Improvement on wear-resistance of ta-C coating with Cu doping as a multi-composite structure under the PAO 4 lubrication

Jae-Il Kim[1)], Young-Jun Jang[2)*], Jongkuk Kim[2)], Noritsugu Umehara[1)]

[1)]Department of Micro-Nano Mechanical Science and Engineering,
Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan
[2)]Tribology Lab., Extreme Environmental Coatings Department,
Surface Technology Division, Korea Institute of Materials Science, Changwon 51508, Republic of Korea
*Corresponding author: yjjang@kims.re.kr

Diamond-like carbon (DLC) has excellent wear-resistance due to its high mechanical properties. However, its high hardness and elastic modulus have a problem of promoting the wear of the counter-part by acting as an aggressiveness against the counter-part. In this study, Cu was doped as a method to reduce the wear of both the tetrahedral amorphous carbon (ta-C) film and the counter-part, at the same time. By doping Cu, the hardness and modulus of elasticity of ta-C were reduced to decrease the aggressiveness against the counter-part and increase the fracture toughness of the film.

Keywords: tetrahedral amorphous carbon, fracture behaviors, wear-resistance, Cu doping

1. Introduction

For the durability of the total tribo-system, it is necessary to reduce the wear of film and counter-part together. Preventing abrasion by increasing the mechanical properties of the film should be avoided as it can promote the wear of the counter-part. Recently, as a method of improving the wear characteristic of a film, many studies have been conducted to increase the fracture toughness by modifying the coating structure [1]. In this study, we expected the improvement in the fracture characterization of DLC films by doping Cu through its ductility and changing coating structure without the generation of carbide due to low solubility with carbon. Simultaneously, it is believed to reduce the abrasion of the counter-part by its low hardness.

2. Methods

2.1. Preparation of specimen

Cu-doped DLCs were co-deposited via filtered cathodic vacuum arc and unbalanced magnetron sputter with an arc discharge current of 60 A and sputtering discharge power of 50, 100, and 200 W, and the deposition time is differently set to be the thickness of 1 μm.

2.2. Tribological characterizations

The tribological characteristics were evaluated under PAO 4 using a ball-on-disk tribometer, with WC ball as counter-part. The tribo-test was employed with the following testing environment; room temperature, and applied load 10 N. The sliding linear speed is fixed as 0.063 m/s with a sliding distance of 753 m.

2.3. Results

It was confirmed that the coefficient of friction is increased by increasing Cu contents and the wear rate of the ta-C film is decreased. Additionally, The wear rate of the counter-part decreases, which is considered to be the effect of the decrease in the hardness of the films. Especially, it is discovered that even though the hardness of the films decreased, the wear rate of the film also decreased with the increase of Cu.

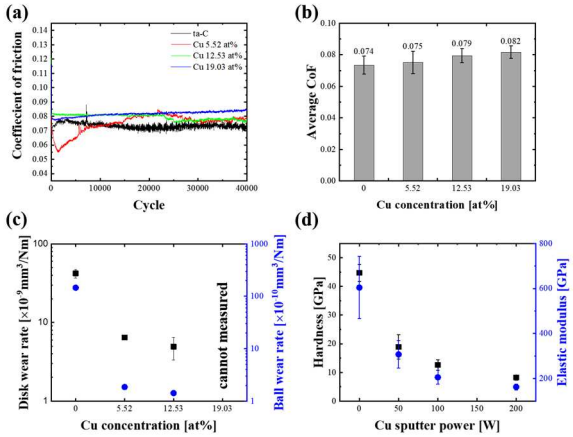

Figure 1: (a) The curves of CoF, (b) average CoF, (c) specific wear rates, and (d) variations of mechanical properties based on Cu concentration

3. Discussion

It is presumed to be wear due to fracture in relatively stress-intensive surface defects. Therefore, the wear dependence on the fracture characteristics of the film was evaluated. Fracture analysis was carried out through micro and nanoindentation and scratch tests. The decreases in the number of cracks generated by the indentation at the same indentation loads and the increase in scratch crack propagation resistance (CPRs) are confirmed. As the results, it is inferred that the fracture toughness increased based on the increase in the crack initiation and crack propagation resistances together and the wear-resistance improved due to the increase in the fracture toughness.

4. References

[1] M. M. Bin Mustafa et al., “Effect of mesh structure of tetrahedral amorphous carbon (ta-C) coating on friction and wear properties under base-oil lubrication condition,” Tribol. Int., 147, 2020, 105557.