Raman thermometry reveals efficient heat dissipation to air molecules in ultimately thin free-standing $MoSe_2$ crystals

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The prospect of heat management via 2D-material based nanodevices is rapidly gaining attention within the scientific community. In this regard, the ability to tune thermal transport properties of layered materials is of utmost relevance [1]. Here, we study the effects of flake thickness (in the range of 0.7—50 nm) and environment (vacuum, air and N_2) on the in-plane thermal conductivity (κ) of large, free-standing $MoSe_2$ single-crystals using Raman thermometry [2,3]. In vacuum, our results suggest a weak influence of flake thickness on κ (~20—40 W m^{-1} K^{-1}) given by a unique in-plane cooling channel from the hot spot towards the heat sink. Interestingly, the results in air and N_2 environments suggest enhancement heat dissipation capabilities for the thinnest flakes. Owing to the large surface-to-volume ratio, the presence of an out-of-plane cooling channel from $MoSe_2$ to the environmental molecules results in an apparent thermal conductivity (κ_{app}) increase by an order of magnitude (~200 W m^{-1} K^{-1}) for monolayer flakes. We estimate the out-of-plane heat transfer coefficient to adjacent gas molecules as large as 60,000 W m^{-2} K^{-1}. These results are crucial for the design of (sub-)nanometer-thick TMD-based devices with engineered thermal properties that can be comparable, or even better, to those of nanometer-thick Si-based devices.

References

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Figures

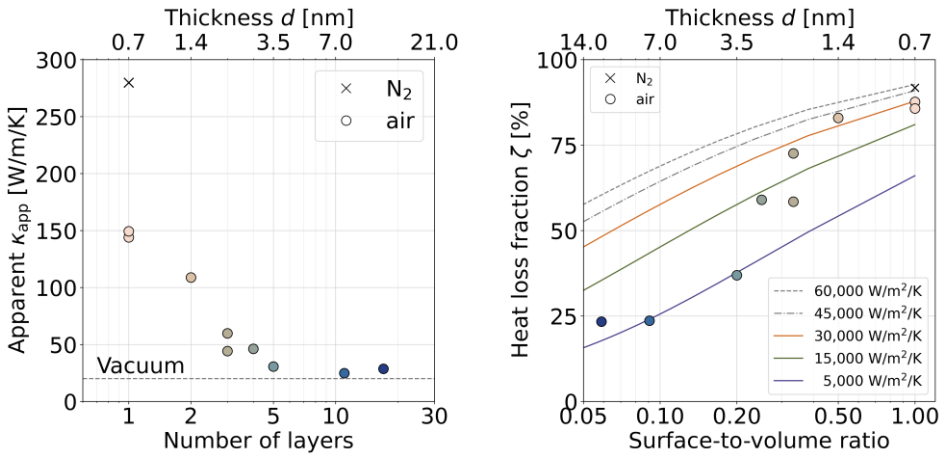

Figure 1: Apparent thermal conductivity of $MoSe_2$ in vacuum, air and N_2 environments (*left*) and heat loss fraction (in air and N_2) as a function of flake thickness (*right*).