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Field emission from nano-patterned amorphous carbon

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Abstract

Electron emission from nano-patterned amorphous carbon is realized in this paper. The patterned carbon consists of islands with size of tens of nanometers, and is formed by etching uniform carbon film in oxygen plasma using a bismuth island-like film as the mask. Uniform and stable electron emission is reproducibly obtained, and the emission efficiency is above 2% at an anode voltage of 3 kV. Small carbon particles between large islands are supposed to be necessary for stable electron emission.

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Keywords: Electron emission; Amorphous carbon film; Bismuth film

1. Introduction

Electron emission from carbon materials, including carbon nanotube [1–4], diamond like carbon [5,6] and amorphous carbon film [7–9], has been extensively studied. Nevertheless, the emission is far from stable and uniform, especially for application in a display panel. When the emitters are used in a diode structure, the emission characteristics are sensitive to the configuration of the emission surface, as well as the intrinsic structure of the carbon materials. Emitters used in a triode structure have displayed improved emission uniformity and stability, but the fabrication process is quite complicated [10]. A simple coplanar structure based on nano-patterned amorphous carbon is proposed and demonstrated in this paper. The nano-patterned carbon is composed of islands with size of tens of nanometers and fabricated by etching as-deposited carbon film in oxygen plasma using a bismuth island-like film as the mask. Configuration of the carbon islands can be conveniently modified by changing thickness of the carbon film and size of the bismuth islands. Uniform and stable electron emission is reproducibly obtained, and the emission efficiency is higher than 2% at an anode voltage of 3 kV.

2. Experiments

The fabrication process started with a carbon film with sheet resistance of 60–70 kΩ deposited on soda lime glass by electron beam (EB) evaporation. Then bismuth island-like film was deposited on the carbon film by vacuum thermal evaporation at substrate temperature of 150–200 °C. The distance between the substrate and the graphite source was about 10 cm. The size of the bismuth islands can be easily modified by changing the evaporated bismuth quantity. Next, the sample was etched in oxygen plasma to obtain nano-patterned carbon film with a certain sheet resistance. During the etching process, the oxygen pressure and the etching power were 11 Pa and 20 W, respectively. Finally, after the bismuth being removed in strong nitric acid, the coplanar cathode and gird electrode of copper were evaporated, using a tungsten straight string as the mask to realize a 100 μm gap between the electrodes.

3. Results and discussion

Raman spectrum and Gauss fitting lines of the as-deposited carbon film are shown in Fig. 1. Renishaw Raman spectrometer was used, and the wavelength and the power of the laser were kept at 514 nm and 50 mW, respectively. The D-peak relative intensity (I_D/I_G) of 1.43 and the G-peak FWHM of 120 cm^{-1} suggest that both sp3 bonds fraction and the grain size of

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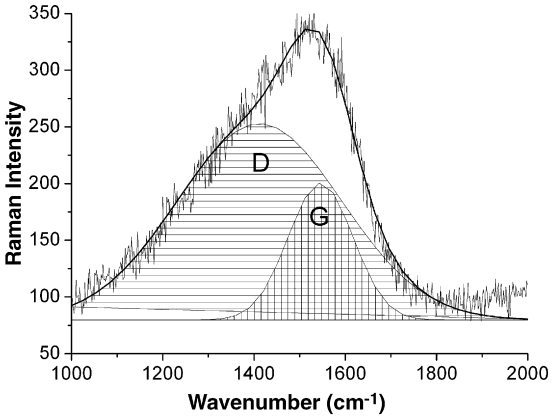

Fig. 1. Raman spectrum and Gauss fitting lines of the as-deposited carbon films deposited by EB evaporation.

graphite in the film are rather small, so the film deposited by EB evaporation is a typical amorphous carbon film [5,11].

Scanning electron microscope (SEM) images of the bismuth island-like films and the corresponding etched amorphous carbon are shown in Fig. 2. The bismuth films are composed of large islands and small particles in between because of surface melting at high substrate temperature [12,13]. Fig. 2a–c are images of the bismuth films for evaporated bismuth quantity of 2.5 mg, 5 mg and 20 mg, and the size of the largest islands in corresponding films are about 50 nm, 100 nm and 250 nm, respectively. After the etching process, the patterns of bismuth island-like films in Fig. 2a–c are perfectly transferred to carbon films, as shown in Fig. 2d–f. Because of side etching effect, the carbon islands are smaller than the corresponding bismuth islands, and part of particles between larger islands disappear.

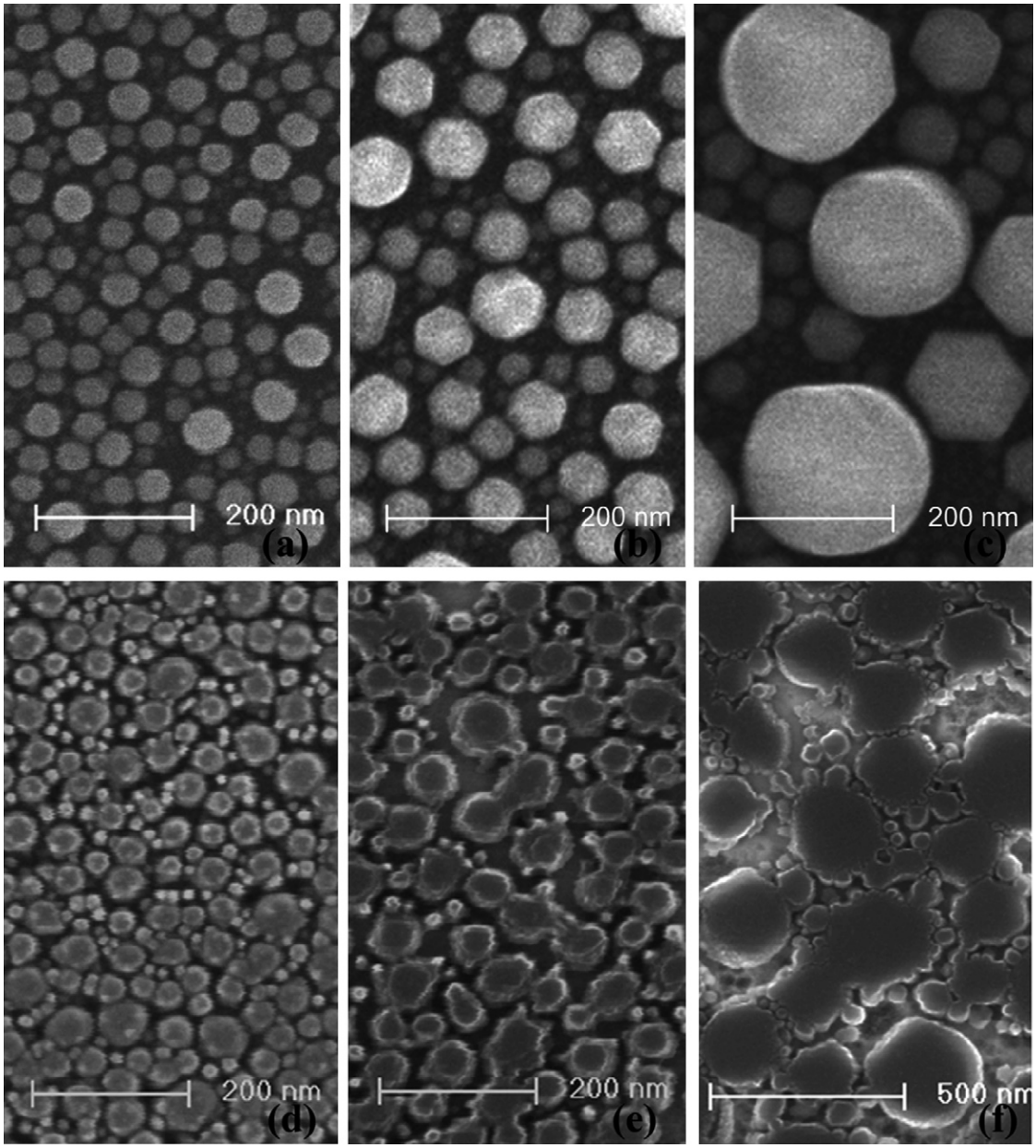

Fig. 2. SEM images of bismuth island-like films ((a) 2.5 mg, (b) 5 mg, and (c) 20 mg) and corresponding carbon films after being etched in oxygen plasma ((d)–(f)). These films consist of many separate islands.