STRUCTURAL ANALYSIS OF CARBON FILMS DEPOSITED FROM ARGON-ACETYLENE GAS MIXTURES

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ABSTRACT

The amorphous carbon films were deposited on the stainless steel substrates at atmospheric pressure from argon-acetylene mixture by plasma jet chemical vapor deposition. The Ar/C_2H_2 gas volume ratio varied from 100:1 to 200:1, while the distance between plasma torch nozzle exit and the samples was 0.005÷0.02 m. Scanning electronic microscope analysis demonstrated that the surface roughness and growth rate of the films increases with decrease of Ar/C_2H_2 ratio. The hydrogen concentration falls from 27 at.% to 5 at.% with the decrease of the distance from 0.02 to 0.005 m. The increase of the Ar/C_2H_2 ratio from 100:1 to 200:1 slightly increases the hydrogen and oxygen concentration in the films. The Fourier transform infrared spectra demonstrated an existence of C=C and C=O sp^2 bonds and presence of sp^3 CH_{2-3} modes in coatings. The Raman spectroscopy indicated that the film prepared at Ar/C_2H_2 = 100:1 and 0.005 m has the highest sp^3 C-C fraction. The coating deposited at 0.02 m has the highest fraction of sp^3 CH_x bonds. The hardness of the carbon films deposited at 0.005 m was in range of 7.1-9.3 GPa.

Key words: Carbon film, acetylene, plasma jet.

INTRODUCTION

Recently much attention has been focused on the deposition and investigation properties of various amorphous carbon films [1-2]. The unique properties such as chemical inertness, low friction coefficient, high hardness, and optical transparency of amorphous carbon are characterized by a combination of sp^2 and sp^3 sites fraction and the hydrogen concentration. The deposition technique and process parameters allow to control and form a carbon films with a desirable sp^2/sp^3 carbon sites fraction and hydrogen content. Thus deposit a carbon films with totally different properties and due to it adjusts these films in a various application fields [1-3].

The objective of the present study is to form carbon films and study the effect of the Ar/C_2H_2 ratios on the growth rate, surface morphology, bonding structure of deposited coatings.

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

A 5 kW power direct current (DC) plasma torch was used to deposit carbon films on the stainless steel substrates at the atmospheric pressure [2]. Argon (flow rate of 6.6 l/min) was used as plasma forming gas, and acetylene as a precursor. The acetylene gas flow was varied in the range of 0.033-0.066 l/min. The Ar/C_2H_2 gas volume ratio varied from 100:1 to 200:1, while the distance between plasma torch nozzle exit and the samples was 0.005÷0.02 m. The plasma torch power was ~600 W, deposition time - 120 s. Surface microrelief was characterized by scanning electron microscopy (SEM). The bonding structure and optical properties of carbon films were characterized using Fourier transform infrared (FTIR) spectrometer (GX FT-IR) and Raman scattering (RS) spectroscopy. The elemental composition of the carbon films was analyzed by Rutherford backscattering (RBS) and elastic-recoil detection analysis (ERDA) techniques. The microhardness measurements were done using MTS Nanoindenter G200.

RESULTS AND DISCUSSION

SEM results indicated that with the decrease of the Ar/C_2H_2 ratio, the surface roughness of the coatings increases. The film deposited at 0.005 m distance is smooth and covered by randomly situated 0.5-1 μm size grains (*Fig. 1*). As the deposition distance increases the surface of the coatings become rougher and consisted from the micrometer size irregular fragments micrographs (*Fig. 1*).

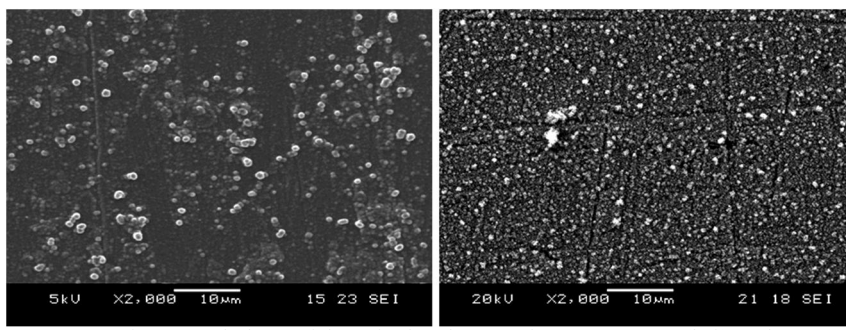

Fig. 1 - Surface morphology of deposited carbon coatings at 0.005 m (left) and 0.02 m (right), Ar/C_2H_2 ratio was 150.

The nature of FTIR spectra of the films prepared at Ar/C_2H_2=150 and different distances are very similar. The wide band at 1580 cm^{-1} is assigned to the vibrations of sp^2 C=C bonds and demonstrates that the carbon bonds are in aromatic and olefin configurations [1, 4]. The band with the absorption maximum at 1725 cm^{-1} in FTIR spectra of the carbon films is associated to the C=O

stretching vibrations. Also the bands related to sp^3 CH_{3-2} (~2960, 2930, and 2860 cm^{-1}) asymmetric vibration and symmetric stretching modes are present in the spectra.

The RBS and ERD results indicated that the hydrogen and oxygen concentration increases with the increase of distance. The film deposited at 0.005 m and Ar/C_2H_2 =100, mainly consist of carbon (94 at.%) with a low concentration of the hydrogen (~3 at.%) and oxygen (~3 at.%). The hydrogen concentration falls from 27 at.% to 5 at.% with the decrease of the distance from 0.02 to 0.005 m, when Ar/C_2H_2 ratio is 150. The variation of the distance also results a different shape of RS spectra. The I_D/I_G ratio slightly increases from 1.26 reaches the highest value (1.41) at 0.015 m, and when decreases down to 0.31 (at 0.02 m). The decrease of I_D/I_G ratio at 0.02 m is explained by the increase of sp^3 CH_3 polymeric chains regarding the decline of sp^2 carbon sites in the coating [1]. The hardness of the carbon films deposited at 0.005 m was in range of 7.1-9.3 GPa. Meanwhile, the films deposited at higher distances are soft (~1 GPa).

CONCLUSIONS

The coatings growth rate increases with the decrease of Ar/C_2H_2 ratio. The oxygen and hydrogen concentration increases with the increase of the deposition distance and Ar/C_2H_2 ratio. The films deposited at the longest distance (0.02 m) are attributed to the polymer-like carbon films. The hardness values of the carbon coatings obtained at the shortest distance varied in range of 7.1-9.3 GPa.

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