Analysis of heat conduction in confined structures by means of scanning thermal microscopy

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Scanning thermal microscopy (SThM) allows the thermal characterization of materials with a submicrometric spatial resolution [1]. Determining reliable thermal data from the experiments is challenging because the probe-sample heat exchange strongly depends on parameters such as the size, geometry and surface states of probe and sample [2-3]. To analyze thermal dissipation in confined systems, we first studied deposited thin films with a thickness ranging from few nanometers to one micrometer. Polystyrene films on silicon (Si) and quartz substrates, and silicon dioxide films on Si substrates were analyzed by means of SThM probes with various sizes. For a low thermal conductivity film on a high thermal conductivity substrate, results show an apparent thermal conductivity decrease as a function of the film thickness (see Fig.1), which persists up to few hundreds nanometers. They also demonstrate that the SThM technique is sensitive to films few nanometers thin and to oxidation. In a second step, 2D lateral confinement is addressed and the heat transferred from a heated probe to silicon cylinders of varying diameters and spaced with different distances was also measured (see Fig.2) under different environments, in particular within a SThM embedded in a scanning electron microscope. The diameters and distances of the cylinders were chosen to be higher than, of the same order of or lower than the mean free path of phonons in Si (~300 nm at room temperature). Results are discussed as a function of the ratios between the characteristic dimensions of the probe, sample geometry and mean free paths.

[1] S. Gomes et al., PSSA 212, 3 (2015), [2] Y. Ge et al., Nanotech. 27, 32 (2016), [3] F. Menges et al., RSI 87, 7 (2016)

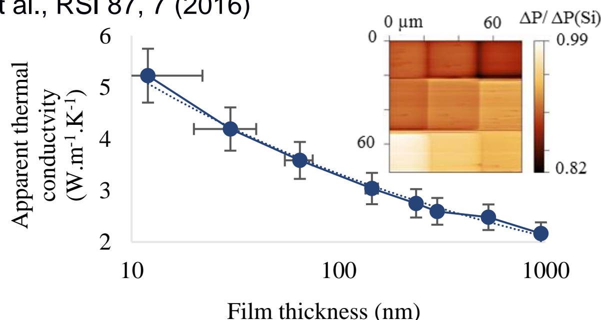

Figure 1: Apparent thermal conductivity as a function of SiO_2 film thickness. The insert provides the relative power dissipated in the sample for each SiO_2 thickness.

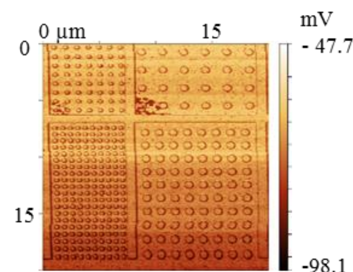

Figure 2: Thermal image (SThM probe voltage) of cylinders (diameters 300 and 600 nm) etched in silicon obtained in vacuum.

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