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Low temperature wiring with silver nano-inks

Institute of Scientific and Industrial Research
Osaka University

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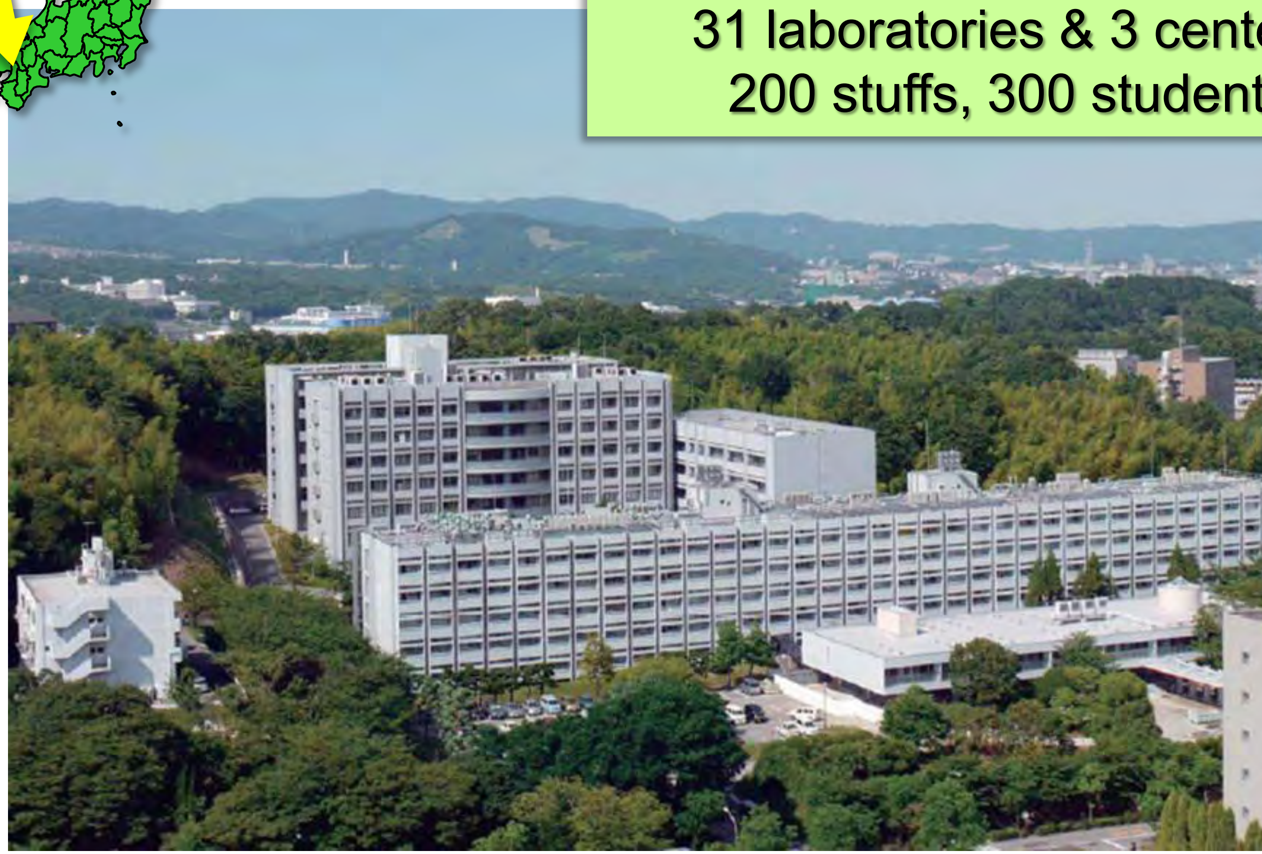
Masaya Nogi, Dr :Stretchable/Cellulose
Mariko Hatamura :Ag carboxylate
Takehiro Tokuno :Transparent conductive film
Teppei Araki :Stretchable electronics
Jinting Jiu, Dr :Nanorods

Institute of Scientific and Industrial Research
Osaka University

Materials, Biology, Information

& Nanotechnology

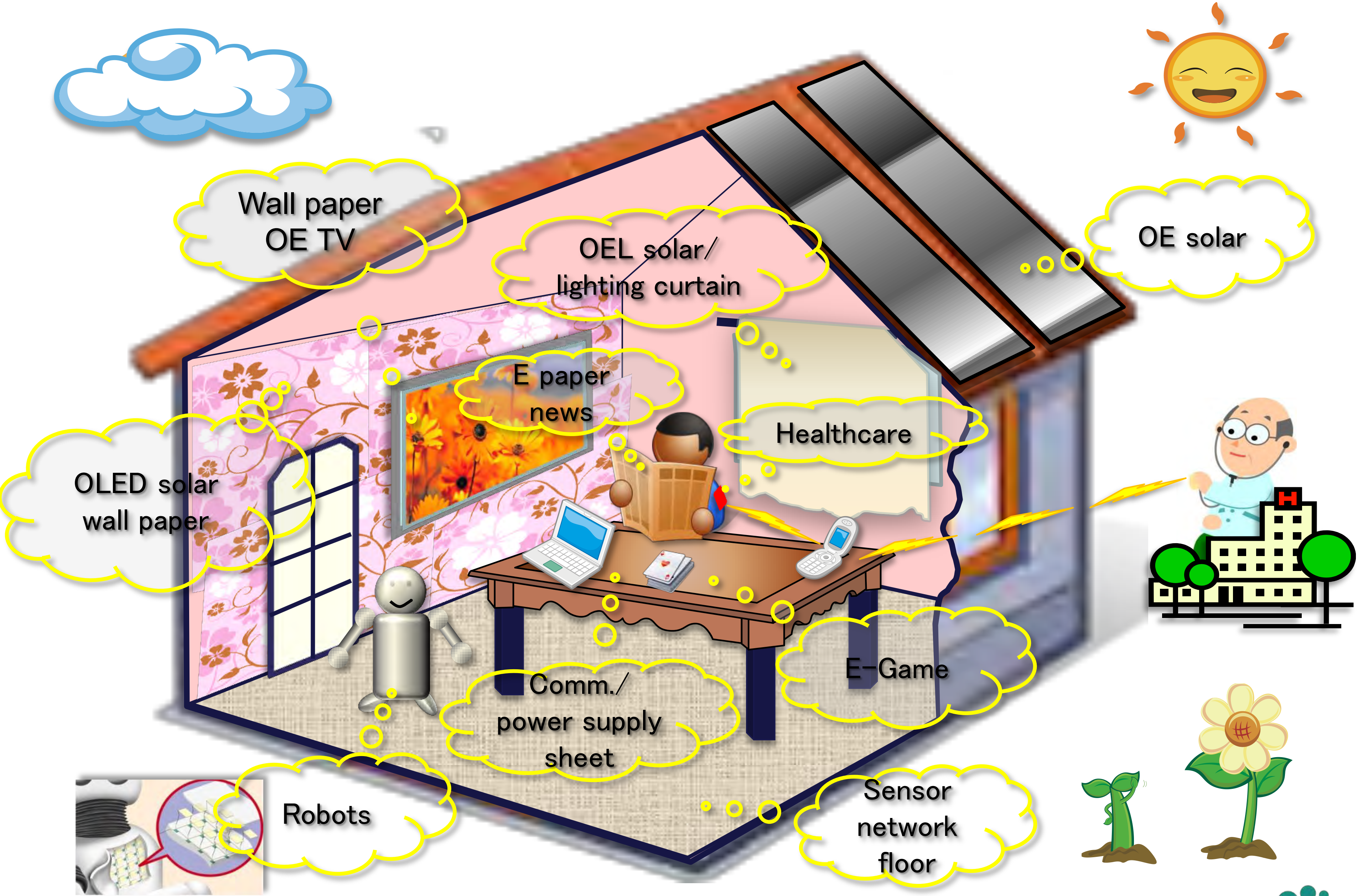
31 laboratories & 3 centers
200 stuffs, 300 students



Outline

- Introduction
- Metallic nano-inks for printed electronics
- Requirements and approach to lower process temperature
- Room temperature sintering of Ag nanoparticle ink
- Ag carboxylate ink
- Cold pressing of Ag nanorods for transparent conductive film
- Summary
- Acknowledgements

New home with printed electronics

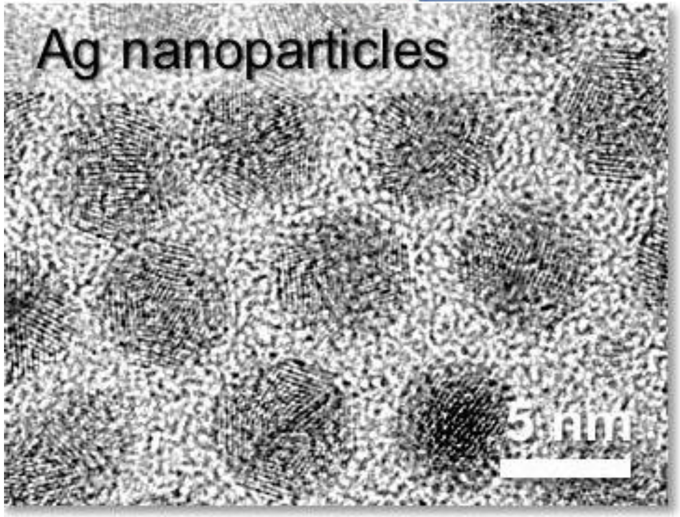


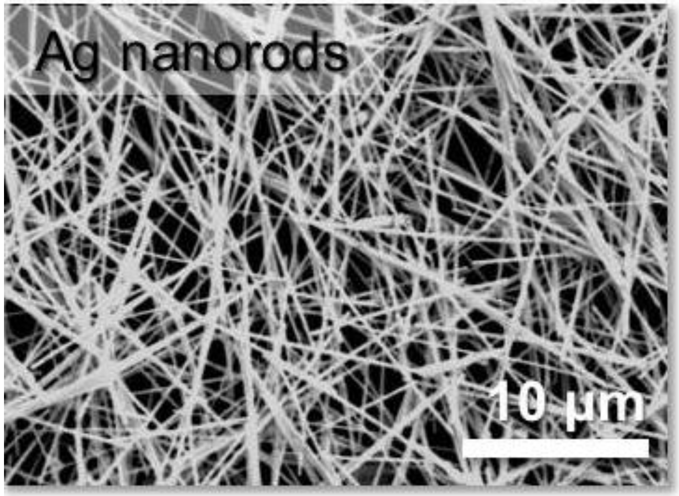
K. Suganuma, ISIR, Osaka University

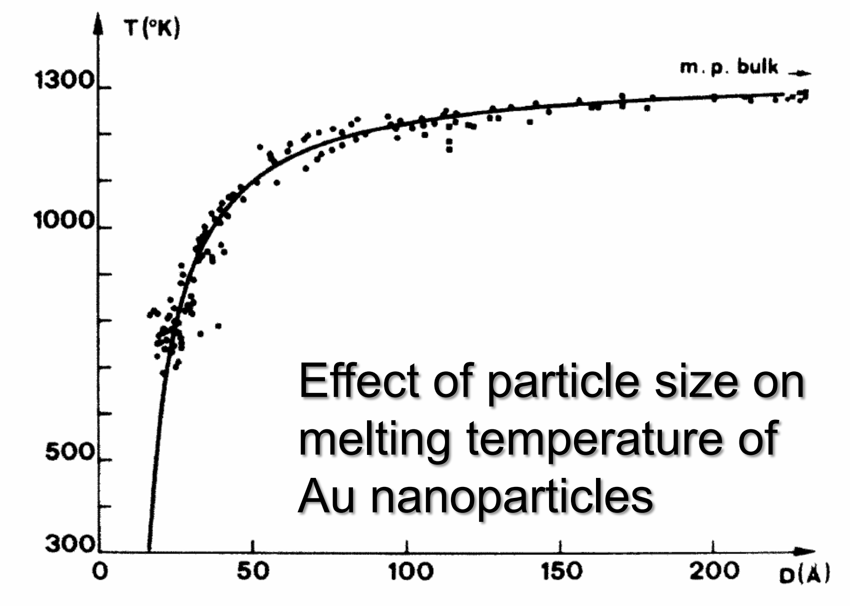
Wiring circuits：Metallic nano-inks

- ✓ Size effect on melting temperature
- ✓ Matching with printers
- ✓ Fine pitch patterning
- ✓ Excellent stability & low resistivity

Monomer/polymers layer protecting nano particles







Effect of particle size on melting temperature of Au nanoparticles

Ph. Buffat and J-P. Borel, Phys.Rev.A13, (1976), 2287

Demands for lower temperature process & materials, why?

- ✓ Organic materials, i.e., devices, substrates…etc., cannot stand for high temperature
- ✓ Thin Si films need low temperature process
- ✓ Thermal stress must be as small as it can be
- ✓ For room temperature applications, low temperature process can be energy saving, low CO_2 emission ….true ECO

Choices:

1) Low temperature ink developments
2) Input other energy (laser, UV, plasma…etc.)

Input of 3rd energy

- ✓Laser a few micro-meters resolution
- ✓Flash lamp wide area
- ✓Microwave heating wide area
- ✓Cold working cheapness
- ✓UV curing well established for conventional printing

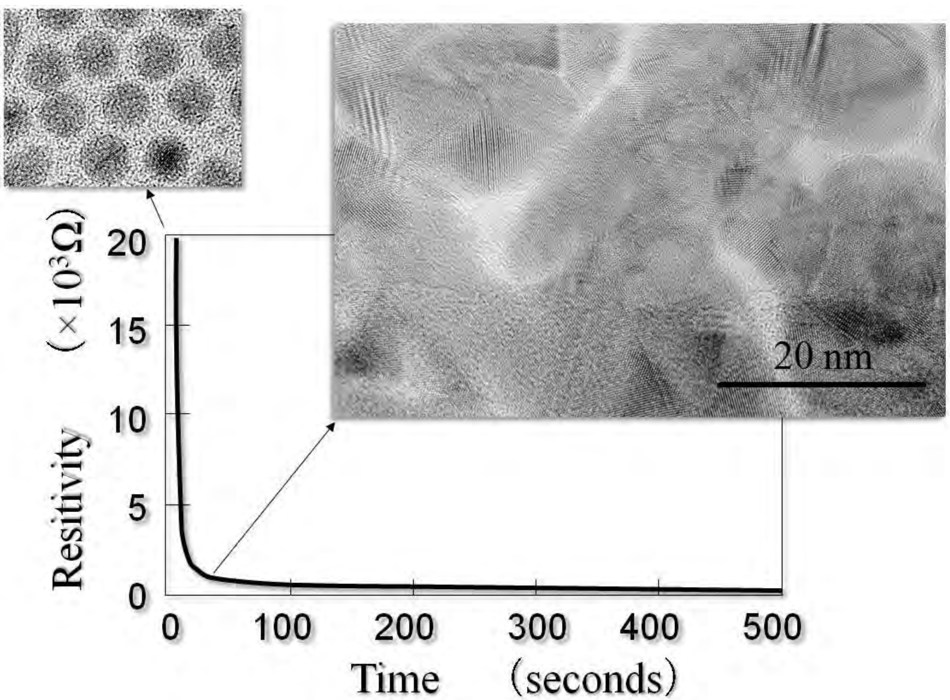
lacking in versatility

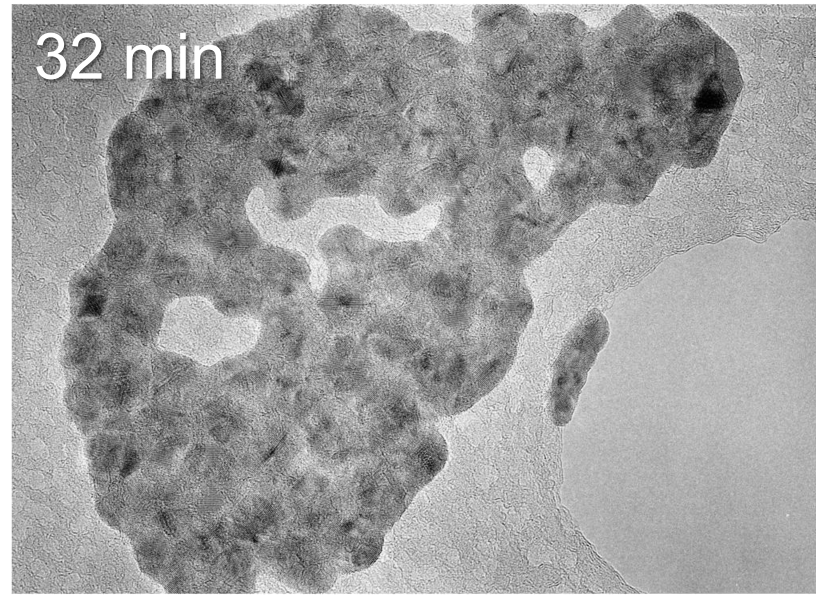
Our new approaches

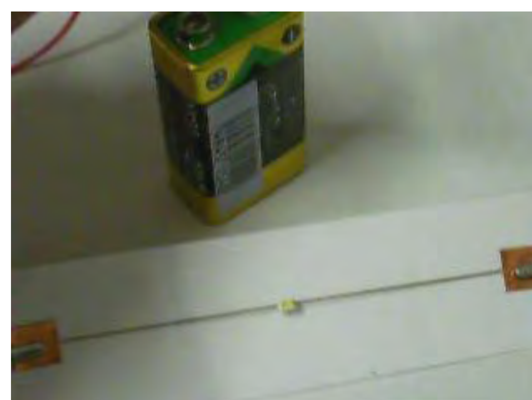
- Room temperature sintering of Ag nanoparticles ink
  → wiring & bonding
- 100 ºC curable Ag carboxylate ink
- Pressing of Ag nanorods for TCF

Room temperature wiring of Ag nano-particles ink

Just by washing with alcohol for a few seconds



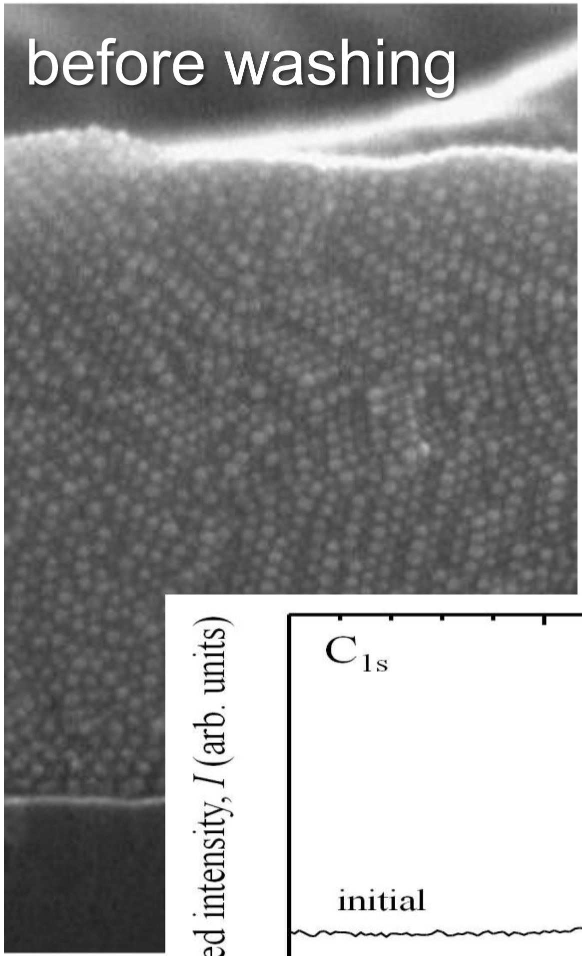


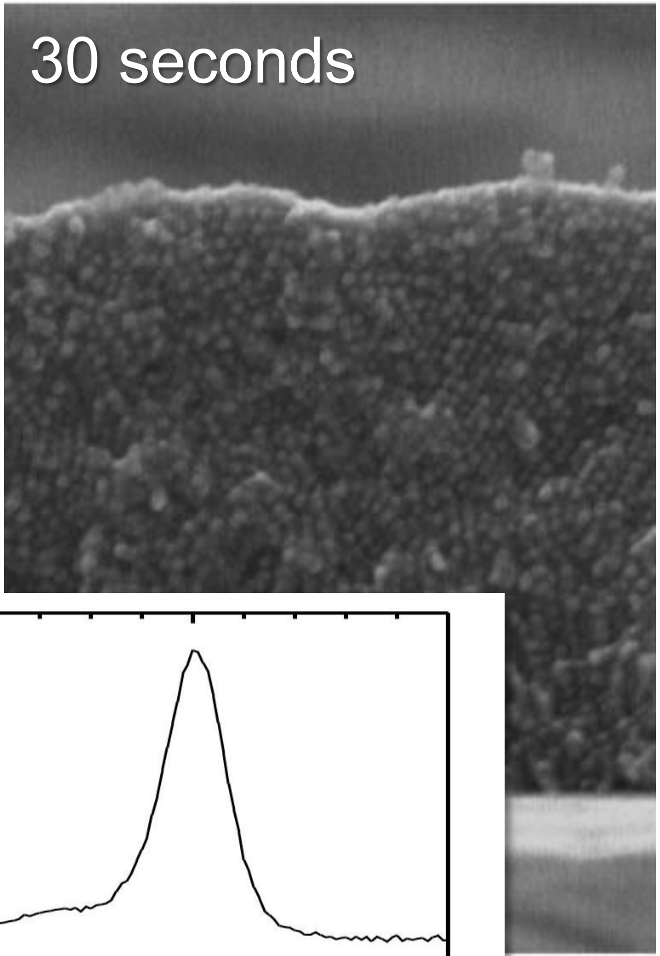


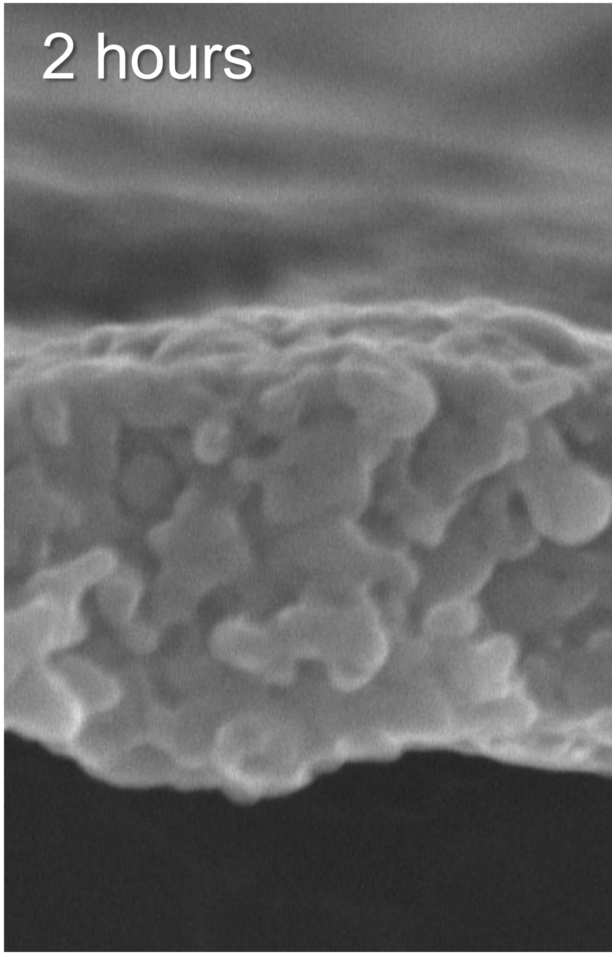
LED wired at room temperature

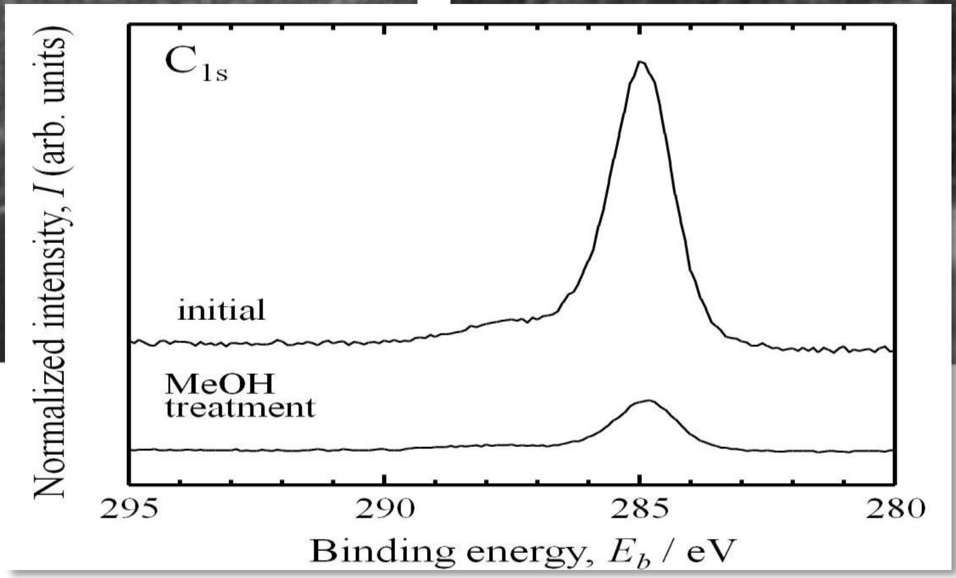
D. Wakuda, et als, Chem. Phys. Letters, 441 (2007), 305

Room temperature sintering process of printed Ag nanoparticle ink









D. Wakuda, et als, IEEE Trans.CPMT, 32[3](2009), 627

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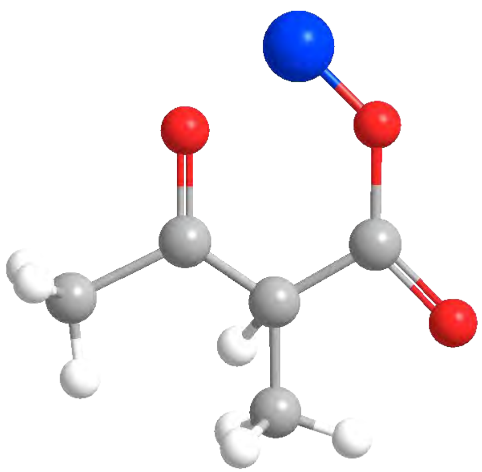
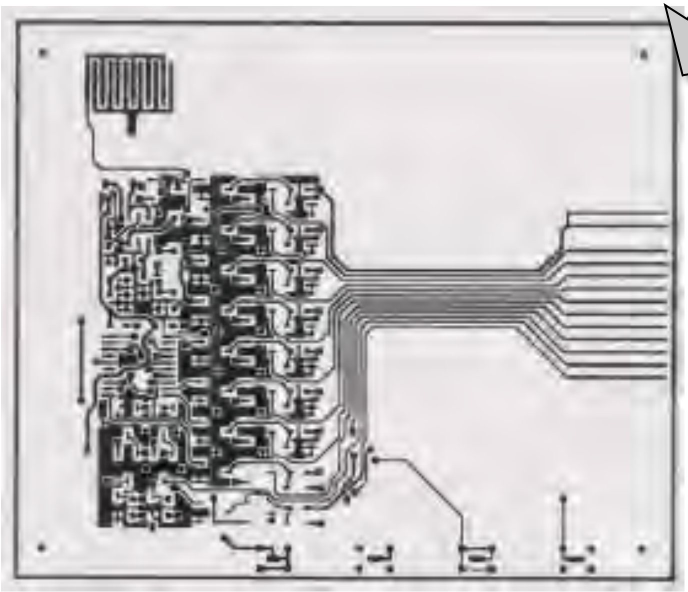
New Ag carboxylate ink enables us wiring at 100 ºC

β-ketocarboxylate Ag



Ag carboxylate

ink



On paper

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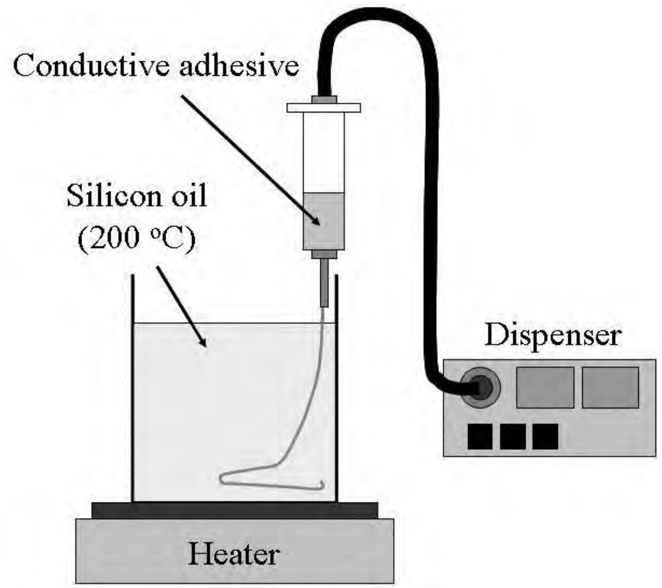
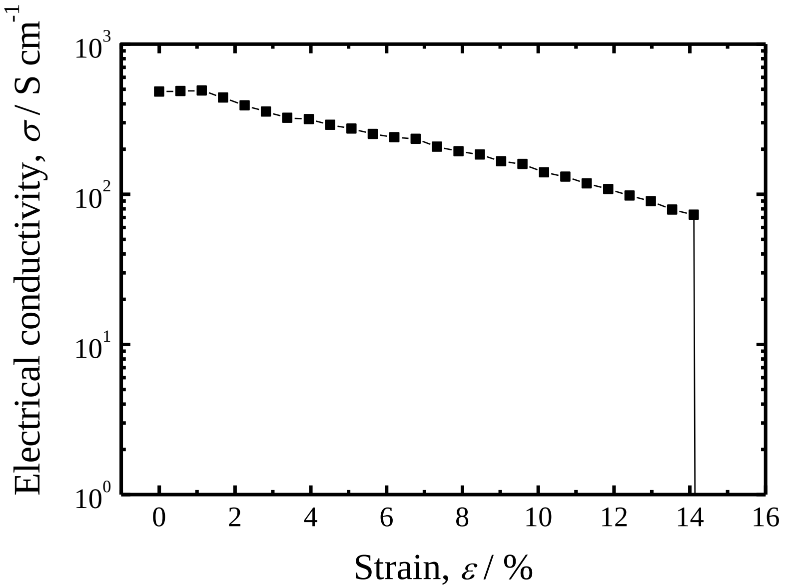
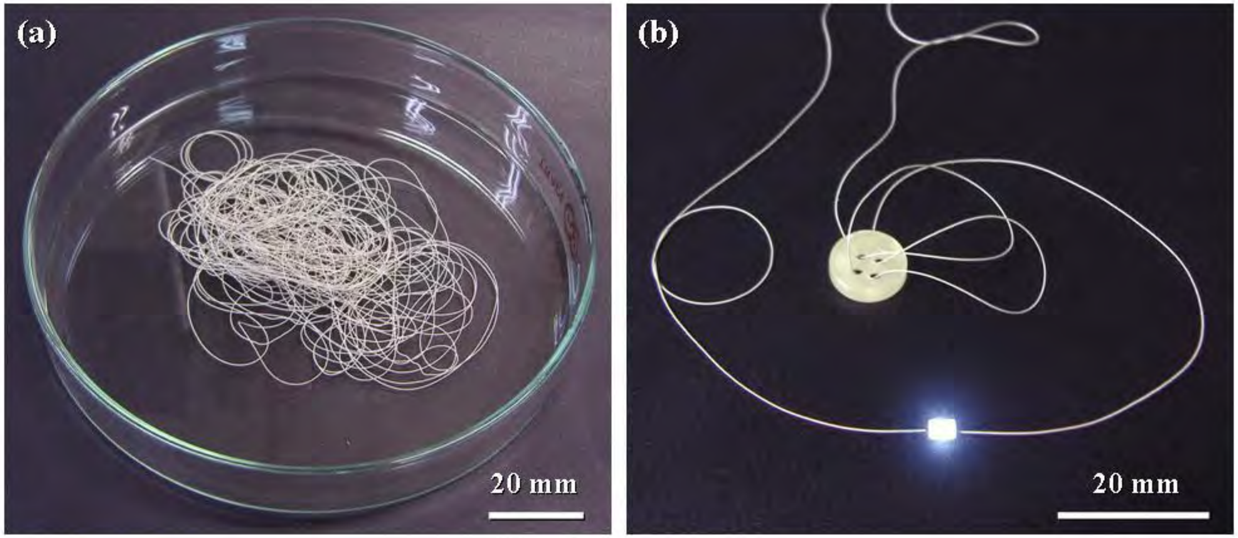
Stretchable fibers fabricated by injection forming

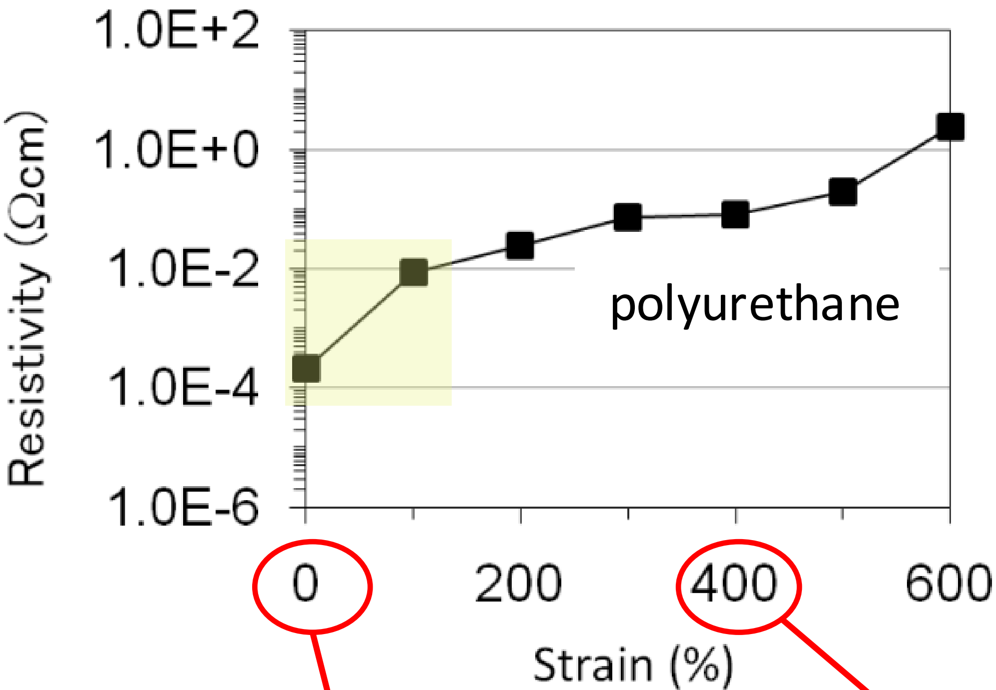




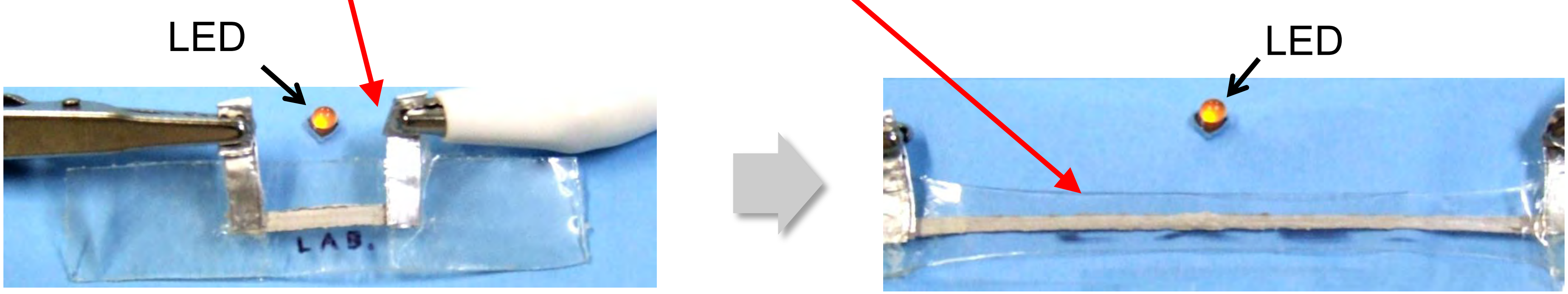


Wakuda et al, Appl. Phy. Letters, 98[7](2011), 073304.

Ultra stretchable polyurethane conductive wiring



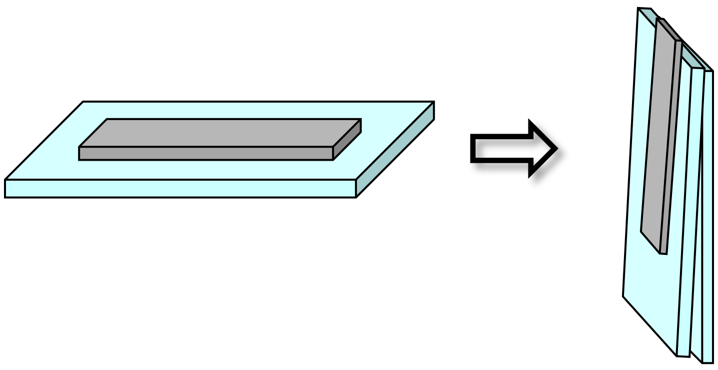
Good adhesion at interfaces provides ultra ductile wiring up to 600 %



in collaboration with Bayer Materialscience

K. Suganuma, ISIR, Osaka University

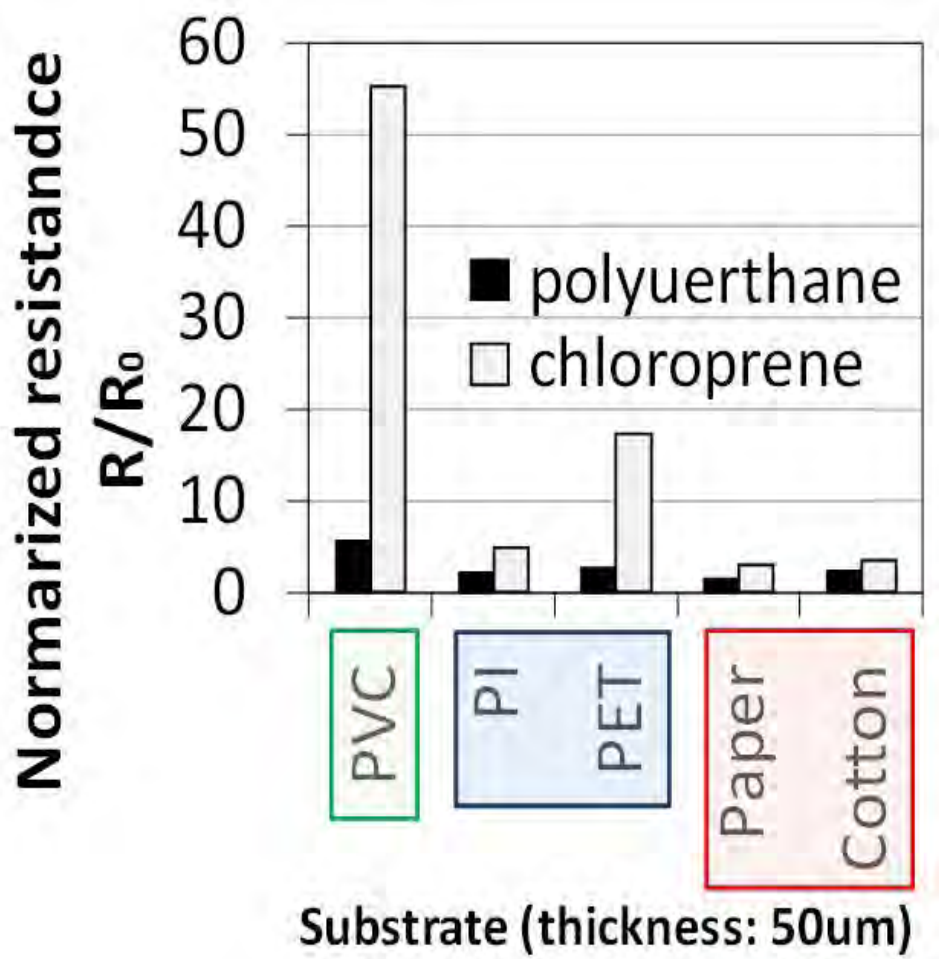
Superb flexibility



Mountain foldable!

Twisting or bending, no problem

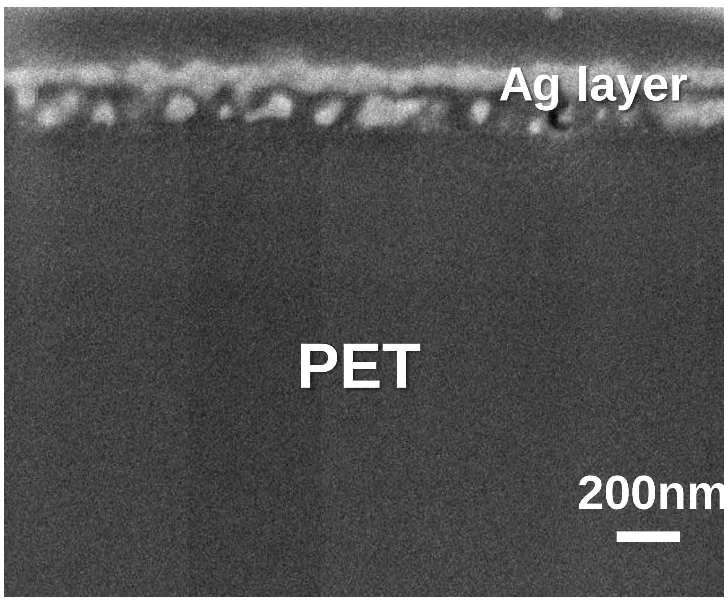
No interface debonding &
stable conductivity



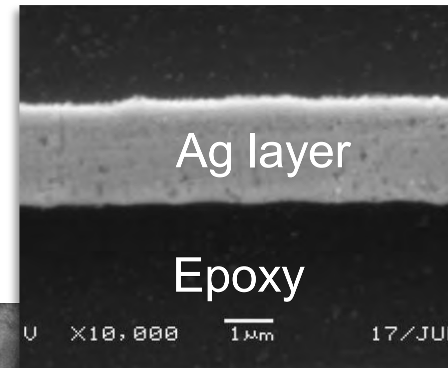
Designing interface

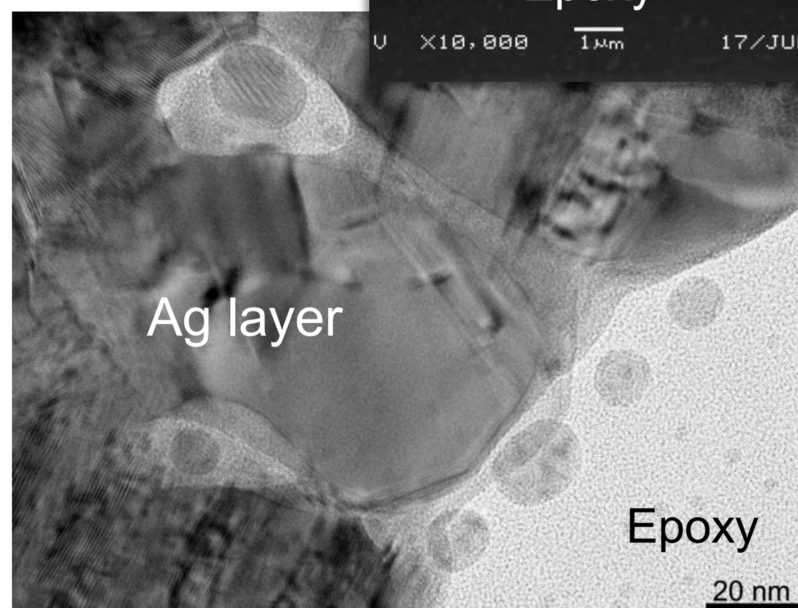
✓How can we get a tight interface?
✓Working function?

Ag carboxylate ink: Ag migrates into PET surface at 150 ℃

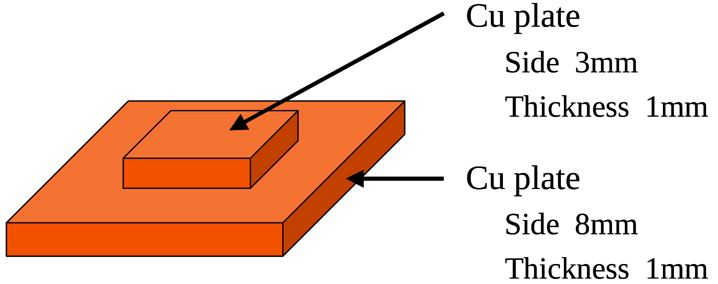


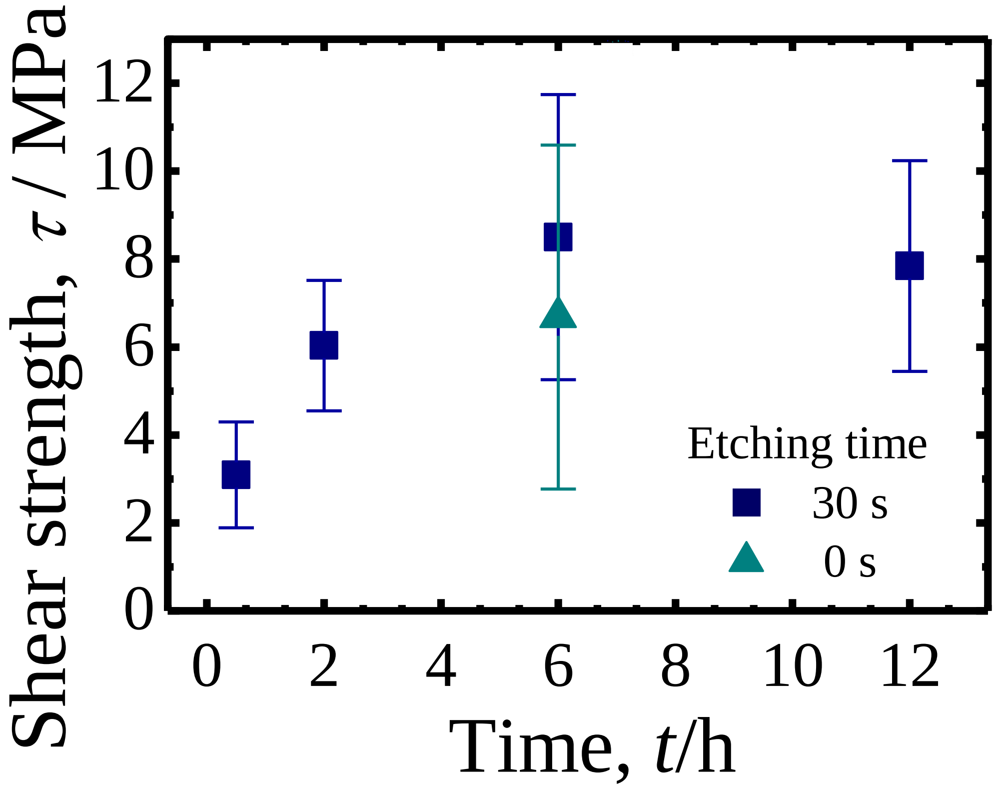
Ag nanoparticles diffuse into epoxy surface at 200 ℃

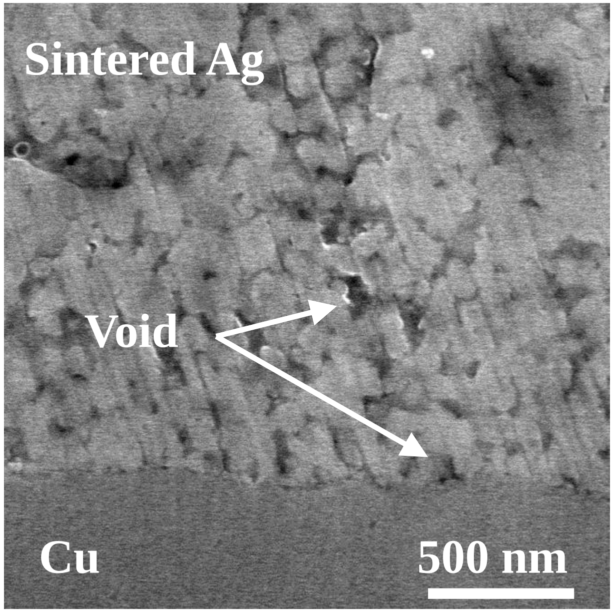




Room temperature bonding







Kuramoto et als, IEEE Trans. CPT, 33[2](2010), 437

Summary and next steps

1. Low temperature curable metallic nano-inks, even room temperature sintering wiring, are available.

2. Ag nanorods becomes TCF at room temperature.

3. Conductive adhesives have been expanding their applications into new PE products.

4. Ultra stretchable wiring: Ag flakes/urethane-based ICA stretches up to 600 %.

5. Room temperature bonding can be possible in air.

Next steps : new challenges for low-temperature processes of nanomaterials for PE and open innovation!

Acknowledgements

- Ag nanoparticle room temperature sintering was mainly carried out by Dr. D. Wakuda (now for Panasonic) with the support of JSPS Kakenhi.
- Ag carboxylate ink was developed in collaboration with Toppan Forms Co.Ltd.
- Ag micro particles bonding research was partly supported by a grant from the NEDO project “R&D of alternatives to high temperature high lead solder” operated by JEITA.
- LED die-attaching was carried out in collaboration with Nichia Chemical, Co.Ltd.
- Stretchable urethane based conductive wiring was carried out in collaboration with Bayer MaterialScience AG.

D. Wakuda, Dr (Panasonic)

M. Kuramoto, Dr (Nichia)