Role of graphite-like tribofilm on the friction reduction of DLC films

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1. Introduction

Diamond-like carbon (DLC) coatings are known as promising candidates for solid lubricant films. DLC has been used and also will potentially be used in a broad range of applications, such as protective coatings of head and disk in magnetic storage systems, low friction and anti-stick coatings in micro/nano devices and also implant materials in human bodies. The excellent frictional behaviors have been investigated extensively in recent years[1-4]. However, the mechanism of friction reduction still remains a mystery.

2. Simulation and experimental methods

In this work, molecular dynamics (MD) simulations based on the second generation of reactive empirical bond order (REBO) potential are conducted to study the frictional behavior of DLC coatings. The DLC film is produced by atom-by-atom deposition [5]. A diamond (100) surface is used as the counterface sliding against the DLC film. Experimental investigations are also conducted. Filtered cathodic vaccum arc (FCVA) method is used to deposit the DLC films. Reciprocal ball-on-disk friction tests are conducted on DLC coated silicon wafer using steel as the ball material. Raman spectroscopy, interferometer and nanoindentation are adopted to study the structure, mechanical properties and chemical compositions of the films.

3. Results and discussion

During the initial sliding, there exist strong adhesive bonding interactions between the DLC film and the counterface. However, the coefficient of friction (COF) drops gradually from about 0.6 to about 0.01. At the same time the DLC film experiences a strong structural transformation. As shown in Fig. 1, the sp^3 to sp^2 transition and formation of a graphene-like interfacial film are observed. The graphene-like film is defective but is sp^2 dominated. The phase transformation is attributed to the shear induced stress relaxation [6], which will contribute to friction reduction due to the weak shear strength between the graphite-like tribofilm.

From white light interferometer, a tribofilm can be observed. The surface of the tribofilm is planarized due to the rubbing of the surface. It can be inferred that the friction occurs between the DLC film and the tribofilm, other than DLC against steel, which accounts for the low friction.

The carbon bonding information can be learned by Raman spectroscopy. It can be seen from table 1 that the deposited DLC film has a very high sp^3 content of 81.1%. However, after friction the sp^3 contents of the tribofilm drops to less than 60%, which verifies the theoretical prediction of the structural transformation.

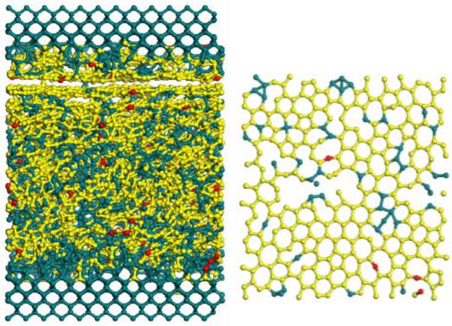
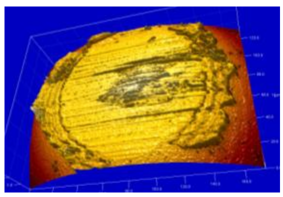


Fig. 1 (a) Atomistic structure after friction; (b) graphene-like film formed at the sliding interface



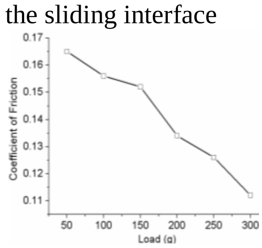


Fig. 2 Tribofilm formation Fig. 3 COF Load dependence

Table 1 Raman spectroscopy

	G peak	D peak	I_D/I_G	sp^3
DLC Film	1564.69	1356.97	0.233	81.1%
tribofilm	1590.27	1367.50	0.682	59.5%

Various affecting factors, especially the applied load on the frictional behaviors of DLC film are studied. As shown in Fig. 3, a decrease of COF with increasing load is observed, for the reason that phase transformation is more favored with larger loads.

4. Summary

MD simulation and experimental studies are conducted to study the frictional behavior of DLC films. The structural transformation and formation of graphite-like tribofilm are observed and are found to have close relationship with the significant friction reduction of DLC films.

5. References

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