Functionalization mediates heat transport in graphene nanoflakes

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The high thermal conductivity of graphene and few-layer graphene undergoes severe degradations through contact with the substrate. Here we show experimentally that the thermal management of a micro heater is substantially improved by introducing alternative heat-escaping channels into a graphene-based film bonded to functionalized graphene oxide through amino-silane molecules. Using a resistance temperature probe for in situ monitoring we demonstrate that the hotspot temperature was lowered by ∼28°C for a chip operating at 1300 W cm^{-2}. Thermal resistance probed by pulsed photothermal reflectance measurements demonstrated an improved thermal coupling due to functionalization on the graphene-graphene oxide interface. Three functionalization molecules manifest distinct interfacial thermal transport behavior, corroborating our atomistic calculations in unveiling the role of molecular chain length and functional groups. Molecular dynamics simulations reveal that the functionalization constrains the cross-plane phonon scattering, which in turn enhances in-plane heat conduction of the bonded graphene film by recovering the long flexural phonon lifetime[1].

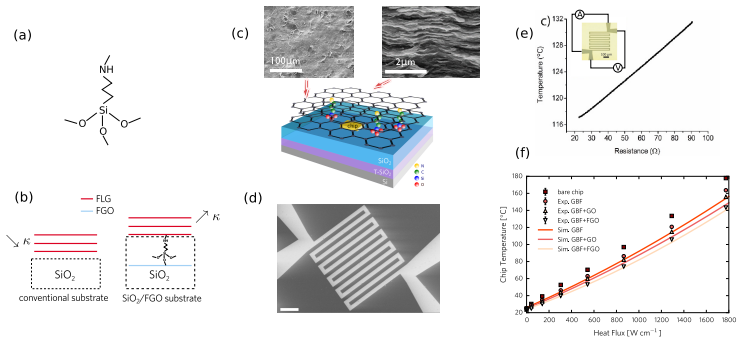

Fig. 1: **Graphene-based film on functionalized graphene oxide as heat-spreader** (a) Sketch of the chemical bonds of the silane molecule. (b) Schematic of a graphene film on different supports. Left: Conventional silica substrate. Right: the proposed silica / functionalized graphene oxide substrate. (c) Schematic of the measurement setup. SEM image of the in-plane and the cross section of the GBF. (d) SEM image of the chip. (e) Calibration relationship between the resistance. (f) Measured (filled markers) and FEM simulated (lines) chip temperatures versus the in-plane heat fluxes dissipated in (rectangles) a bare hotspot, (circles) a hotspot covered by a graphene-based film (GBF), (up triangle) a chip covered by a GBF with non-functionalized graphene oxide (GO) and (down triangle) a chip covered by a GBF with APTES functionalized GO.

[1] H. Han, Y. Zhang, *et al.*, *Functionalization mediates heat transport in graphene nanoflakes.* Nature Communications 7, 11281, 2016