WETTABILITY OF AS-DEPOSITED AND IMPLANTED TETRAHEDRAL CARBON FILMS

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Abstract

Growing and clustering the sp^2 bonded carbon fraction in the tetrahedral carbon (ta-C) films by ion implantation is confirmed by Raman spectral analysis. The examination of the film transforming evolved on an atomic scale indicates the formation of structures with the higher degree of order. The graphitic basal planes are formed preferably in the perpendicular direction to the film surface. The implantation gives the change in measured values of the contact angle, which can vary from original near 70° for as deposited films to about 60 degrees for implanted films. The implanted tetrahedral carbon films display very similar surface properties at the quite different bulk structure.

Keywords: *wettability, tetrahedral amorphous carbon, ion implantation*

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Introduction

The wettability plays an important role in many biological and technological processes. Thus, the knowledge of the carbon film surface properties can be helpful to search the possibility of their wide range of application. In terms of possible medical or biological applications, tetrahedral amorphous carbon (ta-C) films can be structured [1] or plasma treated [2] by precision ion implantation or different ion bombardment at proper ion energies and doses to novel nanostructures and surface properties possessing the properties of interest. It is fact that from a new approach to the estimation of protective properties of amorphous hydrogenated carbon films by solution of different physicochemical composition was reported in [3] to the lot of latest related papers we can not present the complete theory of carbon film interaction with a medium. Now it is necessary to receive more experimental results for different types of contact systems.

The main purpose of this work was the determination of the surface properties variations due to tetrahedral carbon films structural transforming. The motivation for this investigation is further inside and understanding of the ion implantation or vacuum treatment effects on the ta-C film surface properties.

Materials and methods

The wettability of as-deposited and implanted tetrahedral carbon (ta-C) films has been studied by measuring the contact angles using the sessile drop method for distilled water and biosolution (0.9% NaCl in distilled water) at 20°C. For such system, the contact angle measurements were repeated a few times. The precision of the contact angle measurements are about 2° The ta-C films were deposited by a filtered cathodic vacuum arc (FCVA) and subsequently implanted by carbon ion beams extracted from a metal vapor vacuum arc (MEVVA) ion source. The films have been implanted to doses ranging from 10^{15} to 10^{17} ions/cm^2 at the ion energy within a range of 25 to 50 keV. The FCVA system and MEVVA ion source was operated at about 10^{-4} Pa in a pulse regime. The pulse width and repetition rate were 1 ms and 3-7 Hz, respectively. The implantation was carried out at an ion current density of 2.5 μA/cm^2 over an area of 200 cm^2. All the tested films have been oxidized only naturally. Raman spectra were recorded by a Renishaw micro-Raman spectrometers which uses argon laser with the 514.5 nm excitation line. Laser beam transmitted via an microscope objective with 50 × magnification was restricted to maximum 10 mW in order to minimize a possible beam heating effect and consequential atomic reconstruction. A Digital Instrument (USA) atomic force microscope (AFM) was used to study variations of the surface morphology of ta-C film.

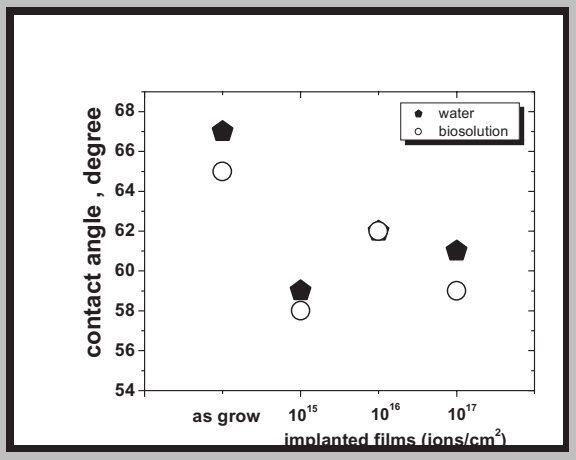

FIG. 1. Wettability of as-deposited and implanted ta-C films.

Results and discussions

The contact angle measurement result of both the implanted to different carbon ion doses and as grown ta-C films are shown in FIG. 1. The all implanted samples give a demonstration of similar capillary characteristics. The average value of contact angle equals to about 60°. We must note that the measurements have error bar scale about 2 degree.

The analysis of Raman spectra in FIG. 2 indicates that originally abundant sp^3 carbon atomic bonding of ta-C is gradually converted to a graphitic phase during the course of ion bombardment. The local order, growth and clustering the sp^2 bonded carbon atoms in the ta-C films by ion implantation is also indicated by Raman spectroscopy. However, the analysis of implanted amorphous carbon films on an atomic scale [1, 4] shows the formation of structure with

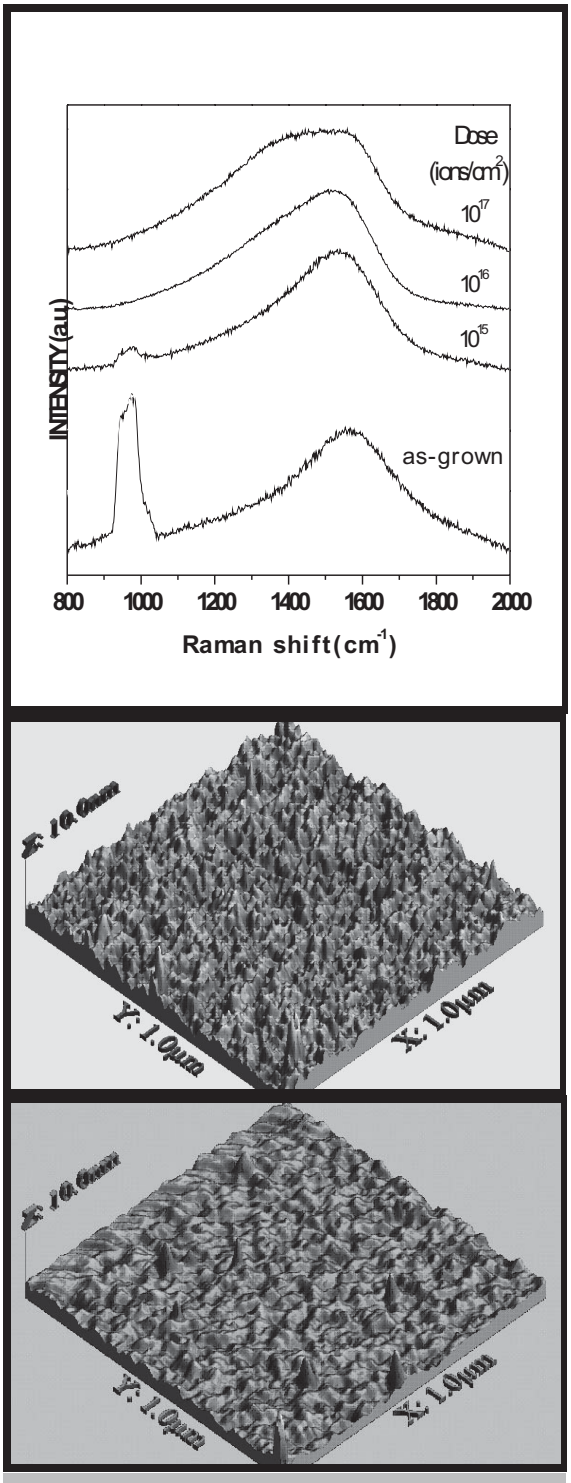

FIG. 4. AFM-image collected from the ta-C film implanted to 10^{17} ions/cm² at E_i = 25 keV.

the higher degree of order. The graphitic basal planes are formed preferably along the ion tracks.

Surface morphologies of the ta-C before and after implantation are shown in FIG. 3 and FIG. 4. The quantitative parameters of the roughness (according to the ASME B46.1 standard) were obtained from statistical analysis of the frontal image for the scanning area of 1.0×1.0 m. After the ta-C implantation the film root-mean-square (RMS) roughness was reduced from 0.9 to 0.7 nm. This is indicative of the ability of ionic bombardment to reduce the roughness of a film surface.

The treatment by vacuum drying increases the mean values of wetting angles. This means that water adsorbed on the carbon film surface affects the adhesion forces.

Thus, it is possible to see the following due to analyzing the plenty of experimental results. By the possible reason of essential difference in the characteristics as-deposited and implanted film can be concluded in sub-plantation growth nature. The initial films have few graphitic atomic layers on a surface. The carbon ion implantation transforms this layer. Indirect evidence for it confirms AFM measurement for both types of film. Unequivocally it is possible also to approve by Raman analysis, that implanted film have rather different structure. It not affected on their surface properties.

Conclusions

The above experimental results confirms that the orientation of basal planes parallel to the normal of sample surface is not associated with the change in measured values of the contact angle but is rather related to the ion beam treatment of film surface or surface functional groups. The detailed structural analysis and capillary characteristics measurements suggest that the implanted tetrahedral carbon films have very similar surface properties at the quite different bulk structure. It can display that the chemical nature of carbon film surface functional groups calls for further investigation.

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