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Structure and Tribological Properties of Moisture Insensitivity Si Containing Diamond-Like Carbon Film

Authors : Mingjiang Dai, Qian Shi, Fang Hu, Songsheng Lin, Huijun Hou, Chunbei Wei

Abstract : A diamond-like carbon (DLC) is considered as a promising protective film since its high hardness and excellent tribological properties. However, DLC films are very sensitive to the environmental condition, its friction coefficient could dramatic change in high humidity, therefore, limited their further application in aerospace, the watch industry, and micro/nano-electromechanical systems. Therefore, most studies focus on the low friction coefficient of DLC films at a high humid environment. However, this is out of satisfied in practical application. An important thing was ignored is that the DLC coated components are usually used in the diversed environment, which means its friction coefficient may evidently change in different humid condition. As a result, the invalidation of DLC coated components or even sometimes disaster occurred. For example, DLC coated minisize gears were used in the watch industry, and the customer may frequently transform their locations with different weather and humidity even in one day. If friction coefficient is not stable in dry and high moisture conditions, the watch will be inaccurate. Thus, it is necessary to investigate the stable tribological behavior of DLC films in various environments. In this study, a-C:H:Si films were deposited by multi-function magnetron sputtering system, containing one ion source device and a pair of SiC dual mid-frequent targets and two direct current Ti/C targets. Hydrogenated carbon layers were manufactured by sputtering the graphite target in argon and methane gasses. The silicon was doped in DLC coatings by sputtering silicon carbide targets and the doping content were adjusted by mid-frequent sputtering current. The microstructure of the film was characterized by Raman spectrometry, X-ray photoelectron spectroscopy, and transmission electron microscopy while its friction behavior under different humidity conditions was studied using a ball-on-disc tribometer. The a-C:H films with Si content from 0 to 17at.% were obtained and the influence of Si content on the structure and tribological properties under the relative humidity of 50% and 85% were investigated. Results show that the a-C:H:Si film has typical diamond-like characteristics, in which Si mainly existed in the form of Si, SiC, and SiO2. As expected, the friction coefficient of a-C:H films can be effectively changed after Si doping, from 0.302 to 0.176 in RH 50%. The further test shows that the friction coefficient value of a-C:H:Si film in RH 85% is first increase and then decrease as a function of Si content. We found that the a-C:H:Si films with a Si content of 3.75 at.% show a stable friction coefficient of 0.13 in different humidity environment. It is suggestion that the sp3/sp2 ratio of a-C:H films with 3.75 at.% Si was higher than others, which tend to form the silica-gel-like sacrificial layers during friction tests. Therefore, the films deliver stable low friction coefficient under controlled RH value of 50 and 85%.

Keywords : diamond-like carbon, Si doping, moisture environment, table low friction coefficient
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