Press Release

January 30, 2019

Institute of Multidisciplinary Research for Advanced Materials, Tohoku University
Mitsui Mining & Smelting Co., Ltd.

Copper Nanopaste for Wiring and Bonding by Printing: Toward Replacing Precious Metals

Printed Electronics and Next-Generation Power Device Bonding are Heading for the Copper Era

[Key Points of Announcement]

- It has been confirmed that the developed copper nanoparticle has unprecedented low temperature sintering characteristics, in which its sintering occurs at a temperature of around 140 °C and above.
- The newly developed synthesis process, or the method for the room-temperature reduction of water-soluble copper complex, prepares copper nanoparticles with low temperature sintering ability under very low environmental impact conditions, namely submerged, atmospheric and ambient temperature conditions.
- Copper nanopaste*[1] produced from the developed copper nanoparticles is expected to replace the silver paste that is currently used in circuit formation in printed electronics*[2] and as a bonding material in next-generation power devices*[3].

[Summary]

A joint study between a group formed by Associate Professor Kiyoshi Kanie at the Institute of Multidisciplinary Research for Advanced Materials of Tohoku University (Director: Atsushi Muramatsu) and other researchers and a team led by Dr. Yoichi Kamikoriyama of Mitsui Mining & Smelting Co., Ltd. (Tokyo; President: Keiji Nishida; "Mitsui Kinzoku," hereinafter) has developed a new process of synthesizing copper nanoparticles with low temperature sintering ability under very low environmental impact conditions, specifically submerged, atmospheric and ambient temperature conditions.

Organic substances with oxidation resistance performance are attached to the surface of the copper nanoparticles obtained. The study has discovered that the decomposition of the organic matter at a low temperature, around 140 °C, triggers the sintering of copper nanoparticles.

Paste produced from the developed copper nanoparticles has paved the way for the formation of good thick film copper wiring with a film thickness of 14 μm by sintering between copper particles at a low temperature of around 180 °C (non-pressurized sintering in a nitrogen (N_2) atmosphere) on polyethylene naphthalate (PEN) film and polyimide (PI) film. This means that the paste is expected to replace silver paste and solder, for example, as a material for forming IoT sensor circuits in printed electronics.

An assessment of the paste as an inter-metal bonding material*[4] using a simulated bonding structure, in which copper paste is employed for joining copper substrates, has confirmed that the paste exhibits a high shear strength of more than 30 MPa after low temperature sintering at around 200 °C (non-pressurized sintering in an N_2 atmosphere). The material is therefore expected to be commercialized as a bonding material for next-generation power devices such as silicon carbide (SiC) and gallium nitride (GaN).

This achievement is set to be published on the date of January 29 in *Scientific Reports*, an online open access journal managed by nature.com (DOI: 10.1038/s41598-018-38422-5).

[Detailed Descriptions]

Active research and development efforts are being carried out on low temperature sintering silver nanopaste containing silver nanoparticles as a circuit formation material in flexible hybrid electronics, which combines printed electronics with existing IC manufacturing technologies, and as a bonding material for next-generation power devices, such as SiC and GaN.

Meanwhile, given that silver is a high-cost metal, research and development activities on the application of lower-cost copper nanoparticles have been gaining momentum in recent years. However, the existing technique of preparing copper nanoparticles uses high polymers for the purposes of controlling the flocculation of the copper nanoparticles generated and preventing their oxidation. This allows organic substances that decompose at high temperature to remain on the surface of copper particles, and these substances hamper sintering at low temperature.

The joint study between Tohoku University and Mitsui Kinzoku has succeeded in synthesizing copper nanoparticles with low temperature sintering ability by reducing water-soluble copper complex under very low environmental impact conditions, namely submerged, atmospheric and ambient temperature conditions.

After heating and sintering the copper nanoparticles obtained, the study has revealed that organic substances decompose at a low temperature of approximately 140 °C to rigger sintering of copper nanoparticles (see Figure 1).

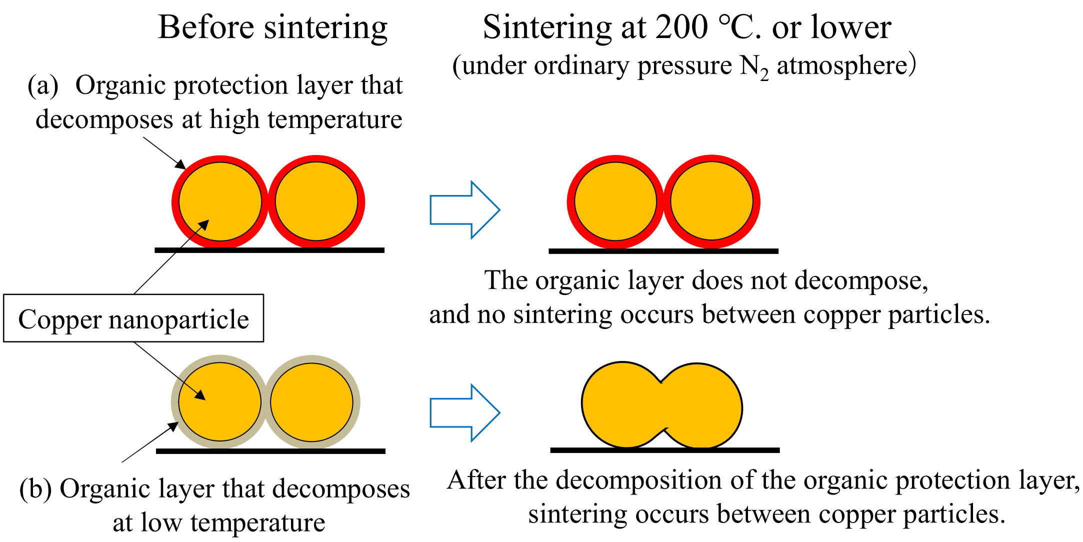

Figure 1: Schematic of Comparison in Sintering Characteristics

(a): Copper nanoparticles obtained using the existing synthesis approach

(b): Copper nanoparticles obtained from water-soluble copper complex

Copper nanopaste prepared from the developed copper nanoparticles shows a good sintered state after sintering at low temperature (ordinary pressure sintering under N_2 atmosphere) for 30 minutes (see Figure 2).

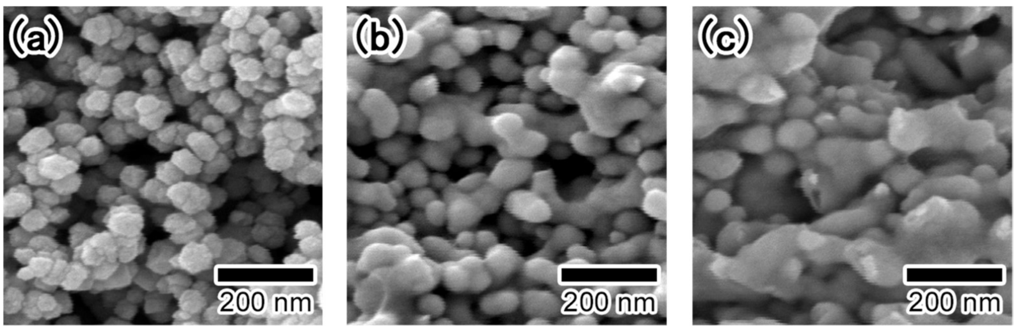

Figure 2: The sintered state of the developed copper nanopaste after ordinary pressure sintering under N_2 atmosphere

(a): Before sintering

(b): The sintered state after sintering at 180 °C for 30 minutes

(c): The sintered state after sintering at 200 °C for 30 minutes

The study has discovered that this copper nanopaste has the potential to serve as a material for wiring formation on PEN film and PI film (see Figure 3) and as a bonding material for power devices.

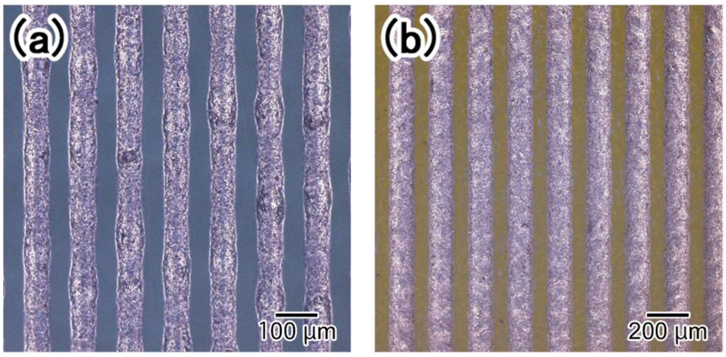

Figure 3: The state of wiring after screen printing the developed copper nanopaste on different films and ordinary pressure sintering in an N_2 atmosphere at 200 °C for 30 minutes

(a): Wiring formation on a PEN film

(b): Wiring formation on a PI film

[Literature Information]
Title: Ambient Aqueous-Phase Synthesis of Copper Nanoparticles and Nanopastes with Low-Temperature Sintering and Ultra-High Bonding Abilities
Authors: Yoichi Kamikoriyama, Hiroshi Imamura, Atsushi Muramatsu, and Kiyoshi Kanie
Publication: Scientific Reports
DOI: 10.1038/s41598-018-38422-5

[Glossary]

*1 Copper nanopaste:
A fluid with high viscosity with nano-sized copper particles (sized 100 nm and less) as well as adhesive ingredients and inorganic substances dispersed in organic solvent. Its viscosity is comparable to jam or cream for spreading on bread.

*2 Printed electronics:
A technology of producing circuit wiring, insulation film and others for electronic devices with the use of printing technologies. It places paste or ink containing metal particles or metal oxide particles in the necessary positions in the necessary quantities and then cures it by applying heat or ultraviolet rays to form conductors, insulators and others. It is therefore recognized as an environmentally friendly production technology.

*3 Next-generation power devices (power semiconductors):
A power semiconductor is a device that converts alternating current to direct current, that increases or decreases voltage and that controls wattage. At present, semi-conductive silicon (Si) is used. The employment of silicon carbide (SiC) and gallium nitride (GaN) as next-generation power devices is expected to considerably cut electric power losses.

*4 Inter-metal bonding material:
A material that bonds electronic components to wiring and electrodes on circuit boards. Solder is commonly used as a bonding material.

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