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Research in Flow Boling in Small to Microscale Heat Exchangers

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Thermal engineers are now faced with the challenging task of designing small to micro-scale heat exchangers that can dissipate extremely high heat fluxes from small surfaces encountered in a number of electrical and electronic applications. The drive towards electrification that can support the use of renewable energy sources and the subsequent reduction in carbon dioxide emissions will not be possible if this thermal bottle neck is not eliminated. In these circumstances, the heat flux to be dissipated ranges from a few megawatts per meter square to significantly higher values. High local component density can also result in hotspots, which require much higher heat flux dissipation rates. At the same time, the designers are also required to deliver these high-power density products to be reliable, efficient and of long lifespan.

Flow boiling in microchannels, directly in contact with the device to be cooled, is one of the best options to meet these current and future developments. They provide high heat transfer coefficients and a possible uniform temperature – below the maximum operational temperature limit of the device to be cooled. The above can be achieved at smaller mass flow rates and hence pumping power compared to, for example, single-phase liquid cooling systems. Additional applications of this method of cooling includes small scale refrigerators, fuel cells and cooling of photovoltaic panels.

The fundamental aspects of flow boiling in small to micro-scale tubes and channels are first mentioned in this presentation. The parameters affecting prevailing flow patterns, heat transfer rates and pressure drop in these designs are then discussed. These include mass flow rate, heat flux, degree of sub-cooling at the heat exchanger inlet and geometric parameters such as channel height and width, length and surface characteristics. Flow instabilities and flow reversal as well as events leading to critical heat flux will also be discussed. The current data will be compared with models and correlations predicting flow pattern transition boundaries, heat transfer rates and pressure drop. Recommendations for design of thermal systems for cooling high heat flux devices will finally be made.