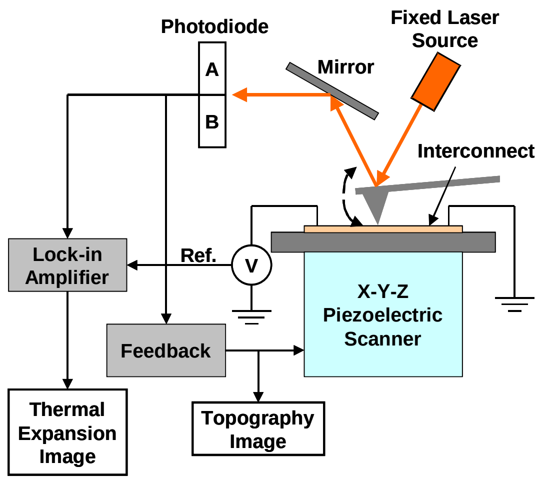

Figure 1: Scanning Joule Expansion Microscopy (SJEM) setup. The interconnect is periodically heated to induce a vertical thermal expansion that causes the cantilever to oscillate at the same frequency. The lock-in amplifier measures the amplitude of this particular frequency. The heating frequency is made much higher than the feedback bandwidth to the piezoelectric scanner, which thus can detect only the topography.

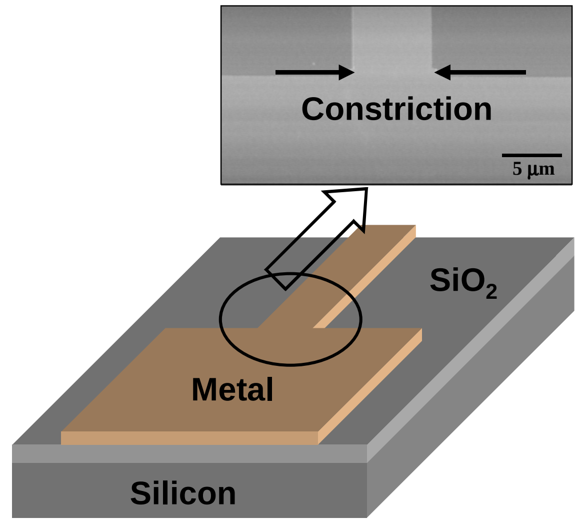

Figure 2: Schematic of constriction in a gold thin film. The metal thickness is ~ 40 nm, which is roughly the mean free path of electrons. A thin layer of parylene (~ 100 nm) is coated on the whole sample to increase the expansion amplitude.

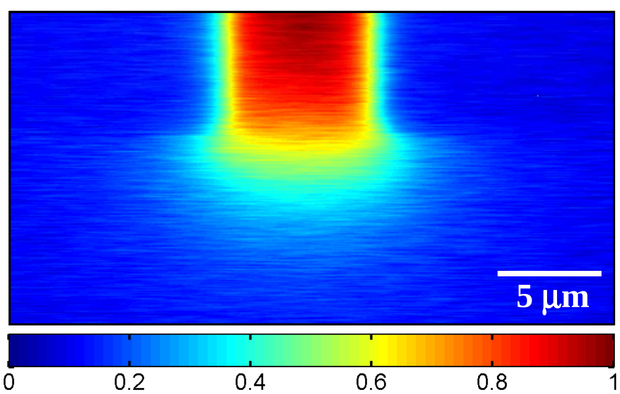

Figure 3: Thermal expansion image of the constriction at 20 kHz heating frequency. The units are arbitrary and the color bar is scaled from 0 to 1.

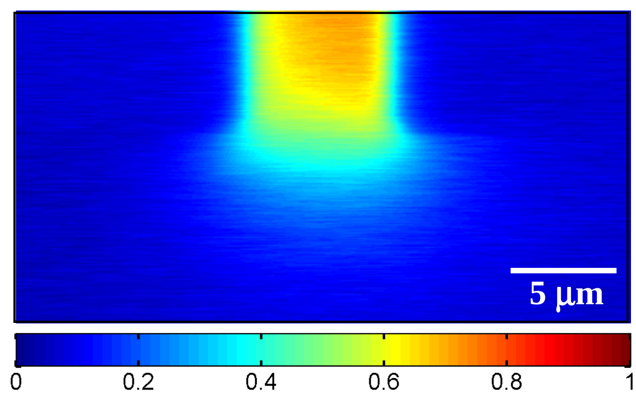

Figure 4: Thermal expansion image of the constriction at 100 kHz heating frequency. Voltage amplitude and color map are same as for the case in Fig. 3.

SCANNING JOULE EXPANSION MICROSCOPY OF A CONSTRICTION IN THIN METALLIC FILM

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Temperature rise in on-chip interconnects is expected to steadily increase with each generation of microprocessors. Continuous scaling has led to feature sizes in the 100 nm range. Existing and future interconnect architectures include *vias* connecting metal lines in different levels. These vias typically cause current crowding and can significantly affect temperature rise. It is thus highly important to characterize thermal phenomena in nanoscale complex structures.

Figure 1 schematically shows the setup for Scanning Joule Expansion Microscopy (SJEM) developed by Varesi and Majumdar (1998). It involves measuring the expansion amplitude of the interconnect surface due to temperature oscillations caused by a periodic voltage input. The topography of the constriction studied in this work is shown in Fig. 2. A thin (100 nm) parylene layer was coated on top of the whole structure. Expansion images obtained using a closed-loop Atomic Force Microscope (AFM) are shown in Fig. 3 and Fig. 4 for 20 kHz and 100 kHz heating frequencies respectively. The technique captures current crowding and heat generation in films as thin as 40 nm, which is roughly the mean free path of electrons. Due to high signal-to-noise ratio, this technique allows quantitative measurement of the lateral penetration depth of the periodic heating signal, from which thermal diffusivity of films deposited on the metal film can be extracted.

J. Varesi and A. Majumdar, “Scanning Joule expansion microscopy at nanometer scales,” *Applied Physics Letters*, vol. 72, pp. 37-39, 1998.