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シリコンナノ構造における熱伝導率の温度依存性

Temperature dependence of thermal conductivity for Si nanostructures

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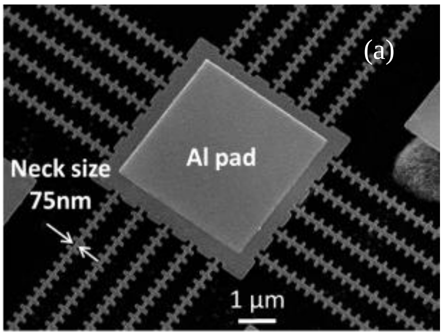
For thermoelectricity to spread further it is necessary to improve its efficiency, which can be achieved by reducing thermal conductivity in the otherwise poor thermoelectric material that is silicon. At the nanoscale, scattering at the interfaces reduce the thermal conductivity [1]. In periodic structures, coherent effects [2] are expected to reduce the thermal conductivity even further, but are hardly visible at room temperature with current reachable structure sizes. At low temperatures, the heat flow properties change and a decrease in thermal conductivity can be observed; its temperature dependence varies with the type and shape of the structure. In this contribution, we report the temperature dependence of the thermal conductivity of membranes and nanowires as well as 1D phononic crystal (PnC).

All the structures are fabricated from a 145–nm-thick SOI wafer using a classical top-down approach, including Electron-Beam lithography. The structure consists of an Al pad, serving as heater for the measurements, deposited on a central Si island. It is attached to the surrounding wafer by the nanostructure of interest, which provides the only way for the heat to flow from the heater since the whole ensemble is suspended (Fig. (a)).

Thermal conducitivities of the nanostructures were obtained by our original micro-TDTR system and simulations [3] between 5K and room temperature by using liquid He cooling. Both membranes and nanowires with a width of 127 nm display a sudden decrease in thermal conductivity below a threshold temperature(Fig. (b)). This is due to the mean free paths of phonons carrying heat becoming longer and reaching the same order that the limiting dimension of the structure. This threshold is determined by the limiting dimension of the structure, namely the width in the case of nanowires. A lower limiting dimension means a higher threshold temperature, at which the phonons transporting heat, though having shorter mean free paths, will still be scattered compared to a bigger structure. We also investigated the thermal conductivity in various 1D PnC nanostructures with different fin widths at room temperature. The detail will be presented in the presentation.



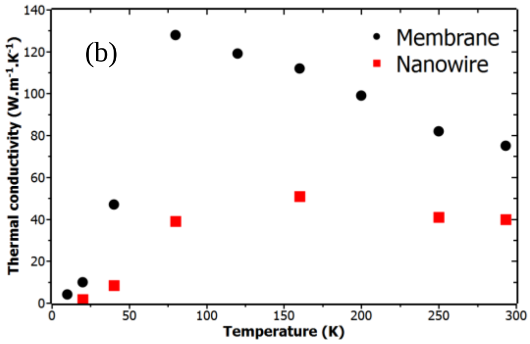


Fig. (a). SEM image of air-suspended 1D Si PnC nanostructures. (b). Temperature dependence of the thermal conductivity of a membrane (blue) and a 127 nm-wide

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