Optimal Thermal Design of Converged-Diverged Microchannel Heat Sinks for High Heat Flux Applications

D. Chakravarthii¹, S. Subramani¹, M. Devarajan¹

¹University of Science Malaysia (USM), Georgetown, Penang, Malaysia

Abstract

INTRODUCTION:
With the advancements in aerospace technology, micro-electro-mechanical systems, hybrid data centres and microfluidics, the miniature size electronic chips in such applications are the need of the century. The major challenge in microelectronic chips is to eliminate the generated heat for stable and reliable operation of the devices. Microchannel heat sinks are efficient method to dissipate heat when the generated heat flux is more than 120 W/cm². The pressure drop and thermal resistance in the microchannel are the important parameters which determine the efficiency of the microchannel heat sink. The configuration of the microchannel in terms of thermal resistance and pressure drop is prior attention to design the microchannel heat sink. In this study, a converged-diverged (CD) microchannel heat sink was designed and optimized for the efficient pressure drop and thermal resistance condition [1].

USE OF COMSOL MULTIPHYSICS®:
In the microchannel heat sink, heat transfer takes place by conduction (through solids) as well as convection (through liquids). Hence, conjugate heat transfer is apt for performance study in microchannel heat sinks. Conjugate heat transfer module is utilized in COMSOL Multiphysics. Optimization module in the solver helps in identifying the optimized size of the microchannel. BOBYQA (Bound Optimization BY Quadratic Approximation) algorithm is used in the optimization solver of this study.

RESULTS:
BOBYQA is the optimization technique used along with the thermal resistance and pressure drop as the minimized goal function [2]. The microchannel heat sinks under study is shown in Fig.1. The models are simulated by COMSOL for detailed investigation [3]. In this study a constant input heat flux of 180 W/cm² is considered. The optimization domain range for microchannel dimensions is 500 µm (Minimum) to 3000 µm (Maximum) with converge-diverge angular constraint. On investigation, both BOBYQA and Conjugate heat transfer simulations, specify that the optimum channel size is found to be 3000µm-500µm with 51.34° converge-diverge angle. The total thermal resistance of the proposed microchannel heat sink is estimated to be 7.06 K/W which is 1.195 K/W less than the thermal resistance reported by Baodong Shao et al [1].

CONCLUSION:
The influence of converging diverging microchannel on heat transfer is proven for
superior thermal performance. The thermal resistance was found to be low for the microchannel dimension of 3000µm-500µm and this is considered as the optimal dimension for the CD microchannel heat sink. For the proposed microchannel, the pressure drop is calculated to be 10% higher than the 0.5mm straight microchannel and 51.75% higher than the 3mm straight microchannel. Converging Diverging section in the CD microchannel prompts for non-nucleated flow and periodic velocity rise which contributes for increased heat transfer. This can be proven by reduction in thermal resistance of CD microchannel heat sink. The $R_{th}$ of the CD microchannel heat sink is 7.04 K/W. Hence the proposed CD microchannel heat sink increases the overall thermal performance.

Reference


Figures used in the abstract

Figure 1: Microchannel heat sink.