CMOS-Compatible SOI MESFETS for Radiation-Hardened DC-to-DC Converters

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A radiation-tolerant transistor switch has been developed that can operate between –196 and +150 °C for DC-to-DC power conversion applications. A prototype buck regulator component was demonstrated to be performing well after a total ionizing dose of 300 krad(Si). The prototype buck converters showed good efficiencies at ultra-high switching speeds in the range of 1 to 10 MHz. Such high switching frequency will enable smaller, lighter buck converters to be developed as part of the next project. Switching regulators are widely used in commercial applications including portable consumer electronics.

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Silicon Heat Pipe Array

Applications include high-power electronic circuits or components such as microprocessors, diode lasers, and concentrated solar collectors.

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Improved methods of heat dissipation are required for modern, high-power-density electronic systems. As increased functionality is progressively compacted into decreasing volumes, this need will be exacerbated. High-performance chip power is predicted to increase monotonically and rapidly with time. Systems utilizing these chips are currently reliant upon decades of old cooling technology.

Heat pipes offer a solution to this problem. Heat pipes are passive, self-contained, two-phase heat dissipation devices. Heat conducted into the device through a wick structure converts the working fluid into a vapor, which then releases the heat via condensation after being transported away from the heat source. Heat pipes have high thermal conductivities, are inexpensive, and have been utilized in previous space missions. However, the cylindrical geometry of commercial heat pipes is a poor fit to the planar geometries of microelectronic assemblies, the copper that commercial heat pipes are typically constructed of is a poor CTE (coefficient of thermal expansion) match to the semiconductor die utilized in these assemblies, and the functionality and reliability of heat pipes in general is strongly dependent on the orientation of the assembly with respect to the gravity vector. What is needed is a planar, semiconductor-based heat pipe array that can be used for cooling of generic MCM (multichip module) assemblies that can also function in all orientations. Such a structure would not only have applications in the cooling of space electronics, but would have commercial applications as well (e.g. cooling of microprocessors and high-power laser diodes).

This technology is an improvement over existing heat pipe designs due to the finer porosity of the wick, which enhances capillary pumping pressure, resulting in greater effective thermal conductivity and performance in any orientation with respect to the gravity vector. In addition, it is constructed of silicon, and thus is better suited for the cooling of semiconductor devices.

The device consists of two silicon wafers, one of which has a mechanically drilled hole for a fill port. Each wafer is lithographically masked and etched to define a hermetic seal ring and the structural support elements. Each wafer then undergoes a mask-free cryo etch to define the black Si wick structure (the etch process developed results in an ≈3× taller black Si structure than has been reported elsewhere). The wafers are then cleaned, thermally oxidized, and fusion-bonded together. Precision metering is then utilized to fill the device with the working fluid (e.g. water) through the fill port, which is then sealed off.

This device is able to absorb a large quantity of heat due to the phase change of the working fluid, and transport the heat efficiently away from the source (i.e., it has a large effective thermal conductivity). Due to the small effective pore radius of the nanotextured surface, high capillary forces are exerted on the working fluid and the device is able to work in any orientation with respect to the gravity vector. In addition, due to the all silicon construction, the device is expansion-matched to the types of high-power die that would potentially be mounted to it.

The novel aspects of this assembly include:

(1) Co-fabrication of the heat pipe structure and the wick. A black Si wick structure is utilized so that the housing of the heat pipe and the wick structure can be co-fabricated. This enables stress-free operation of the device over temperature, as the device is of homogenous material construction. Adhesion of the wick to the structure is not an issue, as the wick is etched from the structure itself, and is not grown or deposited.

(2) Direct attachment or integration of heat-generating elements to the heat pipe. Fabrication of the heat pipe from Si allows stress-free, expansion-matched attachment of high-power semiconductor components or even the direct integration of such components. For example, high-power