Highlights

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Ultralow friction of ink-jet printed graphene flakes

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We report the frictional response of few-layer graphene (FLG) flakes obtained by the liquid phase exfoliation of pristine graphite. To this end, we inkjet print FLG on bare and hexamethyldisilazane-terminated SiO_2 substrates (Fig. (a)), producing micrometric patterns with nanoscopic roughness (Fig. (b)) that are investigated by atomic force microscopy (AFM). Notably, the printed FLG flakes show ultralow friction (Fig. (c)) comparable to that of micromechanically exfoliated graphene flakes. Lubricity is retained on flakes with a lateral size of a few tens of nanometres, and with a thickness as small as ~2nm, confirming the high crystalline quality and low defects density in the FLG basal plane. Surface exposed step edges exhibit the highest friction values, representing the preferential sites for the origin of the secondary dissipative processes related to edge straining, wear or lateral displacement of the flakes. Our work demonstrates that liquid phase exfoliation enables fundamental studies on graphene friction to the single-flake level. The capability to deliver ultralow-friction-graphene over technologically relevant substrates, using a scalable production route and a high-throughput, large-area printing technique, may also open up new opportunities in the lubrication of micro- and nano-electromechanical systems.

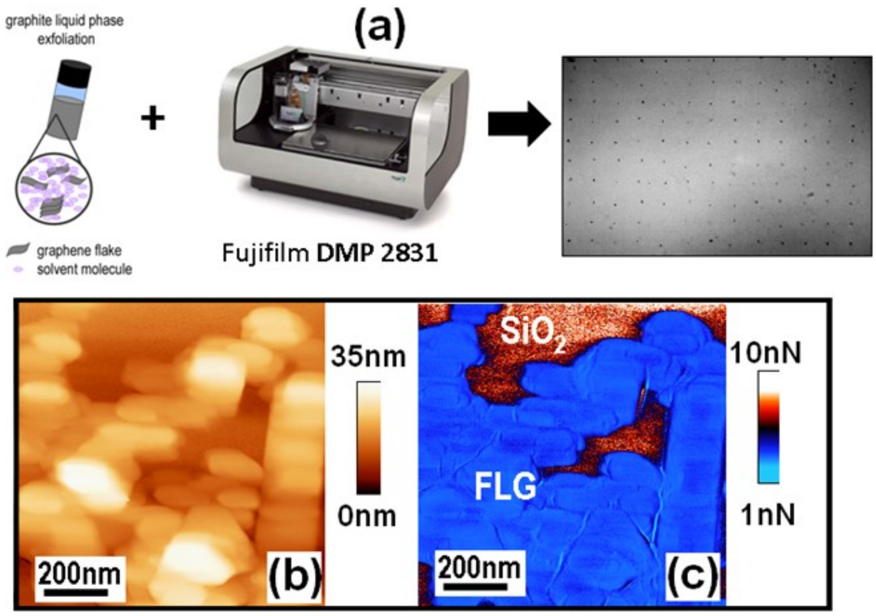

Figure: (a) Schematic illustration, showing a graphene ink printed onto a solid support by means of the materials printer DMP 2831, to produce a square grid pattern of micrometric dots over macroscale areas.
Morphology (b) and frictional response (c) of printed FLG flakes, as measured by AFM. The nanoscale friction map in (c) demonstrates order-of-magnitude reduction of interfacial friction on printed FLG compared with the one registered on the SiO_2 substrate.