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Quantitative scanning thermal microscopy studies of the influence of interfaces and heat transport anisotropy in 2D materials

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Abstract

Since the discovery of graphene, the physical properties of layered and two-dimensional (2D) materials have been widely investigated to enable their applications in real-world devices. In particular, the heat transport in these materials is largely influenced not only by the nature of the measured material itself but also by the interaction with the substrates and the resulting 2D-3D materials interfaces. Given the nanoscale dimensions involved, matching effective thermophysical measurement techniques are required.
Here, we focus on how nanoscale features affect the thermal transport of three different layered materials (graphene, γ-InSe, and perovskite), conducting the measurements with Scanning Thermal Microscopy (SThM). This characterization technique provides us with analogous lateral and thickness resolution to measure the heat transport anisotropy of the layered nanostructures and the effects of the substrate and the interfaces within the diffusive thermal transport approximation. We use the sample preparation method of beam-exit cross-sectional nano-polishing (BEXP), which provides a low-angle cut with a nearly atomically-flat wedge-like surface accessible for the SThM study. We then study the thickness-dependent variation of heat transport of each material deriving their anisotropic thermal conductivities.
By investigating three materials with different thermal transport and anisotropic degree we can compare the interface effects of high (Si) and low (SiO2) thermal conductive substrates. We notice that the interfacial thermal conductivity of the

substrate and the top layer material plays a vital role in the overall heat transport of the structure, which can be observed by the SThM-measured profiles of thermal resistance. With a further analytical model of the experimental results, we are able to extract the degree of anisotropy of the thermal conductivities and estimate the limits of the interfacial thermal resistivity in the material-substrate junction.