Micro Heat Spreaders for Microelectronic Cooling

As integrated circuits become faster and more densely packed with transistors, the power density increases and the heat generated as a by-product becomes more severe. There is a growing demand for heat transfer expertise to aid with the design of micro fabricated transistors, sensors, and actuators for the integrated circuits and MEMS industries. Heat generation and conduction influence the reliability of semiconductor devices and interconnects.

The fundamental need to improve cooling efficiency spans much of developing microelectronics technology. There is constant pressure on military electronics system designers to reduce system volume while increasing electronics complexity and power density. Compound semiconductor phased array radar modules are trending to higher power, smaller module size, and larger arrays. Additional needs for cooling optoelectronics, laser diodes, high speed processors and communication equipment are increasingly demanding. Heat transfer is also important for multilevel interconnects in fast logic circuits, for which the trend to larger numbers of level increases the peak temperature rise induced by Joule heating.

Conventional methods of cooling are not an ideal way to overcome the heat problem. A simple solution would be using micro heat pipe as integrated part of the silicon substrate. These two-phase convection devices, yield by far the highest cooling rates per unit volume in electronic systems, as evidence by the effectiveness and large commercial impact of heat pipes in portable systems. A heat pipe is a closed heat transfer system used to transport heat from one location to another by means of the evaporation and subsequent condensation of an appropriate working fluid. It contains of three components, the container, the wick structure, and the working fluid. The capillary forces in the arteries mainly maintain the liquid circulation inside the heat pipe.

Other two-phase devices that provide even higher cooling rates include microchannels, microjets, and vapour compression refrigerators. However, these devices are rarely found in mass-produced electronic systems because they require high-pressure pumping.

In 1984 Cotter first proposed incorporating heat pipes which are called micro heat pipe as part of semiconductor devices, and defined them as “so small that the mean curvature of the vapour-liquid interface is necessarily comparable in magnitude to the reciprocal of the hydraulic radius of the flow channel.” Micro heat pipes differ from conventional heat pipes in that they are significantly smaller (characteristic dimension measured in microns). Since the initial conceptualization, numerous analytic investigations of micro heat pipes have been conducted, however experimental investigation of micro heat pipes have been very limited.

This talk discusses the theory, modelling and design, fabrication and test results of the flat micro heat spreaders. The emphasis is placed upon a) silicon flat heat spreaders with the final aim to be fabricated in a future as an integral part of semiconductor devices; b) upon copper heat spreaders and c) DBC heat spreaders for 3 dimensional packages. The term “heat pipe” is used because the flat heat spreader works on the principle of a heat pipe.

The presented in the talk models, prototypes, tests of the micro heat spreaders are result of my research in Laboratoire de Génie électrique de Grenoble at the Institut National Polytechnique de Grenoble in the framework of a number of French and European scientific projects and in my university – the Technical University of Sofia.

Slavka Tzanova is MSc. in Automation and Telemechanics from the Technical University of Sofia (TUS), MSc. in ‘Educational and Training Systems Design’ from the University of Twente, the Netherlands, Ph.D. in Microelectronics from TUS. She is professor in the Department of Microelectronics, TUS. Her scientific interests are in IC and MCM design, wearable computers, thermal management of electronic circuits and packages.