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Raman Thermometry Measurements and Thermal Simulations for MEMS Bridges at Pressures from 0.05 to 625 Torr

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The environmental condition inside a packaged MEMS device dictates its performance and long-term reliability. Microsystems devices are often packaged at pressures lower than atmospheric which dramatically affects their thermal performance since energy transfer to the environment is substantially reduced as the pressure is reduced. This study investigates the thermal performance of microelectromechanical systems (MEMS) as a function of the pressure of the surrounding gas. High spatial resolution Raman thermometry was used to measure the temperature profiles on polycrystalline silicon bridges that are 10 microns wide, 2.25 microns thick, and either 200 or 400 microns long in nitrogen atmospheres with pressures ranging from 0.05 to 625 Torr. The beams were heated electrically with powers adjusted to maintain approximately constant peak temperatures in the bridges at each pressure setting. The temperature measurements indicate that increasing the pressure by a factor of 10 from 0.05 Torr to 0.5 Torr hardly changes the temperature profiles and the corresponding powers. This observation indicates that gas-phase heat transfer is negligible compared to solid-phase heat transfer at these low pressures. When the pressure is increased to 5 Torr, the power must be increased by about 4% to keep the peak of the temperature profile around 600 K, so gas-phase heat transfer is about 4% of solid-phase heat transfer at 5 Torr. A similar comparison indicates that gas-phase heat transfer is about 15% and 31% of solid-phase heat transfer at gas pressures of 50 Torr and 625 Torr, respectively. Thus, gas-phase heat transfer is significant for devices of this size at ambient pressure but becomes minimal as the pressure is reduced. The experimental results are compared to thermal simulations of the MEMS bridges. Since noncontinuum effects can become important as the pressure is reduced, a noncontinuum gas heat transfer model is employed that allows temperature discontinuities at gas-solid interfaces. Finite element modeling of the thermal behavior of the MEMS bridges is performed and compared to the experimental results. The model and experimental results are in qualitative agreement and better quantitative agreement requires accurate geometrical and material property values.

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