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Fundamental Research on Laser Irradiation for Surface Profile Control and Friction Coefficient Control of DLC Films

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1. Introduction

The control of surface profile and friction characteristics is important in determining the performance of industrial products. In particular, the growing awareness of environmental issues requires further enhancement of material and manufacturing processes with a low environmental impact (1). One example is the combination of diamond-like carbon (DLC) films and laser irradiation technology. It has been shown that DLC films can be deposited on the surface of materials with fine dimples by laser irradiation, resulting in lower friction (2). However, the changes in surface profile and friction coefficient caused by laser irradiation of diamond-like carbon pre-deposited on the material surface have not been clarified. Therefore, the purpose of this research is to elucidate the possibility and mechanism of surface profile and friction behavior of hydrogen-containing DLC (a-C:H) films by laser irradiation, and to examine the differences in surface profile and friction coefficient of the laser-irradiated materials.

2. Experimental details

2.1 Test specimen processing conditions

In laser irradiation to DLC films was performed by a commercial laser marker (ML-7064A, AMADA WELD TECH, with 1.064 μm laser wavelength), DLC cannot resist heat if the laser power is too high. Therefore, the laser conditions used in this research are controlled as not to occur the laser ablation of DLC. The laser current of 8.6 A, the frequency of 1.0 kHz and the marking speed of 10 mm/s are applied and the material surface was positioned 1.0 mm away from the laser focal position. In this experiment, laser irradiation was performed only once. The material of the specimen on which hydrogen-containing DLC films are deposited is SUS304. (Fig. 1)

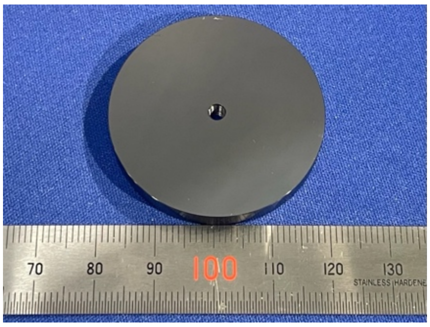

Fig.1 Appearance of DLC disk test specimen

2.2 Friction testing

The following is a description of the micro reciprocating friction testing machine used in this experiment. This can be performed under conditions where the reciprocation distance is shorter than the size of the contact circle defined by Hertz theory. Since the same contact part is repeatedly struck in the micro reciprocating friction test, the test is less susceptible to surface undulation of the surface and other factors of disturbance derived from the contact interface. As a specimen for friction test, a 38mm diameter, 5mm thick disk test specimen with a DLC film (Fig. 1) and a 3-pin test specimen without a DLC film (Fig. 2) are brought into contact and subjected to a micro reciprocating motion. The 3-pin specimen are consisted of a support disk and 3 pins. The support disk has 3 holes with 3.995 mm in diameter at 120° intervals at 10 mm from the center of a support disk, into which 3 pins (SUS304) with diameters of 4.025 mm were cooling-fitted using liquid nitrogen. Only the uppermost 2 mm of the pins protrude from the support disk. The experimental conditions were a vertical load of 14.6 N and a reciprocating motion of approximately 105 μm (0.30 °*2) per reciprocation. A schematic diagram of the micro reciprocating sliding testing machine is shown in Fig. 3.

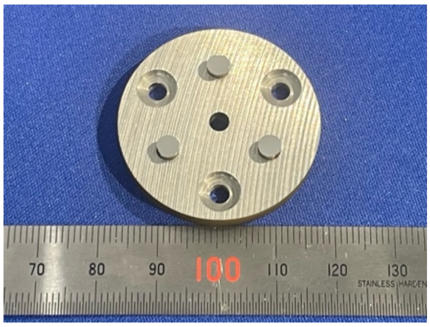

Fig.2 Appearance of 3-pin test specimen

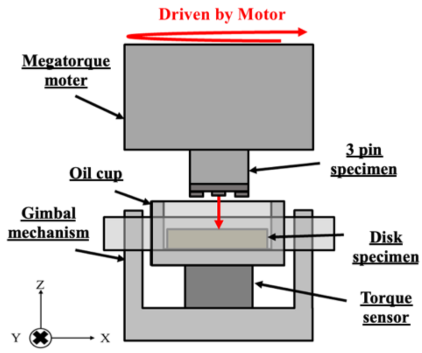

Fig.3 Test equipment

3. Results and discussion

3.1 Profile change of DLC films by laser irradiation

Figure 4 and Fig.5 shows an SEM image (×500) and 3D profile of the DLC films after laser irradiation, respectively. Those figures revealed that tiny bumps with a diameter of approximately 20 μm and a height of 1 μm were rising from the surface. Figure 6 shows an EDS analysis of the surface of the DLC films with the generated bumps. Since the EDS analysis showed no difference in the percentage of carbon on the surface between those parts with and without the bumps, it is considered that the bumps were generated by the DLC film. From these results, it was confirmed that the laser conditions in 2.1 can be used to create bumps in the DLC film. As a factor in the formation of bumps, the laser in this experiment was irradiated under conditions that allowed DLC films to withstand heat, i.e., the intensity was such that it did not cause significant evaporation of DLC films. Although further consideration is required, the bumps were considered to be formed due to changes in material density and/or surface tension effects [3].

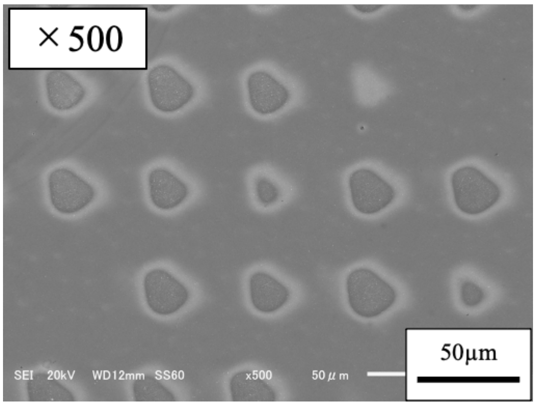

Fig.4 SEM image of DLC after laser irradiation

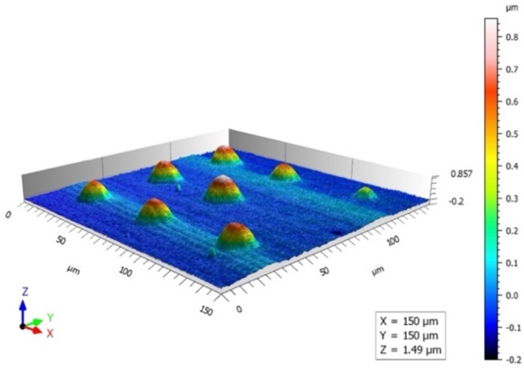

Fig.5 3D profile image of DLC after laser irradiation

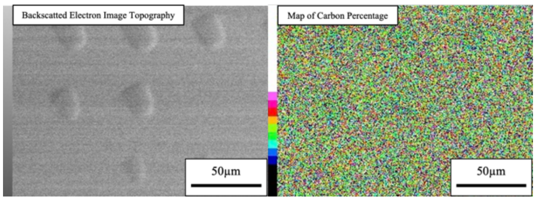

Fig.6 EDS analysis of DLC after laser irradiation

3.2 Friction test results

Figure 7 shows the coefficient of friction for the DLC films with and without bumps. The coefficient of friction for the DLC films with bumps increased by approximately 1.9 times compared to the DLC films without bumps. Surface observation of the DLC film after the friction test showed that the bumps remained DLC after friction test. As a discussion, issues remain such as the stable generation of bumps and the uncertainty of bump generation when DLC is applied to other materials. However, by solving these issues, we consider that the generation of bumps on DLC films could be used to adjust the coefficient of friction at a low cost and used as an enhanced fixation components with micro/nano mechanical interlocking.

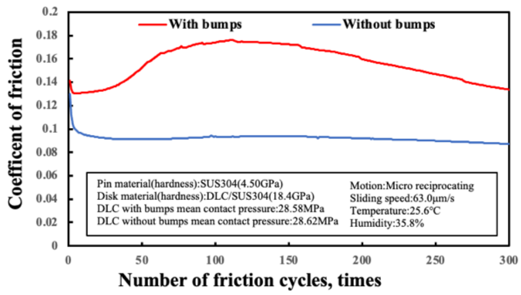

Fig.7 Coefficient of friction for each DLC

4. Conclusions

In order to elucidate the mechanism of the surface profile and friction coefficient of hydrogen-containing DLC by laser irradiation, it is performed on specimens coated with DLC films to investigate changes in surface profile and friction behavior. As a result, we succeeded in creating bumps on the DLC surface by laser irradiation. The bumps are considered to be successfully formed with DLC films remained on the surface. The coefficient of friction of the laser-irradiated DLC film was approximately 1.9 times higher than that of the film without bumps.

References

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2) Hengzhong Fan, Yongsheng Zhang, Tianchang Hu, Junjie Song, Qi Ding, Litian Hu, Surface composition-lubrication design of Al_2O_3/Ni laminated composites-Part I: Tribological synergy effect of micro-dimpled texture and diamond-like carbon films in a water environment, Tribology International 84 (2015), pp142-151

3) Dieter Bäuerle, Laser Processing and Chemistry, Chapter 10 Surface Melting, pp177-198