

# Integrated Water Cooled 3D Electronic Chips: Modeling and Experiments



F. Alfieri<sup>1\*</sup>, A. Renfer<sup>1\*</sup>, M. K. Tiwari<sup>1</sup>, I. Zinovik<sup>1</sup>, T. Brunschweiler<sup>2</sup>, B. Michel<sup>2</sup> & D. Poulikakos<sup>1</sup>

<sup>1</sup>Laboratory of Thermodynamics in Emerging Technologies, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland

<sup>2</sup>IBM Zurich Research Laboratory GmbH, Switzerland

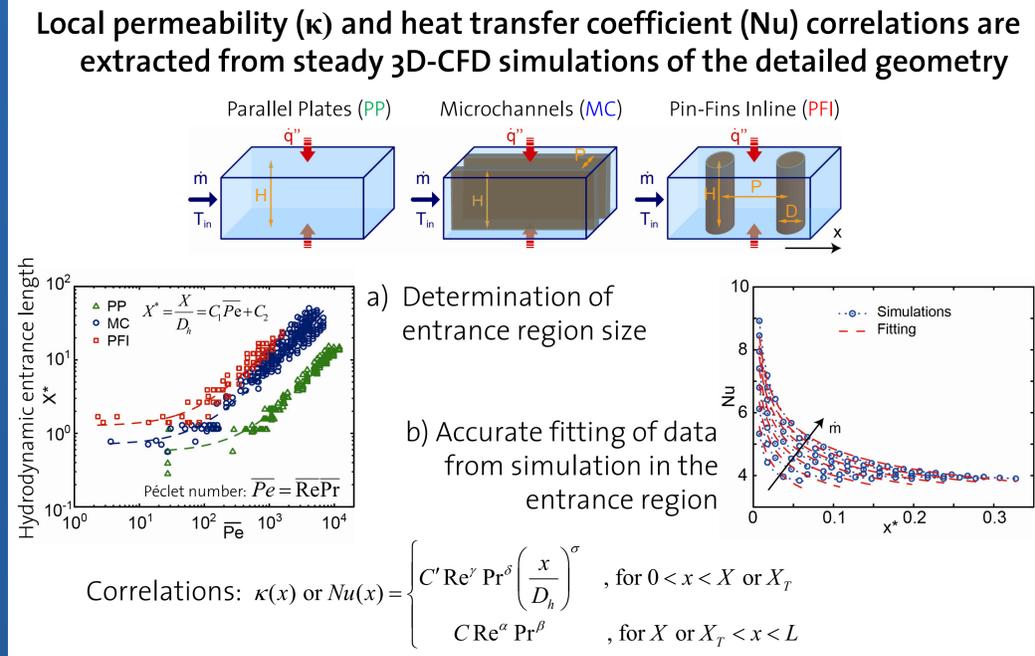
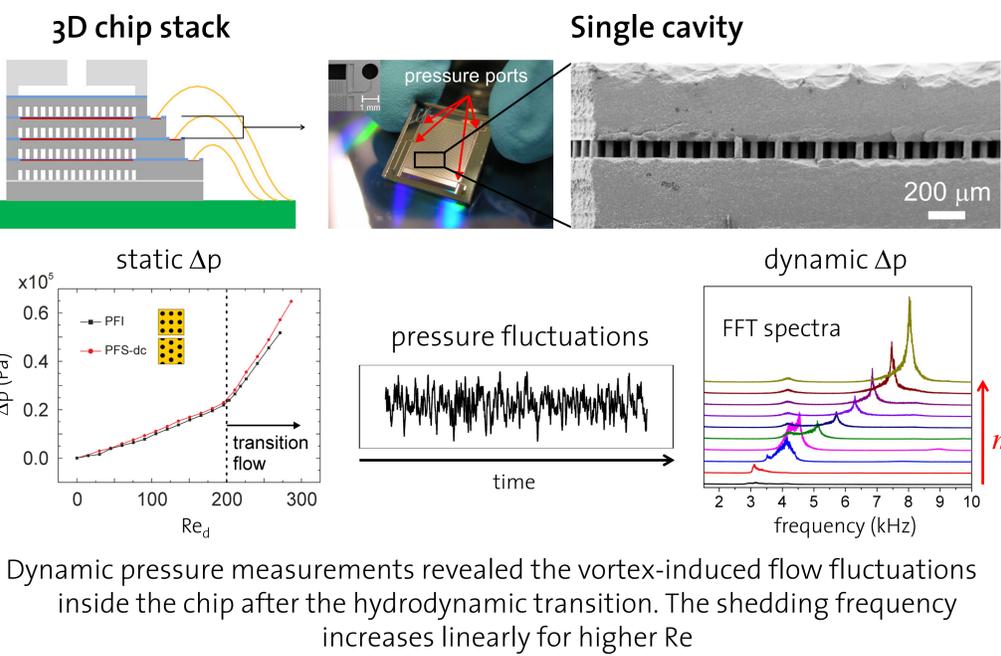
\*Equal contribution

**Modeling** - A novel, non-equilibrium porous medium based model is used to predict high local thermal gradients in vertically integrated (3D) chip stacks. The cooling structures are simulated as ultra thin porous medium with orthotropic thermal conductivity and variable thermophysical properties. Moreover, we specifically account for the hydro-thermal entrance region.

**Experiments** - Hydrodynamics and heat transfer in microcavities with micropin fin arrays, simulating through-silicon-vias, is investigated. High through put, transition flows are characterized through dynamic pressure and flow visualization. Vortex shedding and flow impingement onto the pins enhance the mass transfer and a higher heat transfer is expected.

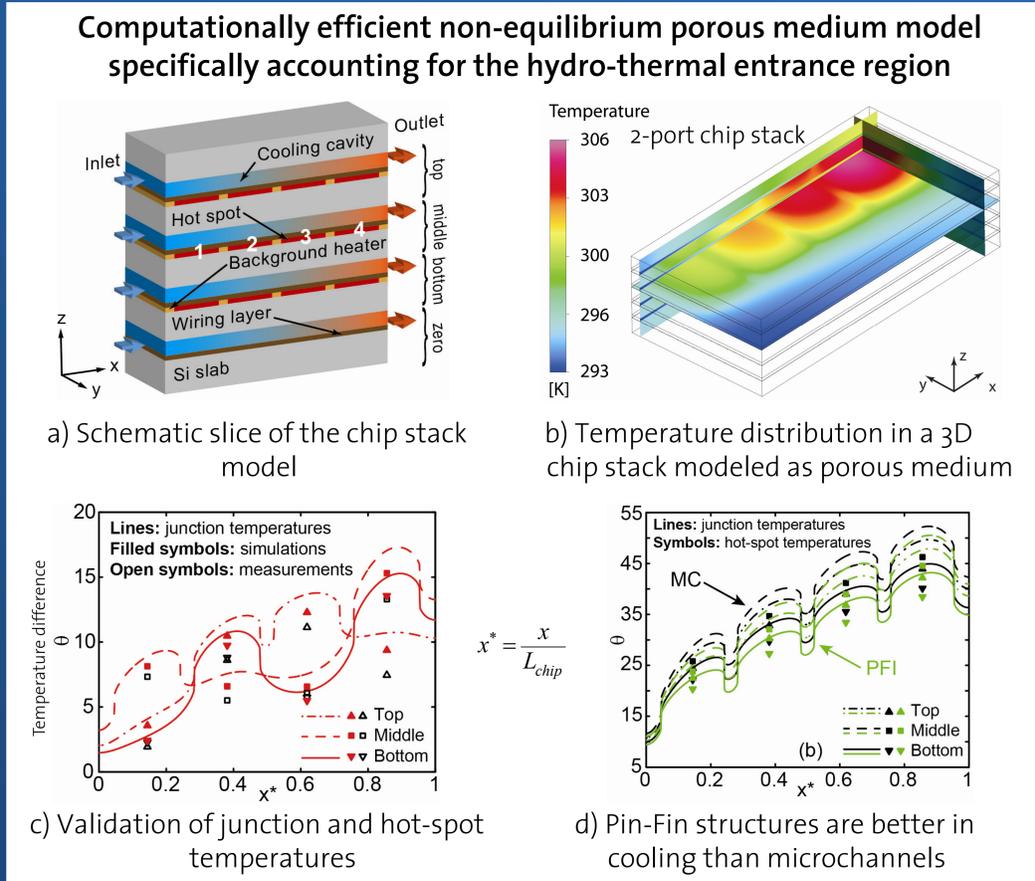
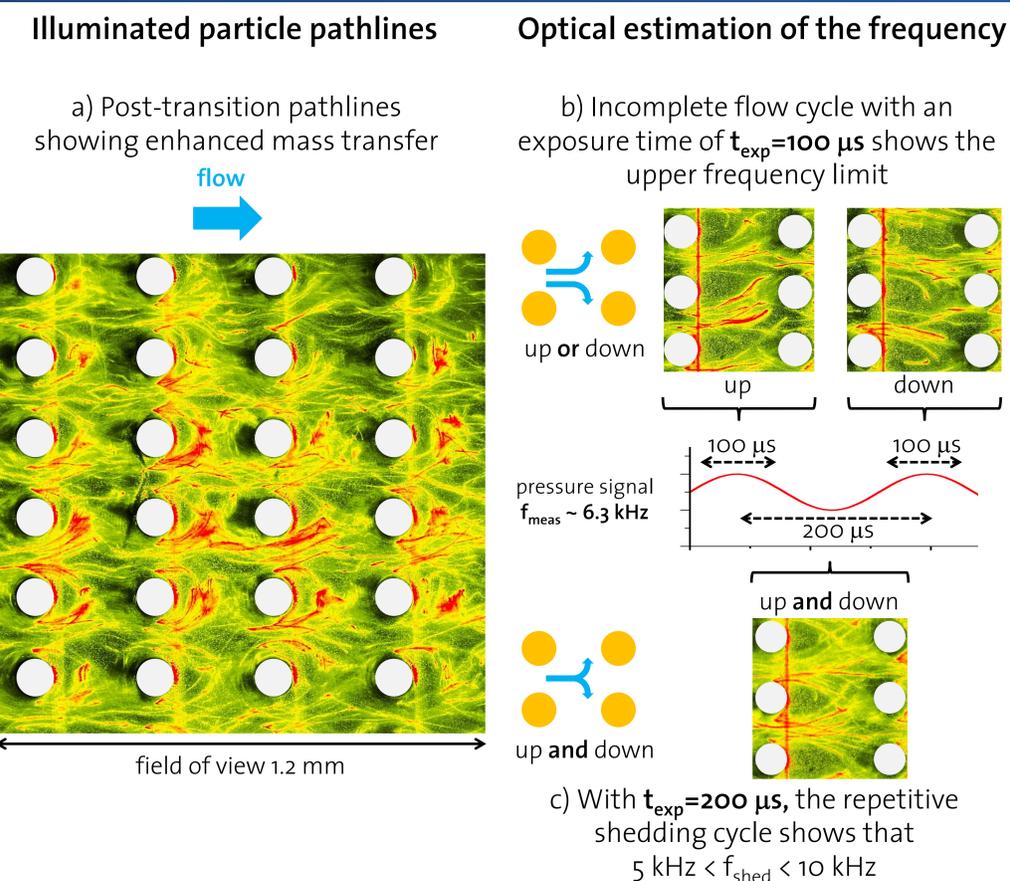
## Dynamic Pressure Measurements

## Conjugate Heat Transfer Model



## Visualization of Flow Fluctuations

## 3D Chip Stack Model



## Future Work

### Experiments:

- Heat transfer: measurement of water and micro pin-fin temperatures in the vortex shedding regime
- Integrate novel results in an improved 3D chip stack

### Modeling:

- Transient modeling: vortex shedding
- Impact on the performance of non-homogeneous micro pin-fin density and heat fluxes

### Publications:

- Alfieri et al., *3D Integrated Water Cooling of a Composite Multilayer Stack of Chips*, J Heat Trans (2010)
- Alfieri et al., *On the Significance of Developing Boundary Layers in Integrated Water Cooled 3D Chip Stacks*, Int J Heat Mass Tran, accepted for publication (2012)
- Renfer et al., *Experimental Investigation into Vortex Structure and Pressure Drop Across Microcavities in 3D Integrated Electronics*, Exp. Fluids (2011)
- Renfer et al., *Vortex Shedding from Confined Micropin Fin Arrays*, Microfluidics and Nanofluidics, to be submitted (2012)