Low temperature wiring with silver nano-inks

Institute of Scientific and Industrial Research
Osaka University

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

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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

- Wall paper
- OE TV
- OEL solar/lighting curtain
- E paper/news
- Comm./power supply sheet
- OLED solar wall paper
- OE solar
- Healthcare
- E-Game
- Robots
- Sensor network floor

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Wiring circuits: Metallic nano-inks

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


Effect of particle size on melting temperature of Au nanoparticles

Monomer/polymers layer protecting nano particles

Ag nanoparticles

Ag nanorods
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 CO₂ 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


K. Suganuma, ISIR, Osaka University
Room temperature sintering process of printed Ag nanoparticle ink

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

K. Suganuma, ISIR, Osaka University
New Ag carboxylate ink enables us wiring at 100 °C

β-ketocarboxylate Ag

Ag carboxylate

ink

On paper

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Stretchable fibers fabricated by injection forming


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Ultra stretchable polyurethane conductive wiring

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

in collaboration with Bayer Materialscience

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Superb flexibility

Mountain foldable!
Twisting or bending, no problem
No interface debonding & stable conductivity

Normalized resistance $R/R_0$

- PVC
- PI
- PET
- Paper
- Cotton

Substrate (thickness: 50um)
Designing interface

How can we get a tight interface?
Working function?

Ag carboxylate ink: Ag migrates into PET surface at 150 °C

Ag nanoparticles diffuse into epoxy surface at 200 °C
Room temperature bonding

Shear strength, $\tau / \text{MPa}$
Time, $t / \text{h}$
Etching time
- 30 s
- 0 s

Sintered Ag
Void
Cu

K. Suganuma, ISIR, Osaka University

Kuramoto et al., 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!
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- 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.