A Study on the Thermal Properties of Thermal Grease with Copper Nanopowders

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Abstract. Electronic devices and main boards have a tendency to increase the internal heat radiation performance for excellent thermal conductive materials, as necessary for miniaturization. In this study, Nano-thermal grease was prepared by mixing copper Nano-powder into thermal grease, one of the types of thermal conductive materials, by volume percentage. The thermal conductivity was measured and analyzed. As a result, the thermal conductivity was excellent in the order of Case 5, Case 4, Case 3, Case 2, Case 1. However, when the copper powder of Case 5 or more samples was added, stirring did not proceed smoothly due to the high viscosity. This is considered to be because the maximum capacity of the thermal grease was exceeded.

1. Introduction
With the need for producing devices and motherboards that are smaller in this modern-day, the need for thermal conductive materials that have excellent internal heat dissipation is increasing [1-3]. Therefore, there is a need for research on materials that possess higher performance heat transfer and resistance. Thermal management is directly related to the performance and efficiency of the equipment [4-6]. Thermal interface materials (TIM) are essential in the improvement of heat dissipation performance of electronic products with heat generation [7-8]. In particular, it is applied to the interface between the heat spreader and sink of the CPU or GPU and used to reduce the thermal contact resistance by removing the air layer present at the interface. In this study, we prepared a Nano-thermal grease mixed with silicone oil to the copper. Nano-powder was used as a heat transfer medium. In addition, the thermal properties of the prepared Nano-thermal grease was measured to compare the performance.

2. Experimental equipment and methods
Copper powder was produced using pulsed wire evaporation (PWE), one of the Nano-powder preparation methods. PWE is a method of producing Nano-sized powder by evaporation and condensation processes after subliming a certain length of metal wire by supplying high density electrical energy to the metal wire within a short period of time (0.0001 s). PWE may control the size of the powder by adjusting the intensity of the voltage applied to the metal wire [9]. The larger the voltage applied, the smaller the powder size, but the uneven size. Agglomeration of liquid particles other than gases during coagulation produces relatively large particles, whereas coagulation of
semisolid particles that do not form a complete solid state produces coarse particles. Therefore, it is necessary to apply an appropriate voltage suitable for the diameter and length of the wire [10]. Figure 1 shows Equipment used to manufacture Cu nano powder. Table 1 shows the production conditions of the copper Nano-powder. Powders of relatively constant sizes were prepared using appropriate voltages that matched the physical properties of copper. When the powder was prepared by the PWE equipment, the inside of the chamber was filled with argon gas to prevent the powder from being oxidized, and the powder was stored and treated by passivation in a sealed state for about 2 weeks after the powder was manufactured. For copper wire, the proper voltage is 4500V.

Figure 2 shows the process of manufacturing Nano-thermal grease. Each sample was mixed with a certain proportion of the powder and silicon oil according to the volume percentage based on the total amount of 100cc as shown in table 2. During the manufacture of the thermal grease, the copper Nano-powder was not uniformly mixed due to the high viscosity of the silicon oil. The mixture was stirred for 30 minutes at a speed of 300 rpm by using a heating plate at a high temperature of about 100 °C.

Table 1. Manufacturing conditions of copper nano powder.

| Material | Voltage [V] | Number of Time | Wire Diameter [mm] | Wire Diameter [mm] |
|----------|-------------|----------------|--------------------|--------------------|
| Copper   | 4500        | 2000           | 0.2                | 32                 |
Figure 3. Thermal conductivity measuring equipment: (a) Photograph of thermal conductivity meter (b) Schematic diagram of hot-wire apparatus.

3. Measuring equipment

Figure 3 is a photograph of the thermal conductivity measurement equipment used in the study, and is a schematic of the experimental setup of a hot-wire system. Thermal conductivity measuring equipment is a hot-wire method that has been widely used to measure the thermal conductivity of a fluid with high accuracy.

Based on the calculation of the temperature transport field around the metal wires inside, the electrical conductivity of the fluid is measured using an electric heating element and a resistance thermometer. It is a principle to measure. This method was first introduced by Nagaska and Nagashima et al. [11] in 1981 and this hot-wire method has the advantage of being able to measure by minimizing the effects of natural convection and relatively fast measurement time [12-13].

4. Results

Figure 4 shows the SEI observed with FE-SEM of the shape and size of Cu powder prepared using PWE. During FE-SEM imaging, platinum coating pretreatment was performed and observed at 100,000x magnification with a voltage of 15.0kx. And then, it can be seen that most of the powders are uniform and spherical in size with a radius of 100 nm. And a graph of EDS (Energy Dispersive Spectrometer) component detection analysis using FE-SEM. Of the components detected, C is assumed to be the carbon tape used for sample fixing, and O is assumed to be detected as the silicone oil and the oxidation reaction component. It can be confirmed that no component other than Cu is detected in the prepared powder. Figure 5 shows the SEI observed by the FE-SEM of the shape and size of Cu thermal grease prepared using PWE, a graph of the component analysis of the energy dispersive spectrometer (EDS) using the FE-SEM. Out of the components detected, C was assumed to
be the carbon tape used for sample fixation, and O was assumed to be detected as the silicone oil and oxidation reaction component. It can be seen that no components other than Cu and Si were detected in the powders produced. And figure 6 shows the comparison of thermal conductivity.

![Graph of thermal conductivity measurement results for each sample.](image)

**Figure 4.** FE-SEM Image of Cu nano powder manufactured using PWE equipment: (a) A SEI of Cu nano powder (b) EDS spectrum of Cu nano powder.

![Image of EDS taken using FE-SEM: (a) A BEI of Cu nano thermal grease (b) EDS spectrum of Cu nano thermal grease.](image)

**Figure 5.** Image of EDS taken using FE-SEM: (a) A BEI of Cu nano thermal grease (b) EDS spectrum of Cu nano thermal grease.

**Figure 6.** Graph of thermal conductivity measurement results for each sample.
5. Conclusions
In this study, Nano-thermal grease was prepared by mixing copper Nano-powder prepared by the electric line explosion method with silicone oil. Thermal conductivity was measured and analyzed. The conclusion is as follows.

• After BEI observation of Nano-thermal grease, Nano-powders are not agglomerated, and are evenly distributed.

• As a result of the thermal conductivity measurement, thermal conductivity was excellent in the order of Case 5, Case 4, Case 3, Case 2, and Case 1.

• It is considered that there may be an error due to air bubbles formed between samples when measuring the thermal conductivity, and further analysis will be performed after removing bubbles using ultra sonic.

• 30 vol% thermal conductivity is not manufactured due to the cohesion and high viscosity of the powder.

6. References
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