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The Dependence of Mechanical Properties on Nano Structures of Carbon Films Prepared by ECR and RF Plasma Sputtering

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1. Introduction

Carbon films are applied to protect structures against potentially damaging contacts, which means that they must have excellent mechanical properties to sustain internal stress and resist delamination. Therefore, mechanical properties of carbon films with different bonding structures aroused research interests in tribology applications[1)]. In this study, hydrogen-free carbon films were prepared by Electron Cyclotron Resonance (ECR) and Radio Frequency (RF) plasma sputtering methods, and the dependence of their structures on the mechanical properties is studied.

2. Experiment

Hydrogen-free carbon films were deposited on monocrystalline silicon (100) substrates with ECR and RF (13.56 Hz) plasma sputtering techniques. Argon was employed as the working gas. Table 1 summarized the deposition conditions. All the samples were deposited for 25 minutes. The nano structures were characterized with High Resolution Transmission Electron Microscope (HRTEM) and Raman spectroscopy. Nano- indentation tests were performed to obtain the load- displacement curves with the load of 500 μN.

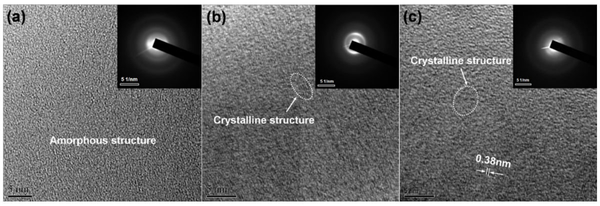
Table 1 Deposition conditions of samples investigated

Sample	A	B	C
Method	ECR	RF	RF
Base pressure (10^{-4} Pa)	3.32	0.26	0.26
Working pressure (Pa)	0.40	1.33	1.33
Substrate temperature (°C)	400	30	30
Substrate bias (V)	+10	-30	-100
Ion energy (eV)*	20	50	120
Thickness (nm)	113	75	62

(*) estimation

3. Results and discussions

The cross-sectional HRTEM pictures of the carbon films are shown in Fig. 1. Nano-crystalline structures formed in the amorphous matrix with the increasing of bombarding ion energy. As shown in Fig. 2, Raman spectrum of the samples consists of a *G* peak at 1584 cm^{-1} and a *D* peak at 1342 cm^{-1}. Note that sample B and C show the additional peak near 1470 cm^{-1}, which also indicates the presence of nano graphite clusters in the amorphous matrix. Figure 3 and Table 2 show the mechanical properties of the samples investigated. Sample B and C with nano-crystalline structures show increasing hardness and higher elastic recovery comparing with sample A.



(a) Sample A (b) Sample B (c) Sample C
Fig. 1 HRTEM pictures of samples investigated

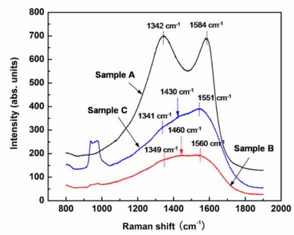


Fig. 2 Raman spectra

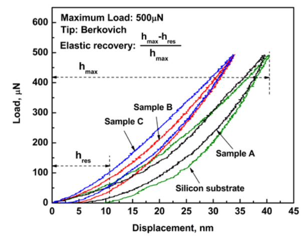


Fig. 3 Indentation curves

Table 2 Mechanical properties of samples investigated

Sample	Elastic modulus	Hardness	Elastic recovery
Silicon	155.2 GPa	11.7 GPa	76.0%
Sample A	131.6 GPa	14.1 GPa	85.6%
Sample B	140.3 GPa	15.6 GPa	87.5%
Sample C	138.4 GPa	15.4 GPa	91.8%

4. Conclusions

Hydrogen-free carbon films were prepared with ECR and RF plasma sputtering methods. With the appearance of nano graphite clusters in the amorphous matrix, RF carbon films showed enhanced mechanical properties and higher elastic recovery comparing with ECR carbon film, which may make them fitful protective materials for tribological applications.

5. References

[1] Donnet, C. and Erdemir, A., "Tribology of Diamond-Like Carbon Films: Fundamentals and Applications," Springer, New York, 2008, 84.

6. Acknowledgement

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