International Communications in Heat and Mass Transfer 38 (2011) 767–773

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

The impact of various nanofluid types on triangular microchannels heat sink cooling performance ☆

H.A. Mohammed *, P. Gunnasegaran, N.H. Shuaib

Department of Mechanical Engineering, College of Engineering, Universiti Tenaga Nasional, Km 7, Jalan Kajang-Puchong, 43009 Kajang, Selangor, Malaysia

ARTICLE INFO

Available online 9 April 2011

Keywords:
Numerical simulation
Triangular microchannel heat sink
Nanofluids
Heat transfer enhancement

ABSTRACT

This paper discusses the impact of using various types of nanofluids on heat transfer and fluid flow characteristics in triangular shaped microchannel heat sink (MCHS). In this study, an aluminum MCHS performance is examined using water as a base fluid with different types of nanofluids such as Al_2O_3, Ag, CuO, diamond, SiO_2, and TiO_2 as the coolants with nanoparticle volume fraction of 2%. The three-dimensional steady, laminar flow and heat transfer governing equations are solved using the finite volume method. It is inferred that diamond-H_2O nanofluid has the lowest temperature and the highest heat transfer coefficient, while Al_2O_3–H_2O nanofluid has the highest temperature and the lowest heat transfer coefficient. SiO_2–H_2O nanofluid has the highest pressure drop and wall shear stress while Ag–H_2O nanofluid has the lowest pressure drop and wall shear stress among other nanofluid types. Based on the presented results, diamond-H_2O and Ag–H_2O nanofluids are recommended to achieve overall heat transfer enhancement and low pressure drop, respectively, compared with pure water.

1. Introduction

Recent developments in nanotechnology and thermal management techniques for improving cooling technology for electronic devices with high heat generation have made possible production of efficient and compact cooling modules to provide reliable system operation. Inspired by the microchannel heat sink (MCHS) idea proposed by Tuckerman and Pease [1] in 1981, many ideas for improving the heat transfer performance of MCHS have been proposed. One of it, due to the development in nanotechnology, is the recent discovery of using nanofluids as coolant in MCHS. Nanofluid is envisioned to describe a fluid in which nanometer-sized particles are suspended in conventional heat transfer basic fluids such as oil, water, and ethylene glycol. Since the thermal conductivity of solid nanometer-sized particles with scales of 1–100 nm such as Al_2O_3, CuO, Cu, and TiO_2 are typically higher than the base fluids even at low concentrations, the heat transfer enhancement of nanofluid-cooled MCHS is expected compared with conventional heat transfer liquid-cooled MCHS [2].

Thus, the potential benefit of using nanofluids as high performance coolants has enticed engineers and researchers to develop such possibilities especially in MEMS applications [3]. Chein and Chuang [4] studied experimentally the heat transfer performance of a silicon trapezoidal shaped MCHS using CuO–H_2O nanofluid as coolant. They found that nanofluid-cooled MCHS could absorb more energy than pure water-cooled MCHS when the flow rate was low. However, for high flow rates, the heat transfer was dominated by the volume flow rate and nanoparticles did not contribute to the extra heat absorption. Lee and Mudawar [5] performed microchannel cooling performance of water-base nanofluids containing small concentrations of Al_2O_3 experimentally. They found that the higher heat transfer coefficients were achieved particularly in the entrance region of microchannels. The results show that nanoparticles are not suitable to be used in two-phase MCHS. Koo and Kleinstreuer [6] computed numerically the conjugate heat transfer characteristics of MCHS using CuO–H_2O and ethylene glycol (EG) nanofluids. They employed a new model for the effective thermal conductivity and dynamic viscosity of nanofluids. They suggested that a base fluid of high-Prandtl number such as ethylene glycol and oil should be used, and using nanoparticles with high thermal conductivity are more advantageous, and a channel with high aspect ratio is desirable.

Lee et al. [7] used 38.4 nm of Al_2O_3 and 23.6 nm of CuO particles to enhance the thermal conductivity of water and EG. It was found that the percentage enhancement in thermal conductivity was not only a function of concentration and conductivities of the particles material and liquid, but it is also function of particle size and shape. The heat transfer performance of a silicon MCHS using CuO–H_2O nanofluid as a coolant with various particle volume fractions was analytically studied by Chein and Huang [8]. They found that the performance was greatly improved by using nanofluids as the coolants compared with pure water due to the increase in thermal conductivity of coolant and the nanoparticles thermal dispersion effect. Jang and Choi [9]

☆ Communicated by W.J. Minkowycz.

* Corresponding author.
E-mail address: hussein@uniten.edu.my (H.A. Mohammed).

0735-1933/$ – see front matter
doi:10.1016/j.icheatmasstransfer.2011.03.024