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Influence of various base nanofluids and substrate materials on heat transfer in trapezoidal microchannel heat sinks ☆

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ABSTRACT

Numerical investigations are performed to investigate the laminar flow and heat transfer characteristics of trapezoidal MCHS using various types of base nanofluids and various MCHS substrate materials on MCHS performance. This study considered four types of base fluids including water, ethylene glycol (EG), oil, and glycerin with 2% volume fraction of diamond nanoparticle, and four types of MCHS substrate materials including copper, aluminium, steel, and titanium. The three-dimensional steady, laminar flow and heat transfer governing equations are solved using the finite volume method. It is found that the best uniformities in heat transfer coefficient and temperature among the four mixture flows can be obtained using glycerin-base nanofluid followed by oil-base nanofluid, EG-base nanofluid, and water-base nanofluid heat sinks. However, the heat transfer performance of water-base nanofluid can be greatly enhanced in steel made substrate heat sink.

1. Introduction

The improvement of cooling technology for electronic devices with high heat generation due to the recent technology advances in microprocessor, microchips, and various other micro scales such as microreactors, fuel cells, and micro-heat sinks, high power applications is constrained by effective heat removal. For the two decades following the pioneering work proposed by Tuckerman and Pease [1] in 1981 which is the microchannel heat sink (MCHS), many ideas for improving the heat transfer performance of the MCHS have been proposed. One of them, due to the development in nanotechnology, is the recent discovery of using nanofluids as coolants in the MCHS. Nanofluid is envisioned to describe a fluid in which nanometer-sized particles are suspended in conventional heat transfer fluids such as oil, water, and ethylene glycol (EG). 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 the nanofluid-cooled MCHS is expected compared with the 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].

Eastman et al. [4] outlined in their experimental work that nanofluid consisting of Cu nanometer-sized particles dispersed in ethylene glycol has a much higher effective thermal conductivity than either pure EG or EG containing the same volume fraction of dispersed oxide nanoparticle. The effective thermal conductivity of EG is shown to be increased up to 40% for a nanofluid consisting of EG containing approximately 0.3% of Cu nanoparticles. Xie et al. [5] investigated experimentally the thermal conductivity behaviors of nanometer-sized Al_2O_3 suspensions in water, oil, and EG. Their experimental results show that the addition of nanoparticles into base fluids leads to increase the thermal conductivities of the suspensions. The enhancement in thermal conductivity ratios increases with the volume fraction of nanoparticles.

Chein and Chuang [6] studied experimentally the heat transfer performance of a silicon trapezoidal shaped MCHS using CuO–H_2O nanofluid as a coolant. They found that the nanofluid-cooled MCHS could absorb more energy than the 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. 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 [7]. They found that the performance was greatly improved using nanofluids as coolants compared with pure water due to the increase in the thermal conductivity of coolant and the nanoparticles thermal dispersion effect. Jang and Choi [8] investigated numerically the temperature contours and thermal resistance of a MCHS using Cu–H_2O and diamond–H_2O nanofluids as coolants. Their results show that the cooling performance of a MCHS with water-base nanofluids containing diamond with 1% particle volume fraction was enhanced by about 10% compared with that of a MCHS with water. Therefore,

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