CHANGE OF THE AMORPHOUS CARBON FILMS BY LASER NANOSECOND PULSE IRRADIATION

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Diamond like carbon (DLC) thin films was deposited, using ion beam deposition (IBD). Samples were irradiated by the first (1064 nm), the second (532 nm), and the third (355 nm) laser harmonics, changing pulse number per spot, irradiation power intensity. After the laser irradiation films were analyzed by scanning electron microscopy (SEM), null-ellipsometry Gaertner L117 operating with He – Ne laser ($\lambda_{He\text{-}Ne}$ = 632.8 nm), Fourier transform infrared (FTIR), and Raman scattering (RS) spectroscopes, Vickers hardness method.

After the annealing by first harmonic (70 MW/cm^2) caused SiC and nc – Si formation in the substrate boundary, the slight increase of the sp^2 C=C sites fraction. A weak influence was on the surface morphology and microhardness values.

Using the second, and the third laser harmonics noticeably caused modification of the DLC samples: graphitization process and formation of the SiC and SiOH fractions.

Introduction

Laser processing has been extensively used in the electronics and photonics since early 1980 [1].

The amorphous hydrogenated carbon films are perspective materials for many applications due to their unique optical, mechanical, electrical, and chemical properties [2]. Typical diamond materials ablation rates depend on laser fluence, wavelength and pulse duration [3]. The irradiation of the diamond-like carbon films by nanosecond laser lead to the structural relaxation and the rearrangement of the dangling bonds. As a result of this the irradiated films properties will be different compared to non-radiated films [4-5]. By a proper selection of laser parameters, it is possible to cause amorphization of the semiconductor surface selectively or to re – crystallize it from the amorphous state [1].

Experimental

The diamond-like carbon (DLC) films produced by ion beam deposition (IBD) on Si (100) wafers were irradiated with nanosecond YAG:Nd laser (Ekspla NL310G) by the first (1064 nm), the second (532 nm), the third (355 nm) harmonics pulses duration – 6 ns, 4.2 ns , and 28 ns, respectively; the diameter of the laser beam spot was 6 mm. The irradiation was performed at various laser pulse intensities and pulse numbers per spot [see Table1]. The modified films were characterized by scanning electron microscopy (SEM) JSM6490LV (JEOL), null-ellipsometry Gaertner L117 operating with He – Ne laser ($\lambda_{He\text{-}Ne}$ = 632.8 nm), Fourier transform infrared (FTIR), and Raman scattering (RS) (Ivon Jobin spectrometer) spectroscopes. Also the Vickers microhardness method (MTS G200 nanoindenter with a Berkovich diamond tip) measurements were performed (see Table1).

Results and Discussion

The irradiation by the first harmonic changes only the interface between the substrate and the film, and almost has no influence on the surface morphology and microhardness values, because DLC films have wider band gap than Si substrate and are transparent for the first harmonics (1064 nm→1.17 eV). The RS and FTIR measurements indicated the slight increase of the sp^2 C=C sites fraction and the formation of the initial stage of SiC and nc - Si starts in the film-Si substrate boundary after irradiation by 70 MW/cm^2 power density.

Table 1. Laser irradiation and film hardness parameters: λ - wavelength, laser intensity, HV - microhardness, and Young's modulus.

Sample	λ, nm	Irrad. int. MW/cm^2	Pulse per spot	HV, GPa	Young's modulus, GPa
P4	-	-	-	23	209
P4-1	1064	70	10	17	206
P4-2	1064	35	10	19	207
P4-3	532	24	10	-	-
P4-4	532	12	10	-	-
P3	-	-	-	24	230
P3-1	355	8	2		
P3-2	355	4	2		
P3-3	355	4	8		
P3-4	355	8	8		
P3-5	355	1	15	12	180

Table 2. Optical parameters: k – extinction coefficient, n – index of refraction, d - film thickness.

Sam-ple	Model	d_{DLC} , (d_{GC}) nm	d_{SiC} , nm	n	k
P4	DLC/Si	145	-	2.41	0.16
P4-1	DLC/SiC/Si	169	50	2.36	0.27
P4-2	DLC/SiC/Si	165	10	2.13	0.4
P4-3	DLC/SiC/Si	61	56	1.81	0.01
P4-4	DLC/SiC/Si	157	174	1.99	0
P3	DLC/Si	60	-	2.06	0.03
P3-1	DLC/SiC/aSi	127	10	1.87	0.06
P3-2	DLC/Si	64	-	1.98	0.01
P3-3	GC/SiC/aSi	124	10	1.89	0
P3-4	SiC/aSi:H/Si	-	81	2.32	0
P3-5	DLC/SiC/aSi	45	12	2.10	0

The irradiations by the second (532 nm→2.33 eV) and the third harmonics (355 nm→3.50 eV) resulted drastic modification of the DLC films. It was observed that irradiation by the third harmonics with 2 pulses at 8 MW/cm^2 lead to the ablation of the film in the center of the laser beam, and strong graphitization at the periphery region of the laser beam. The graphitization process and formation of SiC and SiOH sites started after the irradiation by low intensity (15 pulses at 1 MW/cm^2) laser beam, and

after the 4 MW/cm^2 laser irradiation with 8 pulses per spot.

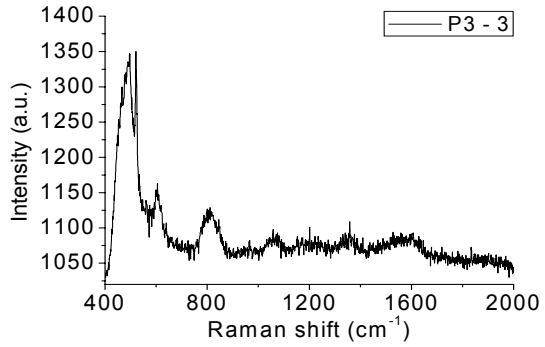

Fig. 1. Raman spectrum of sample P3 – 3 film, irradiated with 4 MW/cm^2 laser beam 8 pulses per spot

SiC and SiOH sites formation prove RS spectrum of P3 – 3 film: curves ~800 cm^{-1} and 960 cm^{-1} (SiC), ~600 cm^{-1} (SiOH) (see Fig. 1).

Conclusions

Laser irradiation with first harmonic (1064 nm) had influence just between the Si – substrate and DLC film interface. Graphitization process was gained and the SiC and SiOH fraction were observed after the use of the second and third harmonics.

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