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## *Adressing Thermal Issues in 3D Stacks in the Nano-Tera CMOSAIC Project*

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Continuous technical advances are fueling the trend toward more sophisticated and high-performance chip designs, increasing functionality and clock rates while shrinking the feature sizes. Interconnects have not followed the same scaling curve as transistors, hence they have become a limiting factor in performance and power consumption.

One solution to the problem of the rising power consumption in interconnects is 3D stacking, which reduces the length of the communication lines through vertical integration of circuit blocks. However, 3D stacking substantially increases power density due to the placement of computational units on top of each other. High power densities are already a major concern in 2D circuits, and in 3D systems the problem is even more severe. The 3D stacked systems exacerbate temperature-induced problems, leading to degraded performance and reliability if not handled properly.

The CMOSAIC project is a genuine opportunity to contribute to the realization of arguably the most complicated system that mankind has ever assembled: a 3D stack of computer chips with a functionality per unit volume that nearly parallels the functional density of a human brain. CMOSAIC's aggressive goal is to provide the necessarily 3D integrated cooling system that is the key to compressing almost 1012 nanometer sized functional units (1 Tera) into one cubic centimeter with a 10 to 100 fold higher connectivity than otherwise possible. Even the most advanced air-cooling methods are inadequate for high performance 3D-IC systems where the main challenge is to remove the heat produced by multiple stacked dies in a 1-3 cm3 volume, each layer dissipating 100-150 W/cm2. State-of-the-art single phase liquid and two- phase cooling systems, using specifically designed microchannel arrangements, and employing coolants ranging from liquid water and two-phase environmentally friendly refrigerants to novel engineered nanofluids offer significant advantages in addressing heat removal challenges leading to practical 3D systems. CMOSAIC aims at developing the engineering science base that will enable a new state of the art in high density electronics cooling.

Specifically, this project brings together internationally recognized experts of leading Swiss universities and industry (EPFL, ETH Zurich and IBM Research Laboratory in Rüschlikon) to thoroughly investigate this interdisciplinary problem at different levels (architecture, microfabrication, liquid cooling, two-phase cooling, nanofluids). These experts are joining forces to research the related physics and to develop the necessary thermal/electronic computational tools/methods. The project includes an intensive experimental program, consisting of challenging flow visualizations and heat transfer measurements in microchannel systems of hydraulic diameter often comparable to or smaller than that of a human hair, with complex fluids flowing through them. It also targets the development of novel theoretical models explaining the physics and new electronics packing models together with new micro- manufacturing processes. The verification of the proposed novel approaches coming out of this project will be conducted using several prototypes that will be built and tested. With respect to the Nano-Tera.CH proposal, this project addresses the vertical axis of micro/nanoelectronics, particularly the aspect of system integration. Specifically, the results of this project will be a significant step toward "achieving system complexities that are two-to- three orders of magnitude higher than today's state-of-the-art", by developing the fundamental understanding, methods and tools required for efficient and reliable design of true 3D integrated circuit systems.

CMOSAIC is one of the most ambitious projects in the field of 3D chips, covering many different areas of research and targeting the goal at different abstraction levels. Only the joint work of research experts and industrial partners allows the persecution of such interesting objectives. Please visit the following website for further information: http://www.nano-tera.ch/projects/67.php

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