INFRARED AND VISIBLE LIGHT PULSED LASER IRRADIATION OF DLC FILMS

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Abstract

Laser irradiation of amorphous diamond like carbon films formed on Si substrate is analyzed in this work. Films were irradiated with nanosecond Nd:YAG laser (Ekspla NL301G) at the first harmonic (1064 nm; 6 ns), and at the second (532 nm, 4.2 ns) harmonic by scanning or repeating (10 pulse to one point) regime. The bonding structure and optical properties of carbon films were analyzed using null-ellipsometry, Raman scattering (RS) and Fourier transform infrared (FTIR) spectroscopy. Scanning electron microscope (SEM) was used to characterize the surface morphology. The microhardness measurements were performed using Vickers method (HV).

Keywords: *diamond like carbon film, laser irradiation, graphitization.*

Introduction

Amorphous carbon films are perspective materials for many applications because of their unique physical and chemical properties [1–3]. It was found that laser treatment is very useful technique for precise patterning of carbon films and the pulsed laser processing has some advantages over mechanical and chemical processing [4,5]. In general, the effect of laser irradiation on carbon films is determined by superposition of three processes, such as: graphitization, spallation, and evaporation; they are characterized by different threshold intensities [6]. Laser-induced graphitization of the surface layer has the lowest threshold and causes the changes of material properties. Among these changes, a noticeable reduction of the mass density is the most important for the surface morphology as it leads to a pronounced surface swelling. Two other processes (spallation and evaporation) cause the material removal and lead to the formation of characteristic surface profiles [4].

Experiment

The a-C:H films were formed using pure acetylene ($C_2 H_2$) and deposited on Si wafers. The thickness of the films was up to 300 nm, hardness HV = 23 GPa, quantity of hydrogen - 27 %. Further details were reported in [7].

Films were irradiated with nanosecond Nd:YAG laser (Ekspla NL301G) at the first harmonic (1064 nm; 6 ns), and at the the second harmonic (532 nm, 4.2 ns) by scanning or repeating (10 pulses to one point) regime. The same power was in both regimes, intensity was increased to the threshold of ablation. Power density of irradiation by the first laser harmonic was (30 – 70) MW/cm^2, and by the second laser harmonic - (5 – 25) MW/cm^2.

The optical properties of laser-irradiated a-C:H films were studied by Raman scattering, infrared spectroscopy, and null-ellipsometry, microhardness by Vickers (Basic and CSM) method. RS was investigated using Jobin Yvon spectrometer with Spectra – Physics Nd:YAG laser beam (532 nm, 50 mW, 0,32 mm spot size) in the 500–1900 cm^{-1} range. The overlapped background corrected Raman spectral bands were fitted with two Gaussian contours, using the least square fitting software. FTIR transmission and reflection spectra were measured by means of a Perkin Elmer spectrometer Spectrum GX in the ranges of 100–4000 cm^{-1} and 670–4000 cm^{-1}, respectively. The thickness and refractive index of surface layers were determined using a Gaertner L115 automatic rotating polarizer null-ellipsometer operating with a He–Ne laser.

Results

Ellipsometric measurements show not only the reduction but also high dispersion of film thickness, changed extinction and refraction index after irradiation (Table 1). Micro relief analysis showed that film swelling proceeded during the graphitization process [8, 9].

Table 1. Data of ellipsometric and hardness measurements

Sample	λ, nm	P, MW/cm^2	k	d, nm	n	HV, GPa
B1P	-		0,23	235	2,25	23
B1P - 1	1064	35	0,23	200	2,2 3	23
B1P- 2	1064	70	0,2-0,29	196 - 179	2-1,8	22
B1P- 3	532	12	0,16-0,2	175 - 145	2,1 -1,9	23
B1P- 4	532	24	0,11	378 - 111	2,2 -1,8	2

Table 2. RS measurement data

Sample	D, cm^{-1}	ΔD, cm^{-1}	G, cm^{-1}	ΔG, cm^{-1}	Id/Ig
B1P non irrad.	1312	227,7	1540,3	172,7	0,41
B1P-1	1322,1	254,3	1545,3	159,4	0,53
B1P-2	1336,4	307,1	1544	163,6	0,76
B1P-3	1300,8	204,4	1536,6	180,2	0,36
B1P-4	1346,2	94,9	1597,9	86,3	1,33

RS analysis indicates (Table 2) that irradiation by the first laser harmonic with the power density (30 – 70) MW/cm^2 stimulates a minor increasing of graphite phase. Irradiated by the second harmonic with low (5 - 12 MW/cm^2) intensity DLC films are counterproductive – remotely enhance sp^3 phase. Graphitization becomes more intensive when intensity of radiation by the second harmonic is increased (>12 MW/cm^2). Films transform to the glass carbon with formation nano/micro crystallite compound at intensive ablations regime (~ 24 MW/cm^2) (Fig. 1).

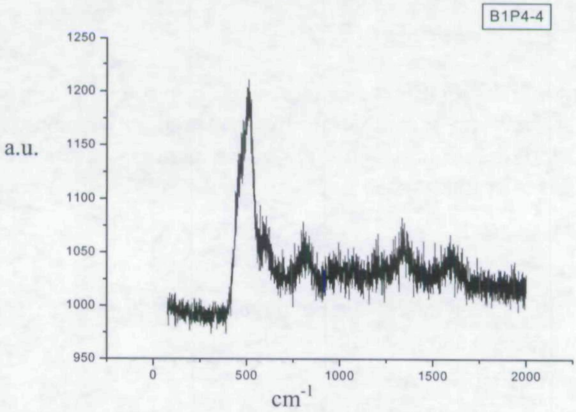

Fig.1. RS of irradiated film by the second harmonic (532 nm), intensity 24 MW/cm^2.

The peaks at ~ 800 cm^{-1} (intensive) and at ~ 970 cm^{-1} (weak) showed SiC formation were observed at the first harmonic irradiation with the large intensity of irradiation (> 35 MW/cm^2).

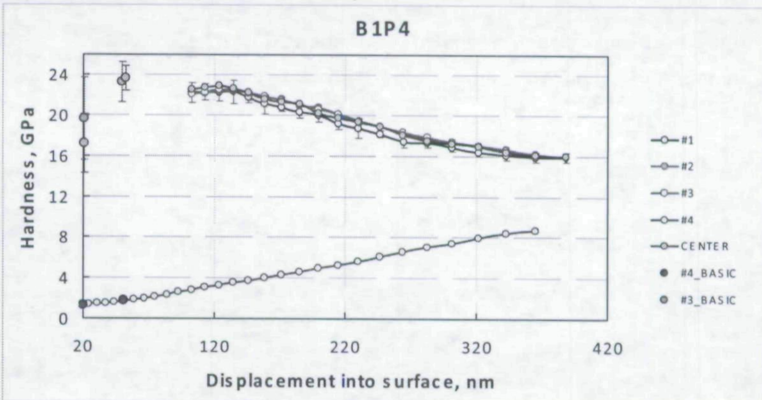

Fig. 2. Hardness measurement results.

Microhardness measurements show that after full graphitization (formation the glass carbon) HV changes fundamentally (Fig. 2 curve 4).

Irradiation by a laser beams first harmonic and low intensity ($I < 10\ MW/cm^2$) second harmonic has led to a slight (2-7%) decrease of transmittance though reflectance spectra remained almost unchanged. The reflectance decreased with respect to the spectra of non-radiated sample at intensity of the second harmonic higher than 12 MW/cm^2. The reflectance decrease after irradiation was frequency-dependent enhancing towards longer wavelengths.

Conclusions

Laser first harmonic irradiation less increases graphite phase a-C:H in films. Intensive ($\geq 24\ MW/cm^2$) irradiation by the second harmonic forms glassy carbon. SiC and diamond (graphite) - like nanocrystals have been formed as a result of laser irradiation.

References

1. Gopinathan N., Robinson C., Ryan F. Thin Solid Films 1999; 401:355.
2. Ostrovskaya Yu. L. Vacuum 2002; 66:219.
3. Robertson J. Mater Sci. Eng 2002; R37:129.
4. Miyazaki K., Maekawa N., Kobayashi W., Kaku M., Yasumaru N., Kiuchi J. Appl. Phys 2005; A80:17.
5. Kononenko T.V., Pimenov S. M., Kononenko V. V., Zavedeev E. V., Konov V. I., Dimitru G., et al. Appl Phys A 2004; 79:543.
6. Kononenko T. V., Ralchenko V. G., Obraztsova E. D., Konov V. I., Seth J., Babu S. V., et al. Appl. Surf. Sci. 1995; 86:234.
7. Silinskas M., Grigonis A., Kulikauskas V., Manika I. Thin Solid Films, 2008; 516:1683.
8. Grigonis A., Rutkuniene Z., Medvid A. Vacuum 2008;.82:1212.
9. Grigonis A., Medvid A., Onufrijevs P., Babonas J., Reza A. Optical Materials 2008; Vol. 30 (5), p.749-752.