# SYNTHESIS, CHARACTERIZATION AND THERMAL CONDUCTIVITY MODELLING OF NANOFLUIDS FOR ADVANCED HEAT TRANSFER APPLICATIONS

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by

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# ABSTRACT

Now-a-days, efficient thermal management has become one of the top technological challenges innumerous industrial sectors, such as electronics, automobile, manufacturing, etc. due to constant demand for faster processing speeds along with miniaturization of the devices. The poor heat transfer properties of most of the commonly used working fluids, namely, water, ethylene glycol, engine oil, mineral oil, etc. are the major constraints in improving the performance and compactness of engineering equipments. The advancement of nanotechnology provides an opportunity to overcome the limited heat transfer capability of these conventional heat transfer fluids by dispersing nanoparticles in the fluids to enhance their heat transfer performance. This type of fluids in which nanoparticles are dispersed are called "nanofluids" and have attracted great attention in many cooling systems in engineering applications due to their markedly enhanced thermal conductivity. It is expected that the nanofluids will be the next generation heat transfer fluids. With the advances in nanotechnology, it is now possible to synthesize nanoparticles with desired size, shape, composition and morphology, as well as to control their dispersion properties. Use of smaller particle sizes of highly conductive metals like Ag, Cu, etc. in nanofluids can meet the requirement of high heat transfer capability of the coolant fluids. However, the stability of nanofluids, particularly when reactive metals like Cu in nano-scale sizes are used in base fluids like water, is likely to be hampered. On the other hand, the use of noble metals like Ag in nanofluids is not recommended due to their high cost. Keeping these factors in mind, nanofluids containing Ag-Cu alloy nanoparticles can be thought as an alternate cooling medium to suppress the oxidation problem of Cu nanoparticles, as well as to reduce the cost of Ag nanoparticles by alloying. Although experimental and theoretical studies reported in most of the literatures have shown anomalous enhancement in thermal conductivity of nanofluids even at low particles concentrations, the poor understanding on the heat transfer mechanism in nanofluids and the lack of proper theory and model for explaining the anomalous enhancement in the thermal conductivity of nanofluids pose hindrance to design the nanofluids and their efficient performance in target applications. Therefore, it is clear that there is a need to develop a systematic approach to prepare different types of nanofluids with markedly enhanced thermal conductivity and high stability and also to compare the experimentally obtained thermal conductivity with the theoretical model.

In the present work, the thermal conductivity of nanofluids containing pure Ag, pure Cu and Ag-Cu alloy nanoparticles has been explored, where pure Ag, pure Cu and Ag-Cu alloy nanoparticles have been synthesized through wet chemical method at room temperature without using any inert gas protection. The synthesized nanoparticles have been characterized by different structural and compositional characterization tools to confirm morphology, composition, crystal structure, size and size distribution of the particles. A simple two-step method demonstrated in this study offers new opportunities in the production of nanofluids containing the pure Ag, pure Cu and Ag-Cu alloy nanoparticles with significantly enhanced thermal conductivity as well as high stability needed for practical applications. Experiments have revealed that the thermal conductivity of nanofluids enhances significantly with loading of nanoparticles. Moreover, it has been observed that the nanofluids possess excellent stability for long period of time. Apart from the experimental studies, a multiscale model comprising of molecular dynamics and Brownian dynamics techniques has been developed in the present work to estimate the enhancement in thermal conductivity of water based Ag nanofluid. The predicted enhancements in thermal conductivity of Ag nanofluids with varying volume fraction loading of nanoparticles are found to be in well agreement with the present experimental data and hence, this model can be used for designing nanofluids for practical heat transfer applications. It is worthy to mention here that the present study would open a facile and effective strategy for the development of stable and effective nanofluids for advanced thermal applications.

***Keywords:*** Nanofluid; Nanoparticles; Thermal conductivity; Stability; Molecular dynamics; Brownian dynamics; Multiscale modelling and simulations.