Carbon Films, Prepared by Electron Beam Evaporation of Graphite Target[1]

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Abstract – The work demonstrates possibility of electron beam evaporation of graphite in helium atmosphere at the pressure range 5÷15 Pa. Carbon films deposition rate was 0.5÷1 μm/min. As AFM investigation had shown, the films, deposited on different substrates (glass, silicon), were packed by scales with structure dimensions of 300÷400 nm and thickness 5÷10 nm. The films have optical energy gap ~0.75 eV and surface resistance of about 1÷2 MOhm/ϒ at 200 nm thickness. These results specify on disordered film structure.

1. Introduction

Carbon films are widely used for different applications. Film properties can vary over a wide range: from soft up to super hard diamondlike, from dark to transparent and from insulating to conductive. Last decades new forms of carbon such as fullerenes and nanotubes were open. Carbon films investigations have convincingly shown that their properties strongly depend on method of synthesis [1]. Therefore, development of a new method promises new properties of such films. Among variety of existing methods of carbon films deposition special interest is for those, which do not require high temperature. It allows using them for coating deposition on low temperature materials or on already existing structures, without disturbing parameters of their surface. One of such methods is evaporation of graphite. Current techniques of the evaporation use two methods: vacuum arc discharge between two graphite electrodes and laser evaporation [2]. Because the dc arc discharge exists only at high enough (tens amperes) currents, the method has the limited opportunities of control and variation of parameters. Laser method requires complex and expensive equipment. Much more convenient is electron beam evaporation which has not found wide application by the present time. The electron beam evaporation has more wide opportunities both in process intensity and in gas pressure range. The objective of present work was investigation and optimization of deposition regimes and properties of carbon films made by electron beam evaporation of graphite. The electron beam was generated by hollow cathode plasma source [3], which was especially designed to operate in fore-vacuum pressure range (5÷15 Pa).

2. Experimental details

The scheme of experiment is presented in Fig. 1.

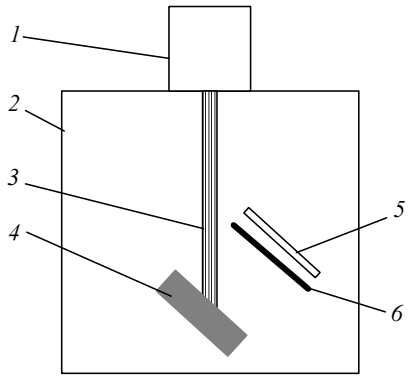

Fig. 1. Scheme of experimental installation

Electron source *1*, displaced on the flange of vacuum chamber *2*, generates electron beam *3*, which is directed to graphite target *4*. Products of evaporation are deposited on substrate *5*. Screen 6 serves for substrate preservation during target cleaning. Graphite evaporation was made in helium atmosphere. The design of installation provided an opportunity of substrate heating and the control of its temperature. Substrate materials were glass and silicon. In some experiments silicon substrate was negatively biased to the grounded walls of vacuum chamber. The films obtained by such method were investigated by AFM and X-ray diffraction methods. Besides, IR and visible absorption spectra and surface resistance were measured.

3. Results and discussion

The investigated carbon films have mirror surface. As it was expected, the film deposition rate depended on distance between target and substrate (Fig. 2, *a*). Carbon films were deposited not only on front side but also on backside of the substrate. This is probably due to high enough gas pressure providing collisions with carbon atoms. Heating the substrate up to temperature about ~ 300 °C increased film deposition rate (Fig. 2, *b*). One of presumable reasons of such behavior can be elimination of adsorbed gas molecules layer, which, most likely, interferes to carbon atoms fastening on a substrate. Negative substrate biasing lowed deposition

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rate (Fig. 2, *c*) because of, probably, ion sputtering. Films with thickness up to ~ 500 nm had adhesion, sufficient for realization of measurements. More thickness films had tendency to drawing off and could be received as slices in the sizes in some millimeters.

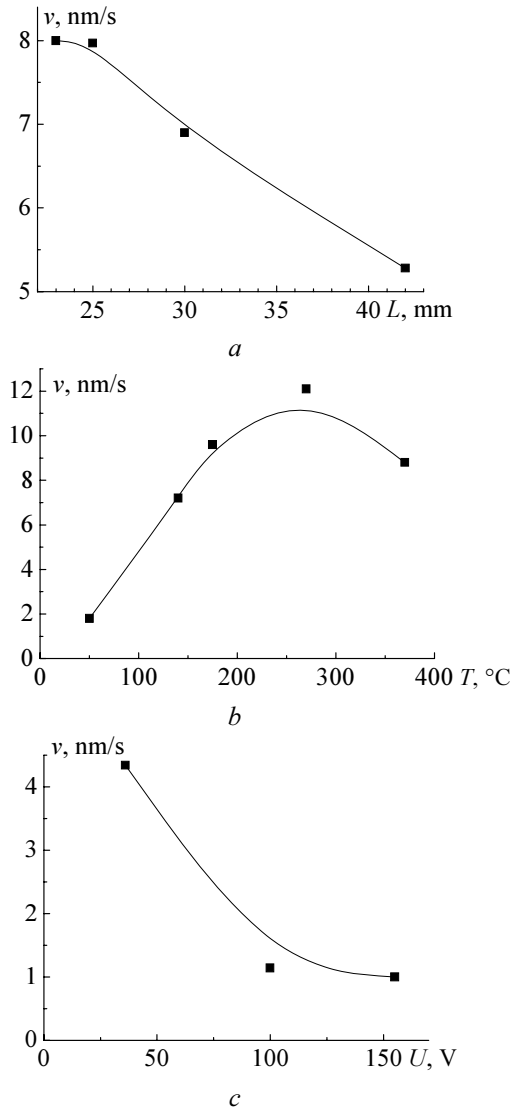

Fig.2. Carbon film deposition rate *v* as function of: *a* – distance *L* between graphite target and substrate; *b* – initial substrate temperature *T*; *c* – negative substrate potential *U*

Absorption coefficient α in visible spectra satisfies to expression $\alpha h\nu = B(h\nu - E_0)$, which is usual for amorphous substances. The use of coordinates $(\alpha h\nu)^{1/2}$ and $h\nu$ gives possibility to define energy gap E_0. Estimated value $E_0 \approx 0.75$ eV appeared much less values ~ 1.2 eV, known from literature for carbon films, prepared by plasma chemical deposition [4]. This fact together with high enough surface resistance (1.8 MOhm/ϒ for 200 nm thickness) can specify on extremely disordered structure of prepared films. IR-reflection spectra contain one maximum at 1240 cm^{-1}. It cannot be attributed to definite bonding, because C–C, C–O and C–N groups have similar frequencies [5].

Film structure, defined by AFM investigations, consisted of scales with dimensions 300÷400 nm and thickness 5÷10 nm (Fig. 3).

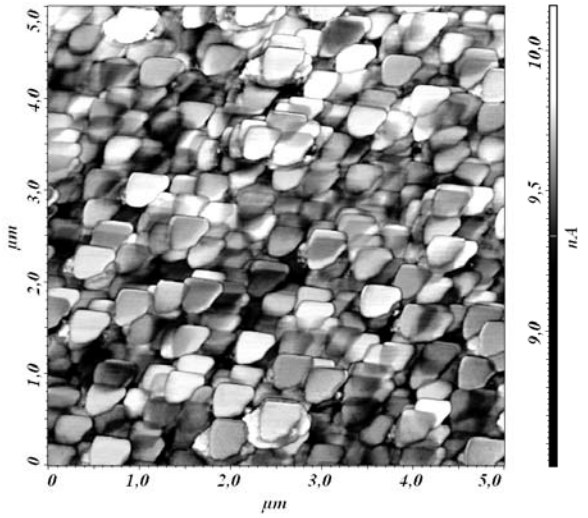

Fig. 3. AFM-image of carbon film, deposited on heating glass substrate (T = 300 °C)

It is difficult to assume this structure formation at substrate during growth from vapor. In our opinion, it is more probable carbon evaporation in form of such scales. X-ray diffraction picture of carbon deposit does not contain any coherent signals.

4. Conclusion

Results of our work confirm possibility of carbon films deposition by electron beam evaporation of graphite in vacuum 5÷15 Pa. The films have amorphous structure. Scales 300÷400 nm dimensions and 5÷10 nm thickness pack them. This structure explains low energy gap and high resistance of carbon films.

References

[1] V.N. Kondariev and E.E. Nikitin, *Chemical Processes in Gases*, Moscow, Nauka, 1981, 264 pp.

[2] V.S. Arutyunov and O.V. Krylov, *Oxidative conversion of methane*, Moscow, Nauka, 1998, 361 pp.

[3] Y.A. Kolbanovsky and I.V. Bilera, *Generation of Synthesis-gas in the Electric Power Installations, Gas chemistry in twenty first Century. Problems and Perspectives*, A.I. Vladimirov and A.L. Lapidus, eds., Moscow, Oil and Gas, 2003, 288 pp.

[4] V.D. Rusanov, A.I. Babaritskiy, A.I. Gerasimov et al., Dokl. Ross. Akad. Nauk **389**/3, 324–327 (2003).

[5] T. Kappes, T. Hammer, and A. Ulrich, *in Proc. of 16th International Symposium on Plasma Chemistry*, Italy, 2003.