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Experimental study about the influence of preparation process on graphene films over steel-bonded carbide samples

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Abstract

Graphene is an effective solid lubricant, which can significantly minimize the friction-induced material and energy loss in mechanical systems. In this study, the solution processed method combined with a specially designed coating device was used for the preparation of graphene films on steel-bonded carbide (GT35) disk samples. And the influence of preparation process on film distribution and corresponding lubrication performance was studied by using atomic force microscope (AFM), scanning electron microscope (SEM) and a pin on disk triboapparatus. It can be observed that after film deposition, graphene films are randomly distributed over sample surfaces. Under the influence of device coating process, a relatively uniform distribution of graphene films can be obtained. The unfolded graphene films would have sufficient contacts with surfaces, which can improve the macroscale lubrication performance of graphene films. The experimental measurements indicated that the lubrication performance of graphene films have a close relationship with its distribution and physical state.

Keywords: graphene; coating process; film distribution; lubrication performance; tribology; friction

1. Introduction

In mechanical systems, minimizing friction-induced material and energy loss is a major challenge to be addressed. Numerous studies have been carried out on the method of friction and wear reduction, such as the design of new lubricants [1, 2] and coatings [3]. One of the most attractive lubricant materials is graphene, which appears unique structural, mechanical and frictional characteristics [4]. It has been indicated that the graphene can serve as an effective solid lubricant between sliding surfaces. And many researchers have employed the solution processed method to realize the transfer of graphene films onto part surfaces [5, 6], which facilitates the practical application of graphene films. However, considering the complexity of preparation method, the influence of preparation process on film distribution and corresponding lubrication performance of graphene is still urgently needed to be studied.

In this study, the solution processed method was used for the transfer of graphene films to substrate surfaces. Then, a coating device was used to complete the preparation of graphene films. Thus, the influence of coating process on graphene films was studied. For experimental measurements, the graphene films were characterized by atomic force microscope (AFM) and scanning electron microscope (SEM). The macroscale lubrication performance was investigated by using a pin on disk triboapparatus.

2. Experimental details

The steel-bonded carbide (GT35) disk samples were used as the deposition substrates. Before the graphene deposition, the disk samples were cleaned ultrasonically with acetone, ethanol and water for 15 minutes, respectively, to remove any contaminants from the surface. The graphene-containing solution with a weight concentration of 0.1 mg/mL was prepared with ethanol and applied to the sample surfaces. The grayish deposited films would form on the surface after the evaporation of ethanol. Then, a coating device was used to evenly distribute graphene films over the surface. During the coating process, the randomly distributed films were smeared uniformly under a controllable load. Thus, the film distribution and thickness can be adjusted. Figure 1 shows the preparation procedure of graphene films and corresponding film coating device. Experimental measurements were carried out before and after the coating process to investigate the influence of processing process.

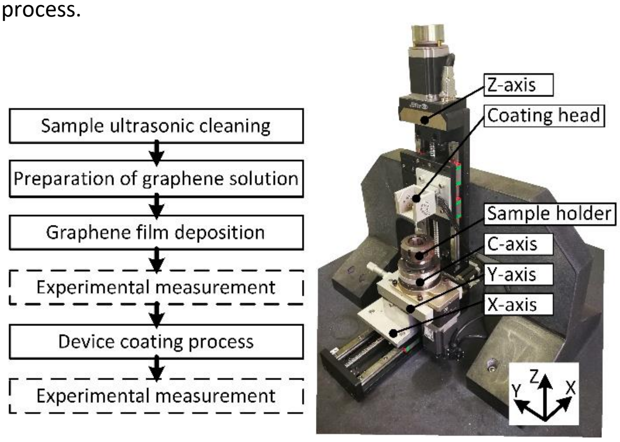

Figure 1. Preparation procedure of graphene films and corresponding coating device.

3. Results and discussion

After the coating device processing, the surface topography of graphene films and corresponding friction voltage map were characterized by AFM operating under the contact mode. During the tests, the AFM tips scan across the sample surface in a direction perpendicular to the cantilever long axis. The frictional force acting on the cantilever would cause torsional deflections and thus generate torsion signal (in volts) in position sensitive detector (PSD), which can be called as the friction-induced voltage. With this method, the surface topography and corresponding surface friction can be obtained simultaneously. Figure 2 presents typical AFM images of sample. For the samples without device processing, it should be noted that the AFM is not a suitable measurement method because of the dramatic topography change of sample surface. As shown in figure 2b, the friction-induced voltage over graphene films is lower than that of bare substrate, and the friction image can present well-distinguished film regions and substrate regions. It can be found that graphene films form a discontinuous layer which provides low friction and good wear resistance.

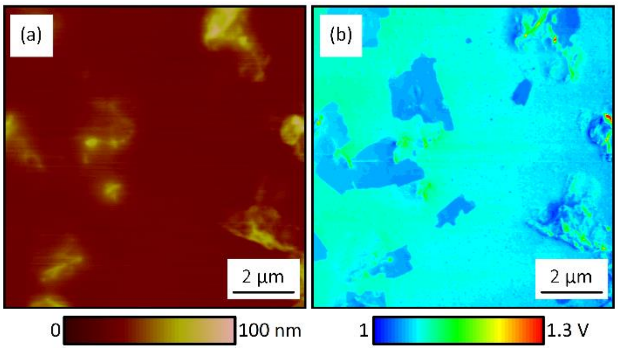

Figure 2. (a) Representative AFM image of film topography after the coating process, and (b) corresponding friction voltage map.

The SEM images present the topography change of samples before and after the coating process. As shown in Figure 3a, the sample without processing contains a random distribution of graphene films, and most of the films curl up forming an irregular shape. After the coating process, a relatively uniform distribution of graphene films can be achieved. Furthermore, as shown in high-magnification image, most of the graphene films are unfolded over sample surfaces after the processing. It can be concluded that the coating process has significant influences on the distribution and physical state of graphene films.

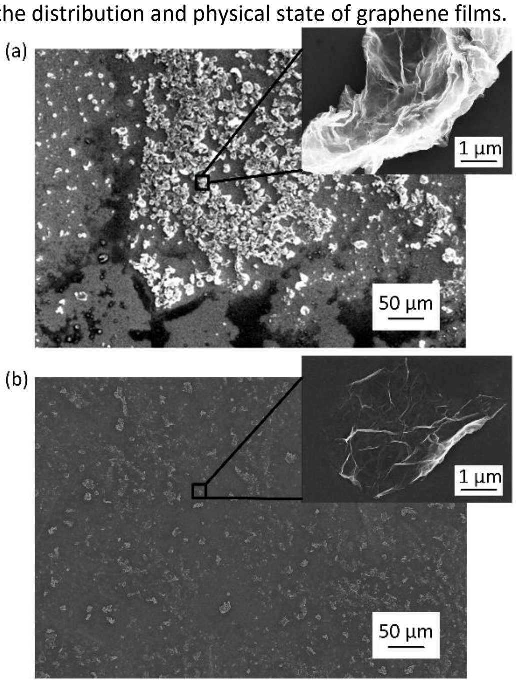

Figure 3. Representative SEM images of graphene films (a) before and (b) after the device coating process.

The macroscale tribological studies were performed to further investigate the influence of coating process on the lubrication performance of graphene films. During the test, steel-bonded carbide pins were used as the counterparts, flat samples were fixed on the stage so that the pin samples can slide in a reciprocating mode at a load of 5 N. The reciprocating distance is 4 mm with a sliding velocity of 1 mm/s, and the testing time is 1000 seconds. Figure 4 shows the coefficient of friction (COF) over the bare sample surface and coated samples before and after processing. The COF of bare sample is around 0.25, which serves as a baseline test. The COF of sample without processing is initially 0.09. With the increase of sliding cycles, the COF increases to 0.25. Under the influence of coating process, the COF of sample increases slightly and maintains at a stable value of 0.13. One possible reason for the observed results is the change in distribution and physical state of graphene films before and after the processing. The unfolded graphene films facilitate the contact with sample surface, and the bonding strength of graphene films can be improved to some extent.

Dry friction happens frequently in precision engineering due to the existence of precision move parts. In some situations, the graphene can be employed as an effective solid lubricant. Also, the coating process proposed in this paper can obviously improve the lubrication performance of graphene films, which would facilitate its application in practical engineering.

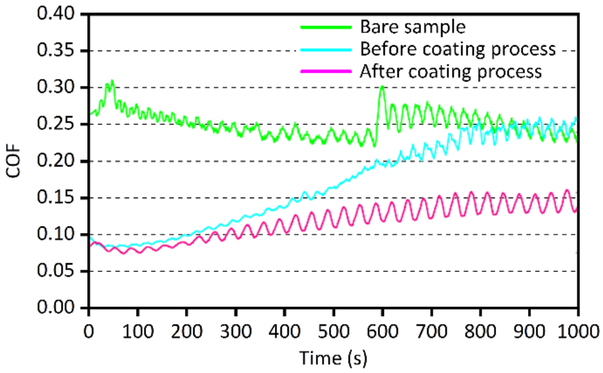

Figure 4. The friction coefficient of different samples.

4. Conclusions

In this study, the influence of coating process on graphene films was investigated. After film deposition, graphene films are randomly distributed over sample surfaces. Under the influence of device coating process, a relatively uniform distribution of graphene films can be obtained. And the unfolded graphene films would have sufficient contacts with surfaces, which can improve the macroscale lubrication performance of graphene films. The experimental measurements indicate that the lubrication performance of graphene films have a close relationship with its distribution and physical state.

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