Thermal conductivity of SiC nanomembranes, nanowires, and phononic crystals

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Silicon carbide (SiC) aims to be the number one material for power microelectronics due to its remarkable thermal and electronic properties. Recent progress in SiC technology finally enabled the fabrication of crystalline SiC nanostructures. Yet, the thermal properties of SiC at the nanoscale remained overlooked, and the thermal conductivity of SiC nanostructures remains largely unknown. Here, we systematically study heat conduction in SiC nanostructures, including nanomembranes, nanowires, and phononic crystals. The thermal conductivity of our samples is measured using micro time-domain thermoreflectance (μTDTR) method (Fig. 1(a)). Our measurements show that the thermal conductivity of nanostructures is several times lower than in bulk and scales proportionally to the narrowest dimension of the structures. In the smallest nanostructures, the thermal conductivity reached 10% of that in bulk. To better understand nanoscale thermal transport, we also probed phonon mean free path and coherent heat conduction in the nanostructures using the slit method [1]. Using Callaway-Holland model, we linked the observed reduction in thermal conductivity with the surface phonon scattering, which inherently limits the thermal conductivity at the nanoscale. Figure 1(b) shows how the measured thermal conductivity correlates with the limiting dimension of the nanostructures. This work uncovers the thermal characteristics of SiC nanostructures and explains their origin, thus enabling realistic thermal engineering in SiC microelectronics.

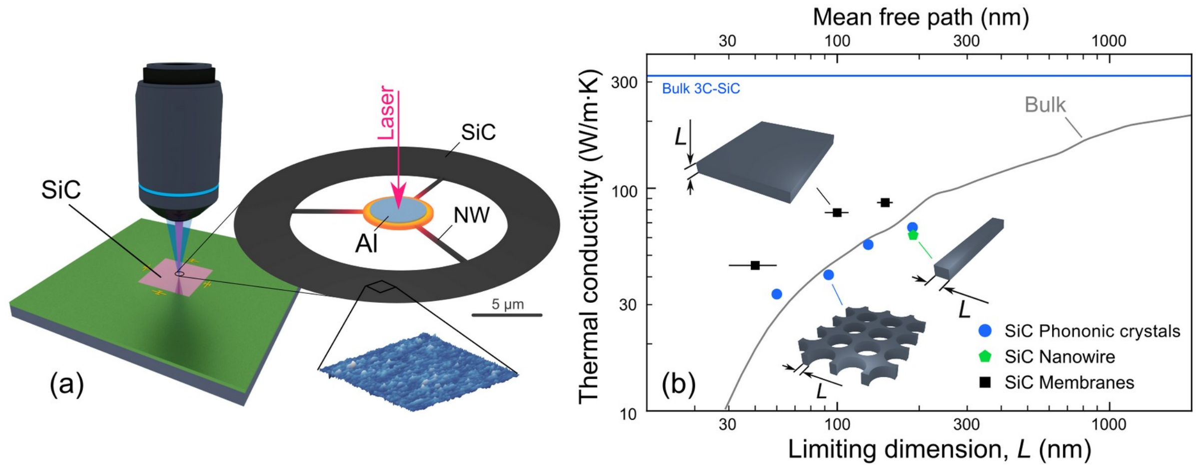

Fig. 1. (a) Schematic of the TDTR experiment on suspended SiC structures. (b) Measured thermal conductivity of different nanostructures as a function of their limiting dimensions.

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References

[1] Anufriev *et al*. Physical Review B 101, 115301 (2020).