Introduction

The concept of thermoelectricity is paramount for both resolving issues related to energy crisis and as well as solutions for global heat management. However, the inadequacy in the value of figure of merit (FOM) still restricts its use in commercial applications and cannot currently compete with the existing techniques.

Methodology

- **Sb$_2$Te$_3$/MoS$_2$** multilayer structures were fabricated with varying thickness of MoS$_2$ layers.
- The electrical and thermal transport was analysed as a function of number and thickness of MoS$_2$ layers.
- KPFM results show the presence of a potential barrier for majority carrier holes.
- The samples were prepared by Beam Exit Cross-sectional polishing (BEXP) which uses Ar ions to create a near-atomically flat low angle (1 to 5°) wedge shaped oblique cut with minimal sample damage.
- The measurement of thermal resistance on wedge samples allows to separate the contribution from the interfacial thermal resistance and to independently quantify in-plane and across-the-plane values of thermal conductivity via simple analytic model.

For bulk isotropic material and a contact radius above the phonon mean free path, the thermal spreading resistance is given by $R_\mathcal{T} = \frac{1}{\kappa_{\text{th}}}$, with small angle wedge cut each InSe measurement point can be approximated as a layer of variable thickness. We can then use the transverse isotropic model for $R_\mathcal{T}$ for the heat spreading within the layer on a substrate $R_\mathcal{T}(l) = \frac{1}{\kappa_{\text{th}}} \int_0^l \frac{1}{1 - \exp \left( - \frac{2\pi l/\xi}{\kappa_{\text{th}}}ight)} \frac{1}{\xi \sin(\alpha)} dl$.


Results

Thermoelectric properties of Sb$_2$Te$_3$ and Sb$_2$Te$_3$/MoS$_2$ multilayer samples with the temperature range 320-484 K (a) electrical conductivity, (b) Seebeck coefficient and (c) power factor and (d) thermal conductivity measured by 3w method.

The carrier concentration, electrical conductivity, Seebeck coefficient, Hall mobility and power factor values of Sb$_2$Te$_3$ and Sb$_2$Te$_3$/MoS$_2$ samples at room temperature.

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Carrier concentration (10$^{19}$ cm$^{-3}$)</th>
<th>Electrical conductivity (S/cm)</th>
<th>Seebeck coefficient (μV/K)</th>
<th>Power factor (mW/mK$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sb$_2$Te$_3$</td>
<td>13.5</td>
<td>688</td>
<td>35.16</td>
<td>188.23</td>
</tr>
<tr>
<td>Sb$_2$Te$_3$/5 MoS$_2$</td>
<td>4.8</td>
<td>357.93</td>
<td>46.84</td>
<td>286.76</td>
</tr>
<tr>
<td>Sb$_2$Te$_3$/10 MoS$_2$</td>
<td>1.9</td>
<td>180.86</td>
<td>59.49</td>
<td>531.07</td>
</tr>
</tbody>
</table>

(a) X-ray diffraction, (b) Raman measurements of Sb$_2$Te$_3$, Sb$_2$Te$_3$/MoS$_2$, and (c) zoom of Raman spectra.

FESEM micrographs and AFM surface topography of Sb$_2$Te$_3$ and Sb$_2$Te$_3$/MoS$_2$ multilayer thin film samples.

- The simulated curves were generated by varying a, k1 and ratio of kxy/kz.
- For Anisotropic model, k1 and teff in Muzychka equation is substituted by k1= $\sqrt{kxy \times kz}$ and teff = $t/\sqrt{(kxy/kz)}$.

Conclusions

- High Seebeck coefficient value (619 μV/K at 347 K) was observed along with lower thermal conductivity values (0.83 mW/mK$^2$ at RT) for Sb$_2$Te$_3$/MoS$_2$ multilayer samples.
- The present work highlights the direct importance of interfaces and the possibility of further improving the thermoelectric response of the material.

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