Synthesis, stability, and thermophysical properties of aqueous colloidal dispersions of multi-walled carbon nanotubes treated with beta-alanine

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ABSTRACT
In the present study, multi-walled carbon nanotubes (MWCNTs) with outside diameters of < 8 nm and 20 – 30 nm were covalently functionalized with β-Alanine using a novel synthesis procedure. The functionalization process was proved successful using Raman spectroscopy, FTIR, and TEM. Utilizing the two-step method with ultrasonication, the MWCNTs treated with β-Alanine (Ala-MWCNTs) with weight concentrations of 0.05%, 0.09%, 0.075%, and 0.1% were dispersed in distilled water to prepare water-based nanofluids. The aqueous colloidal dispersions of pristine MWCNTs were unstable. While for Ala-MWCNTs and after > 50 days from preparation, higher colloidal stability was obtained up to relative concentration of 0.95% and 0.939% for the 0.075-wt% samples of Ala-MWCNTs < 8 nm and Ala-MWCNTs 20 – 30 nm, respectively. The measured values of thermal conductivity were in very good agreement with the model of Narr, Birringer, Clarke and Glättler and increased as temperature, specific surface area (SSA), and weight concentration increased, up to 14.74% for Ala-MWCNTs < 8 nm and 12.59% for Ala-MWCNTs 20 – 30 nm. The viscosity increased as weight concentration increased, up to 25.69% for 0.1-wt% Ala-MWCNTs 20 – 30 nm, and decreased with the increase in temperature. Since the matching between the measured values of viscosity and the classical models of Batchelor, Brinkman, and Einstein was bad, a correlation was developed and revealed good agreement. The density and specific heat decreased as temperature increased. As weight concentration increased, the density slightly increased up to 0.065% for Ala-MWCNT < 8 nm while the specific heat decreased down to 0.95% for Ala-MWCNTs 20 – 30 nm, in comparison with water. The equations of (Pak and Cho) and (Kuan and Rosseti) were in good agreement with the measured values of density and specific heat, respectively. The aqueous colloidal dispersions of Ala-MWCNTs that were prepared in this work displayed robust condensates as successful substitutes for the conventional heat transfer fluids in different engineering applications for enhanced thermal performance.

1. Introduction

To enhance the heat transfer yield of different heat exchangers, nanofluids with superior thermal conductivity and selectable rheological and functional properties have recently introduced [1–5]. After introduction of nanofluid by Choi and Eastman [6] in 1995, different types of nanofluids in accordance with different applications were synthesized, e.g., fouling mitigation, drug delivery, improved heat transfer rate, and antinociceptive properties [7–10]. Among all the applications, a majority of nanofluids are employed in heat transfer apparatuses in order to enhance the heat transfer rate in comparison with the conventional heat transfer fluids. To this end, different additives such as metal oxides nanoparticles, metals nanoparticles, and carbon-based nanostructures were applied. The main problems with metal and metal oxide nanoparticles are their weak colloidal stability and the lack of chemical treatment in the presence of these nanoparticles [11–15]. Alternatively, carbon-based nanostructures are great candidates that can be used as additives due to the promising properties, e.g., excellent thermal conductivity, capability for different chemical manipulations such as functionalization, purification and decoration; and favorable potential for enhancing the solubility/hydrophilicity to the desired level [10,14]. Among all carbon-based nanostructures, some of the

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