Development of MEMS microchannel heat sinks for micro/nano spacecraft thermal control

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ABSTRACT

Future spacecraft used for deep space science exploration are expected to be orders of magnitude smaller and lighter than current spacecraft. However, power requirements for these micro/nano spacecraft are not expected to drop commensurately with the reduction in size. The resultant power densities of the electronics, science instruments, and avionics in these spacecraft are expected to exceed 25 W/cm^2—an order of magnitude greater than traditional spacecraft designed and operated today. To meet the thermal requirements of the high power density components in micro/nano spacecraft, advanced thermal control technologies compatible with the space environment are required. One such thermal control technology is a MEMS-based pumped liquid cooling system. In principle, this system consists of a single-phase working fluid circulated through microchannel heat exchangers by a micropump to remove heat from high power density electronic components.

A MEMS-based pumped liquid cooling system is being investigated at the Jet Propulsion Laboratory (JPL). The current stage of development focuses on the design, fabrication, and testing of appropriate microchannel heat sink devices. Computational fluid dynamics software packages and microchannel modeling codes are employed to optimize channel geometry for heat transfer and fluid flow characteristics. Microchannel heat exchanger devices (Fig. 1) are fabricated in silicon at the Microdevices Lab (MDL) of JPL. On-board heaters and temperature sensors are added to the devices and testing is conducted in a closed-loop facility (Fig. 2) featuring a macroscopic pump and heat exchanger assembly. The test hardware supports working pressures of up 100 psi while rejecting upwards of 200 W of input heating, thereby allowing for the testing of multiple working fluids.

Three microchannel heat sink devices were fabricated and tested for hydraulic and thermal performance in simulated microspacecraft heat loads using de-ionized water as the working fluid. The widths of the microchannels on the three devices were 100, 125, and 150 microns with channel depths of 50, 325, and 400 microns respectively. The channel geometries were chosen to maintain minimal pressure drops across the channel lengths. Each device was tested to determine the maximum cooling capacity prior to the onset of coolant boiling. It was concluded that the design methodology developed for this project produces microchannel heat exchanger devices capable of meeting the thermal requirements of future micro/nano spacecraft with pressure drops achievable by advanced micropump technology.

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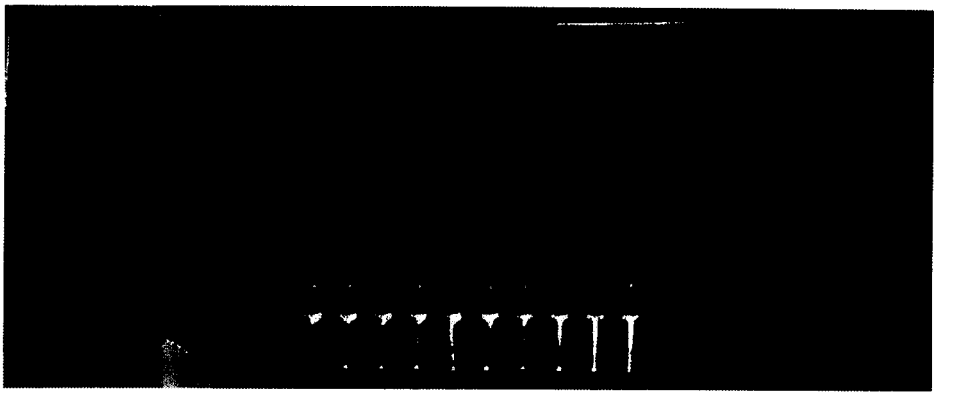

Figure 1. Microchannel Heat Sink Device

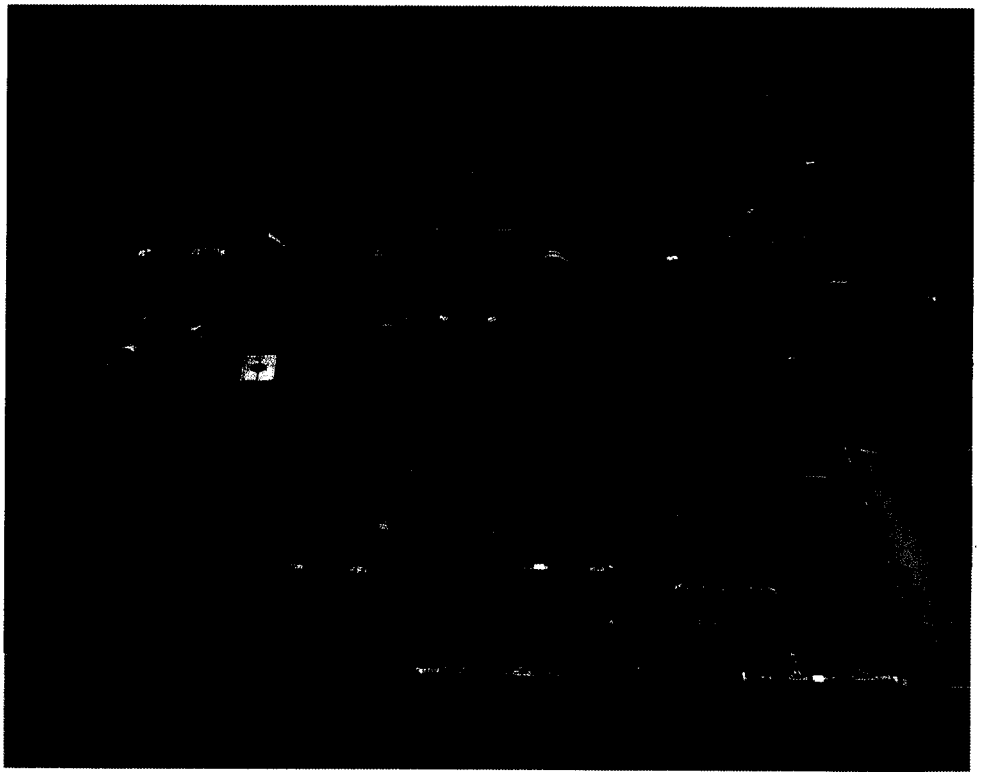

Figure 2. Closed-loop Test Facility