



The Effect of Substrate Surface Roughness on the Mechanical Properties of DLC Film Deposited by RF Magnetron Sputter Ion Plating from Woodceramic as Target

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Abstract

Diamond-like carbon (DLC) film was produced onto stainless steel (SUS304) surface by radio frequency (RF) reactive magnetron sputtering technique with argon as source gas and woodceramics as a target. Surface roughness of the substrate four kinds were prepared by mechanical polishing, sand blasting and electro chemical polishing. Structural evolutions of DLC films were investigated by Raman and XPS spectroscopies. The mechanical properties such as hardness and elastic modulus of films were measured by nano-indentation hardness testing. Contact angle and surface energy of the films were measured by contact angle measurement. Tribological performances of the films were characterized using a ball-on-disk friction tester. The aim study was to compare and study the effects of diamond-like carbon (DLC) films deposition and tribological properties of the films.

Keywords: Diamond-like carbon; Wood ceramics material; Surface roughness; Tribological Properties; Mechanical Properties.

1. Introduction

Diamond-like carbon (DLC) coating films are meta-stable amorphous ones that exhibit unique combinations of properties such as high hardness and elastic modulus, low friction coefficients, optical transparency, good wear resistance, and excellent corrosion resistance. However, DLC films have no sufficient friction coefficient and friction endurance depending on their application environment. Among the many

possible ways to modify the tribological properties of DLC films[1-2], the preparing surface roughness of the substrate material also have effect to film growth has shown to be especially powerful[3-4]. However, further requirements to withstand aggressive environments and to improve oxidation and wear resistance of contact surfaces exposed to extreme conditions constantly lead to the development and introduction of new coatings

method[2-3]. The aim of this work is to investigate the influence of DLC coating from bio-material as wood ceramics and the effect of surface roughness after the coating deposition, respectively, on the properties of coated SUS304 stainless steel. Four different surface roughness of substrate material were produced, and DLC coating was performed by radio frequency (RF) reactive magnetron sputtering technique at room temperature with argon as source gas and woodceramics as a target.

Woodceramics are new kinds of porous carbonaceous materials carbonized at elevated temperatures in a vacuum after impregnating phenol resin, and econmaterials that can be made from biomass like wood wastes[5].

2. Experimental procedure

2.1 Work piece materials and types of surface roughness

Polished stainless steel (SUS304) with manufacturing surface roughness was selected as the substrate material in this study. Four specimens S-40, S-60, S-80 and S-100 where the numbers represent the relative mean surface roughness (Ra) of dimension $3.0 \times 2.6 \text{ cm}^2$ were cut using SiC grinding papers of 2000, 600, 100 grit and electro chemical polishing, to produce different surface roughness levels.

The surface roughness of the substrates was measured by laser microscope OLS4000 (Olympus Corporation, Japan)

2.2 DLC coatings

DLC films were deposited by RF magnetron sputtering (PLASMAN Sputtering Series as Fig.1 system with woodceramics disk target (30 mm in

diameter), mounted on the cathode at a distance of 32 mm from a substrate table. Sputtering mechanism is schematically shown in Fig.2. Stainless steel (SUS304) was used as substrate material and standard chemical cleaning procedure was maintained before deposition.



Fig. 1 Sputtering Equipment for produced DLC film.

Synthesis pressure of the deposition chamber was around $4.5 \times 10^{-3} \text{ Pa}$. Pure argon (99.999% purity) was used as inert gas in the chamber. The sputtering target was pre-sputtered for about 5 minutes before actual deposition to remove some surface impurities present on the target.

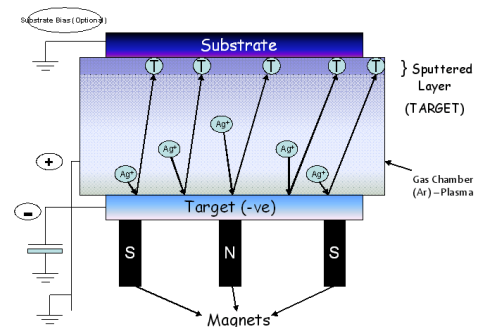


Fig. 2 Schematic view of the RF magnetron apparatus.

The films were deposited at temperatures of 50°C , 80°C , 125°C and 180°C using a resistance heater located behind the substrate holder. The process pressure was 4.0 Pa with RF power of 180 W and holding time of 30 minutes.

3. Results and Discussion

3.1 Surface roughness of DLC films

The total DLC film thickness deposited on the substrate was approximately 200-400 μm . Fig. 6 shows the relation of surface roughness between before DLC deposition and the and after deposition. The slope of dotted line 1. If a plotted point exists on this line, it means that surface roughness does not change before and after the deposition.

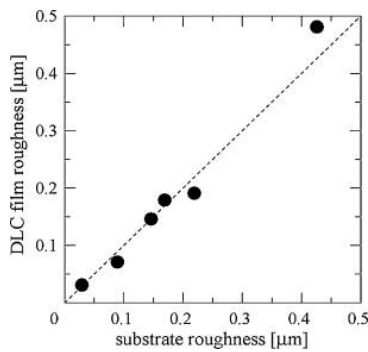


Fig. 3 Relationship of substrate roughness before and after deposition.



Fig. 4 DLC coated (a) S-40 (b) S-60 (c) S-80 and (d) S-100

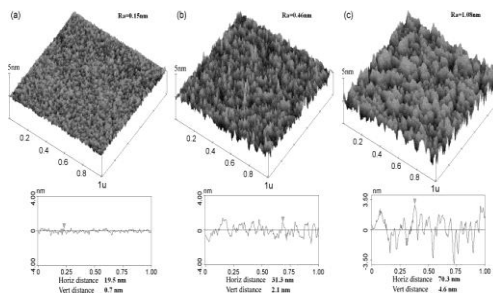


Fig. 5 AFM images of substrate (a) 0.04 μm , (b) 0.06 μm , and (c) 0.08 μm

All plotted data are concurrent with this line. The surface roughness of DLC films is almost the same as that before deposition.

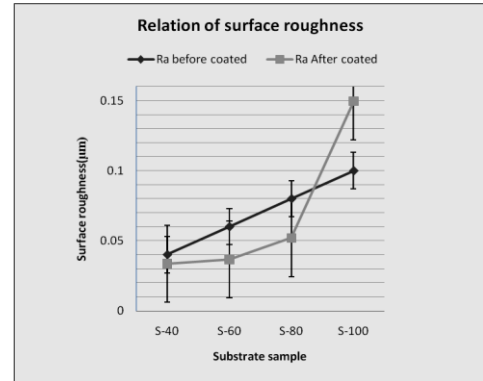


Fig. 5 Relationship of substrate roughness before and after DLC deposition.

The G band corresponds to the stretching mode in graphite-like materials, while the D band is attributed to bond angle disorder in the graphite-like microdomains affected by sp^3 bonds [2]. The ratio of intensities of the D and G bands (ID and IG) increases with increasing sp^2 content.

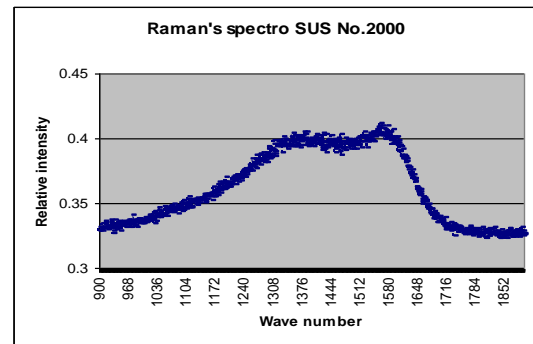


Fig. 6 The Raman spectra of SUS No.2000

The key properties of DLC are sp^3 bonding. From the result of Raman spectroscopy (Fig.8) can notice that there were two peaks, one at 1375 cm^{-1} and the other 1580 cm^{-1} which brought us to the conclusion that we have obtained DLC film (the spectra are typical for sp^2

structure-D and G bands characteristic for such structure.

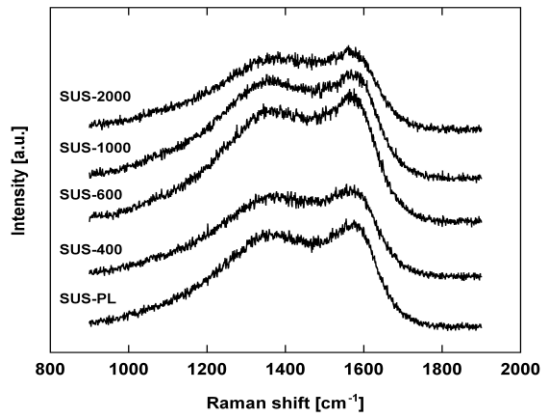


Fig. 7 Raman spectra of each sample follow same produce DLC condition.

3.3 Surface hardness and elastic modulus

The hardness and elastic modulus values of DLC films were calculated from a force curve, which is obtained by the nano-indentation hardness test. When the penetration depth is below 5% of the film thickness, the hardness measurement is unaffected by the substrate [6]. Meanwhile, the maximum penetration depth of films in this paper was about 20% of the total film thickness. The hardness and elastic modulus of DLC films are average 11.2 GPa (lower than normal DLC film). The decrease of DLC film hardness and elastic modulus is believed to be partly due to the film thickness are very thin.

3.4. Friction coefficient

The DLC films were unstable and failed easily during friction tests. The test was combination of the ball and the disk. The friction coefficient of DLC film is stable at a low value and was lower than normal stainless steel

SUS304. Friction coefficients of various substrates surface roughness under ambient air dry condition at room temperature did not show durability because of the lower hardness and elastic modulus of film.

4. Conclusions

The effect of substrate surface roughness on growth of DLC films deposited from woodceramics as target has been studied. The results show that the evolution of the surface roughness as a function of the film thickness depends on the initial surface morphology of the substrate. For a smooth surface substrate, the film surface becomes smoother with the increasing DLC film thickness due to the preferred growth of the valley. On the other hand, in the case of the rough substrate, the film decreased first and then increased with DLC thickness up to a maximum same direction of other research method to produced DLC film.

The friction coefficient of the DLC depends on the coating surface roughness. The coefficient value is high relative at the initial moment of the coating operation, but it is reduced considerably upon alignment of the coating. The substrate surface roughness was found to be decisive for wear resistance of the DLC to external loads. The coating wear resistance is increased several-fold at some optimal Ra as compared to the smooth surface. It was shown that the proper choice of sputtering conditions and regimes provides DLC with required tribological characteristics. This is important for the practical use of DLC.



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6. References

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