The impact of carbon shot number on the morphology of deposited carbons on tungsten

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Abstract

In materials science, one of the most effective ways to improve the properties of base metal is to coat it with another material. The aim of this study is to carbon deposition on tungsten samples using a 4.5 kJ plasma focus device to improve the properties of tungsten. In such a manner, The films were characterized using atomic force microscopy, and Raman spectrometry with different numbers of focus shots. Results showed that the quality of deposited tungsten from AFM images and Raman spectrometry increased when the number of shots increased from 10 to 20 and then to 30. The AFM results show the formed structure tends towards a regular honeycomb structure in which each carbon atom is bonded to three other carbon atoms. In addition, the average and root mean square (rms) values of the measurements are raised when the number of shots increases from 10 to 20 then 30.

Keywords: Plasma focus device, Atomic force microscopy, Raman, AFM.

Introduction

Tungsten and stainless steel are the most important structural materials in the wall of fusion systems. Although tungsten has some advantages such as high strength, it has low corrosion resistance and heat tolerance at plasma operating temperatures. Hence, to improve the performance and properties carbon deposition on tungsten is recommended for use in the structure of the fusion reactors [1-2].

One of the usual methods for coating is the chemical vapor deposition method in a Plasma Focus Device (PFD). This machine has some advantages over other conventional layering methods including dry process, low cost, high energy, and short reaction time. On the other hand, it has differences in ion parameters in different shots. Also, PFD is widely used in various industries, including plasma, dosimetry, and coating materials [3]. A schematic of the PFD is shown in figure 1.

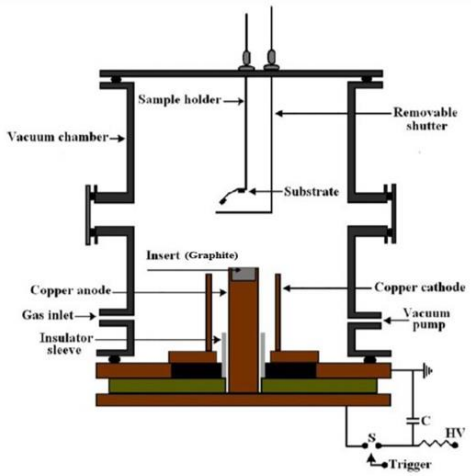

Figure 1. A view of the plasma focus device.

Although several reports and articles on various deposition techniques fields have been studied in recent years [4-5], in this paper analysis of carbon deposition on tungsten substrates using AFM and Raman tests were done by a 4.5 kJ PFD.

Material and methods

In this study, the Amirkabir University of Technology plasma focus device has been selected for tests. This device is a source of high-energy nitrogen ions which react with the tungsten ions eroded from the anode tip. Also, this system is a Mather-type system that is powered by a single capacitor (15 (kV), 40 (µF)) and the tests were done at room temperature [6].

First, the samples were prepared by cleaning with alcohol and acetone. Then the substrates were kept at 10 cm away from the carbon on the tip of the anode. Finally, four different thin films were deposited by 10, 20, and 30 focus shots. According to the type of tests, analysis of the structural properties of all deposited films was done by AFM, and Raman spectrometry.

Results and discussion

AFM test

Using the images acquired by AFM test the surface morphology of the deposited films at various numbers of focus shots at the zero-degree angular position was recorded. Figure 2 demonstrates the histogram of the peak height distribution of samples.

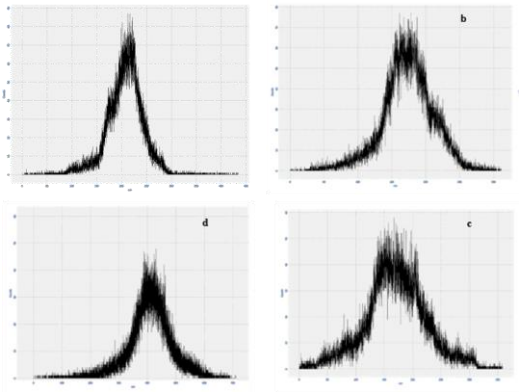

Figure 2. Histograms of the peak height distribution of the specimens exposed to (a) zero shots, (b) 10 shots, (c) 20 shots, and (d) 30 shots at the zero-degree angular position.

In PFD, the ions are radiated in a fountain-like structure, and their energy and flux vary with their angle relative

to the anode axis. In this regard, The roughness of three random areas over the surface of the deposited film was measured as the average and root mean square (rms) values of the measurements to evaluate the surface roughness of the deposited samples. Variations of the average and rms roughness of the film surface in terms of the number of focus shots for the thin films deposited at zero-degree angular position is shown in Figure 3.

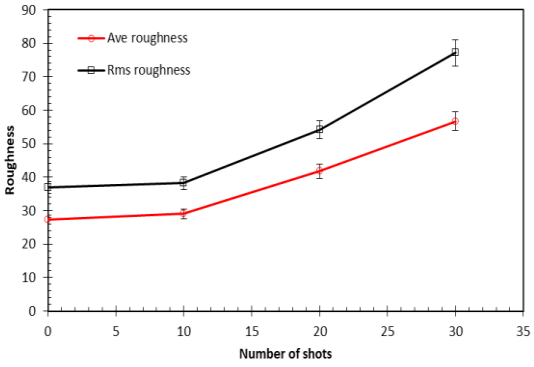

Figure 3. Variations of the average and rms roughness of the film surface in terms of the number of focus shots for the thin films deposited at the zero-degree angular position.

It is obvious, by increasing the number of shots, the surface roughness will be increased, which has appropriate consistency with previous studies [7].

Raman test

The Raman spectra of the carbon-deposited substrates at the same axial and angular positions with respect to the anode axis using dense PFD are illustrated in **Fig. 3**.

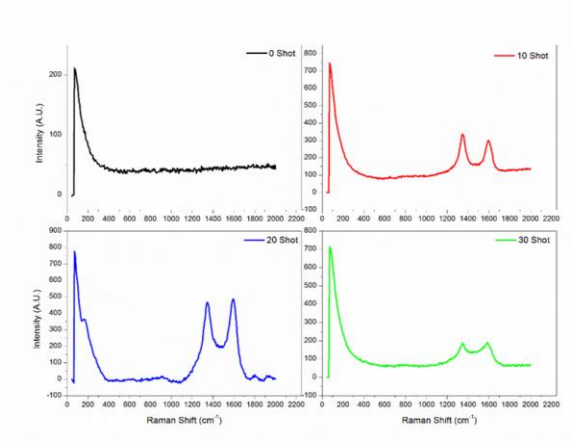

Figure 4. Raman spectra for the carbon-deposited specimens with different numbers of focus shots at a similar angular position (0̊).

Raman spectrum data for carbon deposition with different numbers of focus shots are listed in table 1.

Table 1. Raman spectrum data for carbon deposition.

Number of shots	D peak place (cm^{-1})	G peak place (cm^{-1})	D paek Intensity	G paek Intensity
10	1348	1595	336.6	**299.8**
20	4343	1594	466.5	**488.1**
30	1354	1584	158.8	**190.4**

Peak D is related to structural irregularities, carbon structures with sp^3 hybridization, and G band is related to regular graphene lattice vibrations with E_{2g} symmetry or carbon structures with sp^2 hybridization. According to Table 1, with increasing the number of shots, the wavenumber related to the G band to smaller values, and the ratio of the intensity of the D band to the G band has also decreased. It has been shown that reducing the mean angle of C-C bonds leads to a reduction in the G-peak wave number. Also, the peak intensity ratio of D-band to G-band in the Raman spectrum of carbon structures is very important and indicates the ratio of sp^3 / sp^2 bonds

Conclusions

The main purpose of this paper is to analyze carbon deposition on tungsten substrates using a plasma focus device. In this way, atomic force microscopy (AFM), the surface morphology of the deposited films at various numbers of focus shots at the zero-degree angular position was tested. The AFM results show by increasing the number of focus shots, the crystal defects of carbon structures are reduced. The formed structure tends towards a regular honeycomb structure in which each carbon atom is bonded to three other carbon atoms. In addition, the average and root mean square (rms) values of the measurements are raised when the number of shots increases from 10 to 20 then 30.

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