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The deposition of a thick tetrahedral amorphous carbon film by argon ion bombardment

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ABSTRACT

The argon (Ar) ion bombardment is used in the deposition of a thick multilayer tetrahedral amorphous carbon (ta-C) films. The bonding structure and surface morphology of the ta-C films are modified when the films are bombarded by Ar ion with different energy. Visible Raman spectroscopy and X-ray photoelectron spectroscopy is used to study the modification respectively. The results show that surface layer is etched, the bonding structure of the films is totally modified, and some sp^3 bonds convert to sp^2 bonds in the surface layer of the films. The sp^2 cluster of the bulk increases with the increment of Ar ion energy. Hence, a soft top layer on the films is formed and the stress of the bulk is released. The RMS of roughness and etching pits on the surface of films were increased with the increment of the bombarding energy of Ar ion, which can increase the adhesion between layers. These are very important to deposit thick ta-C film. The surface morphology is tested by AFM. The RMS roughness of thick ta-C film is about 0.54 nm. Using visible Raman spectroscopy, the sp^3 fraction of as-deposited ta-C film with 1 μm thickness is estimated to be about 70%.

1. Introduction

Tetrahedral amorphous carbon (ta-C) films deposited by filtered cathodic vacuum arc (FCVA) have attracted much interest in the past decades [1–4]. The structure of such films has been consisted of a disordered of network of sp^2- and sp^3-bonded atoms, with the fraction of sp^3 coordination being as high as 88%. However, one serious drawback in the application of ta-C films is the high compressive stress due to the sub plantation deposition process [5]. This stress will limit the maximum thickness of films and cause the delamination as the thickness of the coating increases [6]. Several methods have been used to solve this problem, such as incorporating metal [7], thermal annealing [8], thick films deposited by the alternative soft and hard layers [9], or pre-depositing carbide interlayer [10]. But metal incorporation will cause the loss of the optical transparency. In practical industry, thermal annealing will discounts the ability to deposit ta-C films on the temperature-sensitive substrate materials. It is very difficult to accurately control the ultra-thin soft layers in depositing the alternative soft and hard layers to get thick ta-C film. The pre-depositing carbide interlayer can achieve good adhesion, but the substrate must be the carbide forming materials. Hence for practical industry, looking for a simple and effective method to get a thick ta-C film is very important.

Ion bombardment is an important method to modify the property of surface or bulk of films [11,12]. In this paper, ion bombardment technology is firstly used to deposit of the thick ta-C films. The thin ta-C film with over 80% sp^3 fraction is deposited, and then bombarded by the energetic Ar ion (over 1000 eV), afterward the thin ta-C film is again deposited. This method can be used to increase the thickness of ta-C film. It is easy to control the deposition process, and will increase the adhesion strength between layers due to the etching pits. The modification of bonding structure and surface morphology are investigated. ta-C film with 1 μm thickness can be deposited.

2. Experimental details

The ta-C films are deposited on silicon substrates using FCVA system at room temperature. The thickness of the deposited films is 150 nm. The system incorporates the off-plane double-bend filter to effectively get rid of macro-particles. The pressure of deposition chamber is about 1×10^{-4} Pa. The carbon plasma is generated by a dc arc discharge. The arc current is 80 A. The magnetic field strength of the filter duct is 40 mT. The substrate bias and cathode bias is adopted different supply system respectively, the substrate is supplied with 200 V DC pulse bias. After the deposition of the ta-C films, energetic Ar ions produced by a cold cathode penning ion source

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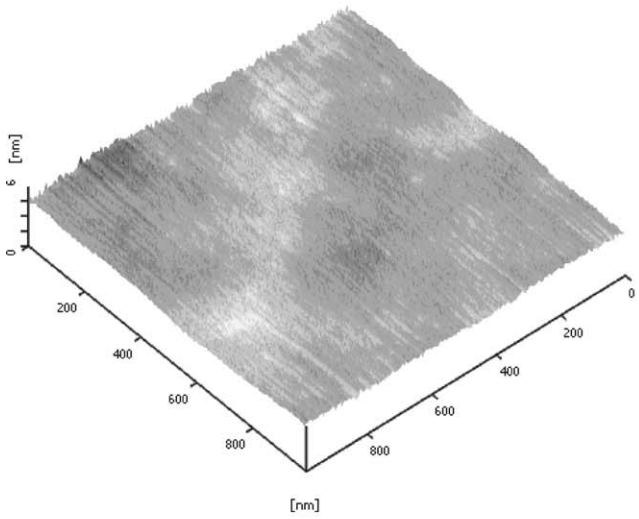
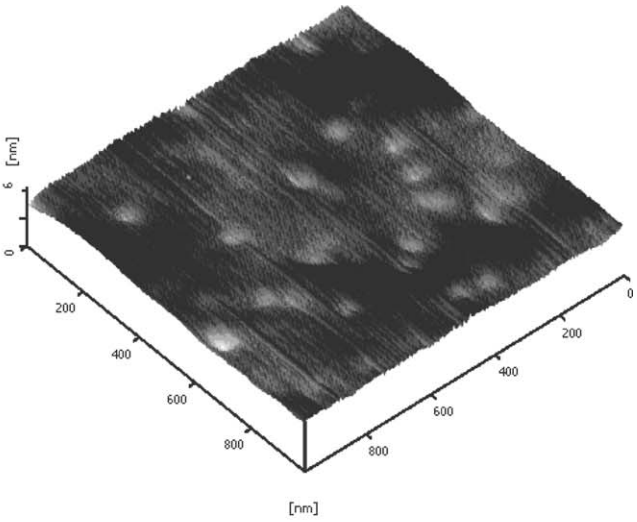
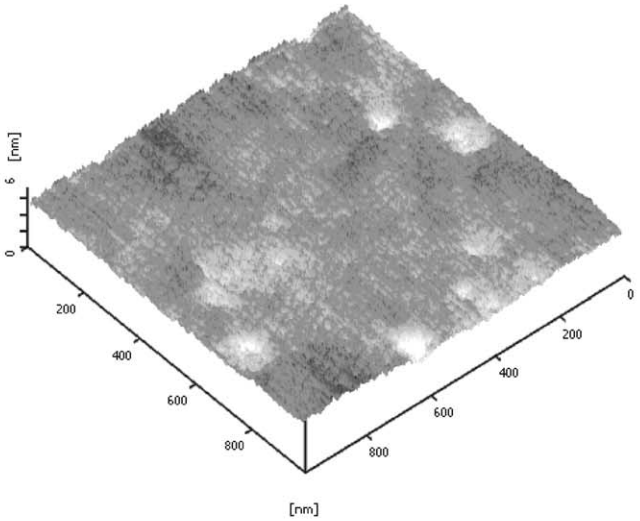


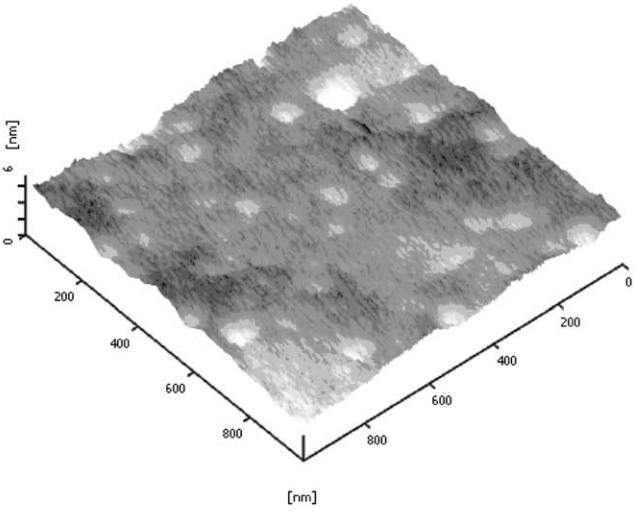
(a) as-deposited ta-C



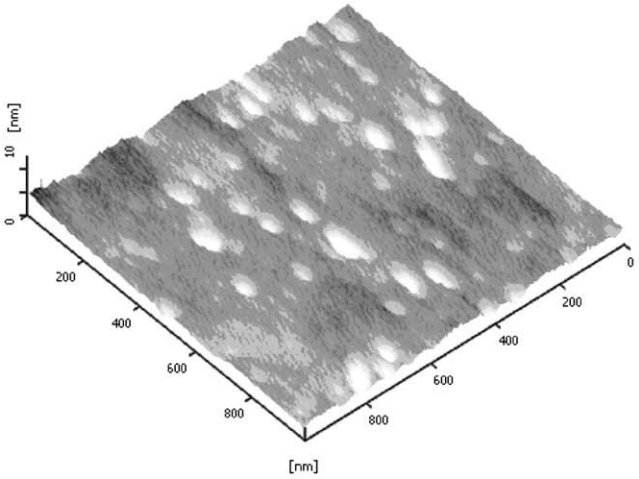
(c) 1400eV Ar ion bombarded



(b) 1000eV Ar ion bombarded



(d) 1800eV Ar ion bombarded



(e) 2200eV Ar ion bombarded

Fig. 1. The surface morphology of the single layer ta-C films (a) prior to argon ion bombardment and after argon ion bombardment at different energy of (b) 1000 eV, (c) 1400 eV, (d) 1800 eV and (e) 2200 eV, respectively.