The in-situ mechanical and tribological properties of carbon nanosurface in TEM

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Carbon nanosurface has been explored with various specific nanostructures for different functions of applications. For the applications of carbon nanosurface within limited space, nanocontact and nanofriction could happen[1]. The in-situ tribo-tests in transmission electron microscope (TEM) during the nanocontact sliding process measures the friction force together with observes the nanostructure evolution, which is the key factor affecting the nanoscale properties of carbon nanosurface. Besides, through quantitatively analyzing the relationships between friction force and interface shear strength, real contact area, nanostructure evolution, it is possible to clarify the physical mechanism of friction in atomic scale. In this study, the mechanical and tribological properties of carbon nanosurfaces embedded with graphene layer cross-linking nanocrystallites were measured at nanoscale, the nanostructure of carbon nanosurface was shown in figure 1(a) below. The nanosurfaces were prepared with low energy electron irradiation during plasma sputtering deposition[2], and the film thickness was about 100 nm. Silicon wedge with a narrow plateau of 150 nm was used as the substrate to facilitate the in-situ tribo-test and TEM observation, which was performed with the tribo-tester (BRUKER, Hysitron PI 95 TEM PicoIndenter) in high resolution TEM (ThermoFisher, Themis G2-300). A cube corner diamond tip with curvature radius of 50 nm was used to indent and slide against the carbon nanosurface. The in-situ nanoindentation was performed with displacement controlled to be 100 nm. The load-displacement curve was consecutive, correspondingly, no film fracture was observed and only very small area of plastic deformation was left, as shown in figure 1(b). When the tip was retracted from the nanosurface, a maximum adhesive force of 20 μN was measured. The in-situ tribo-test was performed by firstly indenting the surface with depth of 100 nm, and then sliding against the nanosurface with distance of 500 nm. Results show that at nanoscale, the tip exhibited stick-slip friction. Since the adhesive force plays a very important role in the sliding process, the shear adhesive force can be high to 62 μN with 174 μN load, the tip will jump with a large distance due to the detachment of tip to nanosurface, as shown in figure 1(c). The results showed that nanoscale adhesion greatly affects the mechanical and tribological properties of carbon nanosurface and the mechanism of graphene layer cross-linking nanocrystallite effect will be further studied and discussed. The research findings can shed light on the application of carbon nanosurface on nanodevices.

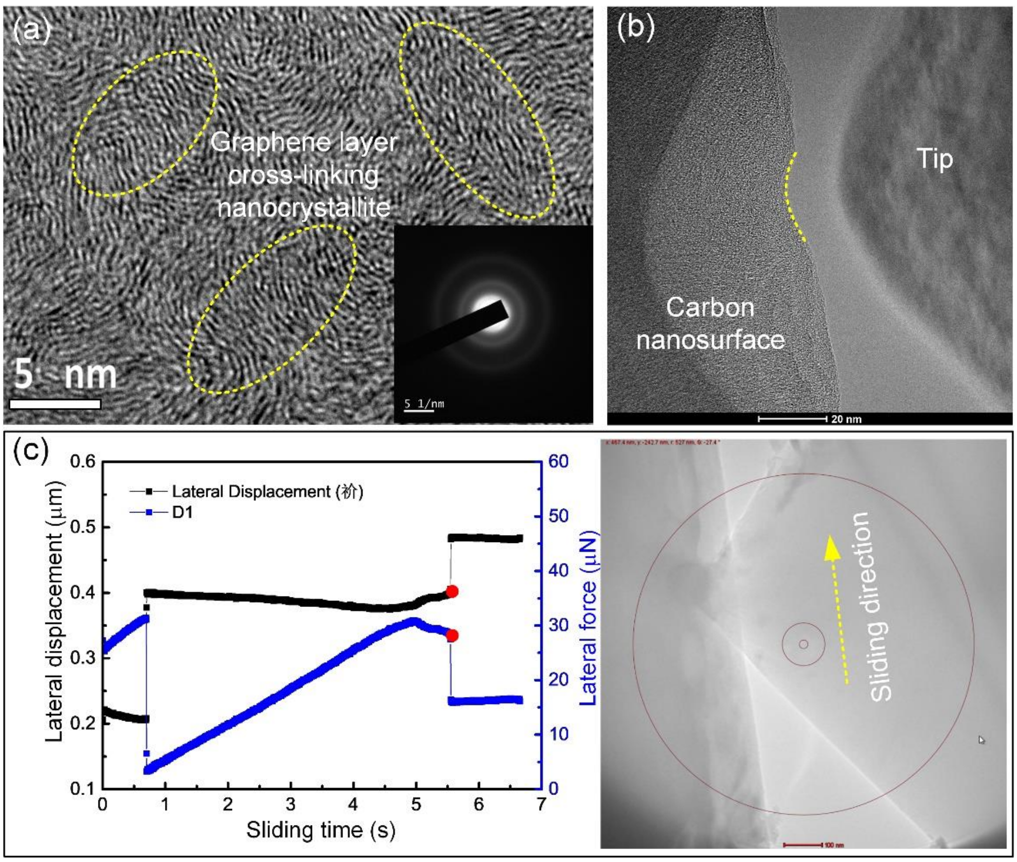

Figure 1 (a) The high resolution TEM image of the carbon nanosurface from plan view, graphene layer cross-linking nanocrystallites can be found in the nanosurface; (b) The TEM image of carbon nanosurface and tip after nanoindentation, a small area indicate with yellow line shows the plastic deformation area; (c) The lateral displacement and force during the sliding process between tip and nanosurface, and the right image shows a snap shot at the red point.

References

[1] Xue Fan, Dongfeng Diao, The adhesion behavior of carbon coating studied by re-indentation during in situ TEM nanoindentation, Applied Surface Science, 362, 49-55, 2016.

[2] Chao Wang, Dongfeng Diao, Xue Fan, Cheng Chen, Graphene sheets embedded carbon film prepared by electron irradiation in electron cyclotron resonance plasma, Applied Physics Letters, 100(23):231909, 2012.