ABSTRACT

Ultra-thin vapour chambers have drawn significant attention of many researchers worldwide to address the cooling challenges offered by the modern electronic devices. These chambers are characterized by their high through plane thermal conductivity which helps in maintaining a uniform temperature and mitigate localized hot spots. The working principle of these devices involves dissipation of heat in the form of vapour via evaporation from the heated end, which then gets condensed at the other end (condenser section) after travelling through the vapour core region. The condensate travels back to the evaporator section through the peripheral porous wick structures and the cycle repeats itself to keep the system within the desired temperature range. The liquid flow in this device is caused by the capillary pressure gradient generated due to the change in the meniscus shape during evaporation-condensation cycle.

Introduction of microstructures in the evaporator section in order to promote the capillary action and therefore, the thermal performance of the vapour chamber has been investigated by researchers over the past several years. One such embodiment is introduction of micropillar arrays. In this thesis, the thin-film evaporation from micropillar array structure is investigated numerically from first principles and its impact on thermal performance is characterized in terms of two performance metrics viz. evaporator surface temperature and dry-out heat flux.

- The effect of topology variations of the micropillar array on the two performance metrics of thin-film evaporation has been thoroughly investigated. The thermal performance has been found to be strongly dependent on the interplay of permeability and capillary pressure gradient which again are significantly impacted by the topology of the micropillars.
- As the interplay of the permeability and capillary pressure effect is found to be significantly dependent on the pillar arrangement, the effect of variable axial spacing (pitch) as well as non-uniform heat flux at the at the evaporator surface has been explored in the subsequent study. The results show that the spacing of the micropillars relative to the hot spots is critically important in determining the overall performance of the vapour chamber.
- A new and unexplored idea of electro-osmosis assisted thin-film evaporation has been investigated next, keeping in mind the flow enhancing effect of electro-osmosis in microscale devices. Due to the addition of electro-osmosis, the flow, and consequently, heat transfer behavior is found to be significantly altered. With their combined effect, the dry-out heat flux

is found be enhanced by almost a factor of 4 times with negligible penalty in evaporator surface temperature.

- In the subsequent study, transient modeling of the complete vapour chamber has conducted taking in to account the transient interface variation in the evaporator and condenser sections. The fluid flow in the evaporator and condenser side has been linked to understand the passive pumping action in the evaporator. The time - mass flux plot for the mass of liquid leaving the evaporator and flowing back to it from the condenser are studied and related to the evolution of the pumping forces due to gradual changes in contact angle during the initial transient period before steady state is reached.
- The final topic of the thesis surveyed yet another novel electronic cooling idea by exploiting high density gradient property of supercritical CO_2 (sCO_2) with temperature via natural convection in a slender enclosure. This topic is studied numerically in Ansys fluent and the properties of sCO_2 with respect to both temperature and pressure variation is accessed from NIST database of fluent. The process of natural convection using sCO_2 for the considered domain is observed to be inherently unstable in nature. The cooling effects using sCO_2 are found to be comparable to that of water and substantially more effective than air.