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Aspects of Flow Boiling in Small to Micro Scale Heat Exchangers

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The high heat fluxes generated by modern electronic equipment necessitate a new approach to cooling these devices, as the dissipation of such high thermal loads using single-phase air or liquid heat sinks is no longer possible. The use of flow boiling in small to micro scale heat exchangers is consider as one of the most viable methods to help alleviate this thermal bottle neck – a few megawatts per meter square on average and reaching significantly higher values at the hot spots – allowing proper operation of these devices and new developments in the area. Other applications include possible use in small scale refrigeration systems, cooling of fuel cells, batteries and vehicle power electronics, solar photovoltaic panels and radar systems. The advantage of flow boiling in such systems is due to the possible small temperature difference of the substrate to be cooled reducing thermo-mechanical stresses and early failure plus small flow rates due to the high heat transfer coefficients resulting in smaller pumps and power consumption by the thermal management system. Fundamental issues that are currently being investigated in order to facilitate adoption of these small to micro scale evaporators include the definition of the macro to micro scale dimensions, the prevailing flow regimes and the effect of mass flux, heat flux, channel aspect ratio and length plus material and surface characteristics. These heat exchangers form part of a thermal system and the return temperature from the condenser and hence the possible degree of subcooling at the inlet of the evaporator is also a critical factor, bearing in mind the short lengths of the heat exchangers and the desire to achieve uniform substrate temperatures along the flow direction. The presentation will cover research in flow boiling in single tubes and channels and in multichannel heat exchangers with rectangular passages. Results for a microgap heat exchanger (single wide channel) of the same height and base area as the multi-channel heat exchangers will form benchmark comparative data. The effect of the parameters mentioned above plus the effect of coatings on the flow patterns, pressure drop and heat transfer rates will be presented. Flow instabilities will be discussed, along with ways to reduce their impact on the thermo-fluid characteristics of the evaporator. The development of correlations predicting the flow pattern boundaries, heat transfer rates and pressure drop will then be presented based on an analytical/statistical approach plus machine learning techniques. Finally, the integration of the micro evaporators in thermal management systems, which requires also the design of small-scale condensers will be discussed.