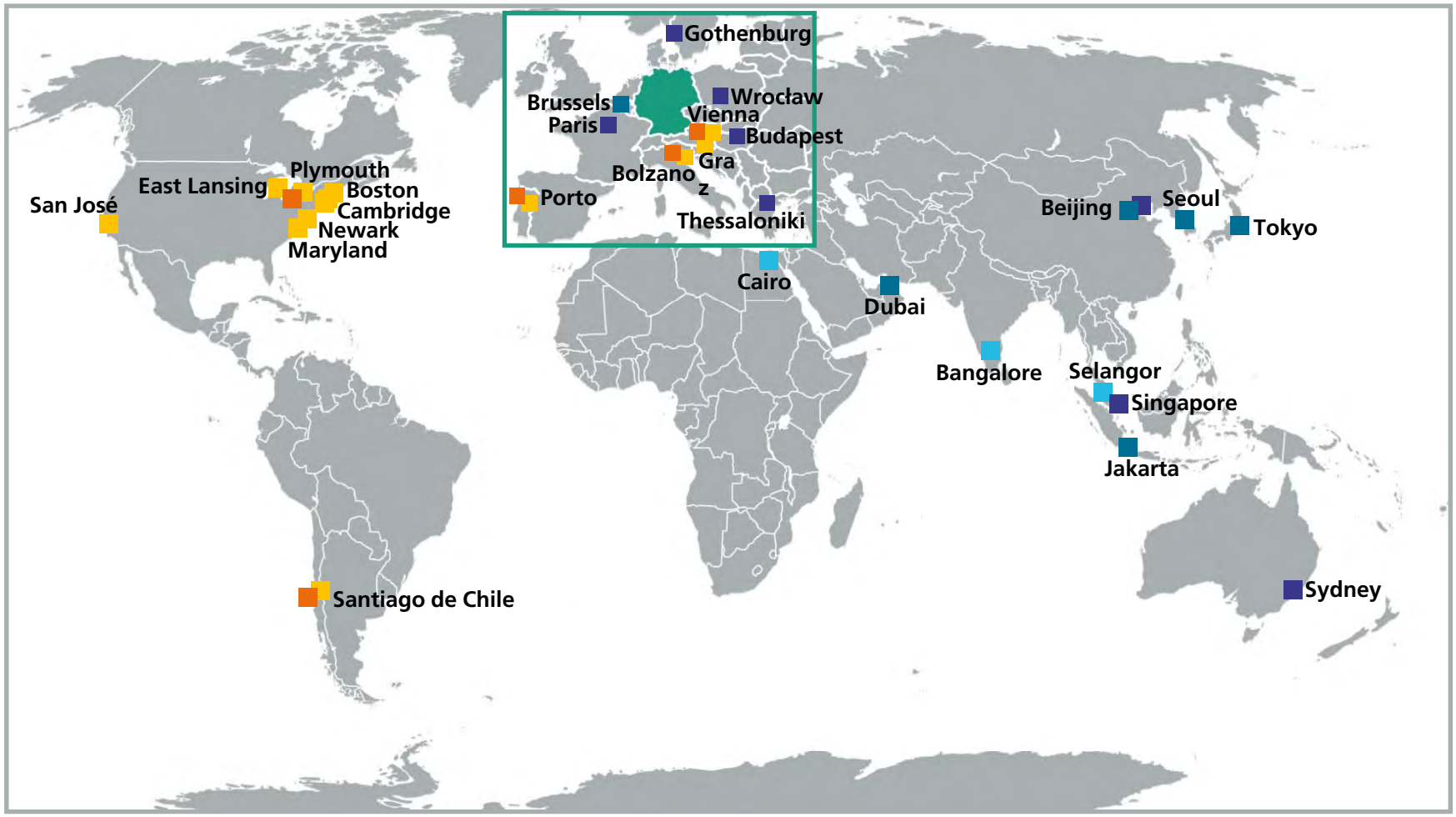






Fraunhofer IKTS

Fraunhofer worldwide

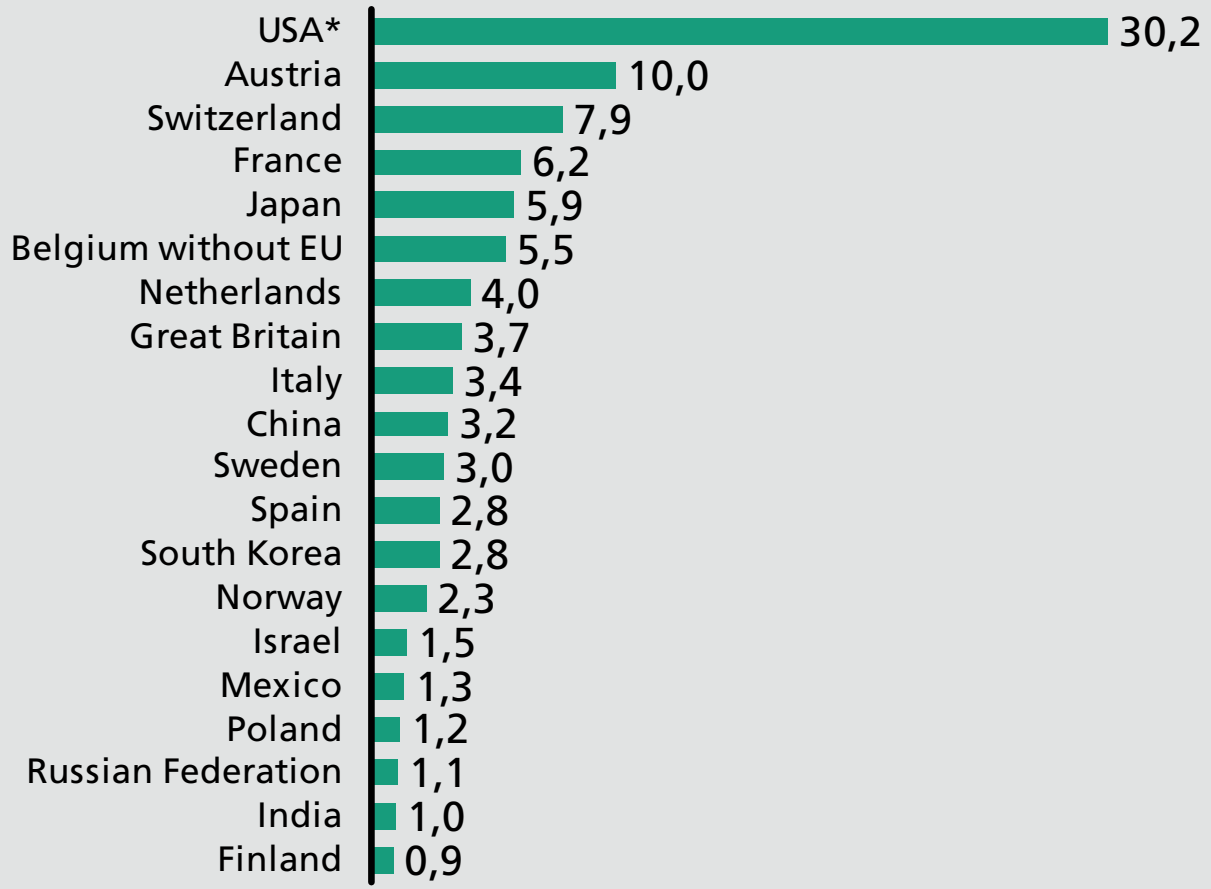


Subsidiary
Center
Project Center / Strategic Cooperation
Representative Office
Senior Advisor

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

International Revenues 2010 by Countries – Top 20

(without EU-Commission) in million €



*USA: of which €19.6 million Fh-USA
Österreich: of which €1.2 million Fh-Austria

Fraunhofer Institute of Ceramic Technologies and Systems, IKTS

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

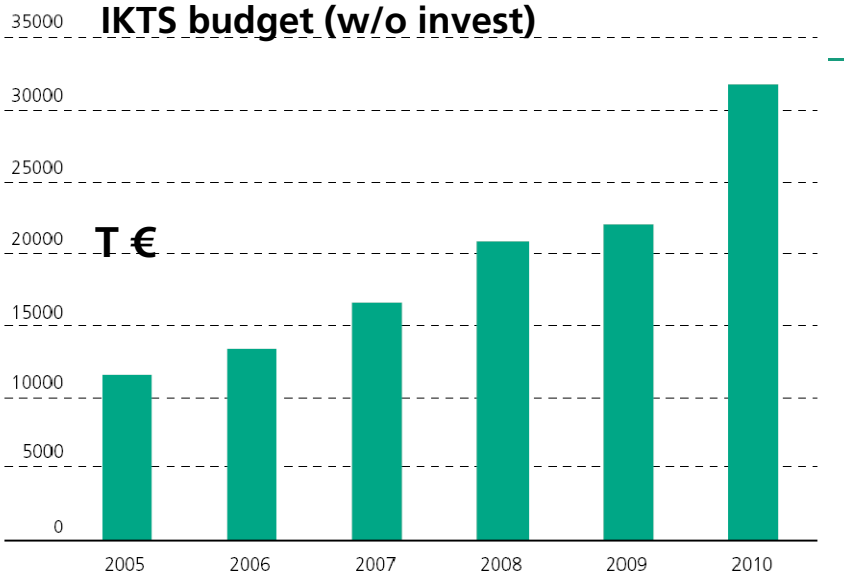
Sites Dresden and Hermsdorf

Staff: 420

Budget: 32 Mio € w/o invest

ca 80 % revenue from contract research

(50 % directly from industry)



Fraunhofer IKTS

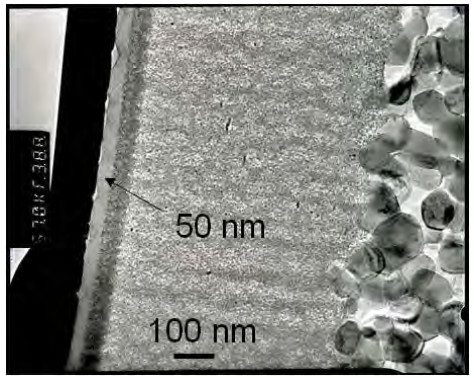
Environmental Engineering and Bioenergy at IKTS

1. CO_2-reduction in combustion plants / CCS gas filtration (O_2-production)
2. Water technology (waste water, potable water)
3. Bioenergy (Biogas, Bioethanol, Biobuthanol, Biodiesel)
4. Diesel particle filter
5. Catalysis and membrane reactors

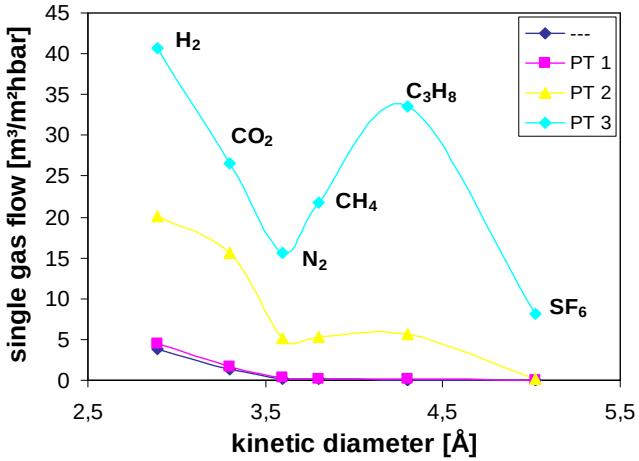
Examples for membrane-materials used at IKTS

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

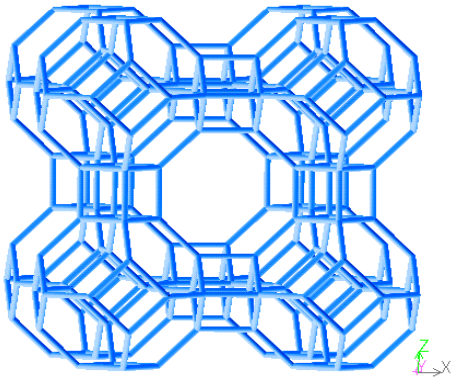


Separation performance of carbon membranes

IKTS develops membranes and catalysts, produces and tests components at appication conditions

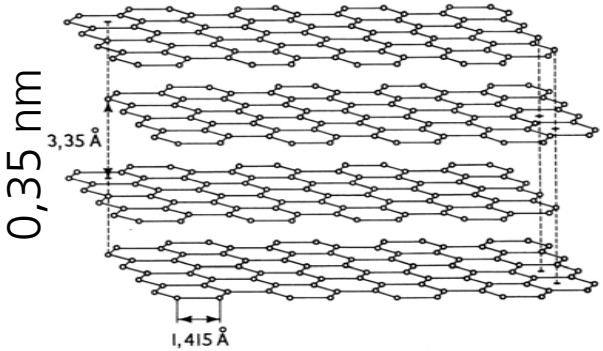
Formation of structural pores < 1 nm

Crystallographic cages/channels

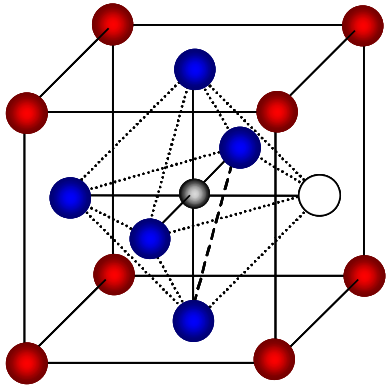


0,4 nm

Lattice plane distances



Crystallographic defects (vacancies)



Formation of structural pores < 1 nm

Crystallographic cages/channels

GFT Membrane Systems GmbH

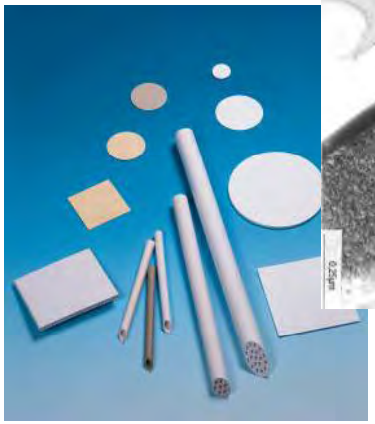
Lattice plane distances

DBI GUT Gas- und Umwelttechnik GmbH

Crystallographic defects (vacancies)

SVT

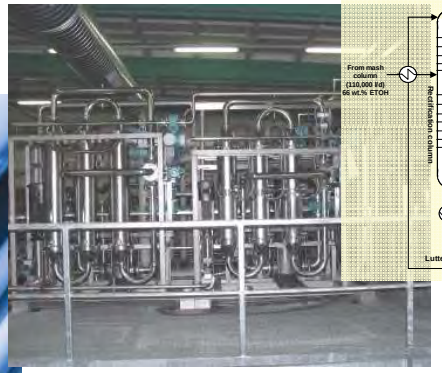
From materials up to the systems / products



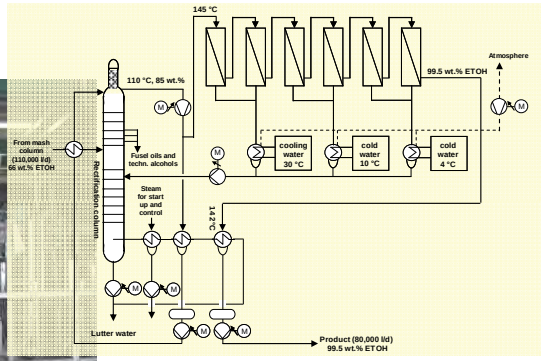
support

membrane

module



system / product



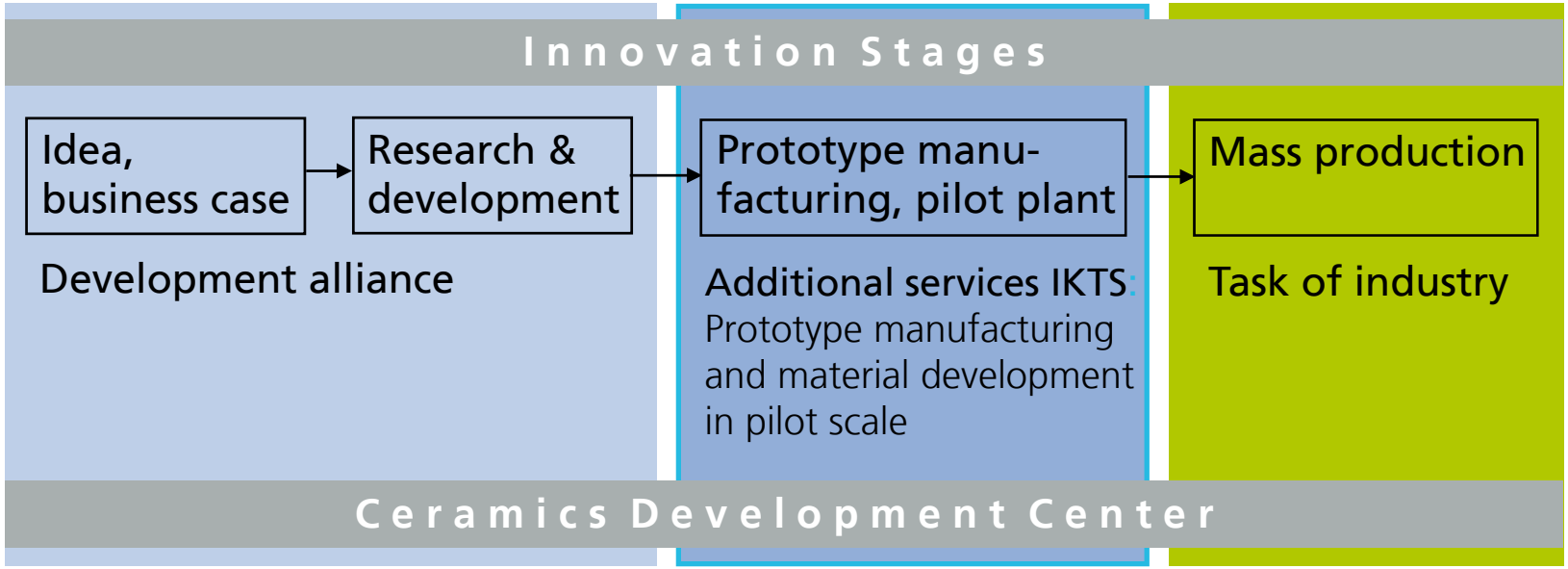
process

Profile of the Fraunhofer IKTS

Range of Services

Realization of R&D projects

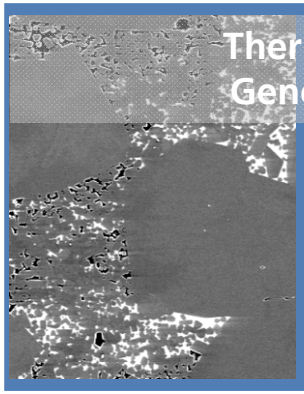
Transfer to pilot scale



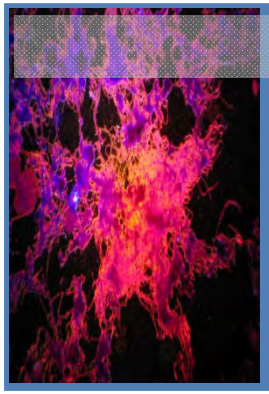
Energy R&D at IKTS: Highlights

eneramic® Energy with ceramics

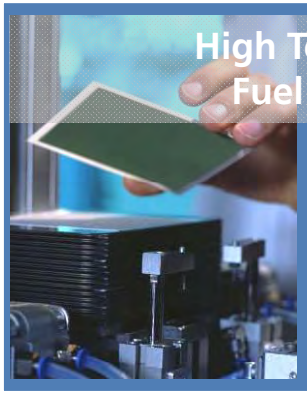
Thermoelectrical Generators, TEG



Bioenergy

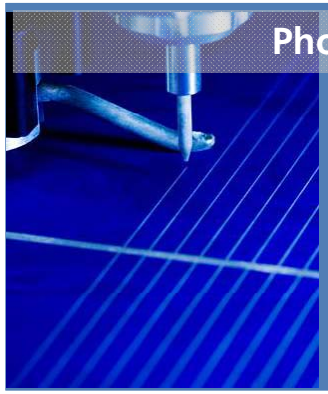


High Temperature-Fuel Cells (SOFC)

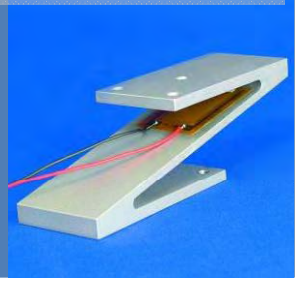


Vaillant

Photovoltaics



Energy Harvesting (piezo-ceramics)

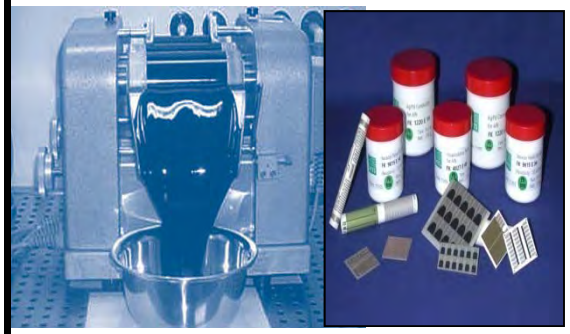


Low Temperature-Fuel Cells(Micro-PEM)

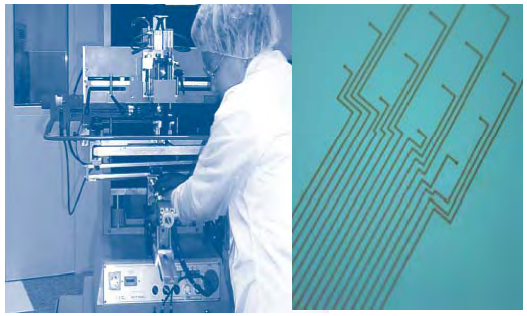
Fraunhofer IKTS

technology plattform functional ceramics / thick film (slurry) deposition

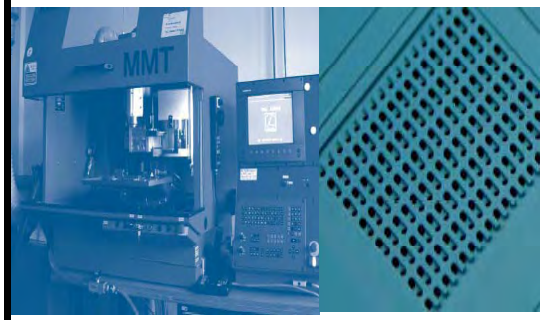
1 pastes / slurry



2 tape casting, printing

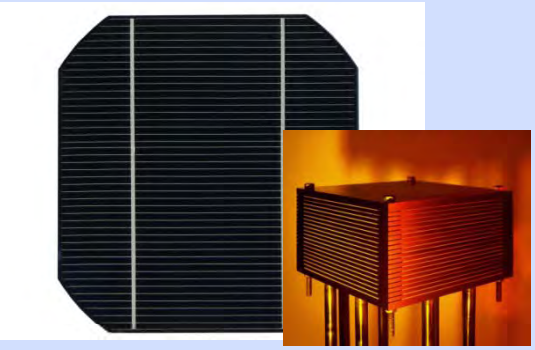


3 stacking

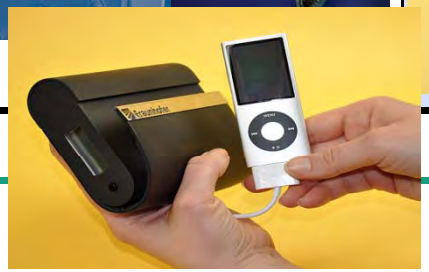


4 lamination, co-fire

Micro- and Energy systems

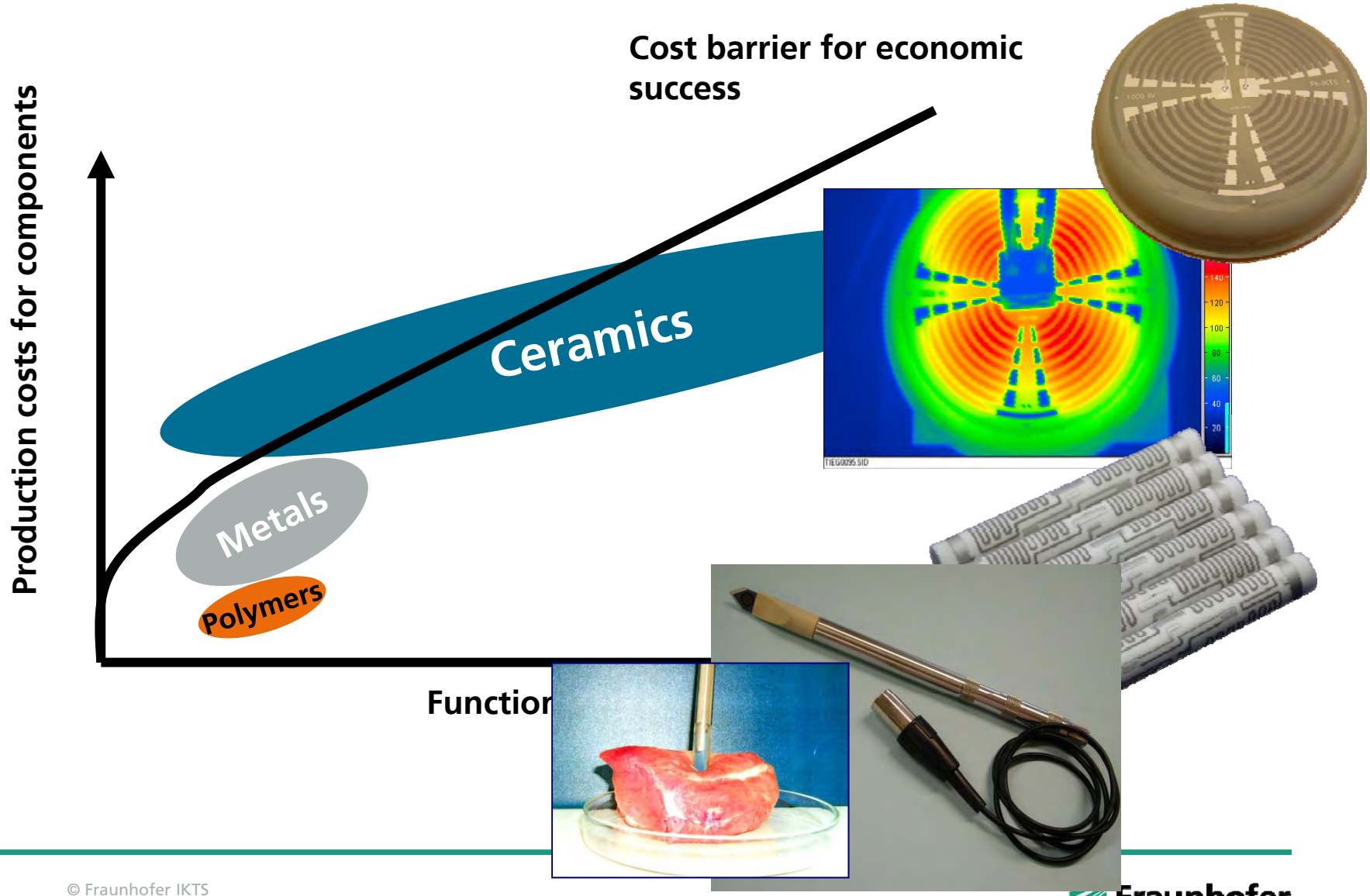


Micro-Fuel Cells

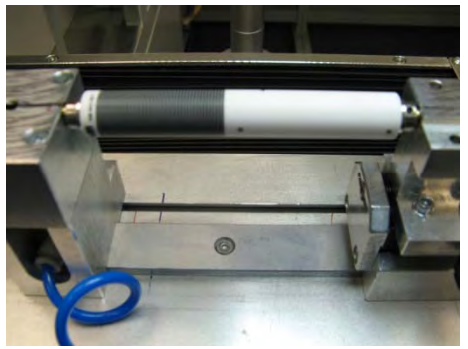


Fraunhofer IKTS

Thick film technology for function integration



Screen Printing at IKTS



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

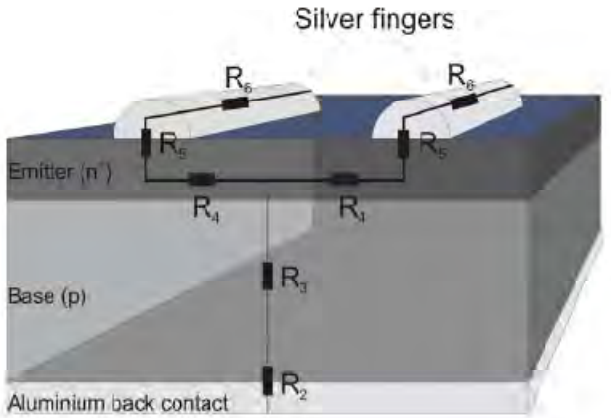
Photovoltaics with Focus on BEOL (Contacting)

Materials for Thick Film Contacting / Issues

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

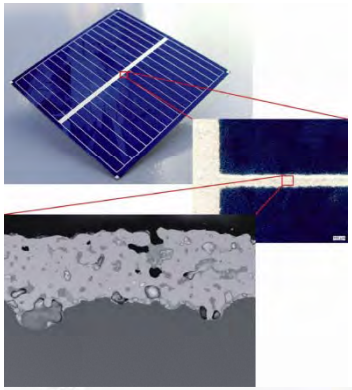
Production Processes

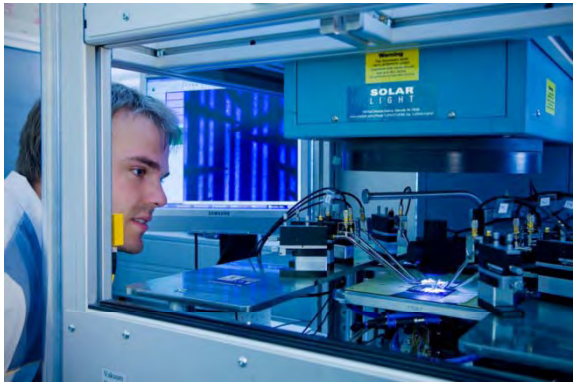
1. Higher throughput
2. Non contact to improve yield
3. Automatization



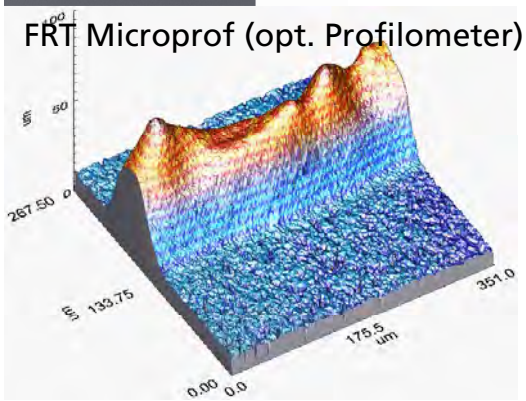
Thick Film Technology for Contacting of Solar-cells

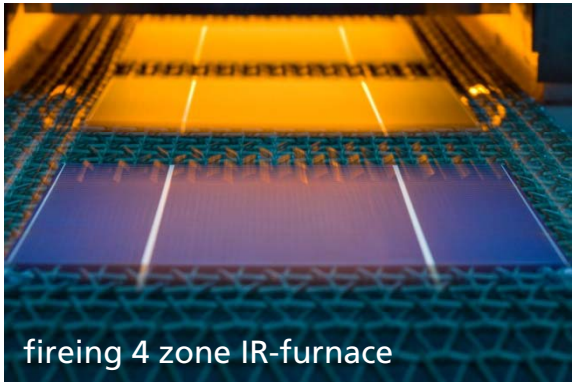
Screen printing





FRT Microprof (opt. Profilometer)





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

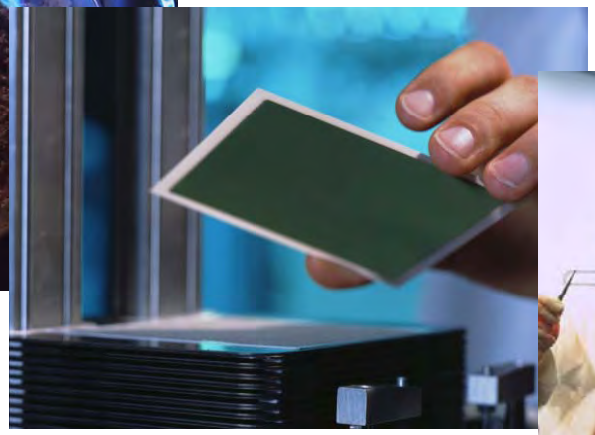
Fraunhofer IKTS

Solid Oxide Fuel Cell (SOFC) value chain

Material

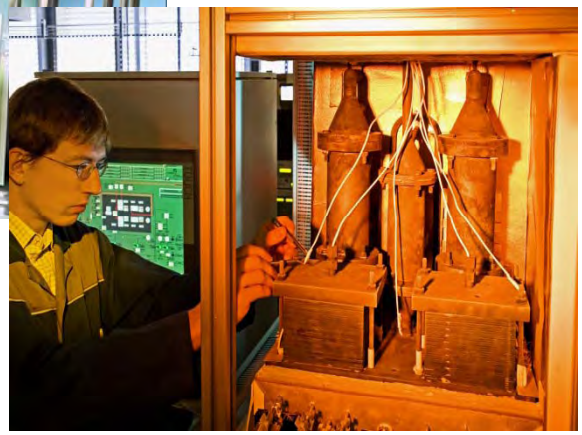
PLANSEE

MEA



Stack

System



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

Fuel cell systems at IKTS

1 W	10 W	100 W	1 kW	10 kW
Hand held		portable	stationary	

ezelleron Power to go

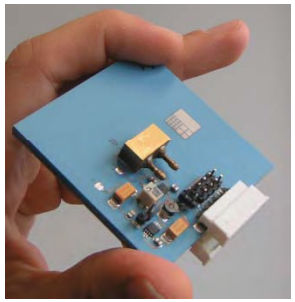
eneramic by Fraunhofer

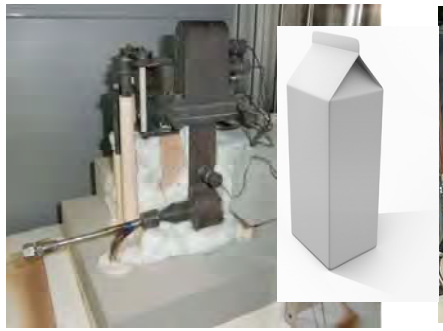
Vaillant

Hydrogen PEFC	Tubular SOFC	LPG SOFC	Natural gas SOFC	Biogas SOFC

Fuel cell systems at IKTS

1 W	10 W	100 W	1 kW	10 kW
mobile		portable	stationary	



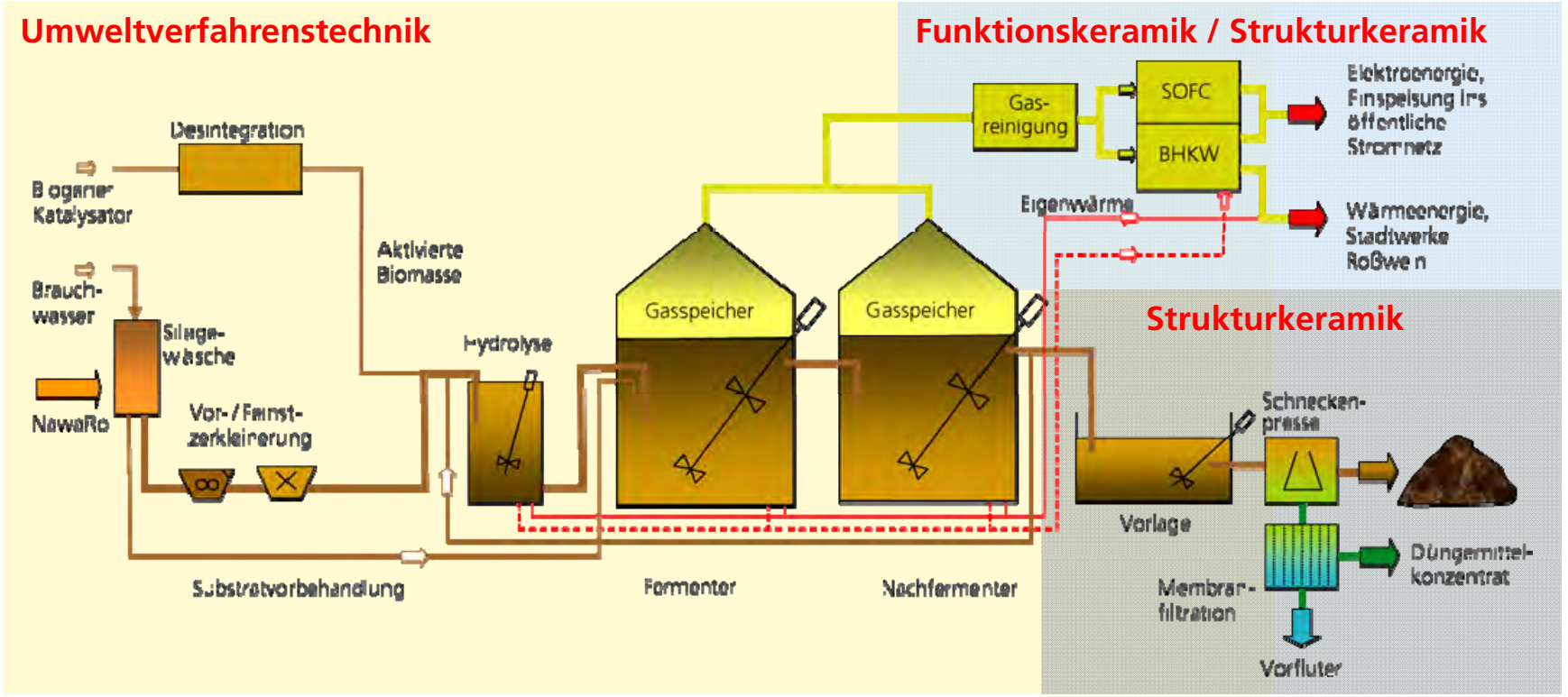


Hydrogen PEFC	Tubular SOFC	LPG SOFC	Natural gas SOFC	Biogas SOFC

Bioenergy Application Center at „Pöhl“ in Saxony

Synergy bewteen structural + functional ceramics

Energy Storage:
Redox - Flow Battery
NaS Battery



Fraunhofer IKTS

Environmental Processing Technology at Fraunhofer IKTS

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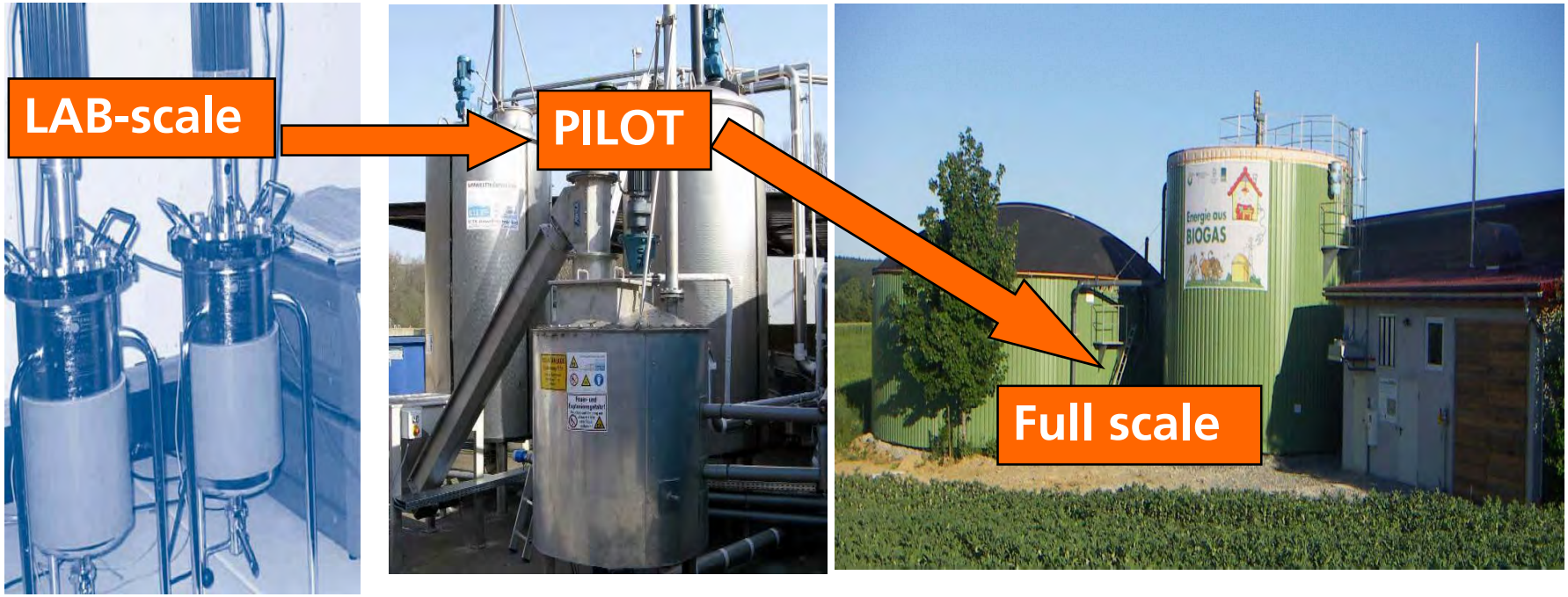
ENERGY/ENVIRONMENT/AGRICULTURE => Project „ More biogas at higher energy level –way to efficient power production“



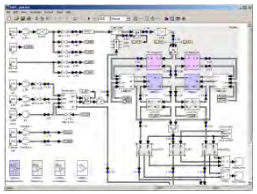
IKTS integrated technology line along complete value chain

Thick film

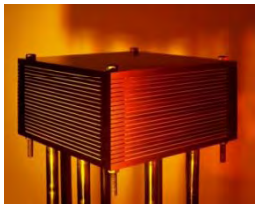
glas sealing

electrochemistry

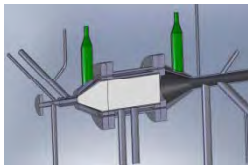
CAD + Simulation

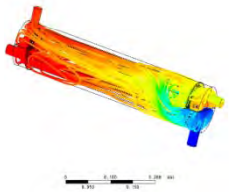


System technology



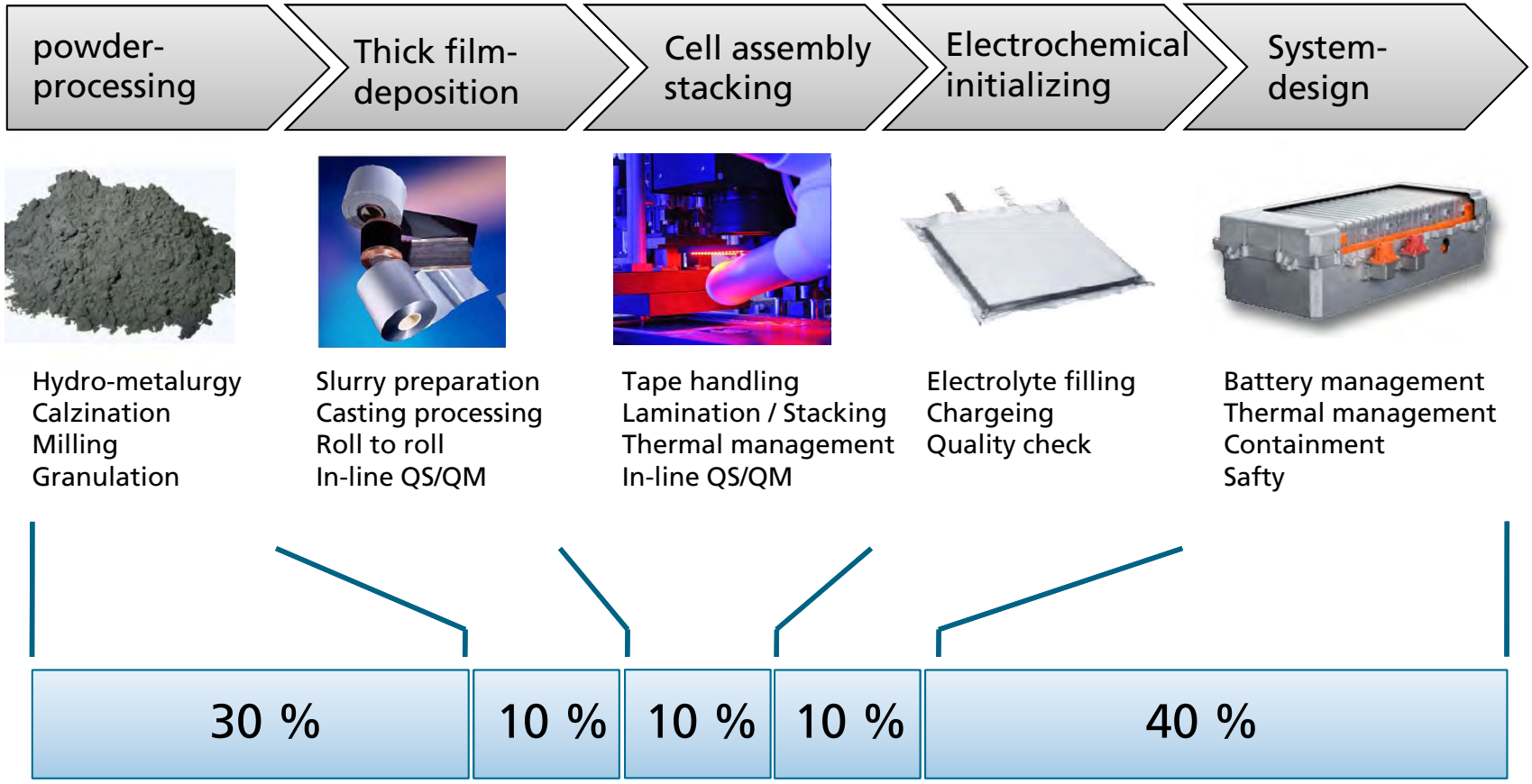
process technology





test facilities

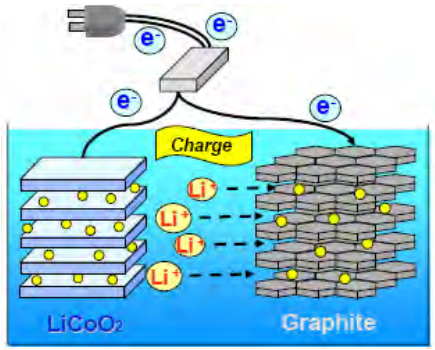
Storage technology:
Li-Ion Battery → value chain / technology line

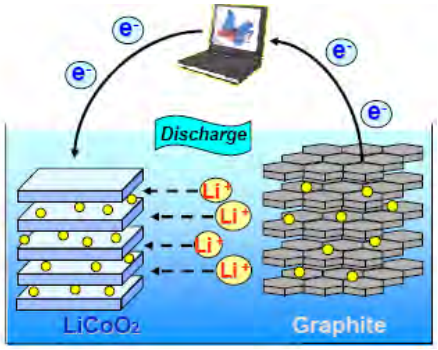


Fraunhofer IKTS

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
$LiCoO_2$ (LC)	3,9	274	150 - 160	580 - 620		
$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ (NCA)	3,8	271,5	180 - 220	680 - 830		
$LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ (NCM)	3,5	278	170	595		
$LiMn_2O_4$ (LM)	4,05	148	100 - 120	405 - 485		
$LiFePO_4$	3,4	170	150 - 160	510 - 540		

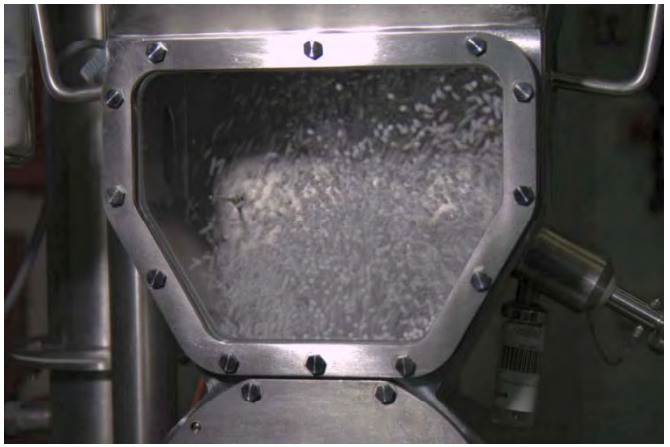
- chemical synthesis
- calzination
- milling, granulation
- electrochemistry

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 / fluidizes 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

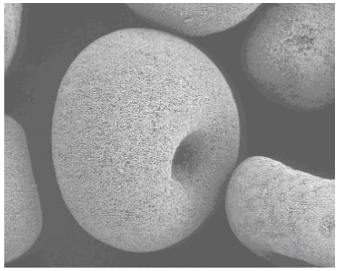
Fluid bed reactor



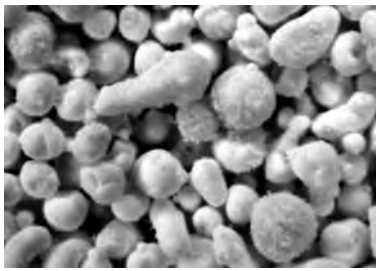
In-process control and measurement

Powder Processing – Shape control

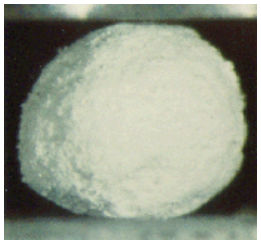
- **Objective:** generate controlled-shape powders, characterisation of powders
- **Approach:** using IKTS know-how from other powders
- **IKTS scope:**
  - Developing process windows for controlled shapes using state-of-the art machinery
  - Using IKTS high-end characterisation methods
- **Advantage:**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

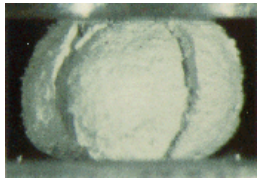


Donut shaped

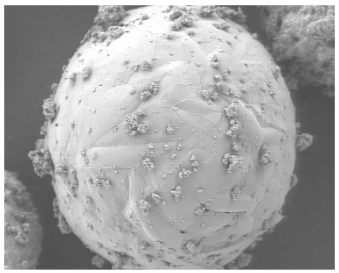


Potato shaped





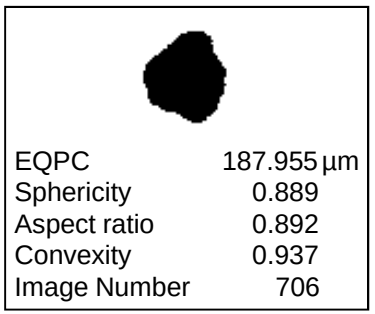
Single granule mechanics



Nano coatings

Hollow and graded

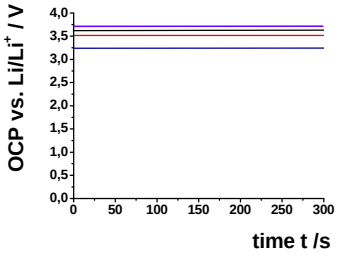
Precise granule shape measurement

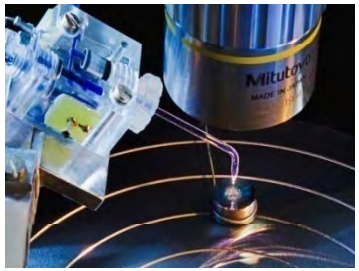


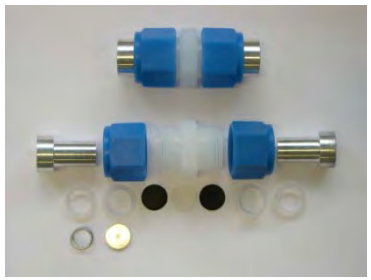
Electrochemistry at IKTS

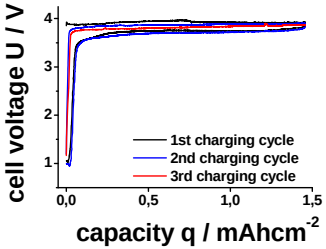
- **Objective:** electrochemical performance of cathode powders and electrodes
- **Approach:** using high-end electrochemical and battery research methods
- **IKTS scope:**
  - Electrochemical assessment of performance in short iteration loops
  - Understanding of structure-performance relationships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

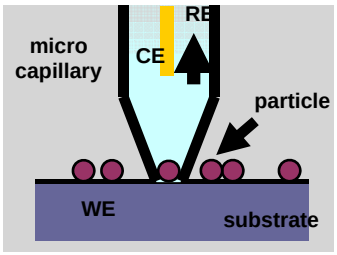
Large scale battery testers

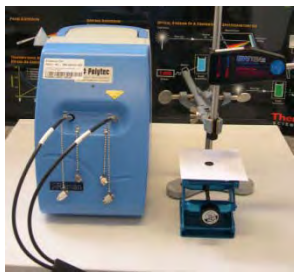










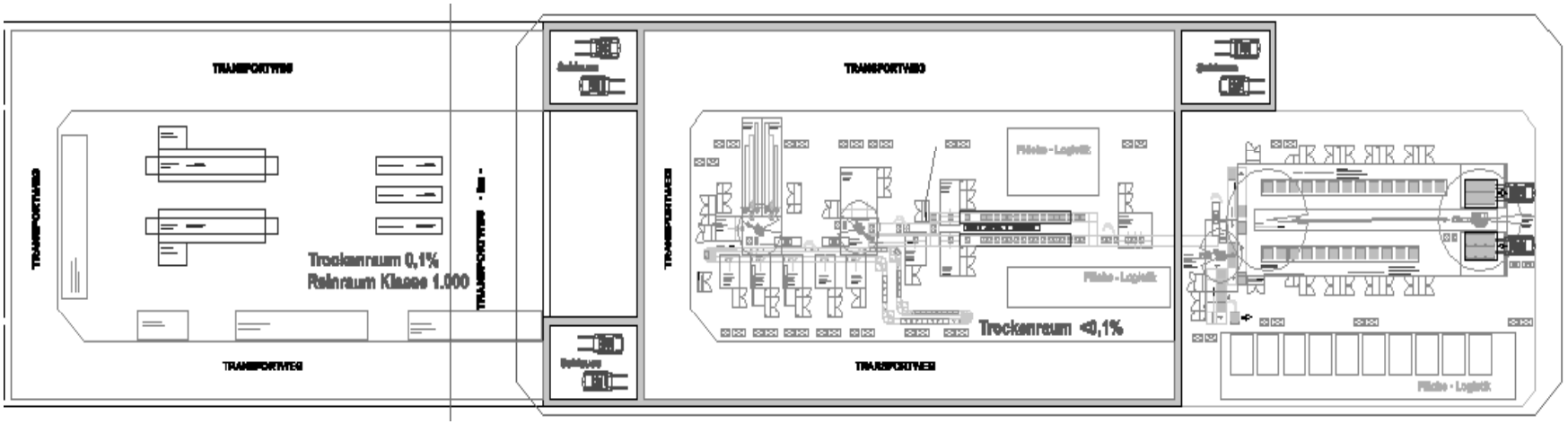


Quick-check cell setup | Standard tests | High end micro equipment

partnerships

Project LiFab

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



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Save the date !

10th CMCEE

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

May 20-23, 2012
Dresden, Germany

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Hosted by

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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 CERAMITEC, 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.

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