JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 9, No. 8, August 2007, p. 2657 - 2659

Mass spectrometry and ion energy analysis of the carbon TVA plasma for the synthesis of DLC films

C. SURDU-BOB*, G. MUSA[a], V. BUCK[b], I. MUSTATA, O. FILIPOV[b], A. POUKHOVOI[b]
Low Temperature Plasma Laboratory, National Institute for Lasers, Plasma and Radiation Physics, Str. Atomistilor 409, Bucharest, Romania
[a]*Physics Department, Ovidius University, 124 Mamaia Blvd., 8700 Constanta, Romania*
[b]*Thin Film Technology Group, Dept. of. Physics, University of Duisburg-Essen, Universitatsstr.3-5, 45141 Essen, Germany*

The Thermoionic Vacuum Arc (TVA) plasma is a very powerful technique capable of producing impurity free dense films using solids as precursor. A large range of metals were successfully deposited using this technique. The use of TVA for the synthesis of DLC is only at the beginning. In order to obtain better quality DLC films using this technique, good knowledge of the plasma constituents, ion energy and density is necessary. The present work presents the first results of the carbon TVA plasma analysis. The TVA technique involves ignition of an arc plasma in the vapours of graphyte obtained by electron bombardment of a heated anode. Mass spectrometry analysis have been employed to study the background gas composition before, and during carbon TVA plasma ignition and its influence on film properties. Determination of carbon ion energy using an in-house, computer controlled ion energy analyzer is presented.

(Received November 14, 2006; accepted April 12, 2007)

Keywords: Carbon TVA plasma, Arc plasma, DLC films, Mass spectrometry

1. Introduction

The TVA technique was observed for the first time over fifteen years ago. A large range of metals were successfully deposited using this technique [1,2,3]. The TVA carbon plasma has never been studied before.

The structure, the texture as well as physical properties of DLC films depend on the growth conditions which determine the relative concentration of the sp^3 and sp^2 bonds. Growth conditions include a series of plasma parameters among which ion energy distributions and ion mass are the most important.

The first spectral mass analysis and ion energy measurements of this particular plasma are presented here.

A large range of systems are currently involved for the analysis of ion energy: time of flight spectrometers, retarding field analysers and quadrupole mass and energy analysers. The simplest technique is the retarding field analyser (RFA) which was also used in this work.

2. Experimental setup and results

The deposition method used here is based on a hot cathode arc plasma and was observed for the first time at the Low Temperature Plasma Laboratory at NILPRP Bucharest, Romania over fifteen years ago.

The carbon plasma is obtained by thermoelectronic bombardment of a graphyte rod. The electrons produced by the W filament are directed by the Wehnelt cylinder (the cathode) to the Carbon rod (the anode) resulting in evaporation of Carbon atoms. A voltage applied between anode and cathode further directs and accelerates the electrons coming from the filament. The plasma is formed in carbon vapors between the electrodes. The ions created in the plasma are accelerated towards the chamber walls (and subsequently towards the substrate) due to the potential difference between the plasma and the grounded walls. The ion energy is directly proportional to the cathode potential fall. This is an important feature of the method, as the ion energy can thus be easily controlled. Neutrals also drift towards the walls due to pressure gradient. Apart from ions, neutrals are also incident on the substrates.

The method uses vacuum of 1×10^{-6} torr. A schematic view of the experimental arrangement is presented in Fig. 1.

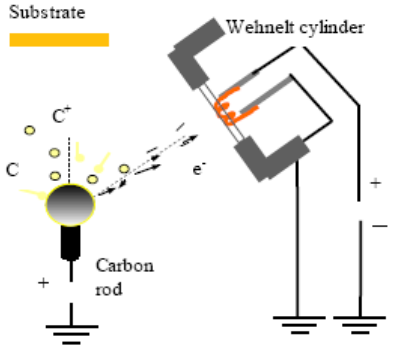

Fig. 1. Schematic view of the electrodes.

Mass energy analysis were undertaken for the background gas, during filament heating on and also during plasma processing. The mass spectra obtained are presented in Figs. 2 and 3.

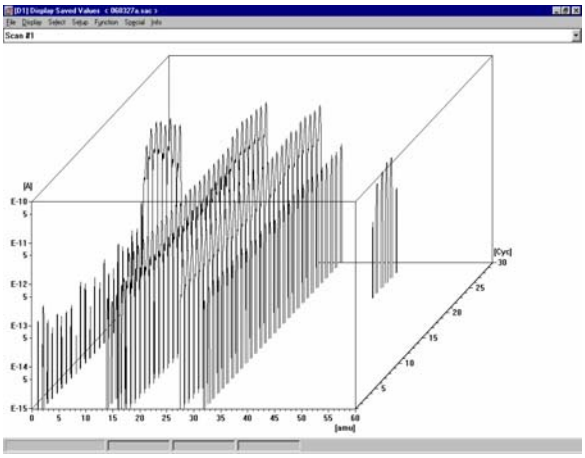

Fig. 2. Mass spectra of the background gas and filament heating (staring with cycle 23).

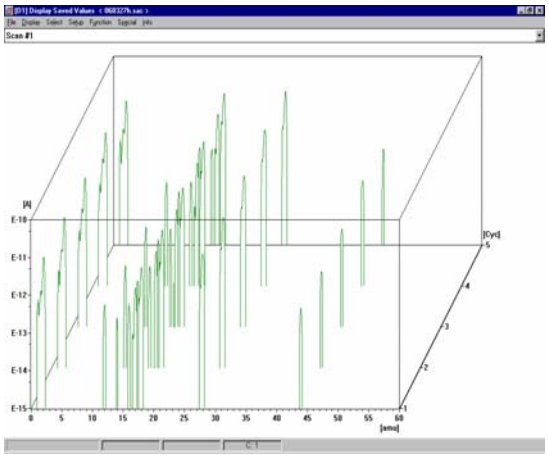

Fig. 3. Mass spectra during plasma processing.

As can be observed in the above spectra, the background gas mainly contains H_2 (Mass 1,2), CO (Mass 14, 28), H_2O (Mass 17), O_2 (Mass 32). On turning the filament heating on (cycle 23, Fig. 2), a simultaneous increase of both H_2 and CO_2 (Mass 44) is detected. This suggests decomposition of H_2O. The presence of H_2O is due to desorbtion from the chamber walls.

On ignition of the carbon arc plasma, apart from H_2, CO, O_2, CO_2 and H_2O, Carbon (Mass 12) is detected (Fig. 3).

Ion energy was determined using an in-house computer controlled retarding field analyser (RFA) presented in Fig. 4.

Fig. 4. Ion energy analyzer.

The analyser consists of a grounded mesh grid separated by two mica spacers and a Mo ion collector. The system is placed in a stainless steel grounded cylinder. A positive increasing bias is applied on the ion collector, which has both the role of repelling the ions with lower energies and also collecting those of higher energies. The ions enter the analyser through a 2 mm diameter apperture, pass the grounded grid and then are decelerated. Only the energetic ions capable of penetrating the potential barrier arrive at the collector. The system acts as a kinetic- energy filter for the ions.

In this type of probe aperture design is important and must include detailed consideration of Debye length, selective transmission, heat flux and space charge effects.

The high energy ions are detected and form the I-V signal from the RFA. The differentiated signal is then fitted with Gaussian functions.

In addition, a computer-controlled automatic system was developed and significantly improved the quality and efficiency of the data acquisition and processing.

Fig. 5 is a plot of the I-V characteristic obtained at the ion collector for a TVA plasma ignited in carbon vapours. The data were acquired during a single fast sweep of the collector voltage in the range (0-210) eV.

The first derivative of the I-V characteristic (presented in Fig. 6) was derived using the least squares procedure. This distribution shows two peaks centered at 180 eV and at 90 eV respectively which most probably represent ion enrgy distributions of single ionised and double ionised carbon ions, respectively.

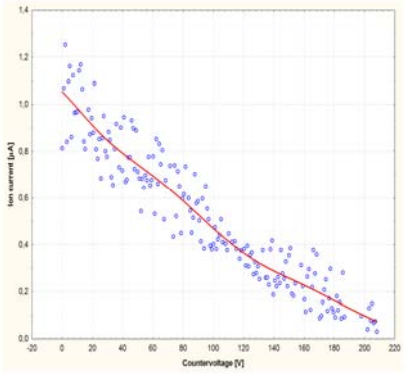

Fig. 5. I-V characteristic of the RFA.

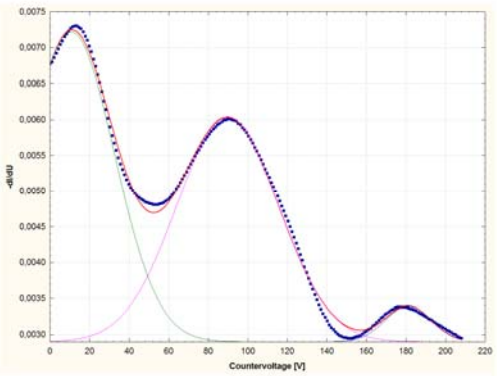

Fig. 6. Ion energy distributions.

3. Conclusions

An important aspect of controlled surface engineering is knowing the process parameters. Determination of plasma constituents and also the ion energy is essential for tailoring the film properties. Further work will include detailed analysis of the dependence of ion energy on plasma parameters.

It was shown here the composition of the background gas before and during plasma ignition. It was thus demonstrated that impurity free films can be obtained using the TVA technology. The main advantage of the technique is the fact that no buffer gas is needed and therefore the films obtained are impurity free.

References

[1] H. Ehrich, G. Musa, A. Popescu, I. Mustata, A. Salabas, M. Cretu, G. F. Leu, Thin Solid Films **343-344**, 63 (1999).
[2] V. Kuncser, I. Mustata, C. P. Lungu, A. M. Lungu, V. Zaroschi, W. Keune, B. Sahoo, F. Stromberg, M. Walterfang, L. Ion and G. Filoti, Surface and Coatings Technology, **200**, 1-4, 980 (2005).
[3] H. Ehrich, J. Schuhmann, G. Musa, A. Popescu, I. Mustata, Thin Solid Films **333**, 1-2, 95 (1998).

*Corresponding author: cristina.surdubob@plasmacoatings.ro