Measurement of the enhanced thermal transport and propagation of surface phonon-polaritons along suspended silica thin films

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The study of thermal transport in nanometric devices such as thin films has become of high interest with the development of microelectronics based especially onsilicon dioxide (SiO_2) thin films, which are indeed important insulators used in the fabrication of semiconductor devices. The bulk thermal properties of amorphous SiO_2 is low (around 1.4 W/(m.K) at room temperature) and decreases as the thickness of SiO_2 thin film is scaled down, due to the increasing effect of the interface thermal resistance with the film substrate [1]. In this work, we consider suspended membranes in order to remove the effect of this thermal resistance. The reduction of the film thickness strengthens the surface effects and therefore enhances the propagation of surface phonon-polaritons (SPhPs). These waves are evanescent electromagnetic waves resulting from the coupling between optical phonons and photons, and in glasses, they mainly appear in the mid-infrared range, which makes them suitable energy carriers for enhancing the thermal performance of thin films.

Previous theoretical computations showed that the contribution of SPhPs to the in-plane thermal conductivity of thin films, is higher in thinner films, [2] whose thermal conductivity can be twice that of its bulk counterpart, for a 40-nm thick silica film at room temperature. This thermal enhancement is due to the increase of the SPhP propagation length from a few tens of micrometers in bulk glass to a few centimeters for 100-nm-thick glass films. By means of AC calorimetry, we experimentally measured the in-plane thermal conductivity of 281, 132 and 82 nm-thick silica films at room temperature, and obtained the values of 0.92, 0.93 and 0.84 W/(m.K); respectively. These values are smaller than the bulk one of glass and thus they do not show any enhancement. This can be explained by the relatively small lengths and width of the suspended area ((4-5) mm x (200 - 450) µm) with respect to the theoretical propagation lengths for these thicknesses. These dimensions limit the propagation of SPhPs and hence their contribution to the thermal transport. We expect to prove this effect by directly measuring the SPhP propagation length, through the attenuated total reflection technique.

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