Characteristics of dry-process based metal nano ink for printed electrodes

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Abstract

The preparation method of copper nanopowder by dry process for conductive ink was investigated. Inert gas condensation method was used to synthesize copper nanopowder. The produced powders was spherical and sized 10~100nm flowing the conditions. The results showed that input voltage and evaporation rate is critical variables for nano-sized copper powder.

1. Introduction

Pattern formation technology is essential process for semiconductor, display, printed electronics, and it is researched as many various ways. Most popular way of it is photolithography. However, it requires a complicated process, a lot of waste of materials and high cost. As one of strong alternatives, inkjet printing shows lots of advantages; simple process, saving materials, quick process time and possibility of various substrates. The key material of inkjet printing for electronics is conductive ink which is sufficient for specified properties [1]. In this ink manufacturing process, most critical factor to determine its properties is metal nanopowder. Nano materials are different from other materials as the particle gets smaller, surface area ratio is rapidly increased, a melting point depression below that of the same bulk material and it allows using various substrates.

So far, silver nanopowder is used for conductive ink, but has high cost relatively. Therefore, recently copper nanopowder is interested with cheaper cost and good electrical properties. For using copper nanopowder in conductive ink, the size of powder should be smaller than 100nm with narrow size distribution [2].

As one of physical methods for metal nanopowder, inert gas condensation method (IGC) has its own benefits that make it possible to produce powder as various sizes since it is easy to control the particle size [3~5].

In this research, copper nanopowder was produced by the IGC for the conditions of gas flow rate and evaporation rate. Several experiments are performed for obtaining high purified copper powder.

2. Experimental

Fig. 1 shows a schematic of the inert-gas condensation unit used for the production of nanopowder. The vacuum chamber was evacuated to a pressure of approximately 10^{-5} torr by a diffusion pump. Cold finger for trapping of nanopowder was cooled by liquid nitrogen and rotated while experimental. Afterwards, He gas was introduced a carrier gas to control internal flow of vacuum chamber. Copper beads (2~8 mm, 99.9995%, Sigma-Aldrich) was loaded on a tungsten boat as a source material and heated by induction coil with constant temperature under constant pressure.

Metal vapors migrate from the hot source into a carrier gas by a combination of convective flows and diffusion. The decreasing temperature leads to a far more rapid decrease in the equilibrium of vapor pressure and correspondingly high supersaturation. At high supersaturation, the vapors rapidly nucleate, forming very large numbers of extremely small particles. The particles then grow by Brownian coagulation. The product particles are generally collected by thermophoretic deposition. In order to enhance the deposition efficiency, a substrate surface cooled with liquid nitrogen may be used [3]. Variables of these methods are evaporation rate, chamber pressure, kinds of inert gas. This experiment, with copper as materials, is focused on size, diameter and shape of particles followed the change of flow rate of inert gas and rate of evaporation rate.

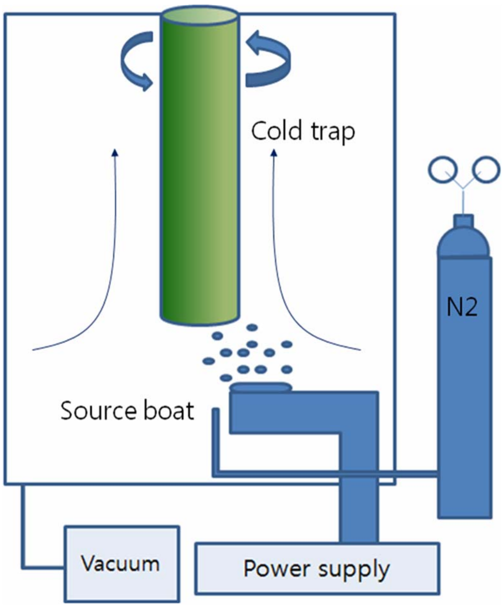

Fig. 1. Schematic diagram of the inert gas condensation unit.

To control the evaporation rate of metal source, input voltage with same current (200A) was checked out. The flow rate of inert gas was changed to control the chamber pressure. Table 1 is a condition chart of input voltage and flow rate that used in this experiment to compare difference of size of nanopowder.

The characterization of collected particles was performed by scanning electron microscope (SEM) analysis.

Table 1. Condition chart

	Input voltage (V)	Flow rate (sccm)
Case A	1.80	10
Case B	2.12	10
Case C	2.09	20

3. Results and discussion

Firstly, the change of particle size by evaporation rate was observed. Fig. 2 shows SEM image of the nanopowder produced for Case A. The nanopowder is spherical and the size is 5~10 nm.

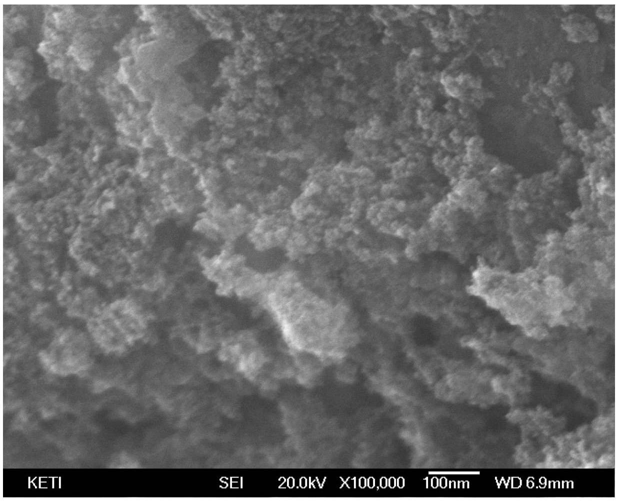

Fig. 2. He 10 sccm, input voltage 1.8 V.

While the metal vapors were migrated from source boat to cold trap, they collide with other metal vapors and cooling inert gas molecules. And more collide lead the nuclei to the bigger nano cluster.

Fig. 3 shows SEM image of the nanopowder produced for Exp 2. The size of the nanopowder is 20~30 nm and is more coarse than Case A. The image shows nanopowder is sintered each other and coagulated. The reason of this situation is the insufficiency of freezing capability of cold finger. Therefore, some nano clusters of copper were not cool downed enough to prevent sintering.

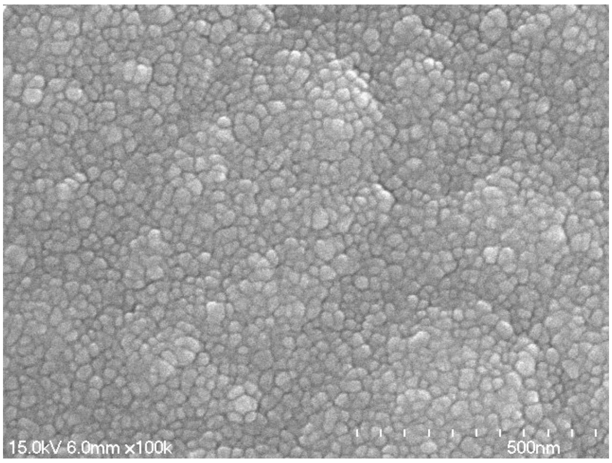

Fig. 3. He 10 sccm, input voltage 2.12 V.

The size of nanopowder is getting bigger as the flow of the inert gas is getting higher. As shown in Fig.

4, when the flow of inert gas was doubled, the size of nanopowder showed 100~120nm. However, nanopowder of Case C was also sintered a little bit each other.

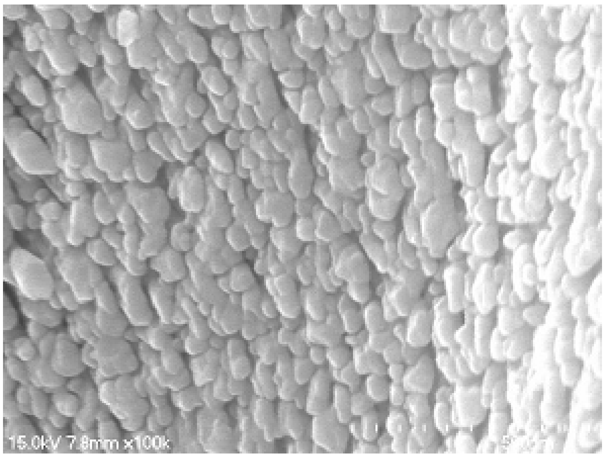

Fig. 4. He 20 sccm, input voltage 2.09 V.

Lower evaporation rate and lower flow of the inert gas into the chamber lead to synthesize the smaller size of nanopowder. When the metal vapors are migrate with inert gas molecules, temperature of the metal vapors are decreasing with collision. In this situation, larger evaporation rate and the flow of the inert gas lead to more collision of metal vapor each other and make larger nano cluster [4]. Hence, to make small size of nanopowder, smaller evaporation rate and smaller flow of the inert gas are needed.

Copper ink was prepared with oleic stabilizer then screen printed onto the glass substrate and annealed in N_2 atmosphere for 30 min. Resistivity was 5.95 and $3.63\mu\Omega$cm at 250 and 320^{o}C, respectively.

4. Summary

In the present work, copper nanopowder was produced by the IGC for the conditions of gas flow rate and evaporation rate. The produced powders was spherical and sized 10~100nm flowing the conditions. As the evaporation rate and flow of inert gas is increased, size of nanopowder is also increased. Copper ink prepared with nanopowder showed good resistivity suitable for the printing.

Acknowledgement

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5. References

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