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TEMPERATURE VARIATION ON THE HEATED BASE OF A SOLID SUBSTRATE COOLED WITH DIFFERENT TYPES OF HEAT SINK

Adewumi O.O[1], Bello-Ochende T*[2] and Meyer J.P[1]
*Author for correspondence
[1]Department of Mechanical and Aeronautical Engineering,
University of Pretoria,
Pretoria 0002,
South Africa.
[2]Department of Mechanical Engineering,
University of Cape Town,
Cape Town,
South Africa.
Email: tunde.bello-ochende@uct.ac.za

ABSTRACT

Three-dimensional numerical studies were carried out to investigate forced convection heat transfer and fluid flow in a solid substrate cooled using different types of micro heat sinks. The objective of this study is to investigate which heat sink type gives the lowest temperature variation on the heated base of the solid substrate which is being cooled. A low temperature variation indicates a low temperature gradient which, in practical application, improves the reliability of the electronic device. The different heat sinks considered are single microchannels, two-layer microchannels with parallel and counter-flow of fluid, single microchannels inserted with circular-shaped micro pin fins and two-layer microchannels inserted with circular-shaped pin fins. All the heat sinks are geometrically optimised using a computational fluid dynamics code with a goal-driven optimisation algorithm subject to global constraints. The thermal performance of the heat sinks considered in this study is based on two objectives namely, the minimisation of the peak temperature which results in maximisation of the thermal conductance and the lowest temperature variation on the heated base. The heat sink with the largest value of thermal conductance and lowest temperature variation on the heated base for the range of pressure drop considered is chosen as the best heat sink design. Numerical results of thermal performance for fixed axial length of the solid showed that cooling the solid substrate with the two-layer microchannel with counter-flow of fluid gave the lowest temperature difference at base of the solid substrate and also performed best in maximising thermal conductance at pressure drops of 20 and 30kPa.

INTRODUCTION

After the pioneering work of Tuckerman and Pease [1] on the removal of high heat fluxes from microelectromechanical systems (MEMS) using single microchannels, numerous investigations have been carried out on the thermal performance of single microchannels [2-12]. The use of stacked microchannels has also been introduced to achieve more effective cooling while maintaining the uniform temperature of the chips because of the larger surface area available for fluid flow [13-15].
In the study carried out by Wei [14], it was observed that for water-cooled silicon microchannels with relatively high aspect ratio, no more than two layers should be stacked since there is no significant benefit in thermal performance beyond two layers while in analytical study carried out by Wei *et al.* [16] where a simple thermal resistance network model was developed and optimisation was carried out using genetic algorithms to minimise the overall thermal resistance of a stacked microchannel heat sink, the optimal number of layers was three for a constant pumping power of 0.01W. Some of the other investigations carried out on multi-layered microchannels are Wei and Joshi [17], Jeevan *et al.* [18, 19], Chong *et al.* [20] and Hung *et al.* [21].
Wei [14] also observed non-uniformity in temperature of the chip being cooled can tremendously affect the reliability and performance of electronic devices. His results showed that the two-layer microchannel with counter flow