Tribology for Space Technology

The solid lubricating films deposited by physical vapor deposition have been used to decrease the friction and wear of space mechanisms. For the WS_2 and MoS_2 films, sputtered pure MX_2 films normally exhibited poor wear resistance due to porous microstructure even in vacuum. Over the last decades, new methods of multilayer and multicomponent designs have been introduced to modify the MX_2 lubricant film structure.

In the application, the capability of tolerance to space environment (especially the high active atomic oxygen) is important for maintaining the tribological performances of the film sand so the reliability of the whole mechanism.

Satisfy the long-life operation of different moving parts in space station, lunar rover and various high-tech equipment models in China

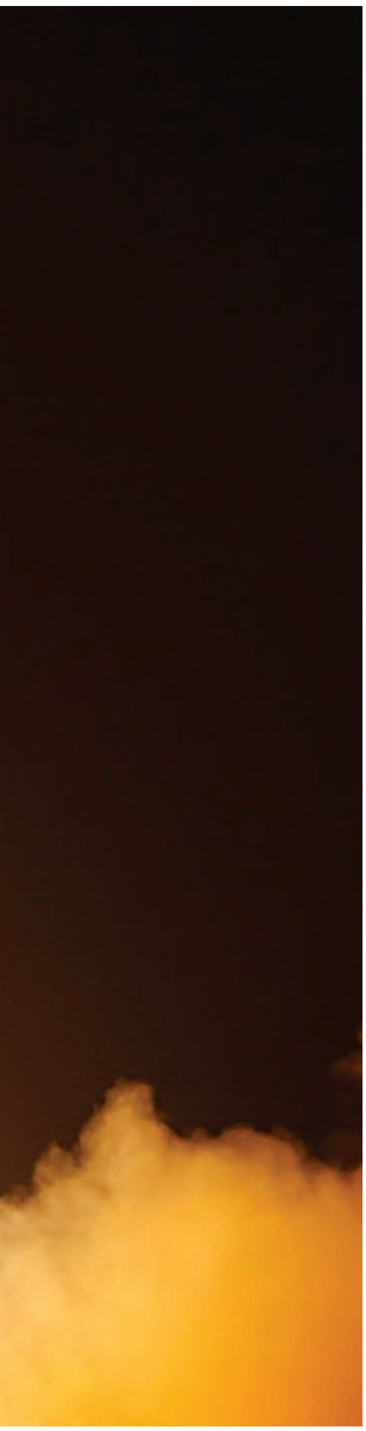
Adding metal elements (Au, Ag, Ni, Cr, Cu, Al, etc.) can significantly improve their wear resistances in vacuum environment. Due to the atomic oxygen irradiation, the oxidation and deterioration of lubricating property are inevitable either for transition metal disulfides (typical for MoS_2 and WS_2) and soft metals (Ag, In, Zn, Pb, etc.).

Adding reactive metals (such as Ag) is invalid to enhance the anti-oxidation from the atomic oxygen

irradiation. Therefore, two kinds of MoS_2 based films, separately composited in the composition and structure by inert metal (Au) were developed for the space application. WS_2 has higher thermal stability than MoS_2, which may provide a wide range of application as a lubricant in films. Nevertheless, the studies on the structure and tribological properties of WS_2 based films are much less as compared with MoS_2.

First, second and third

The evolutions in microstructure, composition and tribological properties of the WS_2 based films after storage in humid air or energetic atomic oxygen (AO) irradiation are systematically studied. There were significant differences in structure between the WS_2 based films with different kinds of metaldopants.



The inhibitory effect of dopants on the matrix columnar WS_2 crystal growth possibly depended on the values of T_s/T_m, where T_s was the substrate temperature and T_m was the melting point of the film materials.

Secondly, the growth of WS_2 crystals with edge-plane preferential orientation were completely prevented by incorporating the nanoscale Cu layer in the WS_2/Cu multilayer films. All the nanoscale WS_2/Cu multilayer films showed high hardness and high bearing capacity. The highwear resistance and low friction coefficient of the multilayer films were obtained.

Thirdly, even after a large dose of AO irradiation, the dense WS_2-Al composite film with compact structure still possessed good AO irradiation resistance due to the formation of protective thinner WO_3 cladding layer in the compact sub-surface layer and restricting the diffusion of AO into the films. WS_2 films with open structure also kept unchanged ascribing to crystal plane dependence of oxidation and huge platelet size of the coarse WS_2 columnar platelet.

After long period storage in moisture air environments, the moisture erosion and oxidation of WS_2/Cu multilayer films was restricted in the surface layer due to the protective effect of the compact structure itself, however, both the film and its substrate suffered severe moisture erosion.In light of these results, the WS_2 based films with modified structure and improved tribological properties may have potential applications in motion mechanisms of spacecraft.

Liquid

For lubrication of long term running mechanisms, liquid lubricants have to be used. Compared with those on ground, liquids for space lubrication have special requirement, ie low volatility, low temperature fluidity, anti-irradiation etc. chlorine containing silicone oil has long been used for space lubrication in China. More hetero-elements are introduced to enhance its boundary lubrication and antiwear life for long term applications.

In recent years, the development of polyolefin-substituted cyclopentane, polyalkylated cyclopentane, silicon hydrocarbon, silicone oil, perfluoropolyether, polyphenylene oxide, fluorine bromine oil and corresponding greases are developed to satisfy the long-life operation of different moving parts in space station, lunar rover and various high-tech equipment models in China.

Significant differences in structure between the WS_2 based films with different kinds of metaldopants

These oils can meet heavy load working conditions such as the lubrication of the moving parts in the environment of -70°C～250°C, hot vacuum environment and vacuum overload conditions. Meanwhile, we have explored potentials of ionic liquids as the additives in base oils.

Ions

The key is to tackle the oil solubility by constituting ionic liquids with large volume ions. Minor concentration of ionic liquids can significantly enhance the friction reduction and antiwear property of base oils. For a similar reason, the anti-irradiation property especially by atomic oxygen has to be considered for low earth orbit spacecraft. The molecular structures more tolerant to atomic oxygen are optimized and some atomic oxygen resistant functionality are introduced to additives to improve the performance of lubricants.

We are designing a lubricant between lubricating oils and lubricating greases. It looks like lubricating greases, but performs like oils. This can apparently obstruct creep of oils along sliding pairs, holding great potentials for space application.

Finally, we have combined both solid lubrication and liquid lubrication to pursue an even longer lubrication service for space mechanisms for China's future space exploration.

State Key Laboratory of Solid Lubrication
Lanzhou Institute of Chemical Physics
Weimin Liu, Lijun Weng, Dapeng Feng, Feng Zhou*
Email: wmliu@licp.cas.cn