Anisotropic thermal transport using xSThM studies in 2D-3D heterostructures and composites

Khushboo Agarwal[1], S. Gonzalez-Munoz[1], Abhishek Ghosh[2], M. Ahmad[2], B. R. Mehta[2] and O. V. Kolosov[1]

[1] Physics Department, Lancaster University, Lancaster, UK
[2] Physics Department, Indian Institute of Technology-Delhi, India
Email: k.agarwal1@lancaster.ac.uk

Thermal conductivity is a crucial parameter defining the thermal transport as well as thermophysical properties of materials in thermoelectric, manufacturing and processing applications of materials where heat transport plays a major role. To address a current challenge of measuring these properties locally, in the areas of few tens or hundreds nanometres, we used a novel approach of cross-sectional scanning thermal microrcopy, or SThM, (xSThM). In this method, we first create a fine low angle wedge of the studied material via precision Ar ion cross-sectional polishing [1] and then measure a thermal conductance via SThM with each measurement point providing thermal conductance of the material with different thickness. Furthermore, an analytical model is then used to extract not only anisotropic values of thermal conductivity but also determines the effect of interfacial thermal resistance between the substrate and complex structured materials (heterostructure and composite structures). This technique thus facilitates a direct measurement of thermal conductance as a function of thickness in 2D-3D based heterostructures (Sb_2Te_3/MoS_2) and composites structures ($Sb_2Te_3/AgSbTe_2$). The thickness and number of layers of MoS_2 was optimized to achieve extremely lower values of thermal conductivity (0.7 ± 0.1 $Wm^{-1}K^{-1}$) along with higher values of power factor ($(4.97 \pm 0.39) \times 10^{-3}$ $Wm^{-1}K^{-2}$) leading to high values of ZT of 2.08 ± 0.37 at room temperature. Similarly, the concentration of Ag in $Sb_2Te_3/AgSbTe_2$ is optimized for highest values of ZT. A major enhancement in the value of TE performance was observed due to the effective majority carriers filtering and phonon scattering at the potential barrier present due to multiple interfaces. The current methodology provides an efficient tool for quantifying the thermal transport in thin films and 2D materials, and hence is useful in establishing the thermal transport in such complex structures.

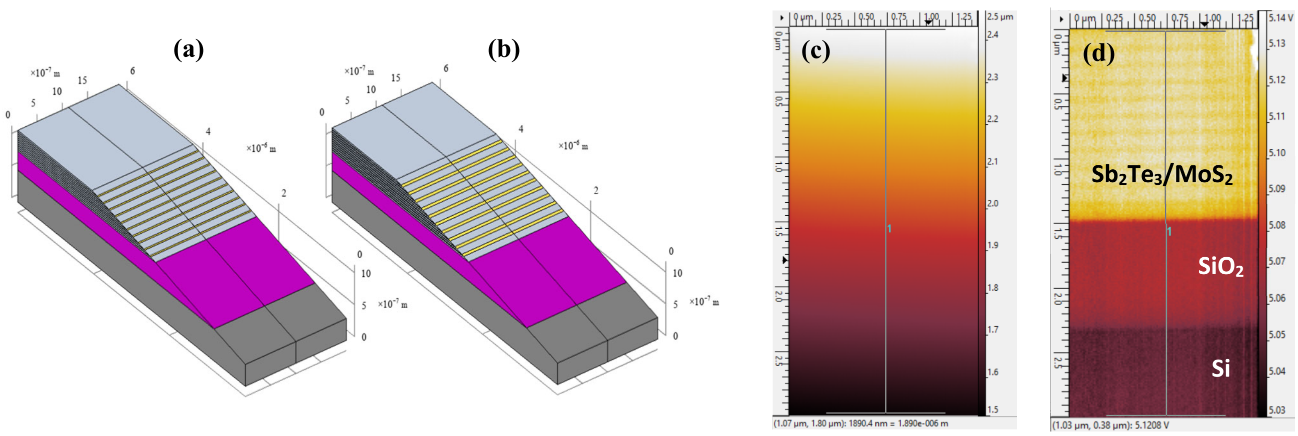

Fig. 1. (a) and (b) schematic diagram of the wedge cut sample of Sb_2Te_3/MoS_2 heterostructure with different thicknesses of MoS_2 layer. (c) topographical image and (d) thermal of Sb_2Te_3/Mos_2 sample with MoS_2.

References:

[1] Jean Spièce, Charalambos Evangeli, Alex J. Robson, Alexandros El Sachat, Linda Haenel, M. Isabel Alonso,○ Miquel Garriga,○ Benjamin J. Robinson, Michael Oehme, Jörg Schulz, Francesc Alzina, Clivia Sotomayor Torres, Oleg V. Kolosov, Nanoscale, **24,** 10829 (2021).