Tribological properties of DLC films on polymers

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Our study is to search for tribological properties of diamond-like carbon (DLC) films as known as anti-wear hard thin film on various polymers. This report deals with the deposition of DLC films on various polymer substrates in vacuum by magnetron radio frequency (RF) sputtering method with using argon plasma and graphite, titanium target. The properties of friction and wear are measured using a ball-on-disk wear -testing machine. The properties of friction and wear have been remarkably improved by DLC coating. Moreover the composition of DLC films has been analyzed by using auger electron spectroscopy(AES). The wear rate of titanium-containing DLC film is lower than that of no-metal-containing DLC film.

Keywords : Diamond-like Carbon, Thin film, Coating, Surface, Friction

1. INTRODUCTION

Since the polymer material has the outstanding tribological characteristic, it is used in various fields such as tribo-material, etc. [1], [2]. However, with constantly demanding the improvement of requested performance and striving to adopt the application of novel technology due to the change of times, the characteristics, such as hardness, heat resistance, and wear resistance, can not satisfy those requirements of performance, and have some defects. This research is focused on studying and investigating the tribological characteristics of various polymer materials coated DLC film [3] and their influences.

2. EXPERIMENTAL METHODS

2.1 Polymer substrates

Polyamide6 (PA6), Polyphenylenesulfide (PPS), and Polyetheretherketone (PEEK) were used as substrate.

2.2 Film deposition

Magnetron RF sputtering equipment was used in forming a DLC film in a polymer material and its schematic illustration is shown in Fig.1. Graphite (C) was used as a target of in this research. RF electric power (13.56MHz) was exerted on both substrate and target sides. DLC films was deposited by the magnetron radio frequency (RF) sputtering with forming Ar plasma in vacuum under conditions RF electric power 200W on substrate side and 0 ~50W on target side, vacuum pressure 10Pa, and depositing time 60 minutes. As installing a fan-shaped piece of titanium on the graphite target, Deposition of titanium films addition-DLC [4] was performed. The addition amount of titanium can be changed according to the area of graphite and titanium.

2.3 Friction and wear test

In order to know the friction characteristic of the polymer coated DLC film, the friction examination is progressing with using a ball-on disk type wear-testing machine in a dry environment under conditions which are a SUS440C (φ6mm) indenter, indenting load 1.0N, rotation rate 100rpm, turning-radius 3mm, rotation 2000 times. A circumferential speed is 31.4 mm/s as a result of calculating from the above conditions. In order to know a wear form, the wear marks of the piece of an substrate and ball were observed under the differentiation interference microscope.

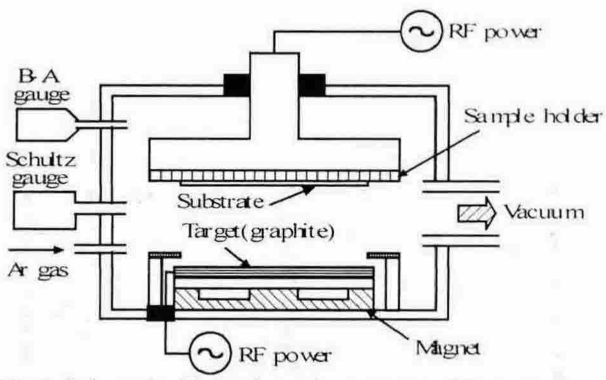


Fig.1 Schematic illustration of magnetron RF sputtering

2.4 Characterization of film

The formation of DLC film was analyzed using Auger Electron Microscopy (AES), and its hardness was measured by nano-indentation method using Atomic Force Microscopy (AFM). Using the silicon wafer as the substrate and measuring the bending amount of a sample with the measurement equipment of surface form, and basing on the following c the formula of Stoney shown equation (1), the remain stress in the DLC film can be computed.

$$\sigma = 4E_s d_s^2 \delta / 3(1-\nu_s) l^2 d_f \qquad \text{------ (1)}$$

3.RESULTS AND DISCUSSIONS

Although a friction coefficient is about $\mu=0.15$ at first in unprocessed PA6 (Fig. 2), it goes up to the value which increases with increasing the number of cycles, and exceeds $\mu=0.7$, and change is remarkably large. On the other hand, although $\mu=0.55$ and the value are shown high when a DLC film is formed, it is stabile and changeable. As observing sliding-traces, the surface of unprocessed sample was damaged seriously but the damage on DLC films coated sample was obviously decreased (as shown Fig. 3). In the same way, it can be considered that the friction coefficient of unprocessed sample could be increased as contact area was increasing in wear test when increasing the rotation times. On the other hand, it is shown that the wear-resistance of DLC film coated sample is very high and friction action is stable as its contact area is small. The friction coefficient of PPS is shown low and is about μ=0.2 in test beginning. Along with increasing rotation times, it is going up to μ=0.5 in the end of test. In the case of DLC film coated sample, its friction coefficient eventually keeps a steady value from beginning to end. It can be found that the effect of DLC film is so significant based on the fact in which friction coefficient of DLC film coated PEEK is μ=0.35 in corresponding that of untreated PEEK is μ=0.45.

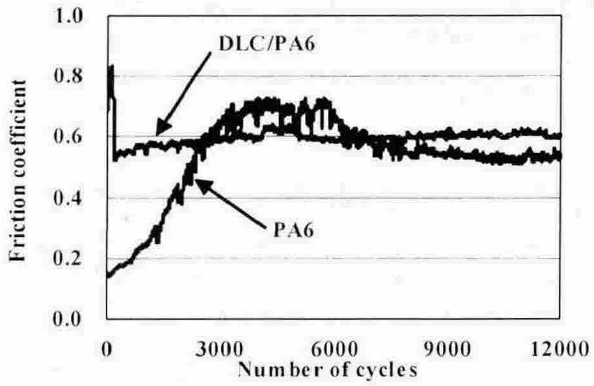
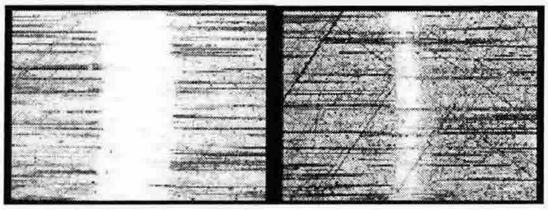


Fig.2 Friction properties dependence on number of cycles



(a)PA6 (b)DLC/PA6

Fig.3 Photograph of scratched surface

The formation of the DLC film added titanium is investigated to strengthen the adhesion of a DLC film and mechanical intensity. It is confirmed whether the quantity contained titanium in DLC film would be increased along with increasing the piece area of titanium used as target by the analysis of AES. Otherwise, it can be made sure that addition titanium is uniformly distributed on the DLC film.

With the measurement equipment of surface form and the formulate about Stoney shown in equation (1), The inside stress of a film was calculated. On the base on increasing the area of titanium, the inside stress of DLC film without addition titanium shows value about 7Gpa and that can be decreased half as increasing 1/8 of titanium.

Furthermore, as shown in Fig.5, with nano-indentation method, the nano-indent hardness of the DLC film can be enhanced to about 35Gpa with increasing the target area of titanium, whereas it shows about 45Gpa at 1/8 titanium area. It is considered that the combination of titanium and carbon is the reason by which can remedy the defect of DLC film.

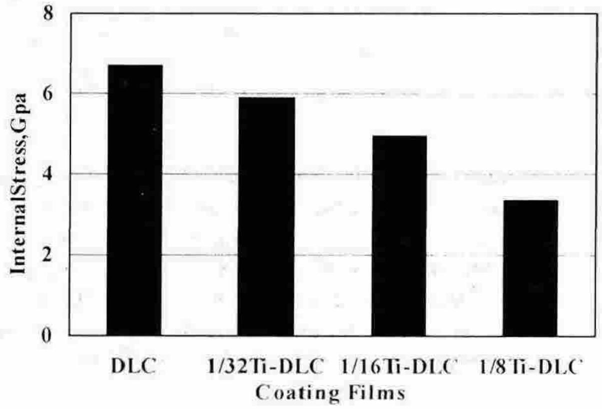


Fig.4 Internal-Stress dependence of coating films

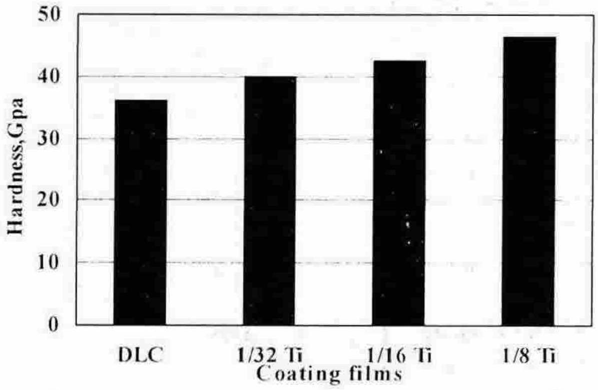


Fig.5 Hardness dependence of coating films

4. CONCLUSIONS

The tribology characteristics, such as reduction of a friction coefficient and wear-resistant increase, are improved by forming a DLC film in a polymer material.

By adding titanium in a DLC film, the internal stress of a surface film can be decreased and hardness is improved.

5. REFERENCES

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