超格子におけるコヒーレントフォノンの異方的熱輸送

Anisotropic Heat Conduction of Coherent Phonons in Superlattices

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Heat conduction due to phonons is dominated by incoherent scattering processes from crystal defects and anharmonicity. While the contributions from low frequency phonons with long wavelengths are not significant, they go through coherent scattering processes, which are challenging to control and therefore, remain as a major challenge for mastering the conduction of heat in solid. As such, understanding the propagation of coherent phonons is of fundamental interest in thermal management technologies. Superlattices in this regard provide an excellent platform since its heat conduction is attributed to coherent phonons.[1] Experimental studies are typically performed on artificial superlattices, but they exhibit dislocations at interfaces, which increases anharmonicity and affect coherent scattering processes. For this reason, there has been some discrepancies between experimental and theoretical research efforts.

In this study, we investigated the heat conduction in $InGaO_3(ZnO)_m$ superlattices with pristine interfaces to demonstrate several important concepts in phonon engineering, including the discrepancy between coherence length and mean free path, scattering mechanism changes according to the coherence length, specular phonon propagation along the in-plane direction, the suppression of Umklapp processes.

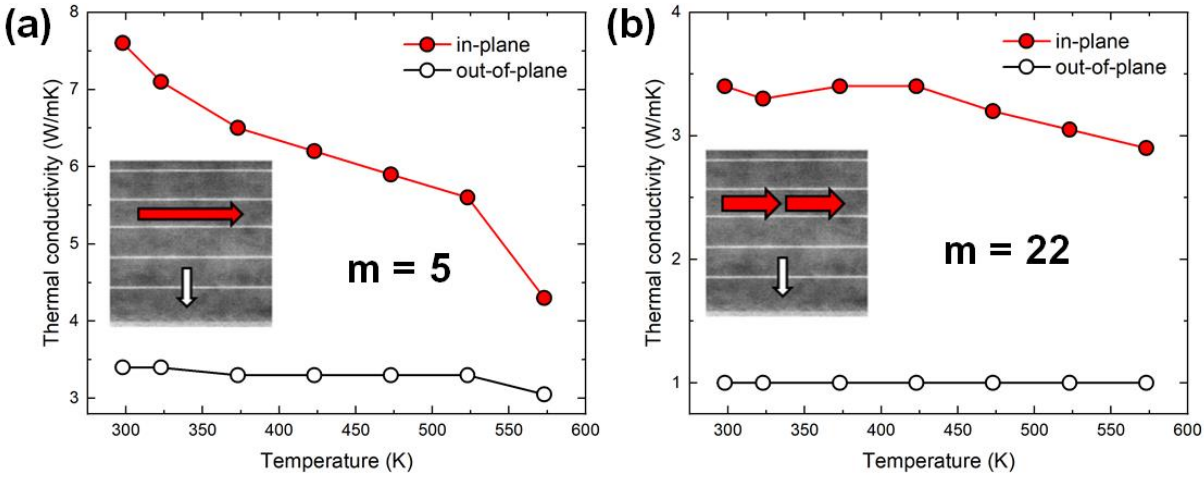

Figure | Anisotropic heat conduction of coherent phonons in $InGaO_3(ZnO)_m$ superlattices as a function of m. (a) m = 4. (b) m = 22. At m = 22, coherent heat conduction dominates the out-of-plane direction while Umklapp processes dominate the in-plane direction. However, at m = 4, the effect of Umklapp processes is greatly hindered along the in-plane direction.

Reference

[1] M. N. Luckyanova *et al*., Science **338**, 936 (2012).