Low Temperature Bonding by using Nanoporous Gold

Dr. Wei-Shan Wang
Department System Packaging
Fraunhofer Institute for Electronic Nano Systems ENAS

Fraunhofer
ENAS

International Symposium on Smart Integrated Systems, Chemnitz, 12.08.2014

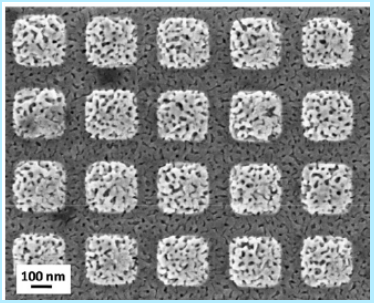
Outline

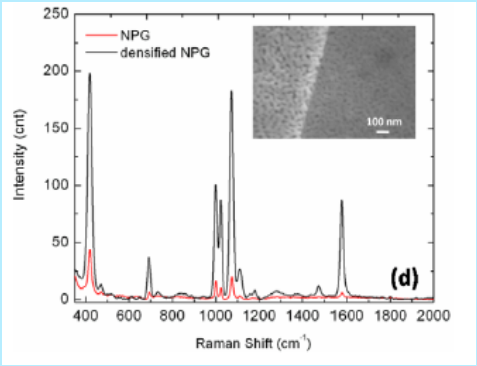
- Introduction of nanoporous metals
- Low temperature bonding by using nanoporous gold
  - Substrate bonding at low temperature
  - Substrate bonding by using plasma-activated porous gold
  - heterogeneous bonding
- Summary and outlook

Nanostructured Metals

highly active surface area ⇨ sensors, actuators, catalysis, packaging…

As SERS Template



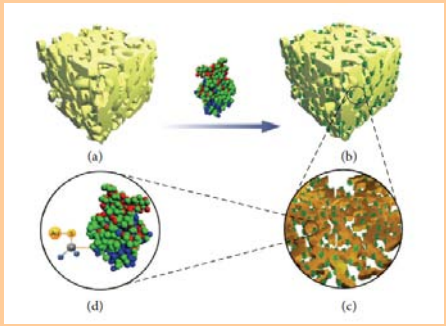


SERS spectra of benzenethiol molecules

Nanotechnology **22**, 295302, 2011

SERS: surface-enhancement Raman scattering

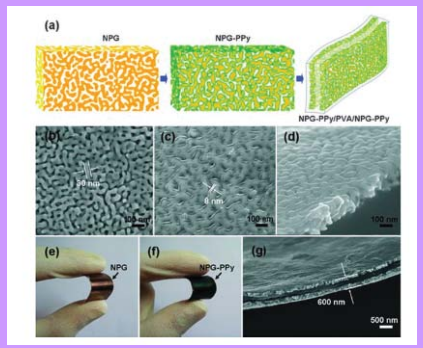
Enzyme-Based Biosensors



Adsorption of lacease on nanoporous Au

J. Phys. Chem. C **112**, 14781, 2008

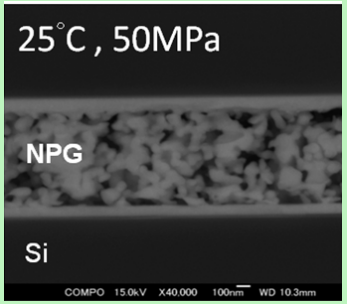
Energy systems



Nanoporous Au for supercapacitors

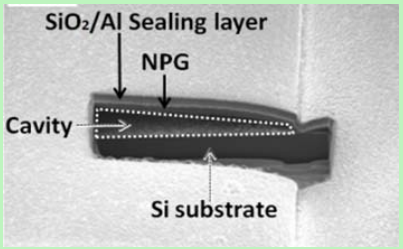
Adv. Mater. ***23***, 4098, 2011

Packaging Applications



Low temperature bonding

2012 IEEE Sensors, 355, 2012



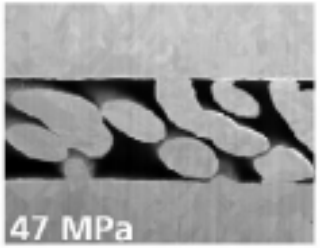
Thin film encapsulation

J. Microelec Sys. **12**, 998, 2013

TOHOKU AIMR wpi μSIC MicroSystemIntegrationCenter Fraunhofer ENAS

Bonding by using Nanostructured Metals

Nano-lawn Au

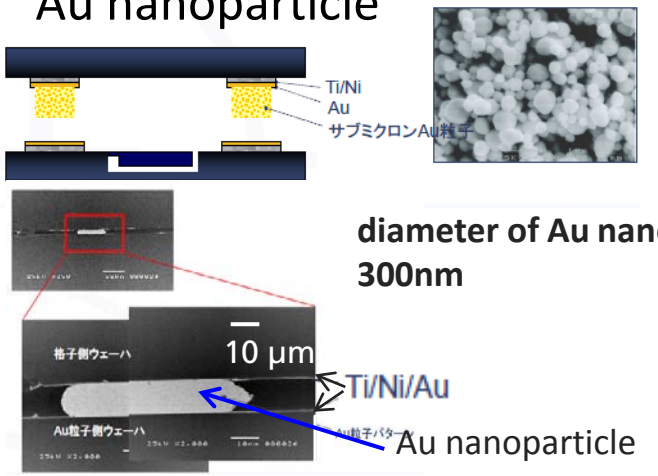


wire diameter 600nm,

length 1-5 microns

S. Fiedler et al., *IEEE Electron Systeminte.Tech. conference, 886, 2006.*

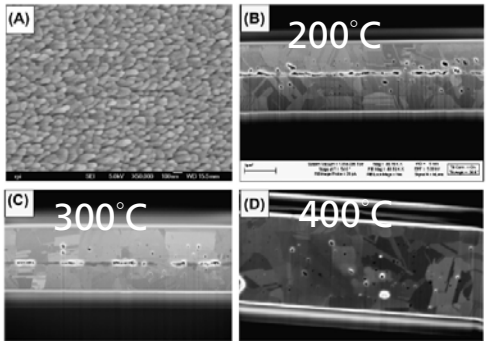
Au nanoparticle



diameter of Au nanoparticle: 300nm

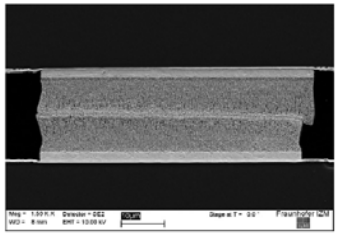
Tanakakikinzoku Kogyo K.K. www.tanaka.co.jp

Copper nanorod array



P.I. Wang et.al., Electrochemical and Solid-State Letters, 12 4 H138-H141 2009 . (Rensselaer Polytechnic Institute, USA)

Nanoporous Au bump

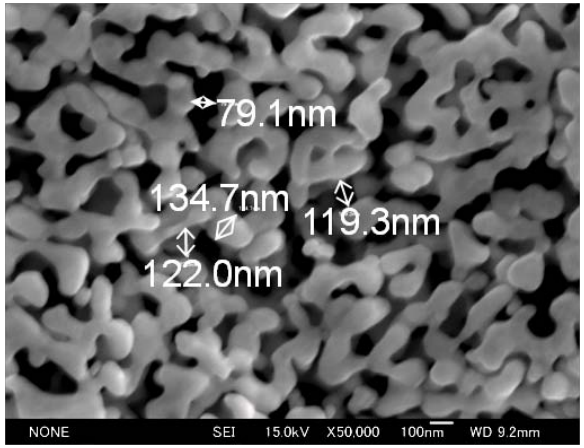


H. Oppermann and L. Dietrich, *Microelectronics Reliability* 52, 356, 2012

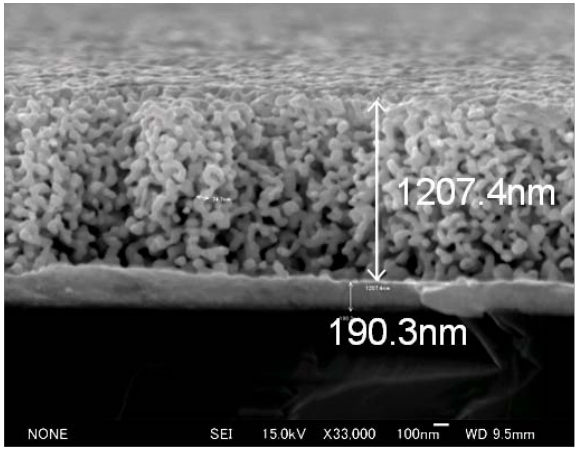
Fraunhofer ENAS

Structure of Nanoporous Gold

Top view

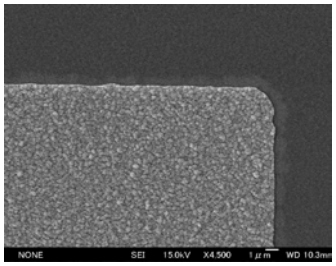


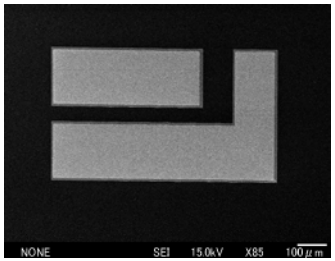
Cross section

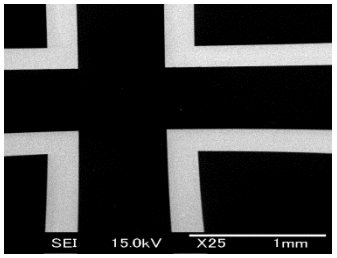


- **thickness:**
  from hundreds of nm up to several µm
- **porous size:**
  around 100nm
- **ligament size:**
  up to 100nm

Patterned porous Au





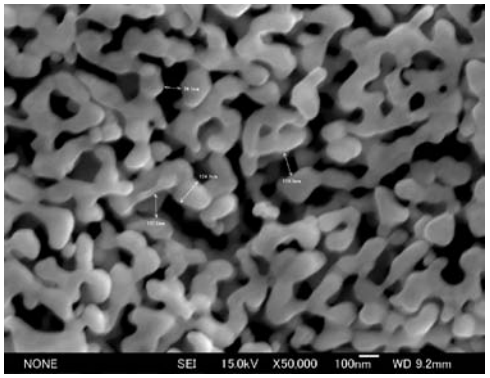


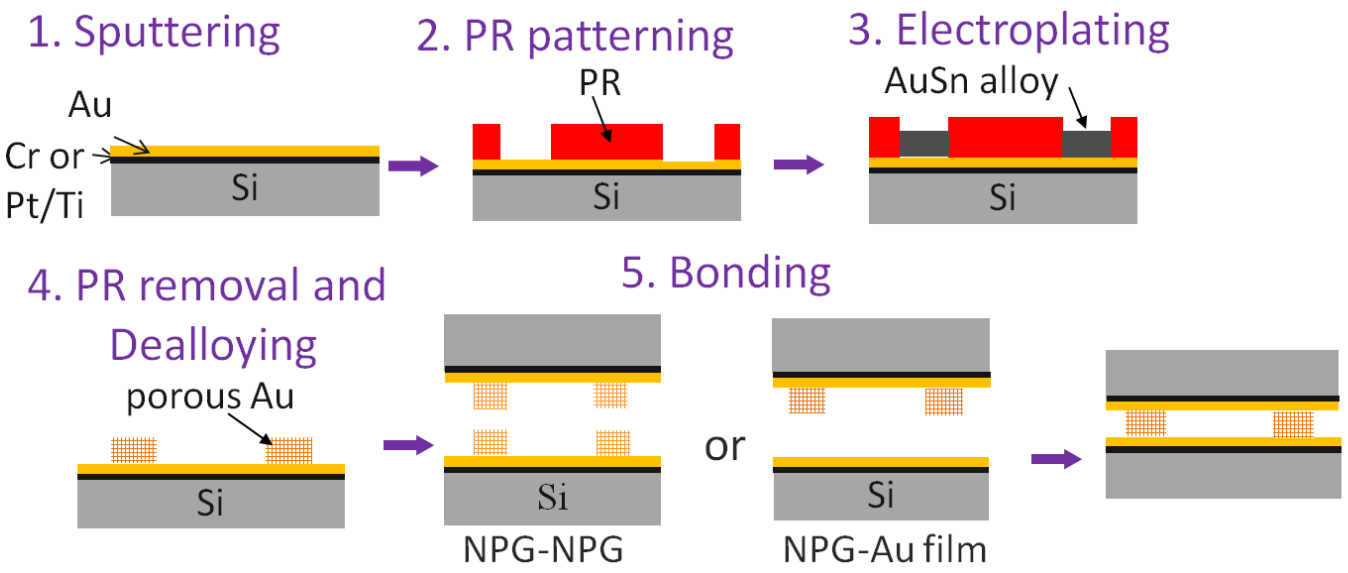
- **pad width:**
  40~700µm
- **frame width:**
  100~500µm

Fraunhofer ENAS

Concept of using Porous Au for Bonding

- High surface to volume ratio
- Low temperature bonding (thermalcompression)
- Electrical inter-connection achieved during bonding
- Sponge-like compressibility, tolerate implanarities

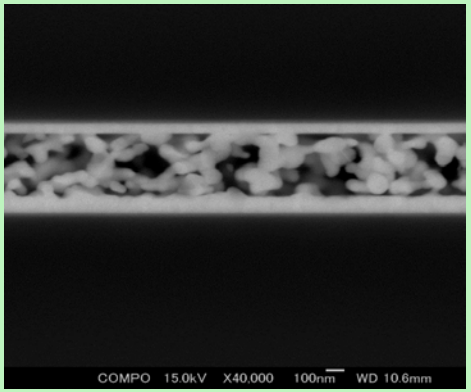
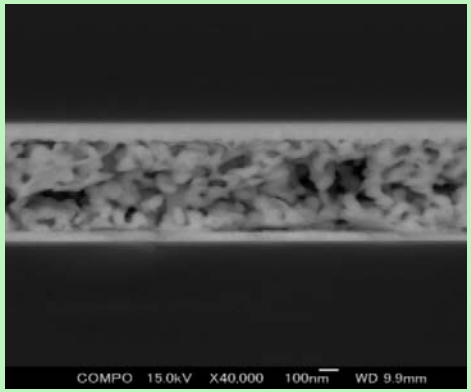
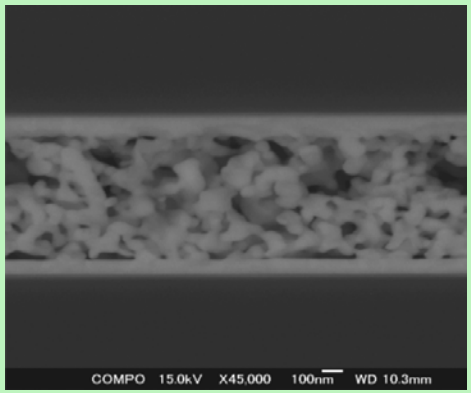
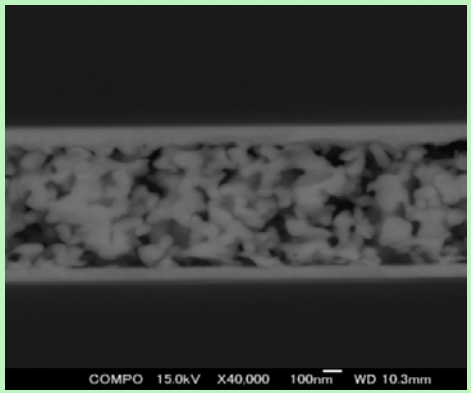


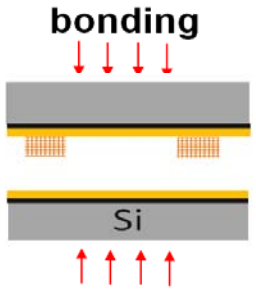


Fraunhofer ENAS

Substrate bonding by using plasma-activated NPG

- bonded at room temperature with plasma-activated NPG

150°C, 50MPa	100°C, 50MPa
	
50°C, 50MPa	25°C, 50MPa
	



- **NPG thickness:**

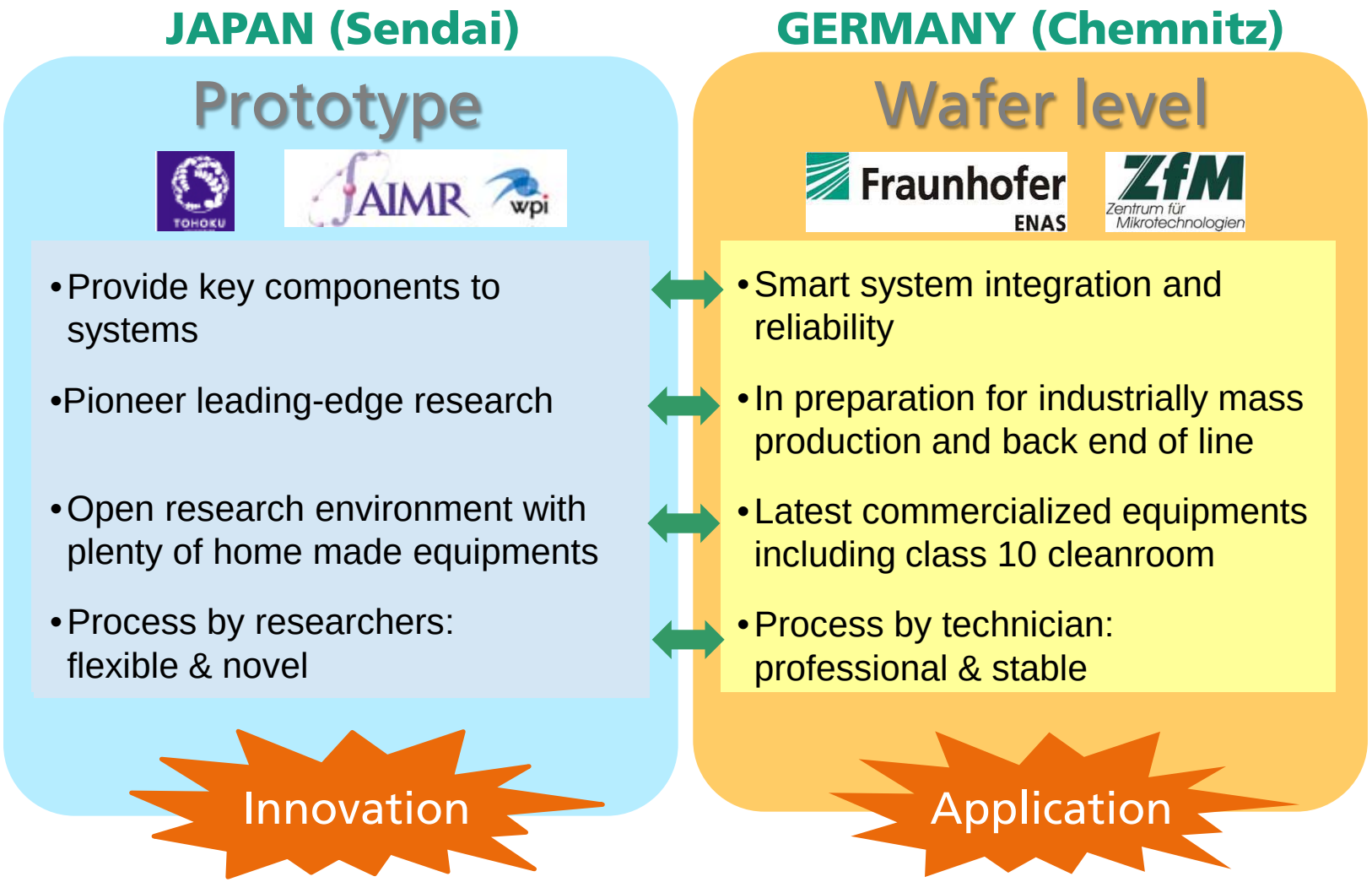
  400-800nm, flexible thickness control for bonding
- **Au thin film:**

  200nm
- **Bonding condition:**

  in ambient air

Fraunhofer ENAS

Cooperation - special strengths



Summary and Outlook

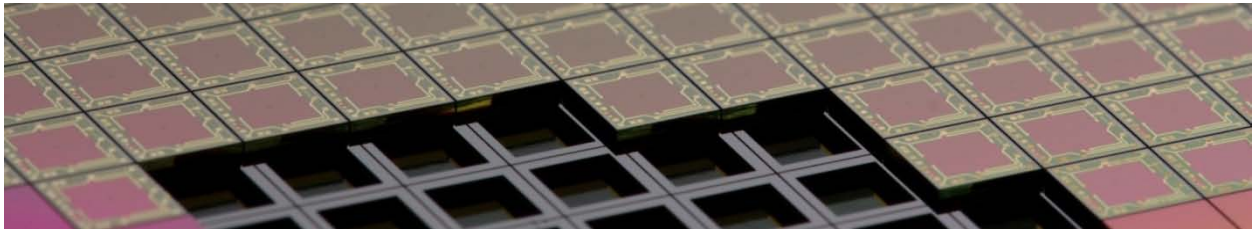
Characteristics of Nanoporous Gold

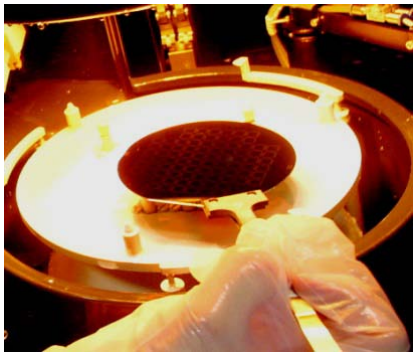
- **MEMS-compatible** fabrication process
- **High surface area**:
  - decrease bonding temperature - down to 200°C or even at room temperature
  - potential candidate for heterogeneous bonding
- **Sponge-like compressibility**:
  - bonding without critical requirements of surface cleanliness and roughness
- **Flexible control of thickness**:
  - bonding achieved regardless of thickness of NPG

More Possibilities of Nanoporous Metals

- Advanced materials for packaging
- As catalysts for electrochemical applications
- Biosensors, chemical and physical sensors
- Energy storage/conversion systems

Thank you for your attention





Contact

Dr. Wei-Shan Wang

Fraunhofer ENAS
Department System Packaging

Mail: wei-shan.wang@enas.fraunhofer.de

Phone: 0371-45001-495

Technologie-Campus-3
09126 Chemnitz
Germany

Fraunhofer ENAS