Effects of Micro-Structures on In-Plane Thermal Conductivity and Electrical Conductivity of Silicon Thin Film

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Microstructure affects the transport of heat and electricity, and also physical properties. We propose design guidelines for a reduction in the thermal conductivity and electrical conductivity by evaluating the mean free path of phonons and electrons. We measured the in-plane thermal conductivity and electrical conductivity of free-standing Si thin films with periodic micropores at -100 to 0°. They were measured by using the temperature dependence of electrical resistance to measure the average temperature rise of a Si bridge and electrical heating in patterned and non-patterned Si bridges. The Si thin film serves both as a heater and thermometer. The Si thin films with micropores were prepared from silicon-on-insulator (SOI) wafers by standard micro fabrication processes. The dimensions of the free-standing Si thin films were 200×150×4 micrometer^3, with 4 micrometer pores having an average pitch of 4 micrometers. The average temperature rise of the thin film is a function of its in-plane thermal conductivity. The effective thermal conductivity was calculated using a simple one-dimensional heat conduction model. The electrical conductivity was calculated from electrical resistance. Our study suggests the thermal conductivity and the electrical conductivity values are lower in patterned than non-patterned Si bridges. The measured thermal conductivity was much lower than that expected based on classical model evaluations. A significant phonon size effect was observed, even in the microsized structures, and the mean free path for phonons is very long, even at the room temperature.