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Short communication

Low voltage and ambient temperature electrodeposition of uniform carbon films

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ABSTRACT

Diamond-like carbon (DLC) films are prepared by electrodeposition technique on SnO_2-coated glass substrates in chloroacetic acid aqueous solution. The applied voltage between the electrodes is mere 3.0 V for 2 h. The films composed of small and compact grains that show two distinct Raman characteristic peaks at ~1340 and ~1580 cm^{-1}. With the method reported in this paper, the DLC films are firstly fabricated the DLC films at both low voltage and ambient temperature.

1. Introduction

Recently, much attention has been focused on diamond-like carbon films (DLC), which represent a promising material for optics, electronics, solar cells, bioengineering, field of tribology and magnetic due to their superior properties such as chemical inertness, high hardness, low friction, high thermal conductivity, etc. [1–4].

Traditional methods for carbon films deposition consist of vapor phase physical or chemical processes, typically PVD or CVD, and their variants [5–6]. However, these techniques require high temperature, high vacuum and complex equipment. In this context, electrodeposition, which is conducted at ambient temperature and favors the industrial applications, gradually becomes a desired alternative to traditional methods for its flexibility in operating parameters.

Namba et al. [7] used organic solutions as electrolyte and carbon source, obtaining, initially, films from ethanol. Cao et al. [8] deposited carbon films on Si substrates from an organic methanol solution, the deposited films are composed of small, compact grains. Ismail et al. [9] and many other researchers reported the possibility of deposition DLC films from acetic acid, N,N-dimethylformamide and other organic liquids. The deposition was carried out at a high electric field (~2 kV) and the operating temperature was also higher than ambient. Gupta et al. [10] obtained DLC films from acetic acid where the applied voltage was 2.1 V, while the bath temperature was 358 K.

2. Experimental

In this communication, the DLC films were deposited onto SnO_2-coated glass substrate via simple electrodeposition technique at much lower voltage (3.0 V) and ambient temperature, with chloroacetic acid aqueous (0.5 ~ 10 g/L) solution as the electrolyte. A graphite rod was used as the anode and the distance between the anode and SnO_2-coated glass acting as cathode was 7 mm. A DC power supply was used to supply voltages to the substrate.

The morphology of the DLC films was characterized by scanning electron microscopy (SEM, JSM-6360LA, JEOL). The thickness of the films was determined by cross-sectional SEM and step profiler (Dektak XT, Bruker). The roughness of the DLC films was tested by optical stylus profilometer (Contour GT, Bruker). An attenuated total reflection, Fourier transform infrared (ATR/FT-IR, Nicolet iN10, Thermo Fishier) was used to study the functional groups on the surface. Raman spectra was recorded at ambient temperature by a microscopes Raman spectrometer (Raman, DXR, Thermo Fishier) to evaluate the film adherence and the electronic structures of the films were characterized with the X-ray photoelectron spectroscopy (XPS, AXIS ULTRA DLD, Kratos) in ultra-high vaccum. The electrical conductivity of DLC films was measured using four-point probe (4-point Probes Resistivity Measurement System, RST-9, Probes Tech).

3. Results and discussion

The SEM image (Fig. 1) of the DLC films deposited from chloroacetic acid shows the films composed of small and compact grains. This result

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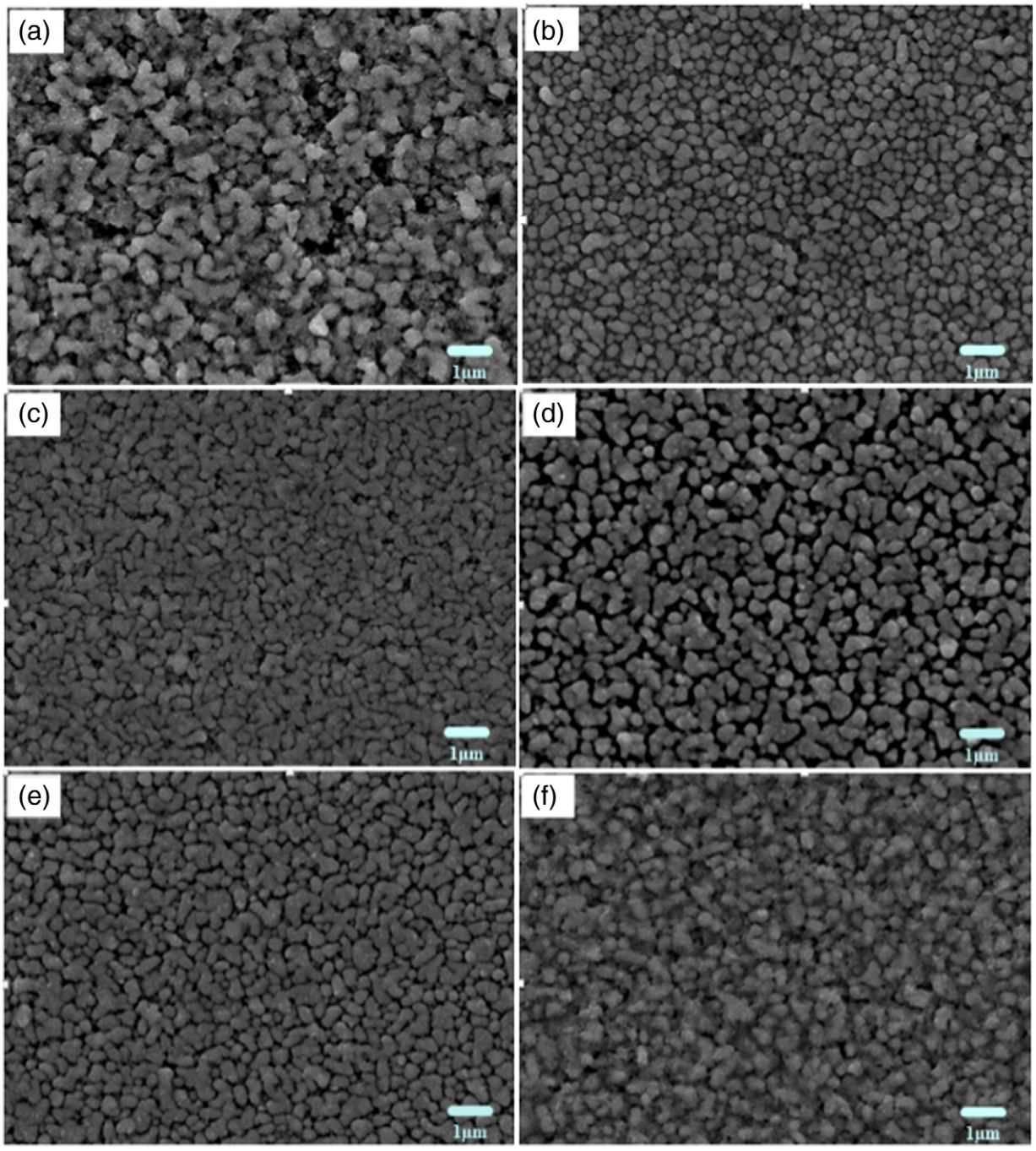

Fig. 1. SEM images of the DLC films obtained by electrodeposition from chloroacetic acid aqueous solution with different concentrations, 1, 2, 3, 5, 8, and 10 g/L from (a) to (f), respectively.

agrees with those reported by Cao et al. [8] and Gupta et al. [10]. It may be observed from Fig. 1(a–f) the film surface is quite smooth and uniform. Table 1. shows the average roughness of films deposited from 2, 5, 8, and 10 g/L chloroacetic acid aqueous solutions. It is observed that the average roughness Sa of the films from 8 g/L chloroacetic acid aqueous solution was lower than the films deposited from other concentrations of chloroacetic acid, only 15.6 nm.

Table 1
Roughness of the DLC films obtained by electrodeposition from chloroacetic acid aqueous solution: 2 g/L, 5 g/L, 8 g/L, 10 g/L.

Concentration/(g/L)	2	5	8	10
Sa/(nm)	57.2	25.1	15.6	49.6

The FTIR spectra (Fig. 2) of the films deposited from different concentration are similar to each other. The spectra are dominated by two peaks at ~2920 and 2850 cm^{-1}, which could be related to sp2-CH group and sp3-CH modes, respectively. These are followed by two peaks at ~1640 and 1540 cm^{-1} for C = C stretching [11–14]. Thus, the DLC films deposited here contain both the sp3- and sp2-bonded carbon atoms. The results indicate that hydrogenated carbon films have been obtained.

Raman spectroscopy is one of the most important nonmultilative techniques to characterize and identify the chemical composition of