DESIGN & CHARACTERIZATION OF A MEMS THERMAL SWITCH

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The ability to control heat transfer on small time and length scales would have a significant impact in many areas: for example, thermoelectric micro-coolers, DNA amplification via Polymerase Chain Reaction (PCR) and harvesting waste heat to do work on the microscale.

In this paper we present the design, fabrication, and characterization of a MEMS thermal switch. Two switch designs are presented: one in which the conductive material is in the form of liquid-metal 30-µm diameter micro droplets and one in which the conductive material consists of aligned carbon-nanotube arrays.

Heat transfer measurements using guard-heated calorimetry are presented for both micro-droplet and aligned carbon nanotubes array based thermal switches in both static and dynamic operation. The switch performance is characterized by the ratio of thermal resistance in the switch off and on position. For example, the thermal resistance of a thermal switch based on a 4mm square array of 1600 thirty-micron diameter mercury micro-droplets deposited on a silicon substrate in the “on” condition is shown to decrease from 3.5 K/W to 1 K/W as the micro-droplet array is squeezed against the second silicon surface with an applied load of 0.1 N. The thermal resistance of the thermal switch in the “off” condition is shown to increase to 50 K/W for a gas gap of 100 microns

The thermal resistance ratio may be increased by increasing the resistance in the off position by operating in vacuum or with low conductivity gases. The ratio may also be increased by decreasing the thermal resistance of the switch in the on position by employing a highly conductive material such as carbon nanotubes.

The experimental measurements are used to validate a numerical heat transfer model of the thermal switch. Thermal contact resistance at the interfaces is addressed.