MECHANICAL ENGINEERING
DISSERTATION DEFENSE

*The Department of Mechanical Engineering presents:*

# *The Ph.D. Dissertation Defense of*

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## in Winston Chung Hall 215

## Critical Thermal Analysis & Thermophysical & Geometrical Effects on the Thermal Performance & Optimization of 3D Integrated Circuits & Heat Transfer Optimization

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Dr. Kambiz Vafai, Chairperson

The existing integrated circuit technology is not sufficient to fulfill the requirements of future electronic systems. Three-dimensional (3D) integration has been proposed as a promising solution for future needs of miniaturized systems since it offers less complexity in design and fewer quantity of interconnections compared to the so-called embedded systems. However, thermal management of 3D- ICs is more challenging than 2D-ICs due to higher power density and lower surface-to-volume ratio of 3D structures. In this dissertation, several key attributes of a 3D integrated chip structure including effect of the size of the substrate, heat sink, device layer, through silicon vias (TSVs), thermal interface material (TIM), and the pitch and arrangement of core processors and TSVs as well as variation of thermal conductivity and total heat dissipation and distribution of power within the device layers core processors are investigated. In addition, the thermophysical and geometrical parameters that have a significant impact on the thermal signature of the 3D-IC as well as those that have an insignificant impact were established. In the next step, the thermal and hydrodynamic performance of a microchannel heat sink - an efficient cooling technique for 3D structures - have been studied numerically. The effect of different geometrical attributes on thermal resistance and pressure drop characteristics are investigated and optimal values for channel width and height, wall width and base thickness have been reported. The comprehensive analysis of different geometrical and thermophysical attributes can guide the design and optimization of a 3D-IC structure and decrease the cost.

In the last chapter, a design analysis and performance evaluation of a proof-of-concept data center based on Indirect Evaporative Cooling (IDEC) is presented. The details of IT room design as well as HVAC design are discussed and the details about the physical design based on BIN data analysis and CFD simulations are unveiled. Finally, the performance of the physical design in terms of Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), Total Cost of Ownership (TCO) and finally recommendations are made on operating conditions for optimal performance.