Probing phonon mean free path in silicon membranes at different temperatures

IIS Univ. of Tokyo[1], Pprime, CNRS, Univ. de Poitiers[2]

°Roman Anufriev[1] , Jose Ordonez-Miranda[1,2] and Masahiro Nomura[1]

E-mail: anufriev@iis.u-tokyo.ac.jp

The thermal properties of semiconductors are largely defined by the spectral phonon mean free path (MFP). Although several experiments measured the phonon MFP in bulk Si, the MFP spectra in thin membranes remain unknown. Recently, Hao *et al*. [1] proposed a semi-analytical precedure to reconstruct the phonon MFP in a thin membrane from measurements on membranes with arrays of nanoslits.

In this work [2], we experimentally probe the phonon MFP spectra in suspended Si membranes, using an improved and fully analytical approach. Using the micro-time-domain thermoreflectance method (Fig. 1a), we measure the thermal conductivity of membranes with arrays of slits at different temperatures and with different width of passage (w) between the slits (Fig. 1b). Next, we develop a fully analytical procedure to extract the accumulated thermal conductivity as a function of the MFP. At room temperature, the phonon MFP does not exceed 400 nm. However, as temperature is decreased to 150 K and further to 4 K, the MFP becomes longer. At 4 K, the MFP spectrum shows that some phonons can travel ballistically for up to one micrometer. These results thus shed light on the long-lasting question of the range of ballistic and coherent phonon transport at different temperatures in nanostructures based on Si membranes.

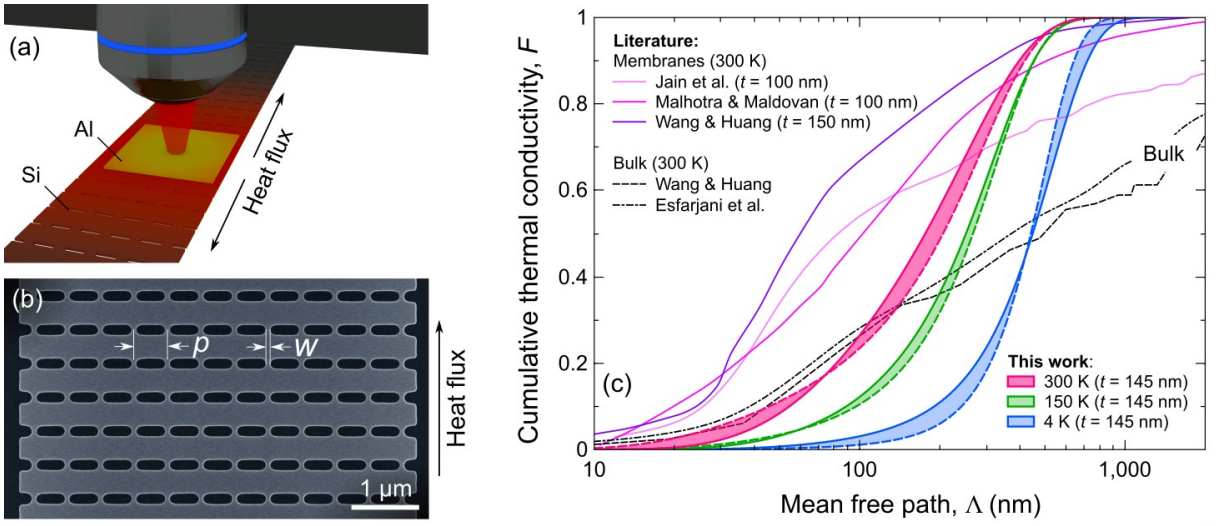

Fig. 1. (a) Schematic of the TDTR experiment. (b) A TEM image of a sample membrane with an array of slits. (c) Obtained phonon MFP spectra in Si membrane compared to the literature.

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References

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