ランダム配向多結晶よりも低い単結晶超格子セラミックの異常に低い熱伝導
Anomalously Low Heat Conduction in Single-Crystal Superlattice Ceramics Lower than Randomly Oriented Polycrystals

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Understanding heat conduction in ceramics is an essential requirement for achieving low thermal conductivity for thermoelectrics and thermal barrier coatings. While grain boundaries greatly hinder the conduction of heat, they also damage other functional properties. In this regard, superlattices offer a great solution in thermal management technologies. However, experimentally clarifying the heat conduction in superlattices has been challenging due to the presence of crystalline defects in artificial superlattices.

Here we investigate thermal conductivity of defect-free single crystalline $InGaO_3(ZnO)_m$ superlattices and report the in-plane as well as cross-plane thermal conductivities (κ) using time-domain thermoreflectance method. The cross-plane κ of $InGaO_3(ZnO)_m$ (**Fig. a**, ⊥) was always lower than the in-plane κ (**Fig. a**, //). Interestingly, the in-plane κ values were similar to the κ of randomly oriented ceramics. This clearly indicates that heat conduction predominantly occurs in the in-plane direction.

The thermal resistivity (κ^{-1}) linearly increases with increasing interface density (d_{SL}^{-1}) until 0.5 nm^{-1}, then decrease with increasing d_{SL}^{-1} (⊥) or shows a plateau (//). This behavior suggests the phonon scattering mechanism transform from particle-like (diffusive) to wave-like (specular). The interfacial Kapitza resistance in the diffusive scattering regime was calculated using ⊥ data as 1.76 m^2 K GW^{-1}. In specular regime, the wave nature of the phonons such as the increasing phonon group velocity from to phonon band folding dominates the heat conduction. The minimum κ was 1.1 W m^{-1} K^{-1} when m = 4−5, which is lower than that of amorphous $InGaO_3(ZnO)_m$.

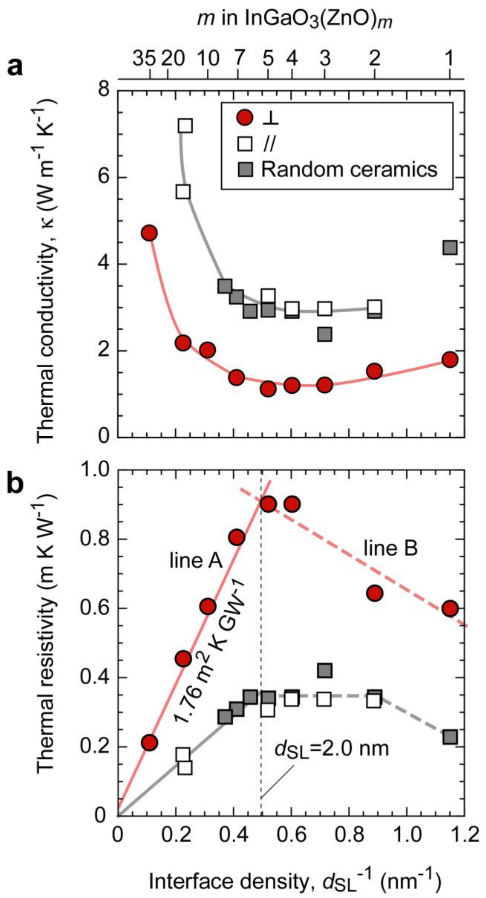

Figure (a) Thermal conductivity (κ) and (b) thermal resistivity (κ^{-1}) of $InGaO_3(ZnO)_m$ (m = integer) at room temperature as a function of the interface density.