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Carbon thin film deposition by Thermionic Vacuum Arc (TVA)

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Carbon thin films were deposited on the Si and glass substrate by using TVA method Carbon films were deposited (thickness appr. 50-90 nm) by TVA at about 10^{-5} Torr. The refractive index (n) and thickness of the deposited thin films were measured by Filmmetrics F20 device. Atomic force microscopies (AFM) were used for the surface morphology of the deposited film. In addition, Roughness of the deposited carbon thin films was realized by using AFM Roughness mode.

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1. Introduction

In a number of papers we presented Thermionic vacuum arc (TVA) as a new technology for thin film deposition [1-4]. Deposition of the thin films using TVA is obtained in high vacuum conditions and also under the energetic ions bombardment of the depositing thin films, we may expect a high quality of such obtained films, namely, high purity, increased adhesion, low friction, low roughness, compact and nanostructured films. TVA can be used to deposit thin films of various materials like metals, alloys, ceramics, DLC (Diamond Like Carbon) and refractory metals such as W, Mo, Ta, Nb, Re and B. This new technology is especially adequate for the deposition of refractory metals due to the high density of the power on the unit surface of the evaporating refractory metals.

2. Experimental Arrangement

TVA can be ignited in vacuum (or UHV) between a heated cathode surrounded by an electron focusing Wehnelt cylinder and an anode (crucible) containing the material to be evaporated and deposited Due to the electron bombardment of the anode by the accelerated thermo-electrons from the grounded cathode towards the anode (which is at a high voltage), anode material first melts and afterwards starts to evaporate ensuring a steady state concentration of the evaporated atoms in the cathode – anode space. At further increase of the applied high voltage, a bright discharge is established inside of the vacummated vessel in the vapours of the anode material. The produced metal vapour plasma is localized around the electrodes, the plasma density quickly decreasing radially.

Experimental arrangement of TVA system especially used for depositions is shown schematically in Fig. 1 and it consists of a simple electron gun as a cathode and anode [1-7].

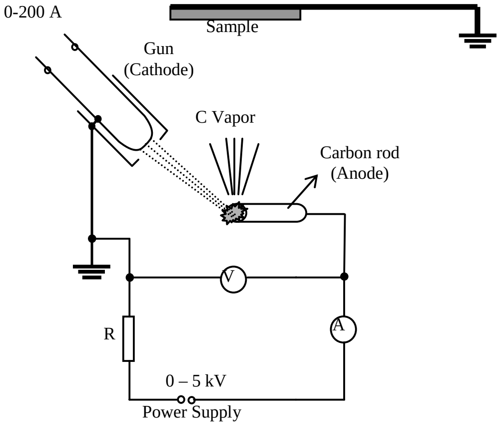

Fig.1. Experimental arrangement of TVA.

Carbon deposition parameters are followings. If= 60 A, V= is 3kV, $\phi=45^o$, d=6 mm. Deposition rate of the carbon materials 27nm/min. Thickness measurements are realized double method. One of these methods was realized during the depositions and other was realized after the depositions. Thickness were adjust in between 50-90nm.

Following substrates were used for the deposition of carbon thin films; glass and Si wafers. As carbon thin films were deposited glass and Si wafers substrates, Thickness of the thin films were controlled by Cressington Thickness monitor MTM-10. After finishing the depositions, the substrates covered with carbon thin films were analyzed using various techniques: thickness measurements (in process but also after the process), Refractive index measurements, UV spectra analyses, AFM, AFM roughness and XRD spectra of the deposited carbon thin film.

3. Experimental Results

3.1. Thickness measurements of carbon thin films

Thicknesses were analyzed by using Filmmetrix F20 Model Thin Film Analyzer**.** All data were collected at 50 points of the surface of carbon thin films. These data are summarized in Table 1.

Table.1 Thickness of carbon thin films

	(nm)	(nm)	(nm)	(nm)
Statistic	Sample-1	Sample-2	Sample-3	Sample-4
Mean	60	71.67	50.71	89.94
Median	59.95	71.85	50.68	89.92
Std. Dev.	0.267	0.342	0.089	0.187
Min.	59.73	70.14	50.68	89.52
Max.	60.62	72.65	51.12	90.36
Range	0.89	2.51	0.44	0.84

3.2. Refractive index of carbon thin films

The refractive index of the deposited DLC by RF plasma CVD films is situated in the range 1.6 - 2 [9]. Fig. 2 shows represent the graph of the refractive index as a function of wavelengths.

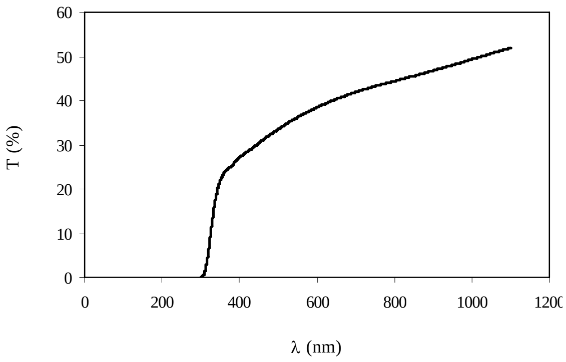

Fig.2. Refractive index of the deposited carbon thin film.

Refractive indexes of produced hard carbon thin films produced by TVA are approximately 1.8758. The refractive index's values are in agreement with those published in the literature.

3.3. UV spectral analyses

UV spectral analysis was realized for deposited carbon thin films by TVA. UV spectra were collected for the wavelengths range of 200-1200 nm. Fig. 3 shows the graph of the transmittance (%)-λ (nm).

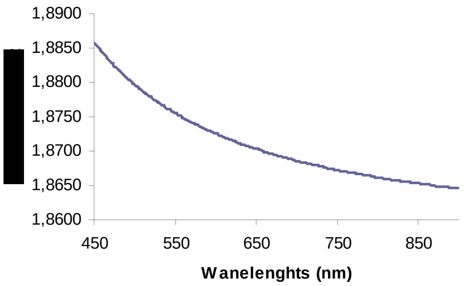

Fig.3. UV spectra of carbon thin film

3.4. AFM analyses of carbon thin films

Fig.4 and Fig. 5 represent the AFM image of the deposited carbon thin films in different scales. The surfaces of the deposited carbon thin films are very smooth. Maximum height is 9.422 nm as seen in Fig. 4.

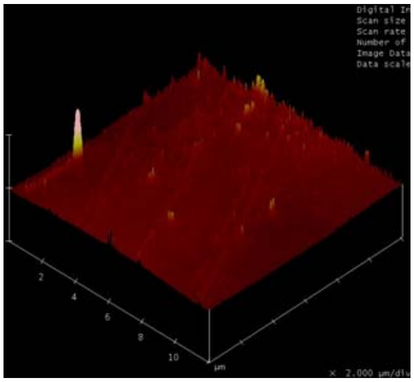

Fig.4. AFM image of carbon thin film (small scale).

The height of the white row is about 10 nm. The scale of the Fig. 4 is 10µ×10µ

The scale of the Fig. 5 is 1000nm×1000nm.

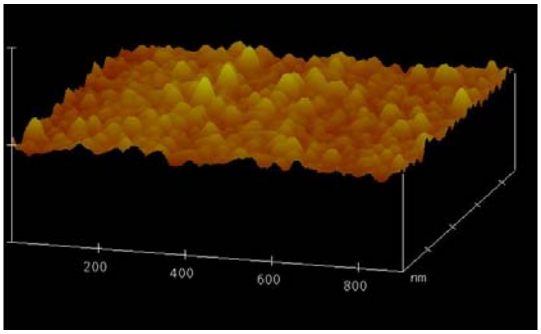

Fig. 5. AFM image of carbon thin film (large scale).

As seen in Fig. 5, the surface of the deposited carbon thin film is very smooth. We obtained very low roughness by using AFM about 0.7 nm from Fig. 4 and Fig. 5.

Statistics data for AFM are illustrated in Table.2. In this Table.2, Maximum height and roughness of the surface are about 10 nm and 0.7 nm, respectively.

Table.2 Statistics data for AFM.

Z range	9.399 nm
Raw mean	-1.745 μm
Rms (Rq)	0.880 nm
Mean roughness (Ra)	0.669 nm
Max height (Rmax)	9.422 nm
LKine density	22.845 /μm

3.5. XRD Spectra of carbon thin films

According to data of XRD spectra of the deposited carbon thin film, data is illustrated that thin films are including three crystal systems as Graphite in Hexagonal form, Diamond in Cubic form and Wolfram carbide in hexagonal form.

Table. 3 Crystal systems in the carbon thin film.

Material	Form	a	b	c
Graphite	Hexagonal	2.47000	2.47000	6.80000
Diamond	Cubic	3.56000	3.56000	3.56000
WC	Hexagonal	2.99704	2.99704	4.72790

4. Conclusion

XRD spectroscopic data of the carbon thin films deposited the Si substrate was summarized in Table.3. In addition, an XRD spectrum collected the data from the Si substrate. Wolfram carbide (WC) has been observed in produced carbon thin film because of the used wolfram filament in the electron gun. Wolfram filament and carbon used for deposition were exhibit significant interaction.

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