PREPARATION OF ADVANCED FUNCTIONAL CARBON FILMS BY PLASMA PROCESSING

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Introduction

Diamond-like carbon (DLC) films have some interesting properties, including extreme hardness, high electrical resistivity, low friction coefficient and good adhesion properties to several materials such as iron and plastics. Although DLC is often used for coating application, DLC study is still in progress in comparison with that of synthetic diamond.

In this study, DLC thin films were synthesized by RF magnetron sputtering method, and their electronic properties and microstructure were investigated by sheet resistance measurement, XRD, XPS, RAMAN spectroscopy and ERDA. The influence of their microstructure on the electronic properties was discussed.

Experimental

DLC thin films were prepared by RF magnetron sputtering method using Ar+10%CH_4 and Ar+10%H_2 mixed gas. The target was high purity (99.999 %) graphite, and the substrate was silica glass (10 x 10 mm, 0.5 mm thick). A series of DLC films were grown under the following deposition conditions ; the radio frequency (13.56 MHz) power was 100 W, the total working gas pressure was 1 to 2 Pa, and the deposition time was 6 hour. Substrate temperature was not controlled (about 50 ℃). These films were characterized by XRD, RAMAN spectroscopy, XPS (X-ray photo- electron spectroscopy), ERDA (elastic recoil detection analysis) and sheet resistance measurement by two probe method.

Results and Discussion

No obvious XRD peak from the films was not obtained in all cases, which suggests that the DLC thin films are amorphous.

Figure 1 shows the RAMAN spectrum of a DLC thin film obtained. This spectrum can be separated into G-peak and D-peak.

Figure 2 shows XPS C1s spectra of a DLC thin film obtained (Ar+10%CH_4, 1 Pa) and HOPG (highly oriented pyrolytic graphite). These spectra are corrected by the O1s peak on the specimen. The peak of DLC thin films (285.0 eV) shifted from the position of graphite peak (284.3 eV) to that of diamond peak (287.5 eV: [1]), and the full-width at half-maximum of the spectrum of DLC thin films was wide in comparison with that of HOPG (graphite). From these results, it is considered that the bonding of carbon atoms in DLC thin films were mainly sp^2 and sp^3, and they were mixed.

The hydrogen content of DLC thin films were investigated by ERDA. Figure 3 shows the ERDA spectra of DLC and Kapton (as the reference material). From the result, we confirmed that the hydrogen content of DLC thin films were about 24 to 29 at %, and it was in the range shown in literature (about 17 to 60 at %)[2]. As for a DLC microstructure, RCN (random covalent network) has been proposed. In this model, sp^3/sp^2 ratio of DLC thin films can be calculated from hydrogen content (X_H) by the following expression.

$$\frac{sp^3}{sp^2} = \frac{6X_H - 1}{8 - 13X_H}$$

By using this expression, the sp^2-C and sp^3-C contents of the DLC thin films was calculated to be about 58 to 69 at %. It is considered that the sp^2-C content of the DLC thin films synthesized by sputtering method was relatively large as is in the past studies.

Figure 4 shows the comparison of sp^2-C, sp^3-C and hydrogen content with sheet resistance. From the result, as the sp^2-C content decreases, the sheet resistance shows a tendency to increase.

Conclusions

DLC thin films were synthesized by RF magnetron sputtering method, and these films were characterized by XRD, RAMAN spectroscopy, XPS, ERDA and resistivity measurement. The hydrogen content of the films was 24 to 39 at %, which is in the range for the existence of DLC. As the sp^2-C content decreases, the sheet resistance shows a tendency to increase.

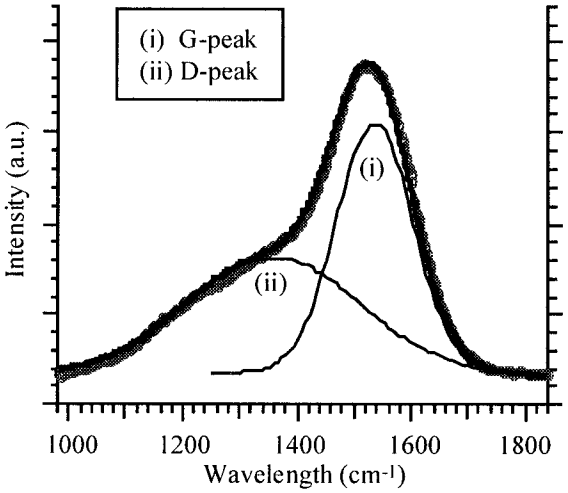

Figure 1. RAMAN spectrum of DLC thin film (Ar+10%CH_4, 1Pa)

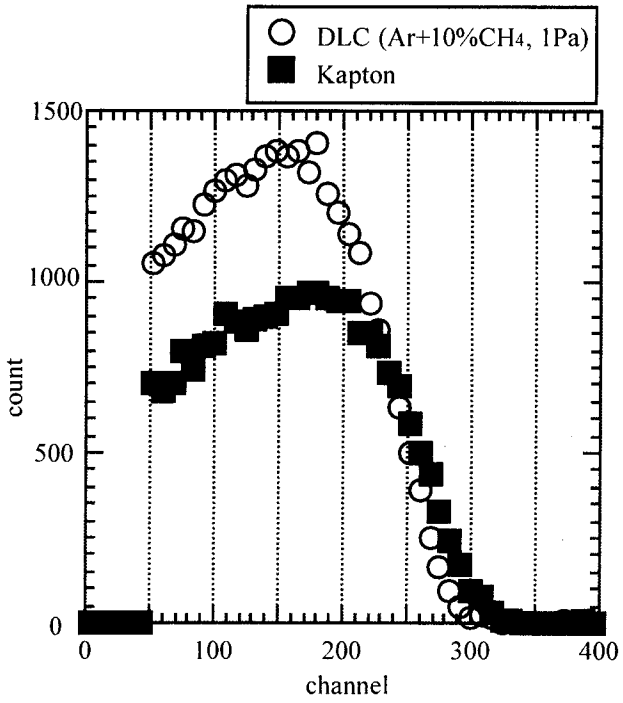

Figure 3. ERDA spectra of DLC thin film and Kapton

References

1. Handbook of X-ray Photoelectron Spectroscopy: JEOL.
2. J. C. Angus and F. Jansen, J. Vac. Sci. Technol. A6 (1988) 1778.

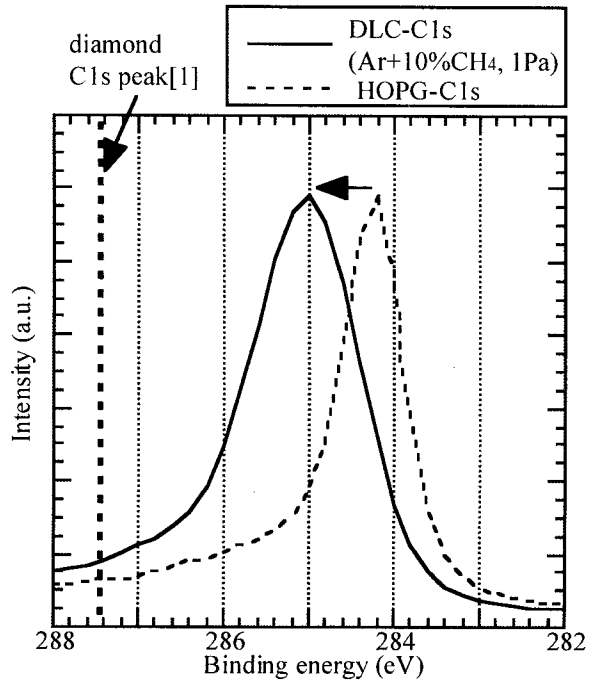

Figure 2. XPS spectra of DLC thin film and HOPG

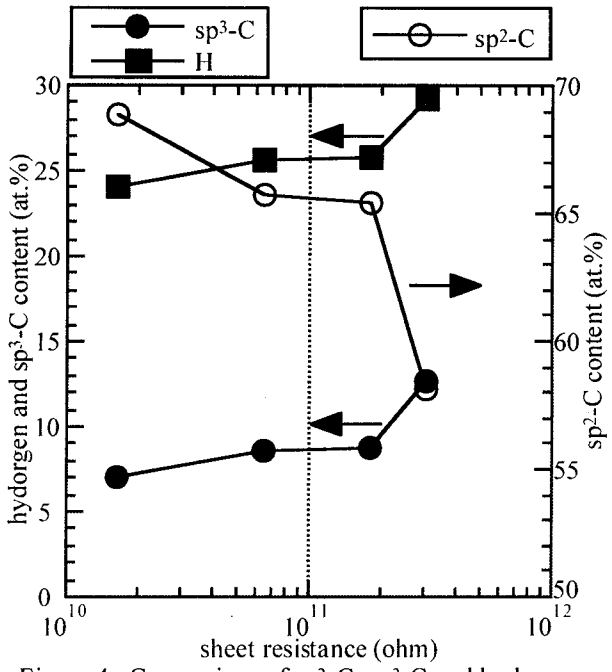

Figure 4. Comparison of sp^2-C, sp^3-C and hydrogen contents with sheet resistance