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

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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/cm^2. 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 51.34º 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 Rth of the CD microchannel heat sink is 7.04 K/W. Hence the proposed CD microchannel heat sink increases the overall thermal performance.

Reference

[1] Baodong Shao, Lifeng Wang and Jianyun Li, "Application of thermal resistance network model in optimization design of micro-channel cooling heat sink", International Journal of Numerical Methods for Heat & Fluid Flow Vol. 19 Nos. 3/4, 2009 pp. 535-545.
[2] Min Woo Jeong, Seung Won Jeon, Yongchan Kim, "Optimal thermal design of a horizontal fin heat sink with a modified-opening model mounted on an LED module", Applied Thermal Engineering 91 (2015) 105-115.
[3] K. Jeevan et al, "Optimization of thermal resistance of stacked micro-channel using genetic algorithms", International Journal for Numerical Methods in Heat & Fluid Flow Vol. 15 No. 1, 2005 pp. 27-42

Figures used in the abstract

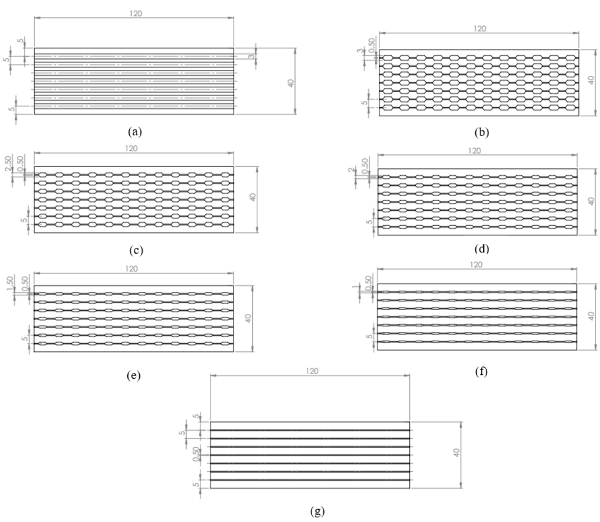

Figure 1: Microchannel heat sink.