Friction of few layer graphene over different substrates

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Abstract

Nanoscale friction properties of chemical vapor deposition (CVD) grown graphene on polycrystalline Ni (Gr/Ni) with respect to mechanical exfoliated graphene deposited on SiO\(_2\) (Gr/SiO\(_2\)) have been studied by Atomic Force Microscopy (AFM). These two types of graphene films possess rather different tribological characteristics. Micron scale, single domain flakes with very low defects and random variable thickness from single layer to thick graphite are routinely obtained by mechanical exfoliation of graphite crystal and are considered a standard for scientific application [1]. On the contrary, for large scale applications, the CVD grown graphene on polycrystalline metal is considered one of the more interesting method. Films obtained with this procedure are continuous over areas as large as few square centimeters but consist of a large number of graphene domains of few layer thickness separated by disordered regions [2].

Recently, friction experiments at micro scale have shown that Gr/Ni systems possess a lower friction coefficient with respect to Gr/SiO\(_2\) [3]. These measurements average out the contribution of graphene domains and disordered regions where nucleation has taken place. In order to elucidate the relative contribution of these regions, we performed AFM friction measurement at nanoscale in ambient and vacuum conditions (10\(^{-5}\) Torr). We observed that the major contribution for reducing lateral force comes from the disordered regions rather than the flat graphene domains, Fig. 1.

We also perform nanoscale measurement on Gr/SiO\(_2\) flakes. Our results confirm that a single graphene layer is sufficient to strongly reduce (about 50 times) the friction with respect to bare SiO\(_2\), but also that friction decreases with increasing film thickness [4]. That is the friction is higher on single-layer region than respect to a bi-layer region and further decreases up to 3-4 layer thickness. We observe this trend both in air and vacuum conditions (10\(^{-5}\) Torr), Fig. 2.

These results point out that properties of few layer graphene as a solid lubricant are dictated by both interaction with the supporting substrate and interlayer mechanical characteristics. Extending [5], a model for rationalizing the observations is also proposed.

References

Figures

**Figure 1:** (a) 3-D Topographic image (7x7 µm²) of CVD grown graphene on polycrystalline Ni showing a large flat domain and disordered region on top right corner. (b) Lateral Force map of region on panel (a) showing high (brighter) lateral force on flat domain relatively lower (dark) on the irregular region. (c) Topography profile and (d) corresponding Lateral Force profile.

**Figure 2:** (a) Topographic image of mechanical exfoliated graphene deposited on SiO2 showing, from left to right, Mono-Layer, By-Layer and Thicker-Layer regions. (b) Friction map of region on panel (a). (c) Lateral force profile corresponding to gray line on panel (b) showing a net decrease of Lateral force moving from ML to TL.