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ARTICLE

Field Emission Characteristics of Metal-doped Nano-diamond Cathode on Titanium Substrate

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Abstract: Field emission characteristics of metal-doped nano-diamond on titanium substrate were studied, wherein metals——Ti and Hf were mixed with nano-diamond separately, and cathode samples were prepared by electrophoresis. Then the structures and morphologies of cathode samples were characterized by SEM and XRD; finally, field emission tests were conducted. Results show that the morphology of 5 mg Ti-doped sample is more uniform and dense, but the morphologies of Hf-doped samples become worse. Meanwhile, compared with the undoped sample, field emission characteristics of Ti-doped samples improve, while those of Hf-doped samples decrease. From the comparison between Ti-doped samples, it is found that the amount of Ti mixed with nano-diamond should not be too much; a moderate amount of Ti can improve field emission characteristics of nano-diamond on Ti substrate. It is determined by the nature of metal Ti and Hf, which influences the bonding reaction between nano-diamond and substrate Ti, thus affecting, field emission characteristics of doped nano-diamond on Ti substrate.

Key words: nano-diamond; metals; SEM; XRD; field emission characteristics

In recent years, carbon-based composites prepared by substrates of carbon materials such as nano-diamond and CNT have become one hot topic of materials research [1], which are mainly prepared by methods of doping, mixing, cladding and modification [2,3]. For example, Chong et al [4] pointed out that field emission characteristics of diamond-like carbon nanodot arrays after doping are better obviously than undoped. Zeng et al [5] studied on field emission characteristics of diamond/Ag composites and pointed out that electron emission area is formed at the interface of Ag and diamond because of the existence of Ag, so field emission characteristics of diamond/Ag composites improve. On the other hand, variations of surface morphologies and structures after doping, mixing, cladding or modification can change field enhancement factor of materials surface[6], and all changes are helpful to improve field emission characteristics of nano-diamond. When heat treatment of nano-diamond cathode samples on titanium substrate is carried out, a solid-phase bonding reaction between diamond and metal Ti occurs and easily-conductive TiC is generated when temperature is above 400 °C[7,8]. Metal Hf has good inoxidizability, good conductivity and thermal conductivity, lower work function; therefore, it is always used as plasma emitters of plasma cutting electrical machines and sputtering target [6]. Meanwhile, carbide of Hf (HfC) is widely used in spaceflight and flat-panel display realm as high-temperature structural material. Therefore, metal Ti and Hf are selected as doping materials in the present paper and their field emission characteristics are compared; meanwhile, the influence of metals on field emission characteristics of nano-diamond on Ti substrate is studied.

1 Experiment

Before electrophoretic deposition, Ti substrates must be ground, polished, and cleaned by detergent, and ultrasonic and rinsed with deionized water. Then they are reserved to be used after ethanol dehydration reaction.

The technical progress of preparing electrophoretic liquid

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was as follows: mixing nano-diamond powder 20 mg, iodine 20 mg, acetone 1 mL, is obutanol 40 mL and deionized water 2 mL into 7 beakers separately, and they were named sample 1~7. Wherein sample 1 was undoped diamond; sample 2~4 were diamond doped with 2, 5 and 10 mg Ti powder (the average grain size of Ti powder was 40 nm and purity 99.9%), respectively; and sample 5~7 were diamond doped with 2, 5 and 10 mg Hf powder (the average grain size of Hf powder was 1 μm and purity 99.9%) respectively.

After uniform solutions were prepared, they were placed in the ultrasonic cleaner to conduct ultrasonic diffusion for 60 min at ultrasonic temperature 50 °C. After ultrasonic diffusion was finished, electrodes were placed into electrophoretic liquid to begin electrophoresis the space between cathode and anode 1 cm, electrophoresis voltage 60 V, and time 1 min. Then deposited samples were placed into Hot Filament Chemical Vapor Deposition (HFCVD) to carry out heat treatment, whose temperature was 800 °C, and time was 10 min. Wherein the thickness of typical Ti-doped samples and Hf-doped samples was 601.50 nm and 1.36 μm, respectively.

Finally, field emission characteristics tests were conducted. In the field emission tester, diode-type structure was adopted, the anode was glass coated with ITO transparent conductive thin film, and the cathode was prepared samples, while the space between two poles was about 200 μm. When vacuum degree reached 10^{-4} Pa level, DC regulated power supply was adjusted to test field emission[6].

2 Results and Discussion

2.1 Morphologies of cathode samples

Fig.1 shows SEM morphologies of all samples after heat treatment. Fig.1a~1d are SEM morphologies of sample 1~4, indicating that surface morphologies of Ti-doped samples change a lot after heat treatment, some larger aggregates appear on the surface and the surface becomes complex; comparatively speaking, the surface of sample 3 doped with 5 mg Ti powder is more uniform and denser. Fig.1e~1g are SEM morphologies of sample 5~7. Obviously, the surface morphologies become worse and worse as the amount of doped Hf increases.

2.2 Characterization of cathode samples

XRD patterns of sample 1. 3 and 6 are given in Fig.2. It can

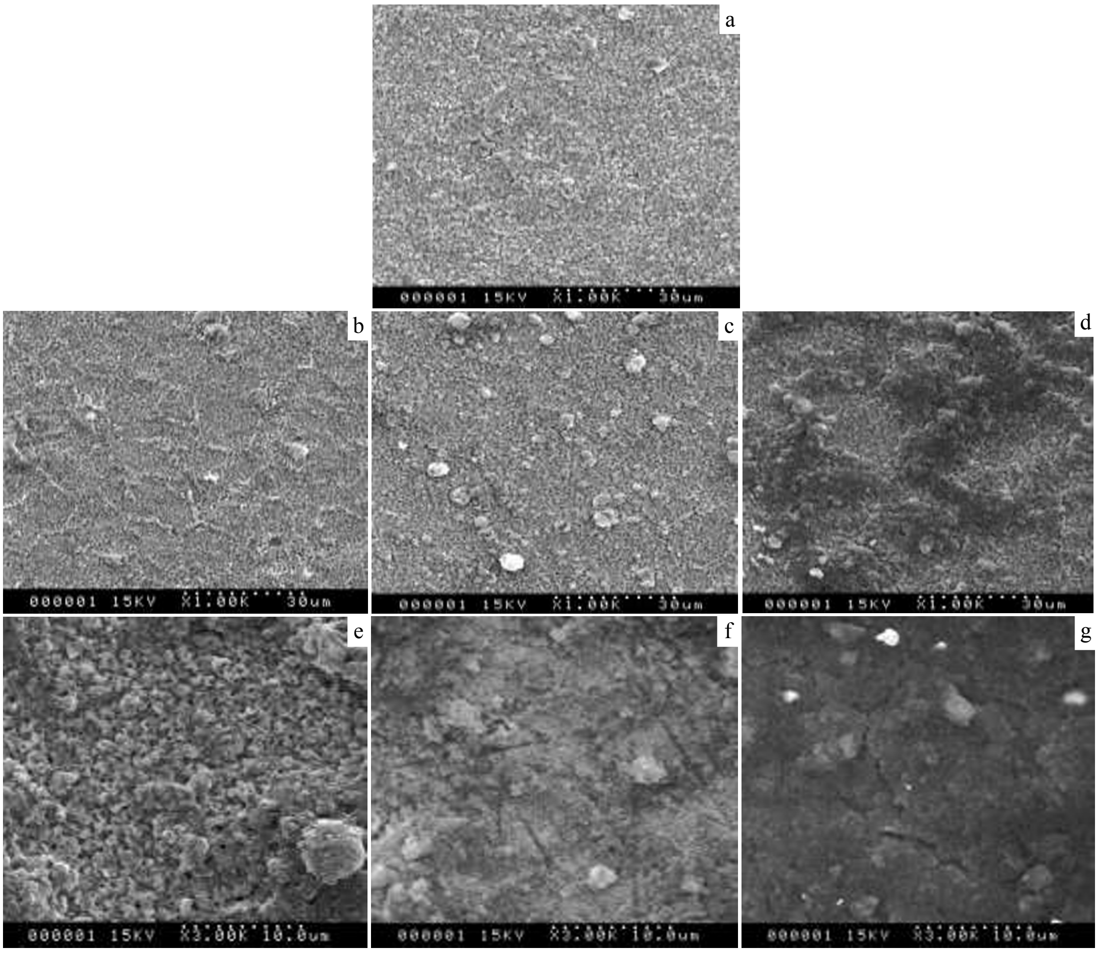

Fig.1 SEM morphologies of each sample after heat treatment: (a) sample 1, (b) sample 2, (c) sample 3, (d) sample 4, (e) sample 5, (f) sample 6, and (g) sample 7