ABSTRACT

Title of Dissertation: THERMAL MANAGEMENT OF HIGH-HEAT FLUX ELECTRONICS WITH INTERLACED FILM EVAPORATION AND ENHANCED FLUID DELIVERY SYSTEM (iFEEDS)

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The increasing power densities of electronic devices due to more compact package requirements make their thermal management a major challenge. Thermal management becomes exceedingly challenging with the ongoing efforts of 3D heterogeneous integration. State-of-the-art electronics can dissipate heat fluxes in excess of $1kW/cm^2$. Therefore, adequate cooling of these devices is required to increase their lifespan, maintain operational capabilities, and enable multifunctionality benefits of a heterogeneous integration. Evaporative cooling has demonstrated a significant heat removal potential in high flux electronics. Embedded cooling with thin film evaporation and enhanced fluid delivery system (FEEDS) has demonstrated significant heat dissipation from the high heat flux surfaces while yielding low pressure drops, thus an efficient operation. In this study, a proof-of-concept style experimental setup was first manufactured to demonstrate the cooling potential of the FEEDS cooler. Two different manifold geometries were experimentally tested to investigate the effect of manifold geometrical parameters on thermal and hydrodynamic

performance of FEEDS cooler. For this, the designed test sections were tested for single and two-phase flow performance. Both coolers demonstrated remarkable thermal performance at low pressure drop/pumping powers. Heat fluxes in excess of 1 kW/cm^2 were dissipated with a surface superheat temperature of 37°C and low-pressure drop penalties.

Based on the above experiments, a first-generation interlaced FEEDS (iFEEDS) cooler of 100W heat load was designed and fabricated. iFEEDS is a system of thinly packed layers with fluidic channels routed to create a manifold-microchannel cooler for realistic thermal management solutions. It utilized an embedded cooling approach in which the silicon microchannels are etched on the backside of power generating thermal test vehicle. Microchannels with aspect ratio's up to 20:1 were fabricated with deep reactive ion etching (DRIE) and bonded (thermocompression) to additively manufactured thin Titanium manifold (2 mm thickness). Two-phase flow regime experiments were conducted obtaining a maximum heat flux of ~700 W/cm^2 and temperature rise of 45°C. At 100W (500W/cm^2 heat flux), a surface superheat temperature of 27°C was recorded. The learnings from these experiments were used to design a second generation iFEEDS cooler which was to be stacked to demonstrate power scaling capabilities of the iFEEDS cooler. The manufacturing methodologies developed were used to fabricate two-stack (200W) and five-stack (500W) thermal test vehicles with four and ten heat dissipating sources respectively. A stack pitch of 2.7 mm was achieved. The fabricated test vehicles were characterized for thermal and hydrodynamic performance. Both test vehicles successfully demonstrated the power scalability of the iFEEDS cooler. The current study is the first to characterize the behavior of manifold-microchannel heat sinks in a multi-stack assembly for cooling of heterogeneously integrated high flux electronics for diverse applications.