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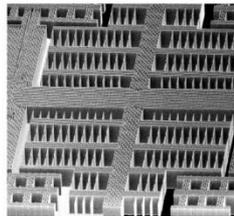
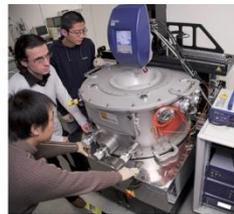
# FRAUNHOFER ENAS INSTITUTES PHILOSOPHY AND INTERNATIONAL COOPERATION

**Dr. Mario Baum**

Business Unit Smart Health

Department System Packaging, Integration Technologies

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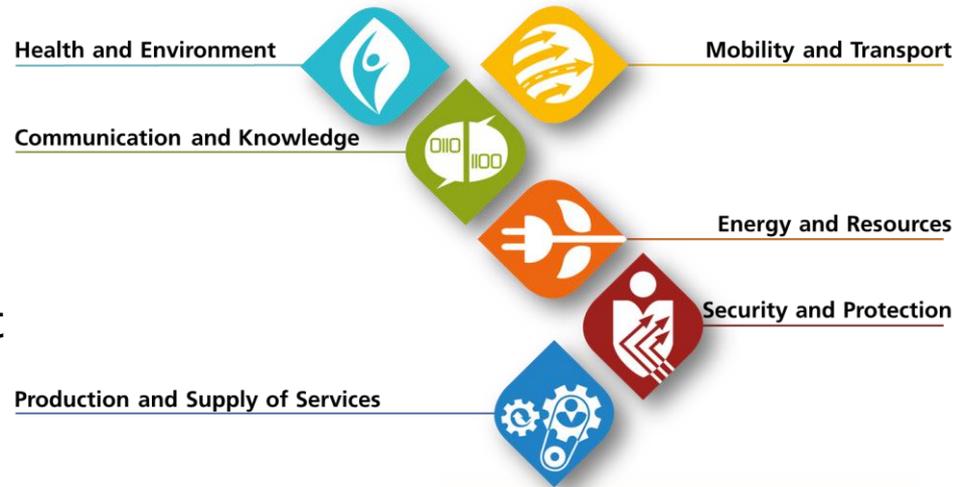


# Overview

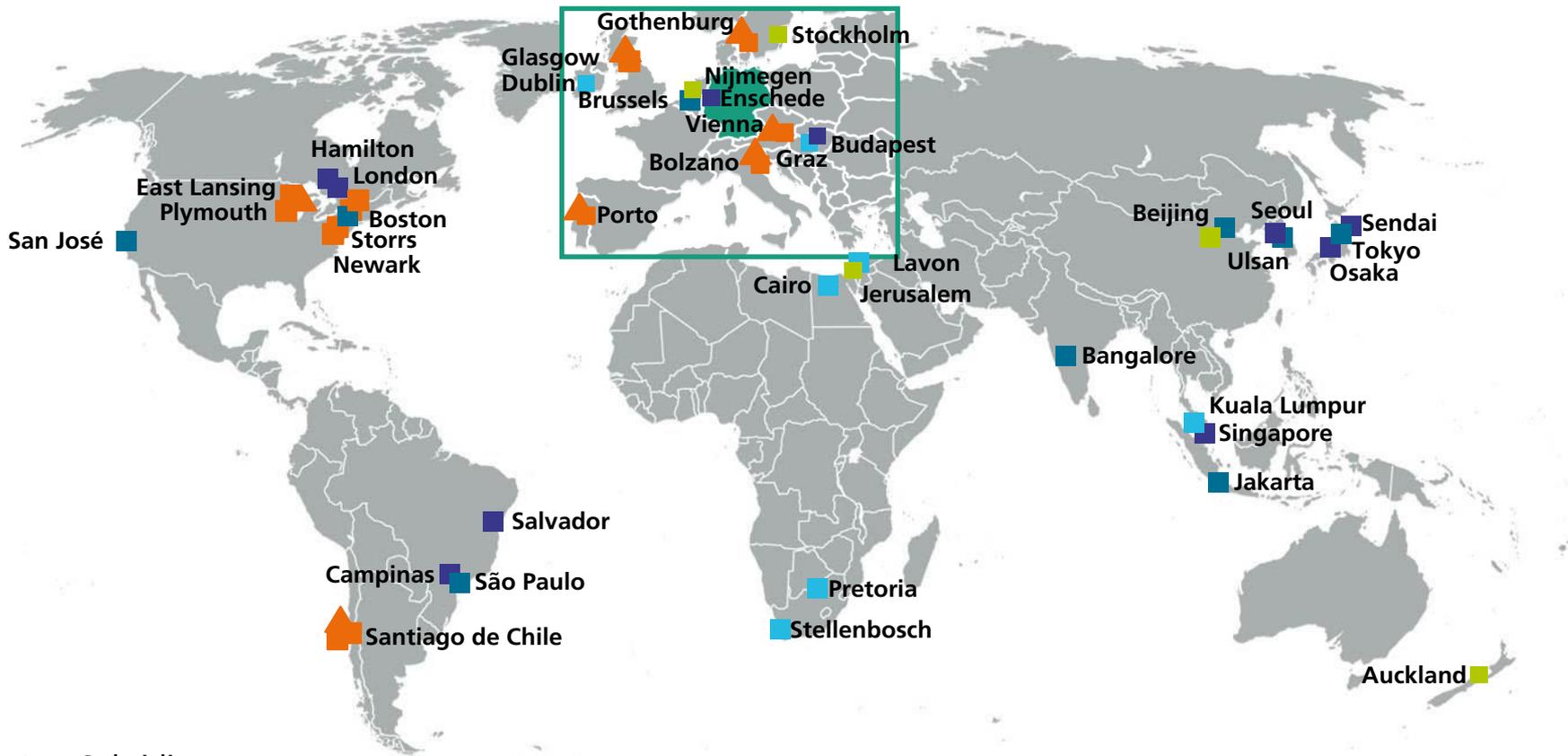
1. Fraunhofer Gesellschaft
2. Fraunhofer ENAS, one of the institutes
3. Cooperation with Tohoku University
4. Research examples
5. Contact

# Fraunhofer-Gesellschaft, the largest organization for applied research in Europe

- 72 institutes and research units
- >25,000 staff
- €2.3 billion annual research budget totaling. Of this sum, more than €1.9 billion is generated through contract research
- Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects
- Roughly one third is contributed by the German federal and *Länder* governments in the form of base funding



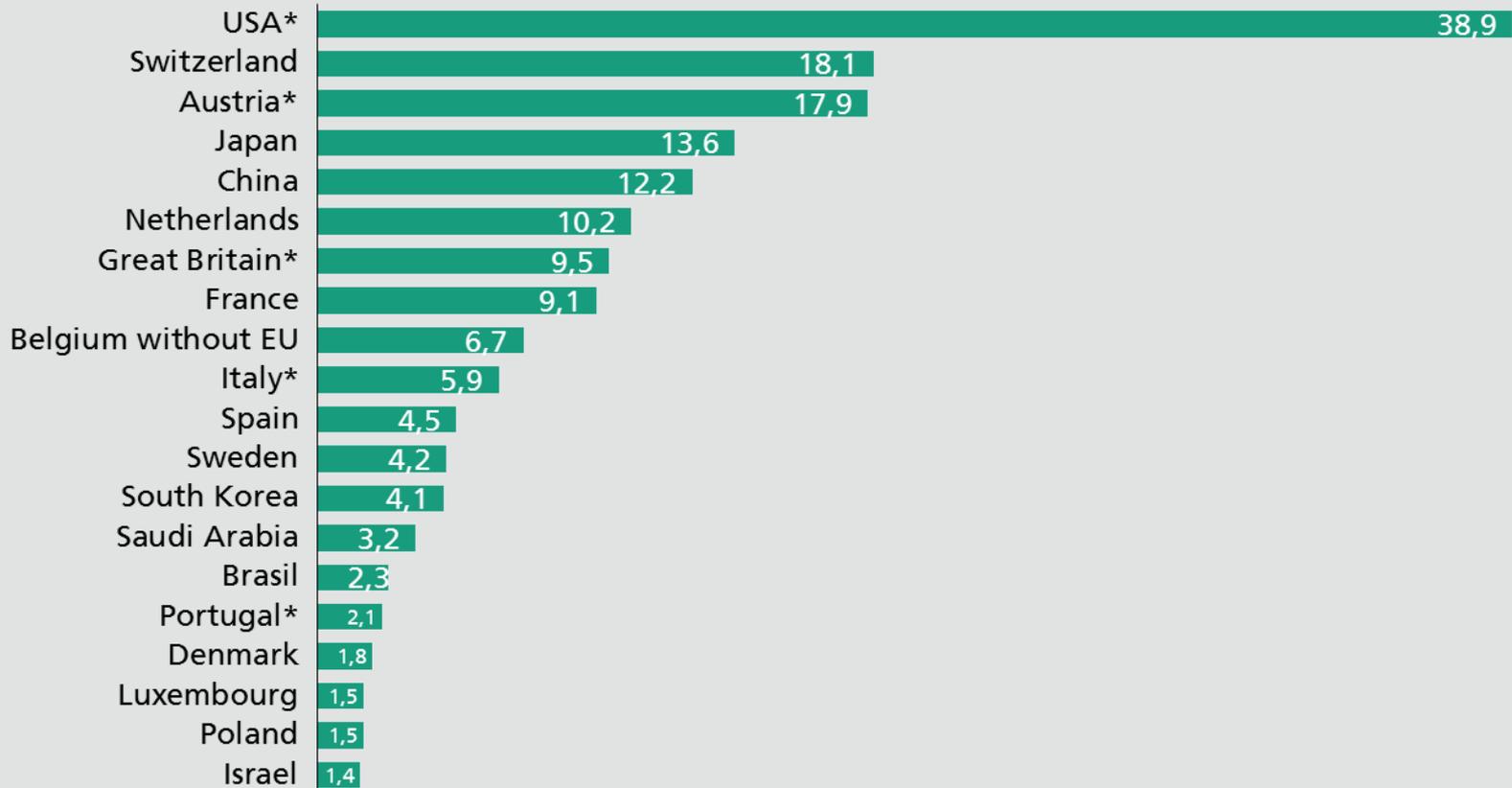
# Fraunhofer Worldwide



- ▲ Subsidiary
- Center
- Project Center
- ICON / Strategic cooperation
- Representative / Marketing Office
- Senior Advisor

# International revenues 2015 by countries – Top 20

(without EU-Commission) in € million, preliminary



\* of which: Fh-USA: 19,4 Mio €, Fh-Austria: 2,4 Mio €, Fh-UK: 2,0 Mio €, Fh-Portugal: 1,6 Mio €, Fh-Italia: 0,5 Mio €

# Our Guiding Principles

## Mission

**Applied research** is the foundation of our organization. We partner with companies to transform original ideas into innovations that benefit society and strengthen the global economy.

Our employees shape the future – in ambitious positions at Fraunhofer or in other areas of science and business.

Fraunhofer therefore places great importance on their professional and personal development.



## Vision

Fraunhofer is the international leader of applied research.

As an innovation driver, we lead strategic initiatives to master future challenges and thus achieve technological breakthroughs.

# Our Guiding Principles

## Principles

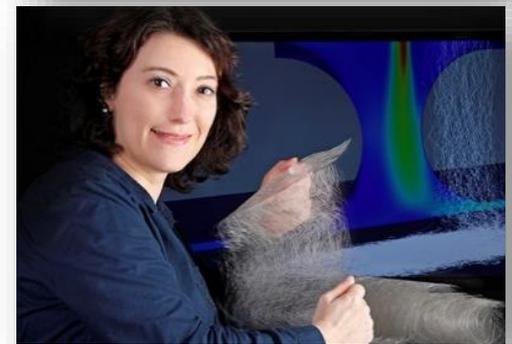
- Through our research we contribute to the sustainable development of an ecologically sound environment, and an economically successful and socially balanced world. We are strongly committed to this responsibility.
- We promote a well-balanced combination of excellent research and application-oriented development. This unique characteristic motivates us and achieves added value for our partners.
- We understand our clients and know their challenges of tomorrow. Together we develop integrated solutions for their long-term success.



# Our Guiding Principles

## Principles

- We cooperate with the world's best in science and business. This strengthens our own innovative capacity and that of the German and European economy.
- We emphasize the great variety and interdisciplinary cooperation of our institutes. Faithful collaboration and team work promote synergies and enhance our performance.
- Our success relies on the knowledge and enthusiasm of our employees for applied research. Fraunhofer offers its staff excellent work conditions paired with a high degree of autonomy.



# Fraunhofer ENAS



## International Offices:

Since 2001 / 2005 Sendai-Japan

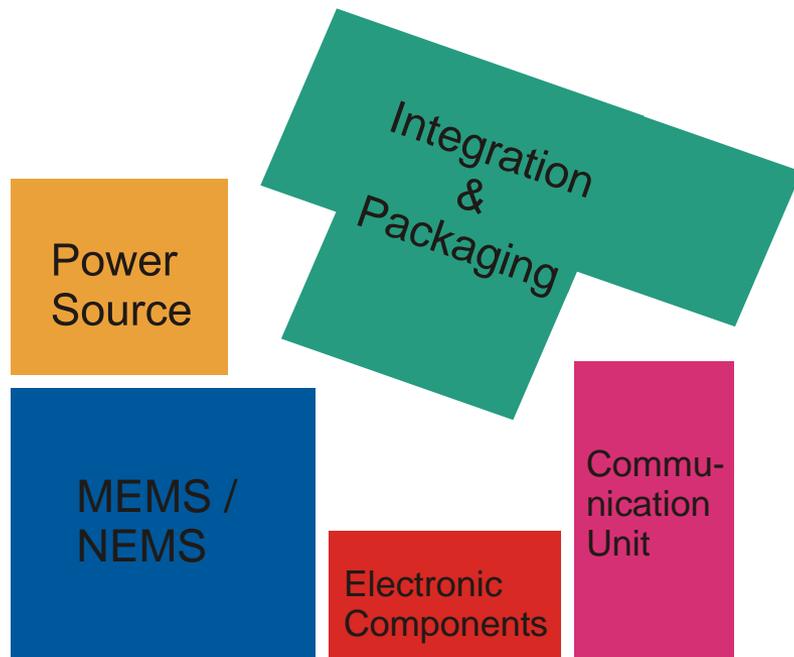
Since 2002 Shanghai-China

Since 2007 Manaus-Brazil

## Systems integration by using of micro and nano technologies

- MEMS/NEMS design
- Development of MEMS/NEMS
- MEMS/NEMS test
- System packaging/waferbonding
- Back-end of Line technologies for micro and nano electronics
- Process and equipment simulation
- Micro and nano reliability
- Printed functionalities
- Advanced system engineering

# Main Working Field - Smart Systems Integration by Fraunhofer ENAS



- Self-sufficient intelligent technical systems or subsystems with advanced functionality
- Bring together sensing, actuation and data processing, informatics / communications
- Autonomous systems
- Highly reliable, often miniaturized, networked, predictive
- Their operation being further enhanced by their ability to mutually address, identify and work in consort with each other

→ Basic components for Internet of Things

# Fraunhofer ENAS

## Applied Research



# Center for Microtechnologies

**Chair Microsystems  
and Precision  
Engineering**  
Prof. Mehner

**Chair  
Microtechnology**  
Prof. Otto

**Chair Power Electronics  
and Electromagnetic  
Compatibility**  
Prof. Lutz

**Chair Circuit and  
System Design**  
Prof. Heinkel

**Chair Materials  
and Reliability of  
Microtechnical Systems**  
Prof. Wunderle

**Chair Electronic  
Devices of Micro and  
Nano Technique**  
Prof. Horstmann

Director: Prof. Otto  
Deputy Director: Prof. Hiller

**Chair Electrical  
Measurement and  
Sensor Technology**  
Prof. Kanoun

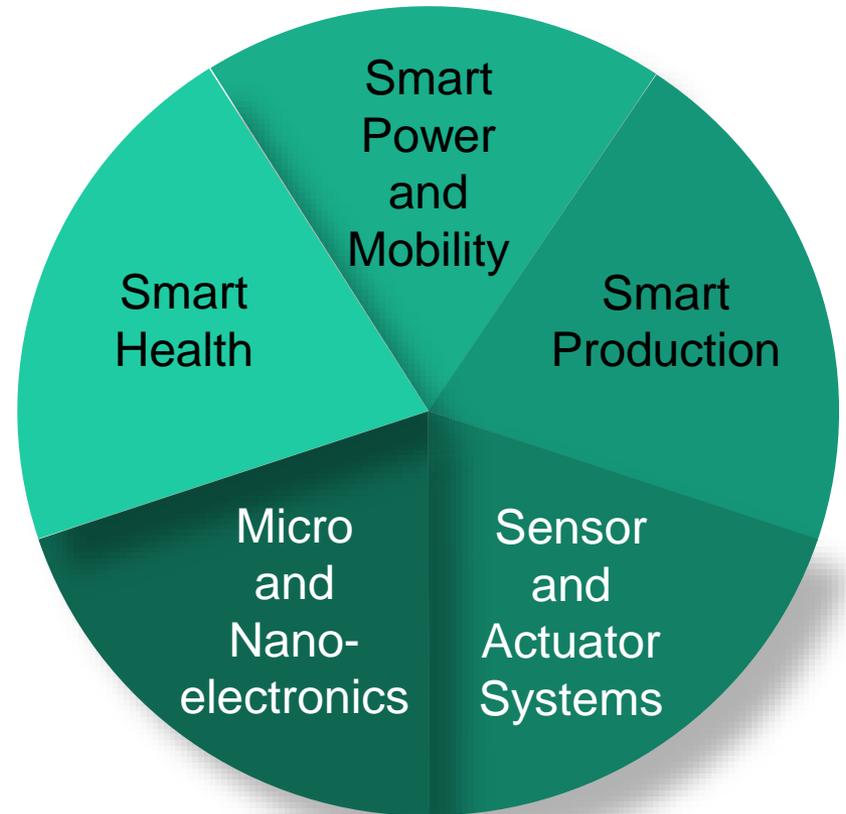
# Business Units

## ■ Application-oriented business units

- Technologies and Systems for Smart Power and Mobility
- Technologies and Systems for Smart Health
- Technologies and Systems for Smart Production

## ■ Technology-oriented business units

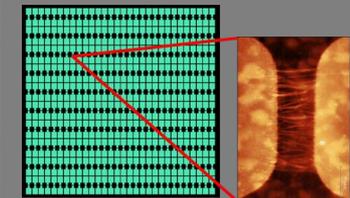
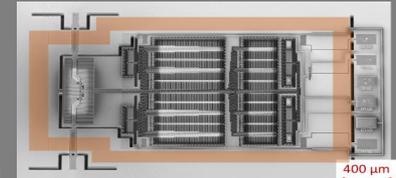
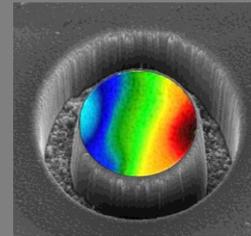
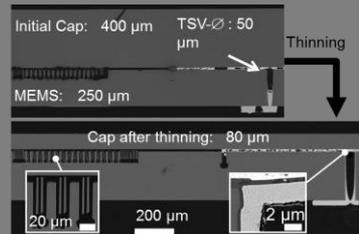
- Micro and Nanoelectronics
- Sensor and Actuator Systems



# Technology-oriented business units

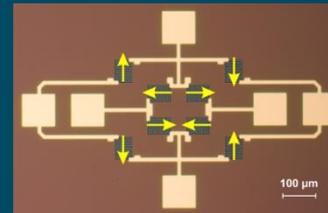
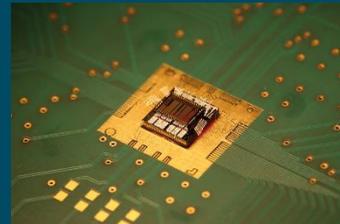
## Micro and Nanoelectronics

- Back-End of Line and Interconnects
- Modeling and Simulation
- Beyond CMOS and RF Devices
- Integration and Packaging
- Characterization and Reliability



## Sensor and Actuator Systems

- Inertial Sensors
- Pressure and Power Transducer
- Material and Structure Sensors
- Optical Systems/MOEMS
- Electromagnetic Sensors



# Application-oriented business units

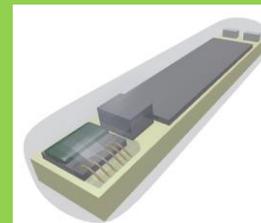
## Technologies and systems for Smart Power and Mobility

- Network Monitoring
- Reduction of Power Consumption
- Power Supply
- Electromobility



## Technologies and Systems for Smart Health

- Microfluidic and Spectroscopic Analysis
- Medical Devices
- Implants



## Technologies and Systems for Smart Production

- Smart Digital Production
- Sensor Systems for Process and Condition Monitoring



# Cooperation with Tohoku University

- Fraunhofer Project Center

established in 2007 under the program

**World Premier International Research Center Initiative WPI, MEXT**

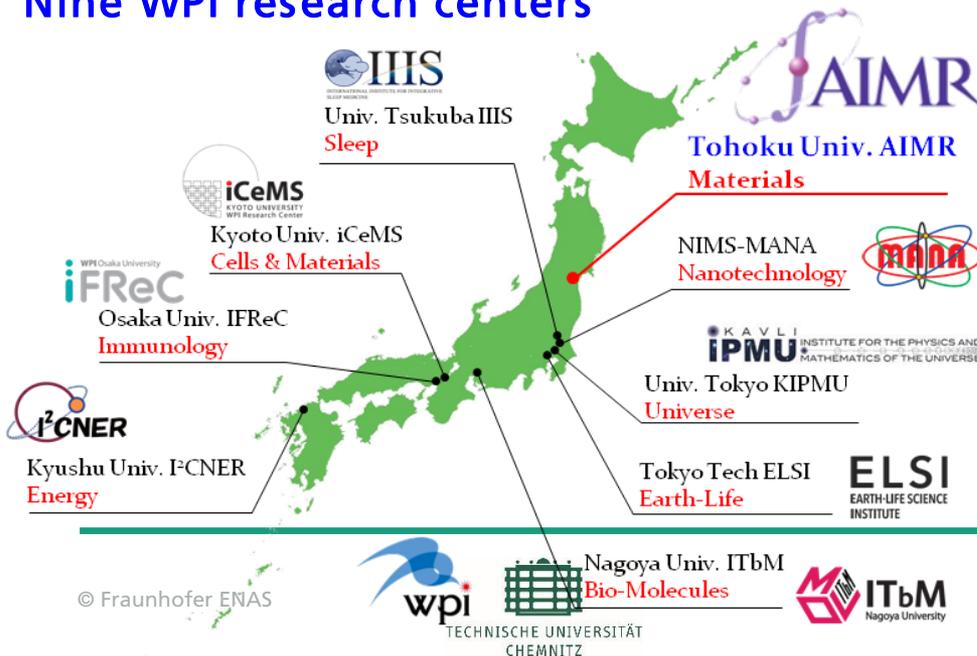
**World Top Level International Research Center**

**Creating New Materials Science**

~1.3 billion JPY / yr support

- Integrate Materials Science, Physics, Chemistry, Engineering, Mathematics to create a New Materials Science and contribute to Society
- Official language is English (half of researchers from overseas)
- Very high research standard and outstanding research environment

## Nine WPI research centers





TOHOKU  
UNIVERSITY

# TOHOKU UNIVERSITY Sendai, Japan

Following University of Tokyo (1877) and Kyoto University (1897), Tohoku University was founded in 1907 as the third University in Japan.

Five campuses in Sendai, 10 schools, 15 graduate schools and 5 affiliated research centers

More than 18,000 students and 5,000 staffs

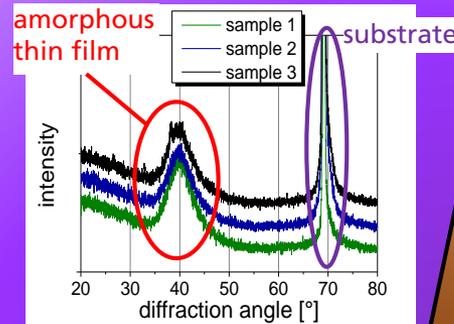
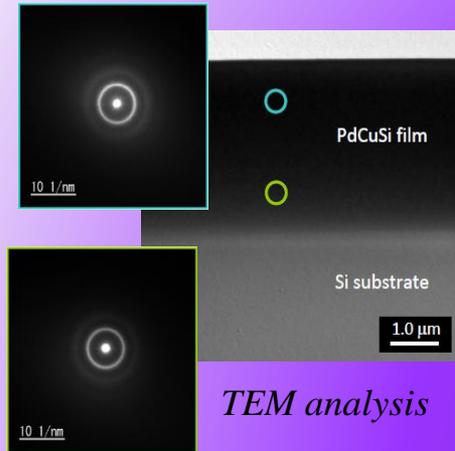
Since its inception, the university has embraced its "research -first" and "open-door" policies and puts strong emphasis on education led by prestigious scholars and researchers.



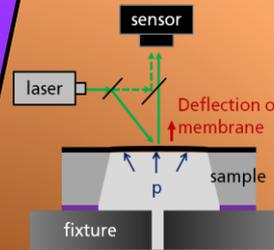
# Research Example of Fraunhofer Project Center at Tohoku University

Characterization of mechanical and structural properties of micro structures made from amorphous metal

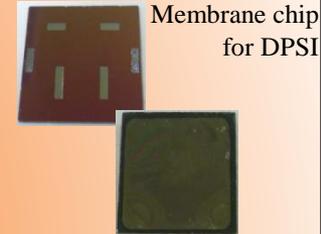
Analysis of crystalline structure



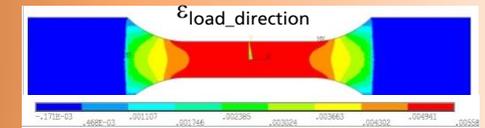
Characterization of mechanical properties



Determination of Young's Modulus by Digital Speckle Pattern Interferometry (DSPI)



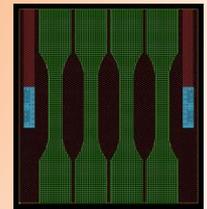
Material properties of amorphous thin films for MEMS application



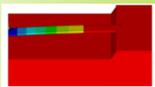
Results of FE-analysis for mask design of tensile

test samples

Sample layout



Layer stress

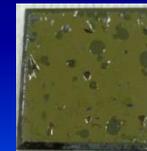


Evaluation of layer properties

Adhesion to different materials



Destruction of layer during wet etching



Verification of process compatibility

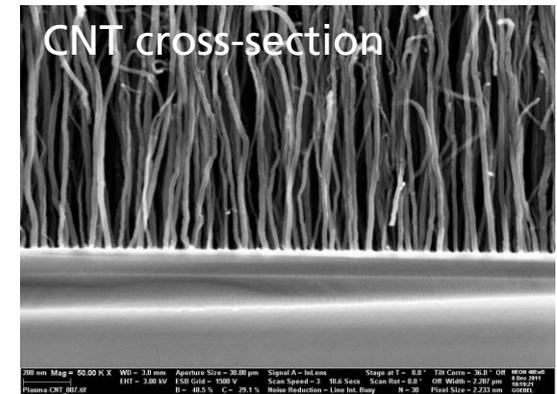
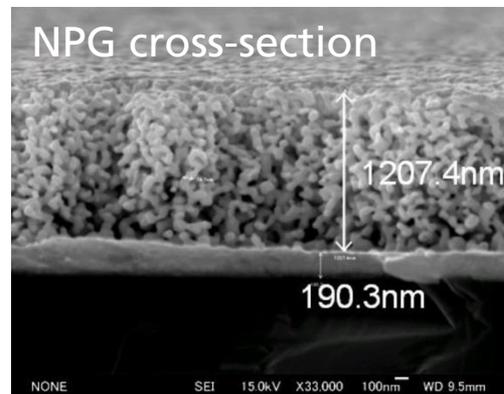
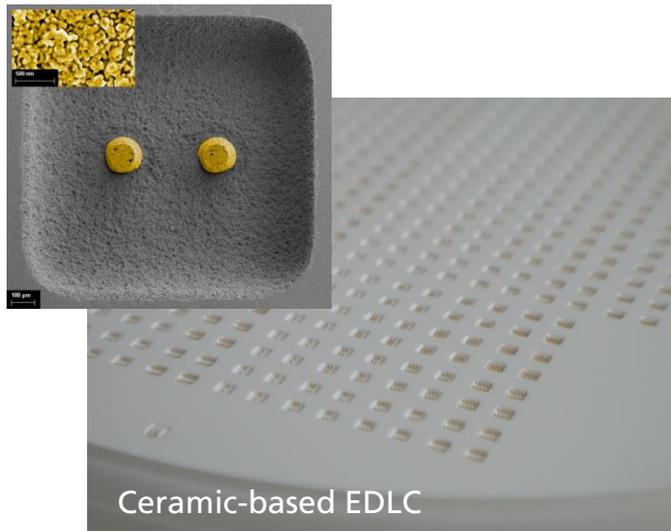
# Research Example: Miniaturized Energy Storage devices by using nano Technologies

- EDLC concept for SuperCap

# Micro and nano porous materials

## Competences and activities of ENAS

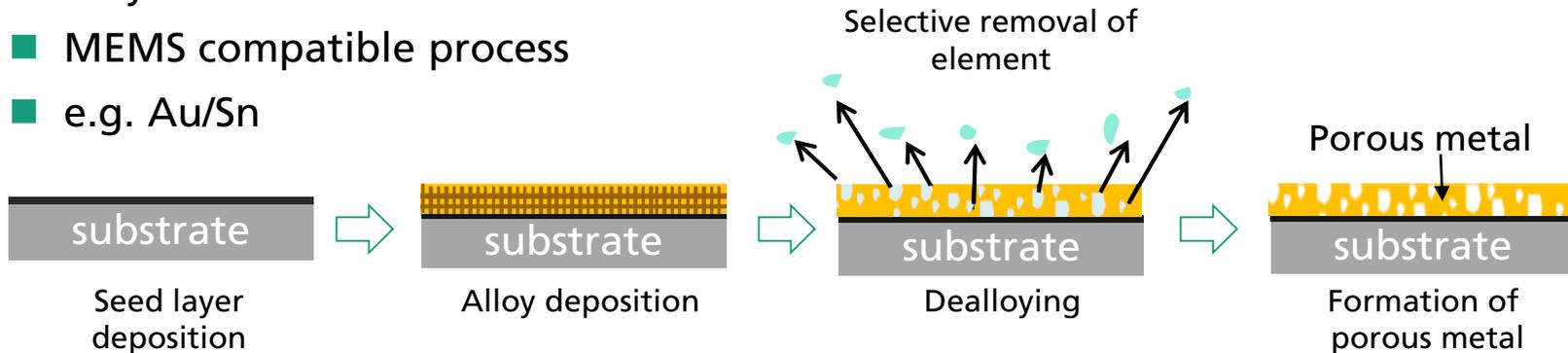
- Deposition of carbon nanotubes (CNT)
- Fabrication of nanoporous metal layers (NPG)
- Parylene encapsulation of liquids
- Wafer-level packaging
- System integration



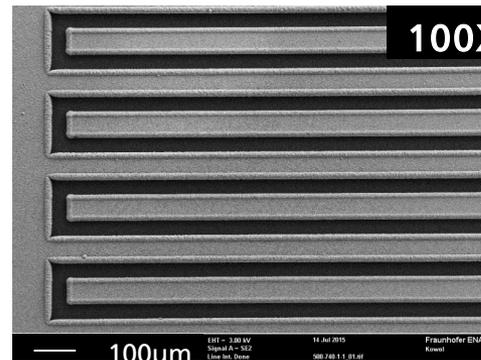
# Micro and nano porous materials

## Nanoporous metal for 3D electrodes

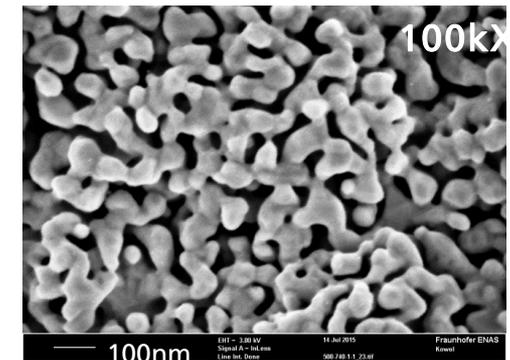
- High surface-to-volume ratio
- Easy fabrication
- MEMS compatible process
- e.g. Au/Sn



- Layer thickness: from hundreds of nm up to several  $\mu\text{m}$
- Pore size: around 100 nm
- Ligament size: up to 100 nm
- Controllable during alloy deposition



- Current Density:  $4\text{mA}/\text{cm}^2$
- Deposition Time: 60min



- NPG Thickness:  $5\text{-}8\mu\text{m}$  for 4 different line-widths

# International Conference & Exhibition on integration issues of miniaturized systems – MEMS, MOEMS, ICs and electronic components

smartsystems  
integration



13. Conference: 10-11 April 2019, Barcelona, Spain

Organizer:



Chair: Prof. Dr. T. Otto, Fraunhofer ENAS

Co-Chair: Dr. Stefan Finkbeiner, Bosch Sensortec and EPoSS

Wolfgang Gessner, EPoSS

# Thank you!

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