INFLUENCE OF HIGH ENERGY X-RAY EXPOSURE ON MECHANICAL PROPERTIES OF SiO_x CONTAINING AMORPHOUS DLC STRUCTURES

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Introduction

Diamond and polycrystalline diamond like carbon are widely used for the constructing of radiation detectors for medical applications, due to the material equivalency to the soft tissue ($Z_{eff,diamond} \approx 6.4$; $Z_{eff,tissue} \approx 7.1$), electrical and mechanical properties. Properties of CVD diamonds and their behaviour in different radiation fields are well investigated [1-3]. Another type of diamond like carbons is amorphous diamond like carbon (a-C:H) films, which are widely used as protective coatings in different applications, also to protect the surface of organic scintillation detectors [4]. Amorphous diamond like carbon films (a-C:H) are tissue equivalent , have a smooth surface and are defined by the excellent optical as well as mechanical properties (high hardness, adhesion, thermal stability, low mechanical stress), depending on sp^3/sp^2 ratio, content of the hydrogen in the films and co-doping. These mechanical properties may be of advantage when developing radiation detector structures with protective coatings for medical applications. However there is a lack of information about radiation induced changes in amorphous diamond like carbons after their exposure to X-ray photons from medical sources.

The aim of this work was to investigate radiation induced structural changes and mechanical properties of different types of amorphous hydrogenated DLC films produced at room temperature using direct ion beam method [5] and irradiated with high energy (medical range) X-ray photons with the scope to assess the possibility of their application as protective coatings for radiation detectors.

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Experimental details

Different types of amorphous diamond-like hydrogenated carbon films synthesized at room temperature by direct ion beam method [5] were used in our investigation. Details on the DLC film preparation conditions and parameters are presented in Table 1.

Synthesized DLC films were irradiated with high energy X-ray photons generated in CLINAC (VARIAN) medical linear accelerator at the X-ray tube voltage of 15MV (average photon energy 10.8MeV) delivering total dose of 2Gy to the DLC film.

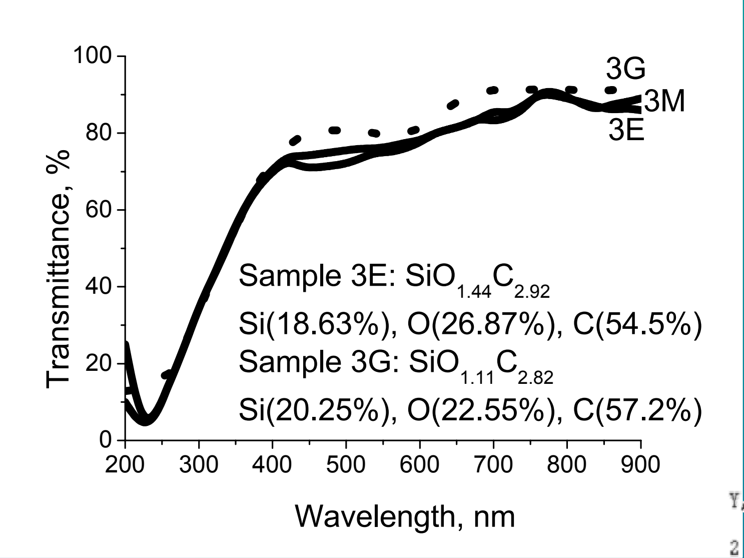
Mechanical stress and strain in irradiated samples were performed by cantilever technique using prism interferometer [6]. The static microhardness measurements of some samples were performed using Vicker's diamond pyramid indenter [7] Surface morphology was characterized by atomic force microscope NANOTOP-206. RAMAN spectrometer operating at λ =514 nm, was used for the investigation of ionization induced structural changes in the irradiated DLC films. FTIR spectra were obtained using Spectrum GX FT-IR (PERKIN ELMER) spectrometer. The X-ray photoelectron spectra were recorded with KRATOS ANALYTICAL XSAM800 XPS analyzer and atomic concentration of SiO_x –containing DLC films were calculated. Laser ellipsometer Gaertner 117 operating with a He-Ne laser (λ =632.8 nm) was used for the estimation of the thickness and refractive index of investigated films. Optical transmittance spectra of the DLC films in UV-VIS range were measured additionally by Ultraviolet and Visible Absorption Spectrometer SPECORD UV/VIS.

Results

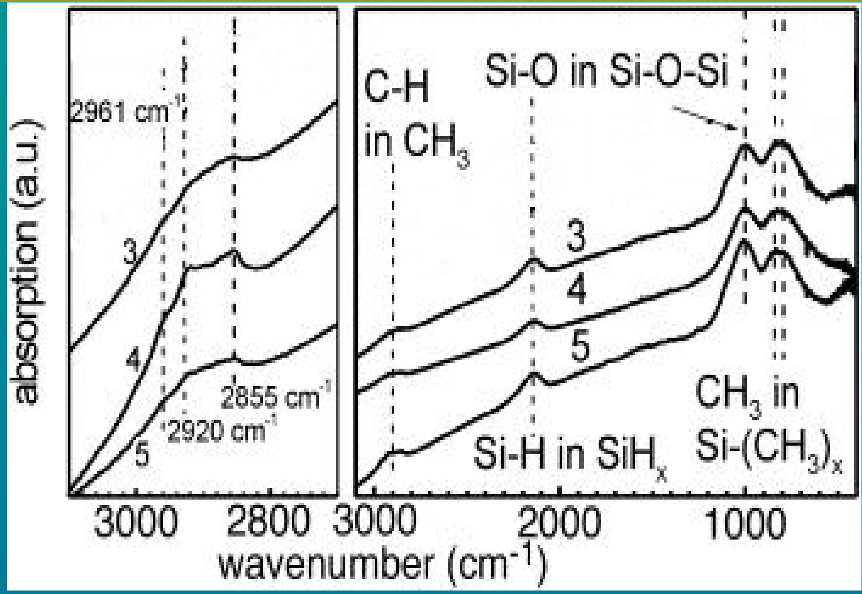
Deposition conditions and characteristics of the DLC films before and after the irradiation

Samples	1 series (1 – 4)		2 series (1G; 2G)		3 series (3G; 4G)	
	Before	After	Before	After	Before	After
Substrate	Quartz glass		Quartz glass		Si <111>	
Reagents	C_2H_2		C_2H_2		$(CH_3)_3SiOSi(CH_3)_3+H_2$	
Gas pressure, Pa	$2x10^{-2}$		$2x10^{-2}$		$2x10^{-2}$	
Ion beam energy, eV	800		240; 300		800	
Ion beam current density, μA/cm^2	50; 75; 125; 150		10 – 20; 20 - 40		100	
Thickness, nm	109; 119; 116; 142	105; 118; 115; 139	~200	173;	~200	
Refractive index	2.4; 2.3; 2.2, 2.2	2.35; 2. 2 2.09; 2.18	2.3	2.12 1.97	1.85; 1.76	1.75; 1.69
Tauc gap , eV	~1.0 - 1.5	1.5 - 1.75	4.28; 2.35	- ; 2.4	3.12; 3.53	~3.5
Density, g/cm^3	1.8 – 2.0		~1.88	~1.6	~1.87	
Hardness, GPa	22,74		17.6	-	17.4 -19.1	
Residual stress, GPa	0.12	0.32	0.33- 0.37	0.6	0.35	
Surface roughness, nm	0.2 -0.4	0.4 – 0.9	0.4	1.1 - 5.0	~0.6	1.1 – 1.7

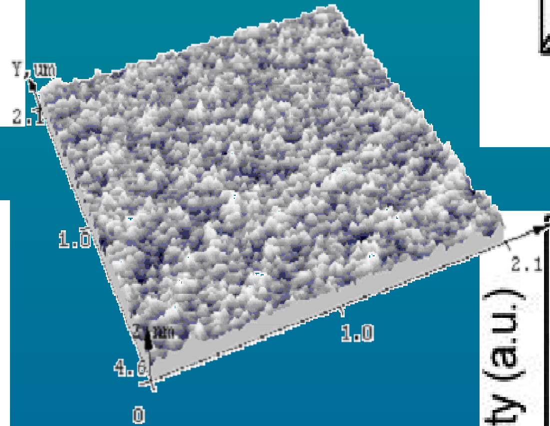
Results
Characteristics of irradiated SiO_x – containing DLC films



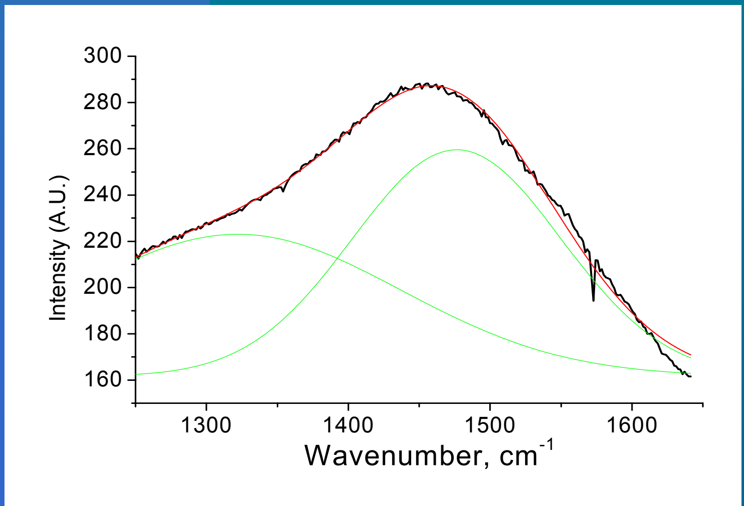
Transmittance spectra



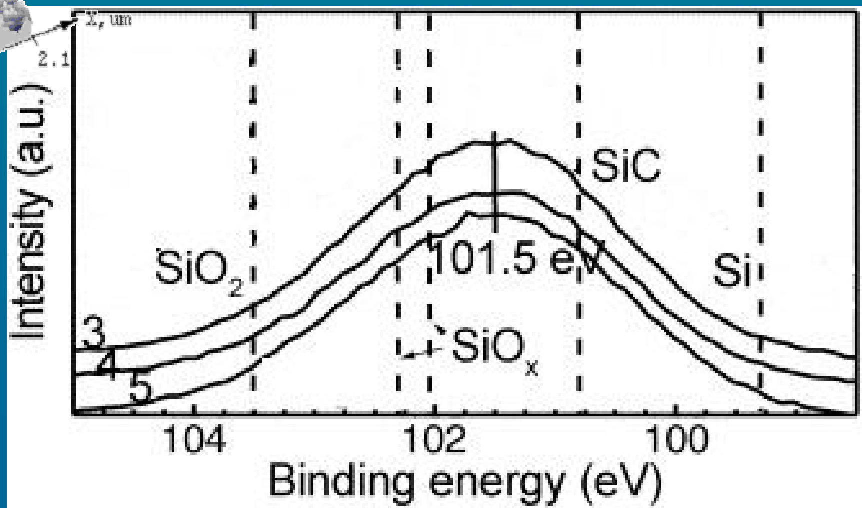
FT-IR spectra



Surface morphology



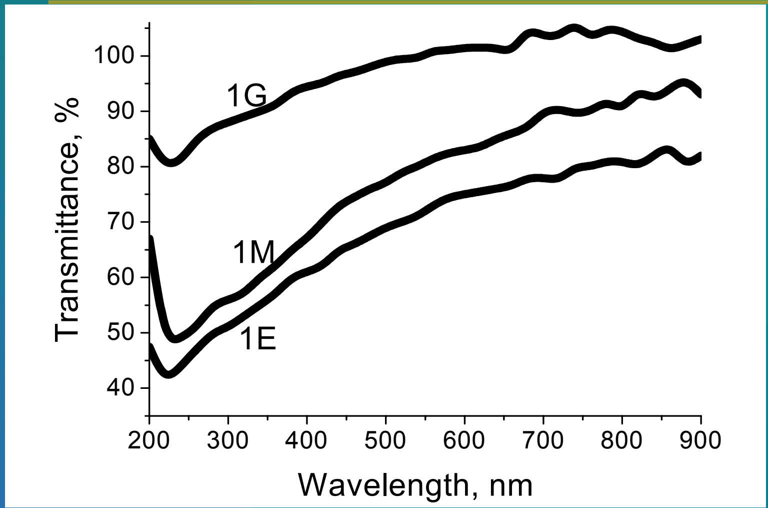
Raman spectrum



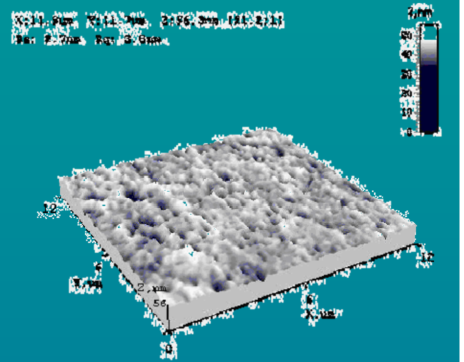
XPS spectra

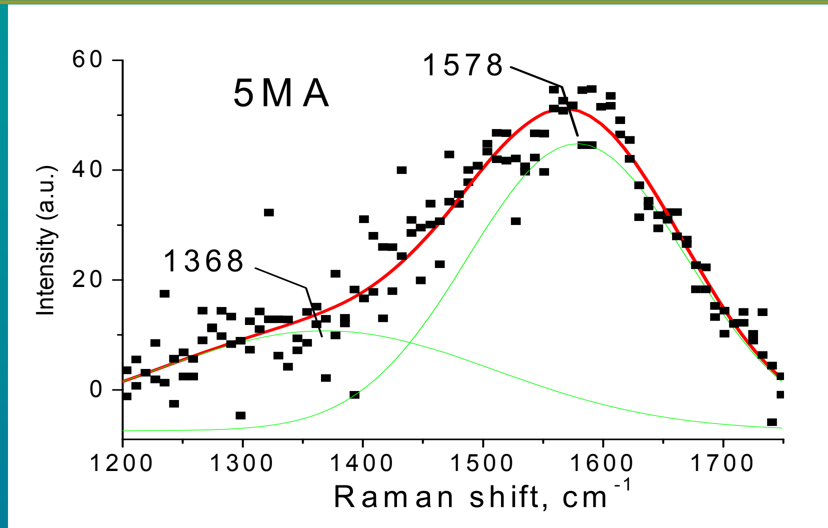
Results

Characteristics of irradiated films with less dense C-H network

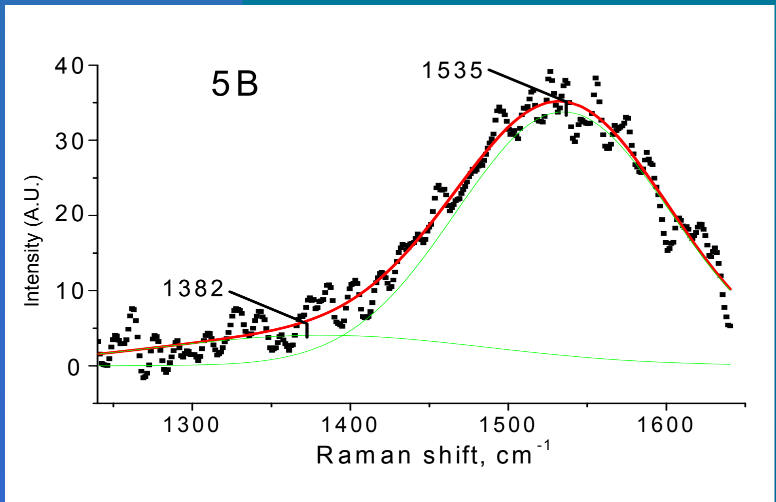


Transmittance spectra

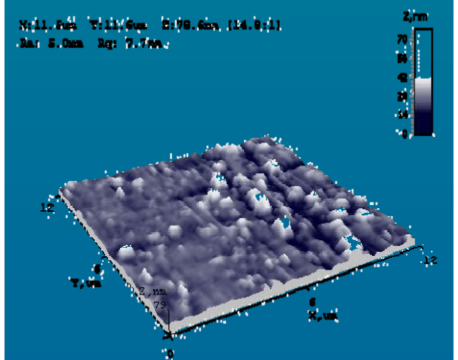


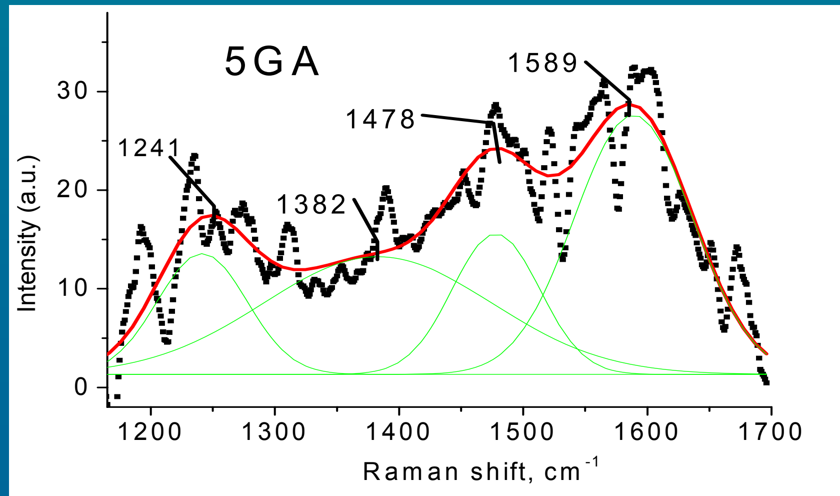


Surface morphology and Raman spectra of DLC film after irradiation with low energy (32kV) X-ray photons



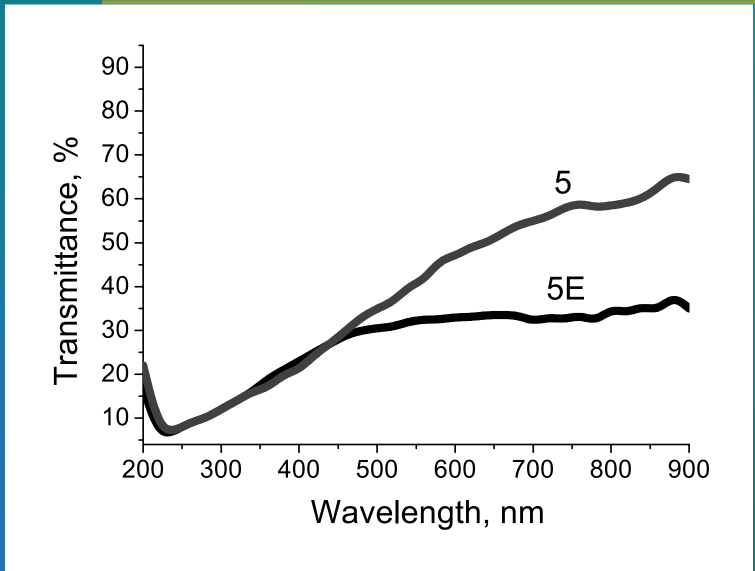
Raman spectrum before irradiation



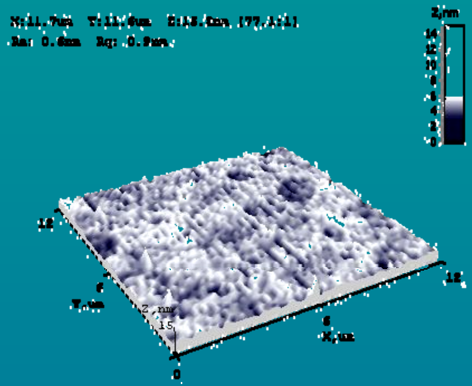


Surface morphology and Raman spectra of DLC film after irradiation with high energy (15MV) X-ray photons

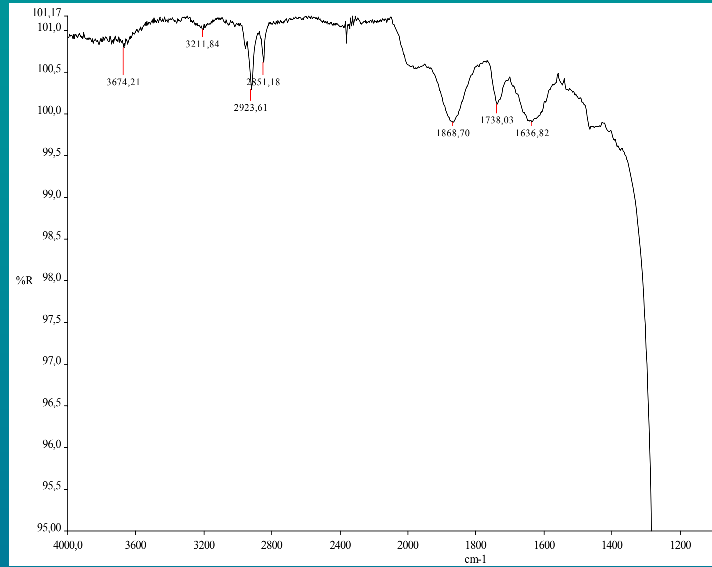
Results
Characteristics of amorphous hydrogenated DLC films



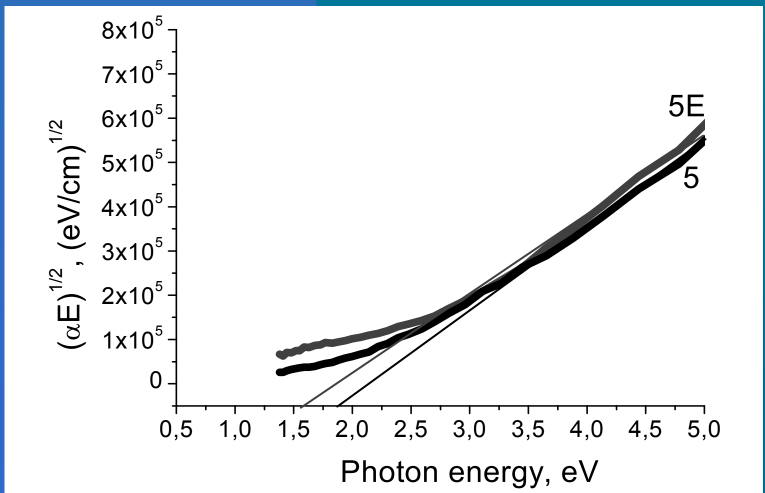
Transmittance spectra



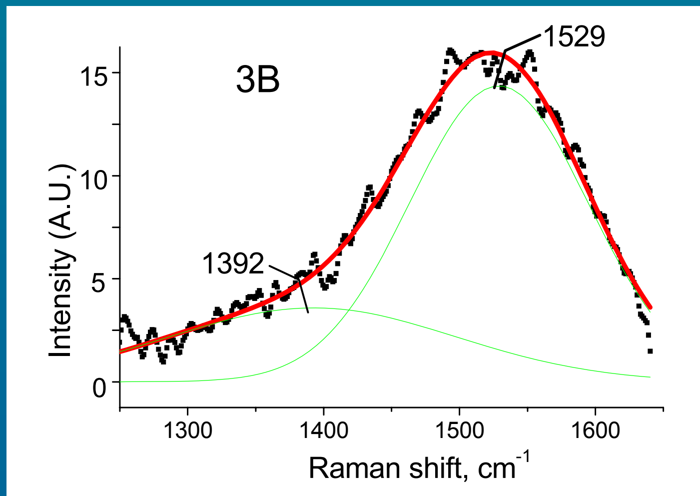
Surface morphology



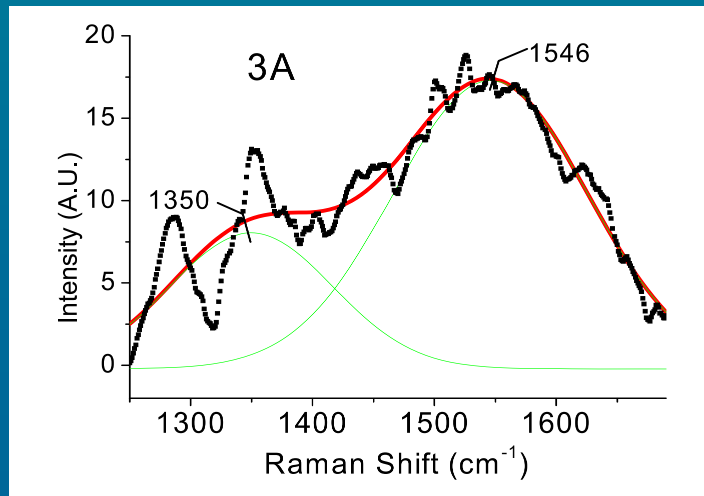
FT-IR spectrum



Tauc gap



Raman spectrum before irradiation



Raman spectrum after irradiation

Conclusions

Investigation of the radiation induced structural changes and mechanical properties of different types of amorphous DLC films irradiated with high energy X-ray photon has shown strong dependency on DLC film preparation conditions, film thickness and hydrogen content in the film. It was found, that the adhesion's properties and stability of SiOx – containing DLC films were not affected significantly by high energy photon irradiation. However some small changes in surface morphology and decreased hardness in investigated samples as compared to not irradiated samples, due to the rearrangements in chemical bonding structure of DLC film under exposure, were observed. The results of the investigation of SiOx – containing DLC films were compared with the results obtained for the irradiated a-C:H films, indicating dramatic changes in the films with less denser C-H network. Analysis of the experimental results and possible mechanisms for the explanation of radiation induced effects in DLC films has shown that SiOx – containing DLC films are most promising candidates as the protective coatings for Si based radiation detectors.

References

1. *F.Atchison, T.Brys, M.Daum, P.Fierlinger, A.Foelske, M.Gupta, R.Henneck, S.Heule, M.Kasprzak,K.Kirch, R.Kotz, M.Kuzniak, T.Lippert, C.-F.Meyer, F.Nolting, A.Pichlmaier, D.Schneider, B.Schultrich, P.Siemroth, U.Straumann. Diam.Rel.Mat.16(2007) 334.*
2. *C.Manfredotti, A.Lo Giudice, C.Ricciardi, C.Paolini, E.Massa, F.Fizzotti, E.Vittone. Nucl.Instr.MethA 458 (2001) 360.*
3. *P.Ascarelli, E.Cappeli, D.M.Trucchi, G.Conte. Diam.Rel.Mat. 12 (2003) 691*
4. *A.Grill.Thin Solid Films 3555-356 (1999) 189*.
5. *V.Kopustinskas, S.Meskinis, V.Grigaliunas, S.Tamulevicius, M.Puceta, G.Niaura,. Surf. Coat. Technol.180-3 (2002) 151.*
6. *S.Tamulevičius. Stress and strain in the vacuum deposited thin films. Vacuum 51(2) (1998) 127.*
7. *M.Šilinskas, A.Grigonis, Ž.Rutkūnienė, J.Maniks, V.Kulikauskas. Mechanical and optical properties of a-C:H films deposited from acethylene using direct ion beam deposition method. Phys. And Chem. of Solid State 6(3) (2005) 394.*