# Modeling, Optimization and Thermal Characterization of Micropillar Evaporator Based High Performance Silicon Vapor Chamber

To overcome the high heat generation challenge and ensure sustainable development in the semiconductor industries, thermal management for high density electronic devices has drawn much attention in recent years. Being a passive thermal management device with high heat removal capability, vapor chamber that spreads concentrated heat via liquid-to-vapor phase change phenomena was proven to be a promising cooling technique. Evaporator is the determinant section that governs the performance of a vapor chamber. Silicon vapor chamber with micropillar evaporator possess large thin film evaporation area, mature manufacturing technique and can be integrated with electronic devices homogeneously to eliminate excess thermal interface layer as well as avoid thermal expansion mismatch. However, comprehensive and systematic study on silicon vapor chamber and micropillar evaporators is lacking. Predictive models that evaluate the performance limit of vapor chamber and evaporators are limited, selection of micropillar geometries is trial-and-error based in previous work. In this thesis, we developed three semi-analytical models in predicting the capillary-limited dryout heat flux of uniform evaporator with squarely packed cylindrical micropillars, biporous evaporators with micropillar islands separated by microchannels and sealed silicon vapor chamber with 2D liquid flow. We performed optimization to determine the best geometric combinations of the evaporators and vapor chambers by taking the temperature rise into consideration. Accordingly, we fabricated the evaporators and vapor chambers by micro-electro-mechanical-systems (MEMS) process to define micropillar patterns with deep-reactive-ion-etching (DRIE) and embedded resistance-temperature-detectors (RTDs). We also conducted systematic experiments to characterize the dryout heat flux and heat transfer coefficient of samples with various geometries. The three models were validated against experiment results with less than 20 % over-prediction. A 1 cm × 1 cm uniform and biporous evaporators were able to dissipate a maximum dryout heat flux of 25.7 and 55.9 W/cm$^2$, respectively. An ultra-thin Si vapor chamber with thickness of 1.25 mm can handle 98.1 W/cm$^2$ heat flux before dryout. Heat transfer coefficient was found to increase with larger micropillar diameter/pitch ratio, smaller micropillar height, wider micropillar islands and narrower microchannel width. This thesis provides deep insights, with experimental verification, into the design and optimization of vapor chamber with micropillar evaporators.