Assessment of Tribological Properties of Diamond-like Carbon with Ion-beam Chemical Vapor Deposition

Seojun Heo[1)], Seongsik Jeong[1)] and Hae-Jin Kim[1)]*

[1)]School of Mechanical & Aerospace Engineering, Gyeongsang National University, Korea

*Corresponding author: hjk@gnu.ac.kr

In this study, research on improving the wear resistance and mechanical properties of DLC film by controlling ion beam intensity distribution of the Ion-beam chemical vapor deposition (IBCVD) was conducted. The experimental results revealed that friction and wear properties could be enhanced by controlling the ion beam intensity profile during the DLC film deposition. It is expected to aid in increasing the lifetime of the mechanical components by optimizing the parameters during the DLC deposition with IBCVD.

Keywords: ion-beam chemical vapor deposition, diamond-like carbon, friction, wear, tribology

1. Introduction

One of the general strategies to achieve relatively high hardness and low friction of the mechanical parts is thin-film technology. In the past decades, thin films such as DLC, TiN, SiC have exhibited not only good mechanical properties but also superior tribological properties. With aim to apply to various mechanical components including automotive parts, cutting tools, and hard disks. However, novel thin film with an optimized deposition technique is required to broaden the application scope. This requires a systematic study of design variables of thin films deposition to provide high hardness and superior tribological properties simultaneously.

Among various thin-film deposition techniques, plasma-applied chemical vapor deposition (PECVD) is a method that forms a thin film on the target through decomposition and ionization of gas compounds. and carbon-based PECVD is typically applied to the surface treatment of mechanical/mold parts. The magnetron sputtering process is depositing the target material by accelerating the ions to the target material. The collision of ions to the target material aid in releasing the material in atomic unit and depositing onto the surface of the target sample. It is notable that PECVD and magnetron sputtering process is advantageous for large-scale deposition, however, most of the deposition materials that enter the surface of the target are neutral particles, making it difficult to control the energy of the deposition particles by accelerating plasma sheath. In this regard, high temperature deposition processes of several hundred °C are required to compact the material within the film to provide superior mechanical properties.

As an alternative route to achieve thin-film with superior mechanical properties, ion-beam chemical vapor deposition (IBCVD) technique is widely used. The ion beam process uses inert gas ions (Ar, He, etc.) and reactive gas ions (CxHy, N_2, O_2) with hundreds of thousands of eV levels of energy, and is applied to pre-treatment, carbon-based organic membrane deposition, and mixing layer formation processes. Furthermore, simultaneous implementation of high thin-film density and low surface roughness at low temperatures could be achieved. Also, ion beam can be generated with a width of 1 m or higher, and hence it can be applied to large batch equipment used in the surface treatment process for mass production of mechanical components. Table 1 summarizes the various mechanical properties of thin-film with respect to different deposition techniques.

Table 1 Characteristics of various thin-film techniques

Techniques	Ion-energy (eV)	Thin-film	Hardness (GPa)	COF	Large-area deposition
PECVD	< 10	DLC	10~15	0.1~0.15	Good
Sputter	< 10	Nitrides (TiN, CrN)	20~30	0.3~0.6	Good
Arc	< 100		20~40	0.3~0.6	Poor
Ion-beam	< 3000	DLC	20~30	0.1~0.15	Good

2. Methods and discussion

In this study, tribological property assessment of fabricated DLC film by using different IBCVD deposition conditions is conducted. In specific, the ion-beam distribution profile is different depending on the design parameters of the ion-beam sources. Depending on the ion-beam deposition intensity, distribution characteristics along the source area, sp^2 and sp^3 bonding ratio of DLC thin-film can varied. To address the bonding ratio of DLC with different ion-beam source profile, X-ray photoelectron spectroscopy (XPS) analysis was conducted. The surface characteristics before and after the tribotests of deposited film were obtained by using atomic force microscope (AFM), scanning electron microscope (SEM) and surface profilometer. Followed by surface characterization, tribological properties were characterized by using a commercially available tribotester which follows the procedure of ASTM-G99. The experimental results revealed that more careful approach when determining the deposition condition is needed to acquire both superior tribological properties and mechanical durability of the DLC film.

3. References

[1] Yang, H. et al., “Increased elasticity and damping capacity of diamond-like carbon coatings by immobilized C60 fullerene clusters,” Nanoscale, 11, 2019, 2863-2870.

[2] Penkov, O. et al., “Ion-Beam Irradiation of DLC-based Nanocomposite: Creation of a Highly Biocompatible Surface,” Appl. Surf. Sci., 469, 2019, 896-903.