Optical properties of fluorocarbon coatings obtained by ion-plasma method at atmospheric pressure in dynamic mode of deposition

V M Elinson, A V Shvedov and D Yu Kukushkin

Moscow Aviation Institute (National Research University), 125993, A-80, GSP-3, 4, Volokolamskoe shosse, Moscow, Russia. Tel: +7 (499) 158-92-09

E-mail: seriousash@yandex.ru

Abstract. This paper presents the results of a study of the formation of fluorocarbon coatings obtained by using a low-frequency plasmatron of a low-temperature atmospheric pressure plasma in a dynamic mode of deposition. The main dependences of chemical vapor deposition (CVD) are investigated. The absorption spectra in the UV range was studied, and the band gap was determined by the Tauc method.

The development of modern components for the optoelectronic industry is largely based on a set of technologies for protection of products from environmental influences by means of production of thin film coatings [1]. In particular, coatings that prevents the deposition of moisture and microbiological contaminants, which may lead to the destruction of polymeric materials [2, 3]. Carbon is often used as a protective coating material, due to its features such as the possibility of forming compensated valence bonds and a wide range of properties that vary depending on the deposition methods and used technologies [4].

Figure 1. Schematic representation of dynamic mode of deposition (A - processing step).
The use of fluorocarbon films allows achieving good barrier properties of the resulting coatings [5]. CVD by the ion-plasma method in vacuum allows getting a reproducible coating with desired characteristics. However, recently, the use of atmospheric gas discharges for surface modification [6], etching and CVD [7] has increased due to the lack of the need to create and maintain a vacuum and the simplicity of control of process. The low-frequency (LF) plasmatron of a low-temperature plasma is capable of local formation with minimized environmental influence on the processes [8].

For creation of reproducible coating with given characteristics over the entire surface area of the substrate (or product) when using an LF plasma torch, a dynamic mode of deposition was proposed. It is a process in which the process of CVD with a constantly moving remote head of the plasmatron over a given surface area is performed (figure 1).

The dynamic mode has been achieved after the installation of an experimental LF plasmatron of atmospheric pressure on a CNC for precision control and monitoring of the geometric parameters of the deposition process, as well as the speed and processing step (figure 1). The installation was controlled by a personal computer with the installed NC-Studio software.

CVD is ensured by supplying a mixture of several gas streams according to the scheme in figure 2.

Figure 2. Gas block connection diagram.

During the CVD, the following technological parameters were monitored: plasmatron-substrate distance (15-24 mm), the deposition rate (1-5 mm / s), the treatment area was 750 mm$^2$ (25X30 mm), the total gas flow was 7.1 ± 0.2 l / min. The frequency of the gas discharge was fixed at 115 kHz, since the highest intensity of the plasma flow was established at this frequency.

Figure 3. The dependence of the thickness of the obtained coatings on the plasmatron-substrate distance.
The coatings were formed on monocrystalline silicon substrates for subsequent thickness measurement on a MII-11 microinterferometer and on polyethylene terephthalate (PET) substrates for studying absorption spectra on a PhotoLab 6600 spectrophotometer (Germany).

A study of the thickness of the obtained coatings showed that the growth rate of fluorocarbon coatings substantially depends on the plasmatron-substrate distance and processing speed (figures 3 and 4), due to the increased energy deposition in the gas discharge between the plasmatron nozzle and the substrate on which the vapor deposition was carried out. In addition, the nature of the distribution of the gas mixture and the increased diffusion of gas particles from the plasma jet into the environment also have an effect.

Figure 4. The dependence of the thickness of the obtained coatings on the processing speed.

Figure 5 shows absorption spectra of fluorocarbon coatings obtained at different technological deposition parameters.

As can be seen from the spectra shown (figure 5) at wavelengths less than 310 nm, fluorocarbon coatings have different absorption peak intensities, which is associated with different chemical composition and relief of the coatings. At the same time, at wavelengths greater than 410 nm, the spectra of the coatings obtained are practically similar in nature, which indicates the same nature of the spectral composition of light absorption in the visible range for both types of coatings.

The band gap was also calculated using the Tauc method, which averaged $4.38 \pm 0.02$ eV. This band gap corresponds to the dielectric material. The influence of technological parameters on the band gap is insignificant.

It should be noted that the differences in the absorption spectra between the samples obtained in the matrix mode, which were not observed during the transition from the local mode to the matrix mode (figure 5). Apparently, this is due to the transition from a point-wise process of coating formation to a continuous process, which entailed a change in the properties of the resulting fluorocarbon coatings.

The result of this work, it was established that:

- The possibility of forming fluorocarbon coatings in a dynamic application mode;
- The thickness of fluorocarbon coatings linearly depends on the distance of the plasmatron-substrate and the speed of movement of the head of the plasmatron;
- absorption spectra and band gap were determined by the Tauc method, averaging $4.38 \pm 0.02$ eV.
Figure 5. Absorption spectra of fluorocarbon coatings: sample 1 – dynamic mode, plasmatron-substrate distance 15 mm, step 3 mm, processing speed 1 mm/s; sample 2 – dynamic mode, plasmatron-substrate distance 21 mm, the step 4 mm, the processing speed 1 mm/s; sample 3 – matrix mode, plasmatron-substrate distance 15 mm, the step 3 mm, the processing time 15 seconds.

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