ABSTRACT

Advances in electronic industry and compactness of devices have significantly increased the heat flux density which can lead to the failure of electronic equipment. Therefore, heat flux removal has become increasingly important to maintain temperatures of such devices within the acceptable limits. Microchannel heat sink has a significant potential of large heat removal due to its high heat transfer area to fluid volume ratio, which leads to its high heat transfer coefficient.

A conventional microchannel generally employs rectangular shaped channels in which fluid flows nearly along a straight line. In such microchannels heat transfer performance deteriorates due to a poor fluid mixing as boundary-layers thicken along the flow direction. An improvement in heat transfer is possible by flow disturbance using obstacles in the fluid domain, change in channel shape, and multi-layering of the channel, etc. These passive methods lead to interruptions of boundary-layers and an increased fluid mixing and as a result an enhanced heat transfer. The present study deals with a computational investigation of flow and heat transfer aspects of microchannels with the combination of various passive enhancement methods using CFD solver ANSYS Fluent 15.0 and FVM based open-source package OpenFOAM 3.0.0.

In the present study, a convergent-divergent shaped microchannel has been considered for *Re* ranging from 120 to 900 and the effect of this shape on flow structures and temperature distributions have been studied to evaluate the thermal performance of the considered microchannel against a reported rectangular shaped microchannel. The primary motivation behind a change in the channel shape is to increase the effective area available for heat transfer and to reduce convective thermal resistance. The results showed that *Nu* increases and thermal resistance reduces up to 20% over the range of *Re* considered.

Further ribs and cavities have been used with the convergent-divergent shaped microchannel in laminar flow condition. When ribs and cavities are included, the streamlines deflect to the cavity causing a stagnation zone. Fluid is again accelerated when passing over the ribs and the maximum velocity occurs. A combined effect of ribs and cavities produces jetting and throttling effects. Besides this behaviour, an increase in heat transfer area owing to the presence of ribs and cavities leads to heat transfer enhancement. The present results show that the ribs and cavities can reduce the thermal resistance up to 40% and make the bottom surface temperature quite uniform.

In another study where convergent-divergent shaped microchannel with bifurcation is considered, the flow is split into multiple flow streams leading to interruption and restart of boundary-layer resulting in an enhanced fluid mixing. It is observed that the heated surface temperature follows a rising and then falling trend and the substrate temperature was quite uniform along the flow direction. Furthermore, it is shown that increasing *Re* leads to thinning of thermal boundary-layers resulting in an enhanced heat transfer in terms of an increased average Nusselt number from 38% to 74%.

Turbulent heat transfer characteristics in a microchannel have also been carried out to investigate the effect of higher flow rates on thermal characteristics. The study aims at highlighting the abilities of higher flow rates with flow disruption methods for a relatively high heat transfer while keeping the pressure drop within an acceptable range. In the present study on the effects of the convergent-divergent shape with ribs and cavities on turbulent thermal characteristics using the SST k-ω turbulence model, a quite low thermal resistance of 0.03 K.cm^2/W has been achieved. Further in the case of the convergent-divergent shaped microchannel with bifurcation lower and smaller variations in the heated surface temperature are observed.

In a single-layer microchannel, the coolant flows in one direction and therefore the fluid temperature increases along the channel length. This behaviour results in deterioration in the temperature distribution uniformity leading to the development of thermal stresses and overheating. Multi-layering of microchannel reduces the undesired temperature variation along the channel length as the bottom channel is cooled by the top channel. In the present study, flow and thermal characteristics of a double-layered microchannel with bifurcation have been investigated for *Re* ranging from 50 to 900. The flow structures and temperature distributions are compared for parallel and counter-flow layouts and the effects of bifurcation plate on the overall thermal performance are also analyzed. It is observed that the double-layer microchannel with bifurcation provides the best performance in terms of a low thermal resistance and it decreases up to 40% over the range of *Re* considered. The double-layer microchannel with bifurcation also provides the lowest substrate temperature along the channel length than the corresponding non-bifurcated microchannel which are essential for an effective electronic cooling.