

LOW-THAN-ROOM TEMPERATURE EFFECT ON THE STABILITY OF CuO NANOFLUID

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Abstract. This study involves the use of copper oxide nanofluid produced by the Submerged Arc Nanoparticle Synthesis System (SANSS) to investigate temperature effect on particle suspension of copper oxide nanofluid. The purpose is to understand the deposition state feature of copper oxide nanofluid in a lower-than-room-temperature work environment and to motion behavior of suspended nanoparticle and to analyze its mean secondary particle size. The amount of the nanoparticle was also varied. The relationship between temperature and particle size was investigated. An analytical method to predict the results was introduced. It was concluded that particle size change stable as the temperature decrease due to Brownian motion of retard. The change of environmental temperature can affect copper oxide nanofluid stability in application. Hence, the phenomenon is important when the copper oxide nanofluid in a lower-than-room-temperature of work environment.

1. INTRODUCTION

At nano-size, surface atom percentage of the material is greatly increased. In other words, the surface physical and chemical attributes become much more important under such material structure. When nanomaterial is under the change of environmental temperature, the surface atoms of nanoparticles become less heat-stable than its inner atoms. And this particle surface instability is the main cause of particle aggregation. In terms of application, it requires excellent temperature stability of nanofluid for practical use [1,2]. Therefore, it is necessary to investigate into the temperature attributes of nanomaterials before exploring their practical application.

The experiment of this study applies self-developed temperature controlling equipment to simulate the working temperature of nanofluid. When

prolonged preservation in deionized water under various low-than-room temperature settings. In order to find out whether the suspended nanoparticles of copper oxide produced by Submerged Arc Nanoparticle Synthesis System (SANSS) can stay in a stable state of even suspension and maintain a good dispersion level. The particle size and distribution of nanoparticles are examined after the temperature control experiment in order to understand how temperature change can affect particles. The experiment findings of this study are expected to be a good reference for practical nanofluid applications requiring particle stability under changing working environment temperatures.

2. EXPERIMENT

Suspended particles in solution have a general propensity of aggregation due to Van der Waals effect

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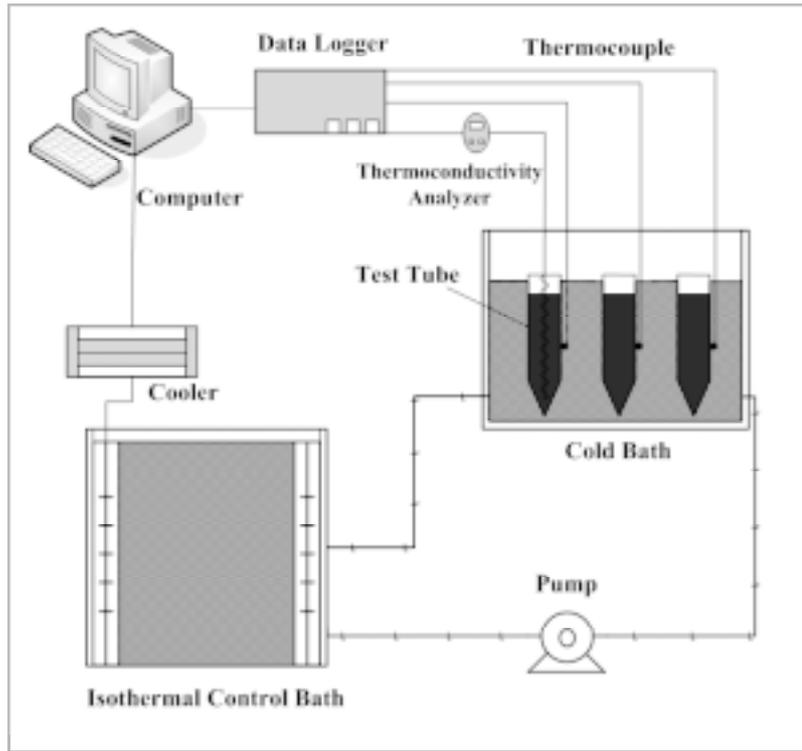


Fig. 1. Schematic diagram of the experiment equipment.

between particles. The electric double-layer of certain electric potential absorbed onto the surface of a particle provides a repulsive force to offset the Van der Waals force. These are the two determining factors of the aggregation of solution-borne suspended particles. In other words, when the attraction effect of Van der Waals force is stronger than the repulsive force between electrical double-layers, aggregation phenomenon takes place [3,4].

The potential energy E_v produced by Van der Waals force between two particles with a radius r can be expressed as:

$$E_v = -\frac{A r}{12 l} \quad (1)$$

In Eq. (1), l denotes the shortest distance between particles, r is particle radius, and A is constant. The potential energy produced by the electrical double-layer can be expressed as:

$$E_o \approx \frac{\epsilon r \psi_0^2}{2} \exp(-kl), \quad (2)$$

where ϵ is the dielectric constant, ψ_0 is the particle surface potential, and k is the degree of diffusion of electric double-layer, which can be expressed as:

$$k = \left(\frac{2e^2 N_A C Z^2}{\epsilon K T} \right)^{\frac{1}{2}}, \quad (3)$$

where e denotes the electric charge, N_A is the Avogadro constant, C is the Molarity of electrolyte, and T is the absolute temperature.

The experiment equipment is illustrated in Fig. 1. Test tubes are 20 mm in outer diameter with 0.5 mm thickness. The tubes were made of polypropylene. Each sample of nanofluid in the test tubes was 40 ml in volume. Test tubes were put in a cold bath and cooled with a constant cooling rate of 1 °C/min by circulating ethylene glycol, which temperature was controlled in an isothermal control bath. The actual temperature error is kept between 0.1 °C. A K-type thermocouple was attached to the outer surface of the test tube. In order to the initiation of freezing could still be detected by a small jump of temperature measurements.

The copper oxide nanofluid used in the experiment is produced by the SANSS [5]. The manufacturing parameters using the processing parameters generated under a relatively good particle size distribution with copper as electrode. The CuO nanofluid with the means of particle size of the obtained cop-

per oxide particle average length is 80 nm and width is 30 nm. The CuO nanofluids used in this experiment is 2 wt.%. The ultrasonic wave was applied to the nanofluid so that the CuO nanoparticle was dispersed well in the tube before conducting the experiment.

The particle size is measured immediately after nanofluid is retrieved from the cold bath device in order to reduce any possible error with the measurement. The particle size distribution and mean secondary particle size is measured by particle-size analyzer (PSA, HORIBA LB-500, Japan). The thermal conductivity of nanofluid was analyzed by thermal conductivity analyzer (Transient Hot-Wire Method, KD2, USA).

3. RESULTS AND DISCUSSION

The influence of the duration of warmth keeping under a fixed temperature on particle size is examined. As the water temperature is controlled at the set level, six tubes of nanofluid with the same component and capacity are placed on the cold bath, taking warmth-keeping time as variable. The tubes are taken out from the cold bath at an interval of 10, 30, 60, 120, 240, and 480 min., respectively for mean secondary particle size and thermal conductivity measurement.

Fig. 2 summarizes the heating time and mean secondary particle size changes under six different temperature settings. As the figure shows, under an environment temperature of 30 °C, the mean particle size gradually dilates from 80 nm at the beginning of the experiment to 146.4 nm after 30 minutes into the experiment. Thereafter, the mean particle size starts to fall to a 139.8 nm and maintains in a stable condition until 480 minutes. Under an environment temperature of 20 °C, the mean particle size gradually dilates from 80 nm at the beginning of the experiment to 105.6 nm after 30 minutes into the experiment. Thereafter, the mean particle size maintains in a stable condition until 480 minutes. Under an environment temperature of 10 °C, the mean particle size gradually dilates from 80 nm at the beginning of the experiment to 109.4 nm after 30 minutes into the experiment. Thereafter, the mean particle size starts to fall to a stable condition and maintains in a level until 480 minutes. Under an environment temperature of 0 °C, the mean particle size gradually dilates from 80 nm at the beginning of the experiment to 118.1 nm after 10 minutes into the experiment. Thereafter, the mean particle size starts to fall to a 92.5 nm after 60 minutes. The mean particle size starts to rise to a 118.8

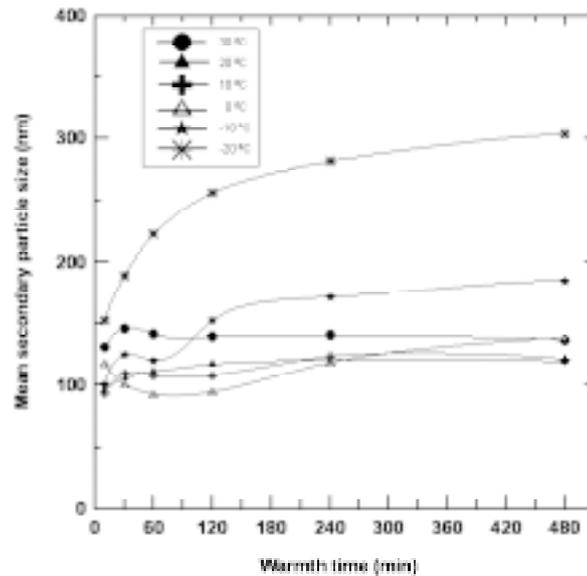


Fig. 2. The relation of mean secondary particle size between warmth time and environment temperature.

nm after 240 minutes maintains in a stable rise condition until 480 minutes into the experiment. Under an environment temperature of -10 °C, the mean particle size gradually dilates from 80 nm at the beginning of the experiment to 100.1 nm after 10 minutes into the experiment. Thereafter, the mean particle size starts to rise to a 152.3 nm after 240 minutes and maintains in a stable rise condition until 480 minutes. Under an environment temperature of -20 °C the mean particle size gradually dilates from 80 nm at the beginning of the experiment to 152.6 nm after 10 minutes into the experiment. Thereafter, the mean particle size starts to rise to a 303 nm after 480 minutes and maintains in a stable rise condition until 480 minutes. As shown in the curve in Fig. 2, different environment temperatures of 30, 20, 10, and 0 °C result in similar mean secondary particle size trends on copper oxide nanofluid, in that the particle size augmentation ceases after a certain period of time and shrinks slightly afterwards. As the warmth-keeping time reaches 60 minutes, the mean particle size stops shrinking and finally stabilizes.

Temperature change will cause k value to change, which then transforms the size of the electric double-layer of copper oxide nanofluid. As Eq. (3) reveals, when the temperature difference is small, the impact on k value is minimal. Eq. (2) further shows a significant influence of the magnitude of surface electric potential on the electric double-layer. The pre-

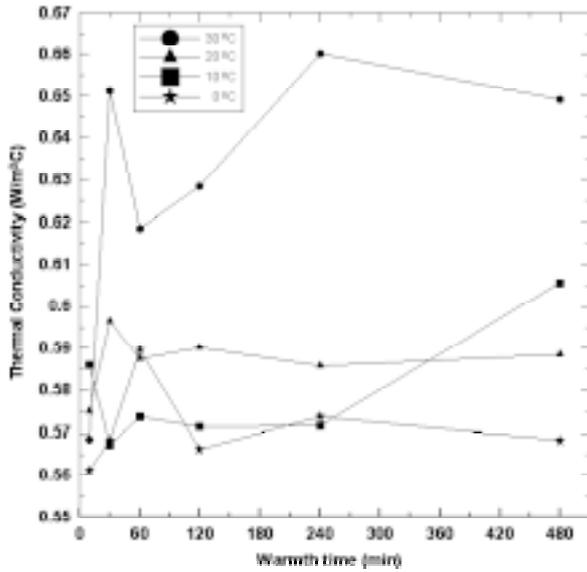


Fig. 3. The curves of thermal conductivity between warmth time and environment temperature.

cooling copper oxide nanofluid has an average surface electric potential of 45.7 mv. However, after cooling the average electric potential drops to 23.4 mv. In other words, surface electric potential change is another contributing factor of aggregation. At the environment temperatures of $-10\text{ }^{\circ}\text{C}$ and $-20\text{ }^{\circ}\text{C}$ however, the accelerated particle movement caused

by the change in work temperature and the change in surface electric potential of suspended particles after temperature fall are the main contributors of the aggregation phenomenon.

Fig. 3 shows the thermal conductivity between warmth time and cooling temperature. The curves of the conductivity are match with mean secondary particle size in Fig. 2. As can be seen, there is great discrepancy between the ratios of effective thermal conductivity to the original fluid. The nanofluid consisting of CuO nanoparticles have been observed to improved thermal conductivity enhancement. It should be note that thermal conductivity is followed mean particle size.

Fig. 4a is the uncooled nanofluid TEM image, which indicates a good diffusion of CuO nanoparticles in a needle-like shape. Fig. 4b is the TEM image with a cooling temperature of $-20\text{ }^{\circ}\text{C}$, which indicates relatively thick nanoparticles and a partial aggregation phenomenon in a wider particle shape than that of Fig. 4a.

4. CONCLUSIONS

Copper oxide nanofluid can be affected by temperature and that the mean secondary particle size will increase due to fine particle absorption. The lower the temperature is, the faster the reaction becomes. After a period of time, the thermal gradient will gradually reduce, which causes particles without suffi-

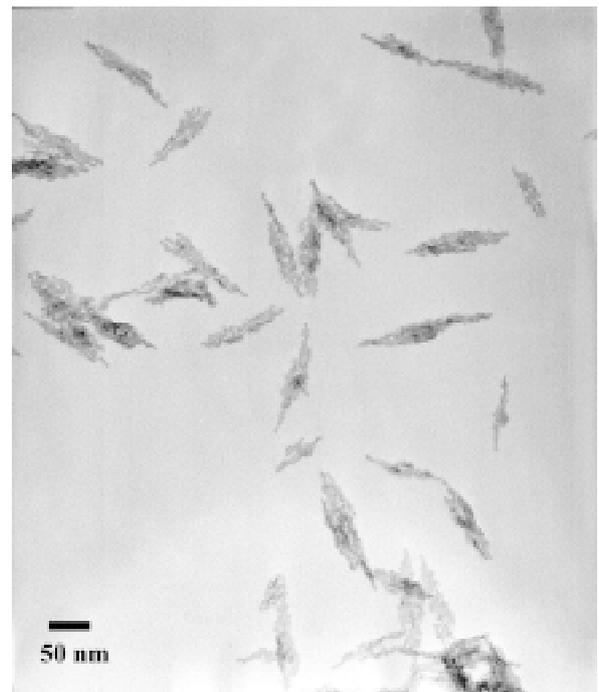
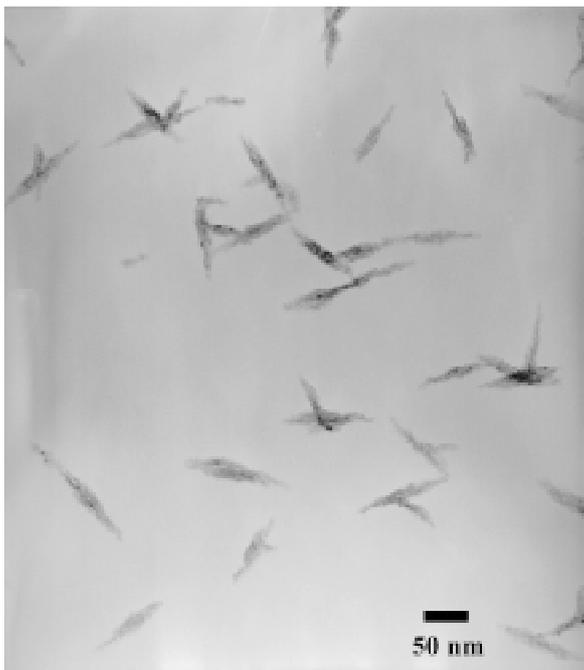


Fig. 4. TEM image of (a) un-cooled (b)cooled (at $-20\text{ }^{\circ}\text{C}$) CuO nanoparticles.

cient absorption to come off, resulting in decreased mean particle size. Finally, as the time passes, the particle size distribution will gradually stabilize. The influence of temperature in terms of causing static repulsion to affect particle aggregation is not significant, while the particle acceleration and surface electric potential change are the main factor influencing the stability of nanofluid. Nanoparticle preservation can be achieved through controlling the size of the double-layer. However, considering the fact that the ambient temperature has a great impact on the aggregation feature of copper oxide nanofluid, it is essential to take into account such temperature effects in order to maintain the stability of copper oxide nanofluid in practical application.

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