Abstract

Nanofluids have emerged as a resourceful alternative for conventional heat transfer fluids due to its enhanced thermophysical properties. However, the practical application of nanofluids is still challenging due to the high cost of nanomaterials, poor stability of the fillers, and lack of predictability of performance. The primary objective of this dissertation is to prepare various cost-effective copper-based nanofillers and compare them for heat transfer (nanofluid) applications. First, we have presented a synthetic protocol for production of sub-10 nm copper nanopowder using continuous stirred tank and tubular flow reactors. Substantially higher throughputs of copper nanoparticles have been achieved in this new protocol by reducing a precursor of copper with hydrazine hydrate/sodium borohydride. Copper nanopowder can be prepared from the sol by centrifugation of the colloid. The proposed synthesis protocol is also greener in compared to other protocols available because it recycles part of the unused material. Second, we have performed green production of sub-100 nm copper particles in kilogram-scale in batch and continuous mode. The proposed method relies on the higher solubility of cuprammonium complex in an aqueous medium and its chemical reduction using hydrazine hydrate. Cost of production is minimal in this method, and nanoparticles are separated from the suspension by a controlled flocculation process instead of time and energy-consuming centrifugation. Moreover, sodium citrate was used as a greener stabilizer in this case. Our subsequent work deals with the synthesis of copper nanowires in gram-scale via wet chemical reduction with ethylenediamine mediated anisotropic growth. In this study also, unreacted reactants have been successfully recycled for subsequent batches after precise quantification by a combination of titration, spectroscopy, and chromatography. Consequently, the improved method reduces the cost of production substantially. Next, we have focused on gram-scale synthesis of copper nanoplates in aqueous phase by using ascorbic acid as a green reducing agent and cetyltrimethylammonium bromide for bidirectional growth of copper. Nanopowder has been extracted with good yield by selective centrifugation. Stable copper nanofluids have been prepared by dispersing copper nanofillers of different morphology (nanoparticles, nanowires, and nanoplates) in ethylene glycol. The Kapitza resistance was significant for small sub-10 nm particles, and no enhancement has been achieved with this type of copper nanofillers. Moderate enhancement (~5%) in thermal conductivity has been observed with 0.6 vol% loading of sub-100 nm copper nanoparticles. Although the Kapitza resistance was reduced and the loading was increased to a reasonable extent, the enhancement achieved was not impressive. Whereas, a significant 20% and 12% enhancements in thermal conductivity have been achieved using 0.15 vol% of copper nanowires and copper nanoplates respectively. Such types of elongated nanostructures probably provide a percolated path for fast conduction of heat in the low conducting fluid. 3-D heat transfer models for nanofluids were created using COMSOL. It is found that simple diffusion model was able to explain the data to a reasonable extent. Hence, elongated nanofillers are essential for enhancement in thermal conductivity of nanofluids.

Keywords: *copper nanoparticles, copper nanowires, copper nanoplates, continuous synthesis, CSTR and PFR, nanopowder, large scale, green synthesis, nanofluid, thermal conductivity enhancement, COMSOL, simulation*