Anisotropic thermal conductivity of layered 2D $SnSe_2$

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Abstract

Thickness, temperature and degree of thermal anisotropy are critical parameters that affect the performance of layered two-dimensional materials in nano-electronics. Here, we systematically study the in-plane and cross-plane thermal conductivity of $SnSe_2$ films of varying thickness (16-190 nm) using two-laser Raman thermometry and frequency domain thermo-reflectance, respectively. We found that both in-plane and cross-plane thermal conductivities monotonically decrease with decreasing film thickness, showing a maximum of 2.5-fold reduction compared to the bulk values. The thermal conductivity anisotropy ratio obtained directly from the experiments was found to be thickness-independent and approximately of ~ 8.4. In addition, we find that the temperature-dependence of the in-plane thermal conductivity gradually decreases as the film thickness decreases. Upon increasing temperature, from 300 K to 473 K, we show that the in-plane thermal conductivity can be reduced more than a factor of 2. Furthermore, using the mean free path reconstruction method, we found that phonons with MFP ranging from 1-53 and 1-30 nm, contribute to 50% of the total in- and cross-plane thermal conductivity, respectively. These calculations are in very good agreement with previous theoretical prediction [1-2]. Our results provide guidelines for the design and thermal management of emerging two-dimensional electronic, optoelectronic, and thermoelectric devices.

References

[1] Y. Ding et al. *J. Phys. Chem. C* **2017**, *121* (1), 225–236
[2] H. Wang et al. *RSC Adv.* **2017**, *7* (14), 8098–8105

Figures

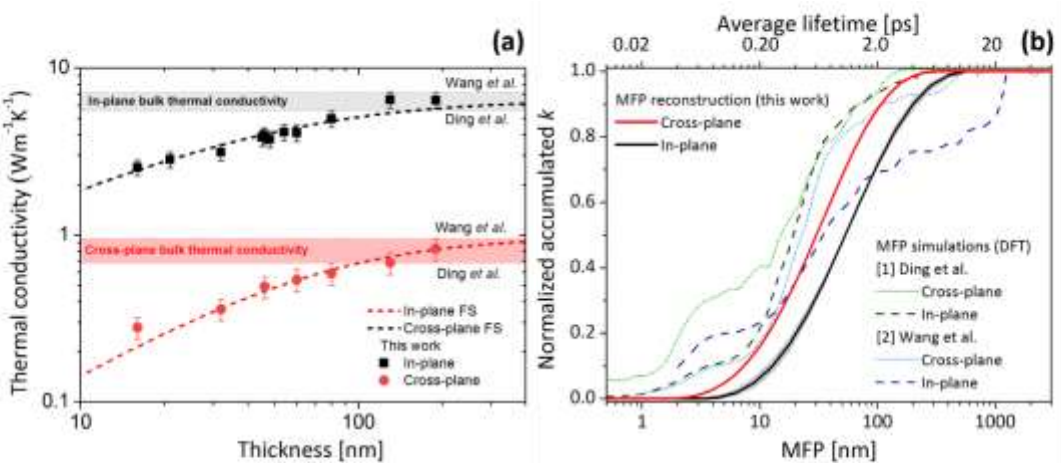

Figure 1. (a) Measured in-plane (black squares) and cross-plane (red circles) thermal conductivities of exfoliated SnSe2 films with thickness between 16 to 190 nm (b) Normalized accumulated in-plane and cross-plane thermal conductivity as a function of the phonon MFP extracted from experimental thermal conductivity.