7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Inception of covalent bonds and nanoscale kinetic friction on graphene / SiC under increasing contact pressure

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The properties of 2D materials change dramatically under high pressure. The application of high contact pressures with the sharp tip of an atomic force microscopy can cause rehybridization of bonding orbitals in epitaxial graphene on SiC(0001) and change interlayer van der Waals forces into metastable covalent bonds. This intermittent bond formation and bond release can be observed as increase in the coefficient of friction by high-resolution friction force microscopy.

Keywords: nanotribology, 2D materials, friction force, graphene, AFM

1. Introduction

Graphene as 2D material is tough in plane but has weak normal to plane interactions. This feature leads to excellent tribological properties, namely ultralow friction which was demonstrated by Friction Force Microscopy (FFM) measurements on many different substrates. FFM experiments have shown that the load dependence of friction for epitaxial graphene on SiC(0001) is not entirely linear [1]. The friction force increases dramatically above a normal force threshold. This observation could be explained by an intermittent and local orbital rehybridization from sp^2 to sp^3 and the formation of covalent bonds between the graphene layer and the surface beneath [2].

2. Methods

We studied the dependencies of the friction force on normal load and sliding speed for epitaxial graphene on SiC [3]. For atomically clean surfaces the FFM experiments were conducted in ultra-high vacuum. Sharp silicon and diamond probes were used in order to induce high pressure and to record high-resolution friction maps.

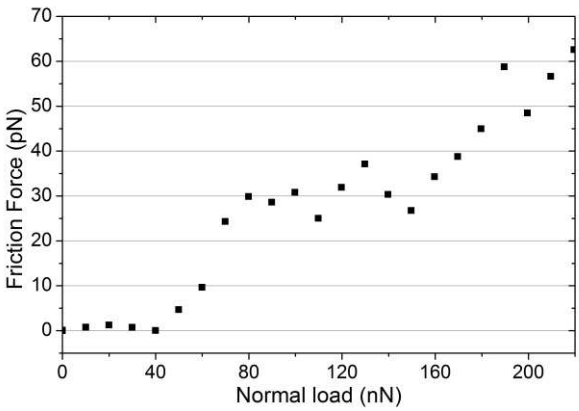

Figure 1: Friction force versus normal load recorded on a monolayer of epitaxial graphene on SiC. Friction increases above a threshold of 60 nN to a plateau value and again above 150 nN.

3. Discussion

As presented in figure 1, the load dependence of friction can be divided into three regimes. At low load below 40 nN, friction is ultralow and increases weakly with load, which is typical for graphite and graphene. The friction force increases steeply to reach a plateau between 80-160 nN. Above this value, friction increases again sharply with increasing load. The same observations were made for different probes and sliding speeds. We will discuss this peculiar load dependence of friction in with respect to the pressure-induced formation of intermittent covalent bonds.

4. References

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