Nano-Friction of Two-Dimensional Materials Studied by Atomic Force Microscopy

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Two-dimensional (2D) materials have layered structure asociated with weak van der Waals forces between the layers. These properties provide easy shearing of the constituent layers and low friction between two layers during the sliding. Since 2D materials are also atomically thin, they could be used as ultra-thin solid lubricants needed to reduce friction between moveable parts in nano-mechanical devices [1, 2]. While previous studies were mainly focused on graphene and transition metal dichalcogenides, we investigated frictional properties of 2D talc [3]. Talc ($Mg_3Si_4O_{10}(OH)_2$) is a van der Waals and naturally abundant mineral belonging to the phyllosilicate (sheet silicates) group. In a bulk from it is well-known solid lubricant, but we revealed that it could serve as a lubricant at the nanoscale as well. Using atomic force microscopy (AFM) and contact angle measurements, it is demonstrated that 2D talc is hydrophobic and associated with a low adhesion and friction coefficient of 0.10 ± 0.02 which is comparable to graphene grown by chemical vapour deposition. Bearing in mind the natural abundance of talc, few nanometers thick talc flakes could be therefore considered as cost-effective solid lubricants in micro- and nano-mechanical devices.

2D crystals are also suitable platforms to study the influence of epitaxial relations between two contacting surfaces on resulting friction [4, 5]. For that purpose, we investigated lateral movements of organic needle-like nanocrystallites on 2D materials, graphene and hexagonal boron nitride, using AFM based manipulations [6]. It was demonstrated that organic nanoneedles move along the needles' growth directions which do not coincide with original pushing directions defined by the movement of AFM probe. Therefore, the needles' growth directions, which define commensurate states, act as invisible rails which determine directions for needles sliding. On the other hand, when the nanoneedles were rotated by the AFM tip across the preferential sliding directions and commensurate states, the lateral force (measured as a torsion of the AFM cantilever) was increased indicating pronounced friction anisotropy.

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