ION-PLASMA MODULES FOR APPLICATION OF NANOSTRUCTURED CARBON COATINGS

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Key words: vacuum system, magnetron sputtering, carbon thin films

Abstract. The basics of forming technology of nanostructured films in the form of composites containing hydrogenated carbon and metal parts was considered. Provides information about the methods used to generate these coatings. A description of the vacuum system provides the most satisfying modern requirements to technological equipment were given: minimum weight and size, power consumption, high stability and environmental safety of the process, tolerance to automate the process.

Thin carbon films in the amorphous state ($\alpha$-C) containing bound hydrogen, are called hydrogenated films ($\alpha$-C: H). The films are submit material with variable optical, electrical and mechanical properties during production process. This gives up great possibilities for application of these films in various devices [1]. In particular, nanostructured films of amorphous hydrogenated carbon with ferromagnetic nanoparticles are promising structures to formation of radio-absorbing materials (RAM) [2-4].

There are two classes of technologies of forming $\alpha$-C and $\alpha$-C: H films - physical vapor deposition (PVD) and chemical vapor deposition (CVD). The first group includes magnetron sputtering system, vacuum arc evaporators, as well as pulsed laser evaporation of graphite and a cathode sputtering with an ion beam of inert gas (in the case of $\alpha$-C films). The methods of CVD include: ion-assisted deposition of hydrocarbon plasma, liquid phase epitaxy, pyrolysis, etc.

It is found that the properties of these coatings are highly dependent on the method and parameters of technological process of their formation, as well as the hydrogen concentration. This is determined by the type of chemical bonds between atoms in the film (a kind of hybridization of valence electrons: $sp^2$ or $sp^3$). The ratio of phases with different hybridization can be estimate by using energy-loss spectroscopy of electrons.

Systematic description of the methods of carbon deposition, the properties of the films and the technological features of their preparation may be found in [5]. Among the results of research in developing methods for producing films as ion-plasma and gas-phase methods received by domestic by the authors, it can be noted in [6] and [7].

Among the above-mentioned technologies for producing carbon films in many ways stands out the ion-plasma technology based on magnetron sputtering systems. Flow of plasma evaporated particles is generated in highly non-equilibrium conditions. This fact defines a very weak effect of
temperature on the parameters of the sputtering process. This circumstance allows flexible regulation of the process parameters of the films and affects their physical and chemical properties and performance characteristics.

The information about the basics of technology of composite hydrogenized carbon thin films with metallic inclusions developed by the modernization of vacuum system ZV-1200 made by company LEYBOLD HERAEUS is given below.

This system is a gateway and a multimodule installation, which allow carrying process for several samples simultaneously. Location of modules installation is shown in Figure 1.

1 – Load chamber, 2- Provisional pump and the final purification chamber, 3- Technological chamber, 4 – Cooling chamber, 5 – Unloading chamber.

![Figure 1 Block-diagram of the ZV-1200 vacuum system](image)

Working algorithm of sputtering system can be summarized as follows. Loading of substrates is carried out in chamber 1. Next, the substrate is moved to chamber 2, which have dry pump system provided by turbomolecular pumps. There occurs degassing of products and finishing ion cleaning of surfaces, which are supposed to be covered by the film. Ultimate pressure in the working volume of the chamber can be up to $10^{-4}$ Pa.

To improve the quality and performance of products before the film formation process the substrate material must be subjected to finishing treatment to activate the surface and remove the water vapor and residual gases from the surface.

In the basic installation finish ion cleaning occurred in the glow discharge in argon at pressures in the range of 2 - 5 Pa. The energy of the ions bombarding the surface, determined by the automatic offset, which is formed to ensure the vanishing of the charge brought in from the plasma to isolated or dielectric surface. In the absence of a magnetic field near the surface the magnitude of the potential difference in the boundary layer is approximately $7kT_e$ ($k$ - Boltzmann constant, $T_e$ - the electron temperature) and for the conditions under consideration is in the range of 20 - 30 V. These energies of ions are close to the critical potential of sputtering, so cleaning conditions in the considered system are far from optimal.

To improve the quality of the finish ion cleaning was developed plasma source of fast neutrals on the basis of non-self glow, construction similar to that described in [8].

The main difference of the developed module is the fact that the energy disjoint-charge of the ions is less than 30 eV, which eliminates the appearance of the charge embedded in the surface layers of the structure and reduces heating of treated surface.
The second feature is the automatic stabilization of the surface potential, which can vary due to the charging of the surface due to the secondary electron emission during its bombardment by fast neutrals.

The process of film formation occurs in chamber 3. Design of this module is provided to ensure maximum coverage area with a given degree of non-uniformity and the possibility of the films application on heat sensitive materials. The module has the possibility to install up to 8 magnetrons (4 on each side) with geometric dimensions 750 * 80 mm disposed vertically. This modification decreases coating non-uniformity to 10% that was observed at the edges of the 600-mm long sample.

Film thickness uniformity in the horizontal direction is achieved by scanning of sheet of material mounted on intracameral element (pallet) with respect to the magnetron at a speed of 0.03 m/s. When applying single-component films, scanning amplitude decrease and deposition rate decrease in the chamber are achieved by using of parallel work of the magnetrons.

Using the targets made of dissimilar materials and independent regulation of the power supplied to the magnetrons allows sputtering composition coatings with controlled properties.

The maximum temperature to which the surface of material is heated during sputtering process is regulating by the selection of magnetron power and a scan rate of the material.

After cooling inside chamber 4, the sample is unloaded to the chamber 5.

Control part of the sputtering system had undergone deep modernization. The system is controlled by means of a specially developed software for PCs in the programming language C++. There are both manual and fully automatic modes of operation of the sputtering system.

In automatic mode, the parameters of the process are supported with a high accuracy by providing feedback to the functional sites, whose modes alter the properties of the formed films.

The basic installation was implemented the ability to handle 2 samples simultaneously. This upgrade is done because of impossibility to handle large amount of data on the basis of outdated electronic components. Therefore, to improve the efficiency of all modules and enhance the performance of sputtering system currently being upgraded software based on programmable industrial data acquisition system and control of processing equipment. Final transfer of the installation to the modern standard of data exchange via RS-485 interface is implemented by replacing the central controller. It will integrate additional equipment, such as components of magnetron sputtering system and means of mass spectrometry with the possibility of feedback with the main device without significant changes of software architecture.

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