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Effect of Particle Size and Aggregate on Thermal Conductivity in Nanofluid using Silica Particle

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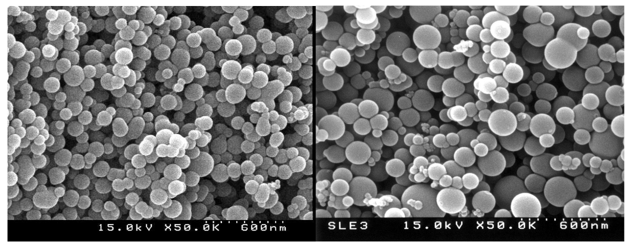
Recently, the 'nanofluid' which contains nano-sized particles in certain liquid has been shown extremely high thermal conductivity. For example, the measured enhancement in thermal conductivity for 1.0vol% carbon nanotubes in oil is 160% while the predicted theoretical value is not more than 10%.[1] Yu et al also reported that the nanofluid using the nanopowder of ~10 nm in diameter shows that the thermal conductivity increases exponentially.[2]

It is well known these days that the thermal conductivity in nanofluid depends on many factors related to materials such as the kind and size of particle, and the concentration and dispersibility of particle in solution.[3] Many works in the material aspect on thermal conductivity in nanofluid are now under way. Generally it is known in nanofluid that the smaller particle, the better thermal conductivity.[2] However, the reduction of particle size leads to the agglomeration between nanoparticles and then brings about settling after the separation of particle from solution. In this work, we present that silica nanopowder with different sizes and aggregates is manufactured both by flame method and by aerosol-assisted chemical vapor synthesis (AACVS), and it is investigated on the effects of the particle size and aggregate on the thermal conductivity.

A precursor of tetraethylorthosilicate (TEOS) was used for synthesis of SiO_2 nanopowder. TEOS has boiling temperature of 208.33ºC, molar weight of 208.33 g and density of 0.934 g/cm^3. In the flame method, TEOS was vaporized from the bottle immersed in the oil bath and transported to the burner nozzle with nitrogen as a carrying gas. The amount of TEOS precursor was controlled by temperature of oil bath and flow rate of nitrogen gas. The flow rates of oxygen (oxidizer) and methane (fuel) were varied separately. In the AACVS, the carrier gas of 1.0 bar was supplied in to the aerosol generator and made the droplets of ~1 ㎛ of TEOS. The droplets were vaporized at the furnace of 800℃ and simultaneously were synthesized as SiO_2 nanoparticle.

The morphology and size distribution of SiO_2 nanopowder were observed with a field emission scanning electron microscopy (FESEM, Philips XL 30) and transmission electron microscopy (FEI Tecnai G^2). The specific surface area of SiO_2 nanopowder was measured by BET.

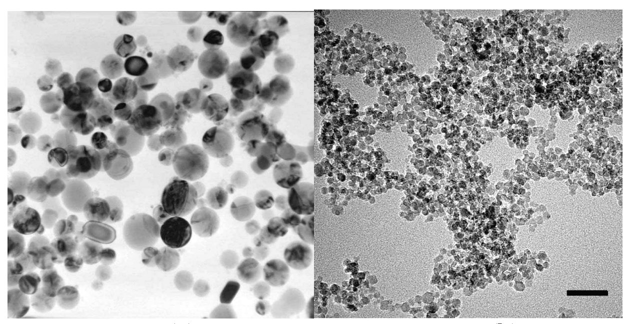
Figure 1 shows SEM morphologies of SiO_2 nanopowder made by flame method. In the synthesis of nanopowder using flame method, particle size is influenced not only by the feeding rate of precursor which depends on the flow rate and the temperature of oil bath, but also by the flow rate of oxygen (oxidizer) and methane (fuel). In Figure 1, the particle size increases with increasing the flow rate of oxygen. It means that we can control the particle size by controlling the flame condition. The typical SiO_2 nanopowder made by flame method has a spherical shape of 50~150 nm in average diameter and then has high possibility, which each particle can move independently in solution without making the flocculation.



(a) (b)

Fig. 1. SEM microstructures showing SiO_2 nanopowders synthesized at two kinds of oxygen flow rates. Here the flow rate of methane and carrier gas (N_2) fixed as a constant.
(a) oxygen/methane/nitrogen = 0.5/0.3/0.5
(b) oxygen/methane/nitrogen = 3.0/0.3/0.5

Figure 2 shows TEM micrographs of SiO_2 nanopowder synthesized (a) by flame method and (b) by AACVS. The average size of each particle is about 70 nm and 5 nm in diameter, respectively.



(a) (b)

Fig. 2. TEM microstructures showing SiO_2 nanopowders synthesized (a) by flame method and (b) by AACVS. The gas ratio by the flow rate was same in two methods. The pressure of reaction chamber in flame method was atmosphere, while one in AACVS kept the pressure of 10 mbar during manufacturing the SiO_2 nanoparticle by throttle valve. Oxygen/methane/nitrogen is corresponding to 1.0/0.3/0.5 and the scale bar indicates 50 nm

Two kinds of SiO_2 powders in Figure 2 show a clear difference in the aspect of powder metallurgy. The silica manufactured by AACVS was smaller 14 times in size than that made by flame method, while has a severe agglomeration. Generally the spherical particle has a monodisperse property. Therefore, we expect that SiO_2 nanopowder manufactured by flame method will have good dispersion stability in the insulating oil of nanofluid. On the other hand, the aggregates formed in the SiO_2 nanopowder of 5 nm will act as a coarse particle in solution and have a low stability. It will be discussed on the effects of the particle size and aggregate of SiO_2 nanopowder on the thermal conductivity in nanofluid

References

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