Integrated Water Cooled 3D Electronic Chips: Experiments and Modeling

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Experiments - We present an integrated water cooling strategy for 3D electronic chip stacks that exploits microscale flow vortices generated by the necessary presence of through-silicon-vias (TSVs), to achieve extraordinary cooling performance. Analysis of microscale flows and instantaneous liquid temperature signatures have opened new frontiers in hydrothermal microscale engineering towards highly efficient micro-heat sinks.

Modeling - In microprocessors, the heat dissipation is not uniformly distributed on the chip surface and different cores (hot-spots) positioning lead to different cooling requirements. The effect of both inhomogeneous hot-spot distribution and pin (TSV) size variation is investigated. Moreover, transition from steady flow to unsteady vortex shedding regime is analyzed on 2D and 3D representative geometries of a chip stack cooling cavity.

Microscale Thermofluidics

- 3D chip with integrated pressure ports at each microcavity layer
- Confining micropin fins simulate the electrical through-silicon-via (TSV) connections
- Hydrothermal effects were investigated in detail using single micro-heat sink cavities

Flow field
Temperature field
Flow direction

Hot-spots Management

- Chip stack with representative geometry modeled
- Experiments in Fluids (2011)
- 3D chip stack
- Core size and distribution
- Thermal performance
- Pin-fins size (TSV)
- Reliability

Enhanced Cooling Performance

- Frequency of vortex-induced fluctuations
- Dynamic pressure
- 300% heat transfer enhancement!
- Chip performance

Confined Vortex Shedding

- Regimes identification
- Transition
- Steady
- Steady vortex
- 3D vortical structures & endwall effect
- Vertical transition

Publications

- Alfieri et al., Experimental investigation into serpentine structure and pressure drop across microchannels in 3D integrated electronics, Experiments in Fluids (2013)
- Alfieri et al., Vortex shedding from confined micropin fins arrays, Microfluidics and Nanofluidics (2011)
- Alfieri et al., Microscale enhanced heat transfer in 3D integrated liquid cooling of electronic chip stacks, International Journal of Heat and Mass Transfer (accepted for publication, 2013)
- Alfieri et al., Computational modeling of hot-spot identification and control in 3D stacked chips with integrated cooling, Numerical Heat Transfer, Part A: Applications (accepted for publication, 2013)