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Application of the modulated temperature differential scanning calorimetry technique for the determination of the specific heat of copper nanofluids

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ABSTRACT

The purpose of this work is to investigate the applicability of the modulated temperature differential scanning calorimetry technique to measure specific heat of copper nanofluids by using the ASTM E2719 standard procedure, which is generally applied to thermally stable solids and liquids. The one-step method of preparation of copper nanofluid samples is described. The synthesized nanoparticles were separated from the base fluid and examined by X-ray diffraction and transmission electron microscopy in order to evaluate their structure, morphology and chemical nature. The presence of copper nanoparticles in the base fluid alters the characteristics of crystallization and melting processes and reduces the specific heat values of nanofluids in the whole studied temperature range.

1. Introduction

Energy production is one of the most relevant subjects nowadays; about 70% of consumed energy is currently produced through the form of heat. Considering the large increase in demand for world energy consumption, improvements in heat transfer processes and the reduction of energy losses become important tasks [1]. Intrinsically, the energy conversion and energy transport processes operate at atomic or molecular levels. The use of materials with characteristic dimensions at nanometric scale may affect physical phenomena that control the energy transformation processes at microscopic level and result in improvement of overall macroscopic properties of materials. This gives a basis for high expectations with respect to the nanoscience and nanotechnology in revitalizing the traditional energy industries and stimulating emerging industries of renewable energy production.

Refrigeration is a technical challenge for most of industries, such as transportation, electronics, medical and food production (to mention a few), because the respective industrial processes involve a heat transfer. The thermal conductivity is a primary property that reflects the ability of a medium to conduct heat. Normally, liquids are better heat conductors than gases and vapors. For example, the conductivity of air is approximately $0.03\ \mathrm{W\,m^{-1}\,K^{-1}}$, while the water is about $0.6\ \mathrm{W\,m^{-1}\,K^{-1}}$. On the other hand, solids are better conductors than liquids. Metals, such as silver and copper have conductivity around $400\ \mathrm{W\,m^{-1}\,K^{-1}}$ and, for example, carbon nanotubes have particularly high thermal conductivity in the order of $3000\ \mathrm{W\,m^{-1}\,K^{-1}}$. Therefore, a straightforward solution to the problem of insufficient cooling efficiency of cooling systems is to increase the conductivity of a fluid by introducing in it suspended solid particles [2,3].

Since thermal conductivity of a fluid is an extremely important factor in developing of efficient heat transfer equipments, numerous theoretical and experimental studies on how to increase thermal conductivity of a liquid suspension of small particles have been conducted for more than a century. Initially, these studies were concentrated on particles with size ranging from micrometer up to millimeter. The main problems found when using these types of suspensions are related to the rapid sedimentation of particles, clogging flow channels and producing a pressure drop in the fluid. In order to avoid sedimentation, the rate of fluid circulation is kept very fast, which can damage the walls of the micro heat transfer devices (e.g. pipes and channels). In contrast, nanoparticles can remain in suspension due to its large surface/volume ratio, reducing therefore erosion and obstruction of flow channels. Nanoparticles are also suitable for the use in micro cooling systems, since they are smaller (by many orders of magnitude) than design elements of these systems [4].

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