$MnCl_2$-$FeCl_3$ 共インターカレーションによるグラファイトの面直熱伝導率の変調

Tuning cross-plane thermal conductivity of graphite by $MnCl_2$-$FeCl_3$ co-intercalation

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Understanding thermal transport in layered materials provides a novel way to design materials with tunable thermal conductivity by leveraging intercalation with large sized guest atoms. In this work, we report a significant tunability in crossplane lattice thermal conductivity κ_z of graphite upon co-intercalation with $MnCl_2$ and $FeCl_3$ forming graphite co-intercalation compound(co-GIC). As presented in Fig 1(a), the controllability is found to be consistent over a broad temperature range spanning from 78 K to 298 K. Furthermore, we also observe such tunability across the entire thickness range of the samples spanning 2-orders in magnitude from as thin as 30 nm to as thick as 1.5 µm as shown in Fig 1(b). Scanning transmission electron microscopy reveals that the dominant phase corresponds to stage-3 superlattice-like layered nanostructure which is further supported by Raman spectroscopy mapping. In order to unravel underlying phonon scattering mechanism at play, a semiempirical phonon scattering based Debye-Callaway theoretical modelling has been employed to fit temperature dependence of κ_z and fit results are shown by the dashed lines in Fig 1(a). Our result reveals a nearly 5-fold increase in boundary scattering rate at room temperature upon intercalation which in turn is found to stem primarily from 2-orders of magnitude suppression in the effective mean free path. This results in nearly 2-orders jump in contribution from boundary scattering component to total κ_z at 298 K and thus conclusively explains the measured large tunability of c-axis κ_z.

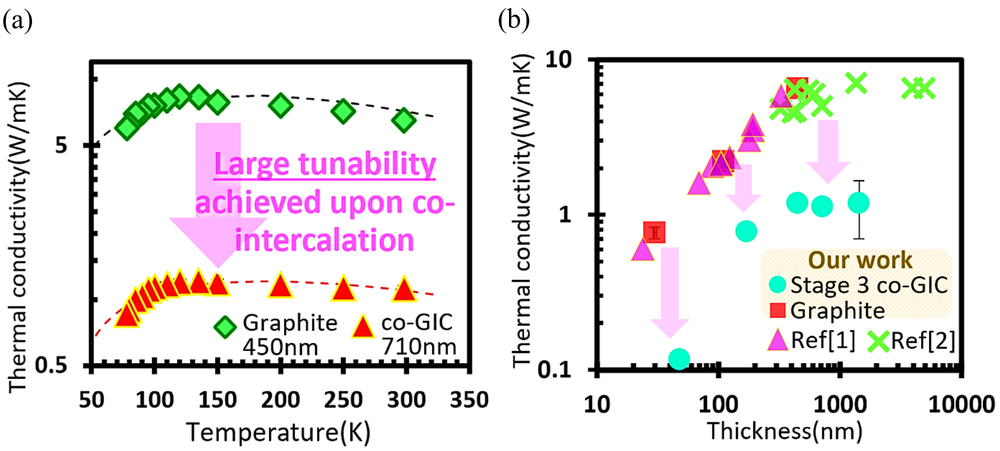

Fig 1: (a) Temperature dependence of κ_z. Arrow shows resulting tunability upon co-intercalation.
(b) Thickness dependance of κ_z reveals the size effect. Arrow shows drop in κ_z upon co-GIC formation.

[1] Fu *et. al* (2015). Appl. Phys. Lett.,106, 031905

[2] Zhang *et. al* (2016). Nano Lett. 16, 1643−1649