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Simple and fast fabrication of conductive silver coatings on carbon fabrics via an electroless plating technique

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ABSTRACT

In this work, silver-coated carbon fabric composites have been successfully fabricated via a simple and universal electroless plating method. The microstructures of the composites were characterized by X-ray diffraction (XRD) and scanning electron microscope (SEM), respectively. Glucose was employed as an environment-friendly reducing reagent. It was found that the reaction temperatures and the dosages of glucose played important roles for the formation of excellent silver coatings. The carbon fabric with a compact and continuous silver coating exhibited excellent conductivity, and the optimal volume resistivity could reach 8.99×10^{-4} Ω·cm. Such composites would have potential applications in electromagnetic shielding fields.

1. Introduction

Recently, the conductive textiles have attracted increasing attention due to their various applications in biomedical devices, energy conversion and storage, electromagnetic interference shielding, and so on [1–4]. Especially, textile-based composites with conductive metals as coatings have received considerable attention among academic scientists and industrial engineers [5–7]. Such composites not only possessed the flexibility and dimensional stability of textiles, but also had excellent electrical conductivity of metals. Several methods have been developed for the fabrication of conductive coatings so far, such as chemical vapor deposition (CVD) [8], DC-magnetron sputtering and pulsed DC-magnetron sputtering [9], and electroless deposition [10]. The CVD and sputtering routs usually need special apparatus and are difficult to fabricate samples in large scale. Among these methods, electroless plating is in simple handle, and can be used to deposit continuous and uniform coatings on substrates with complex shapes.

Much attention has been focused on silver-coated composites so far. Typically, Kwak et al. deposited silver on the surface of cotton fabrics by using organometallic silver 2-ethylhexylcarbamate as the starting material and subsequently thermal heating at 130 °C [11]. Lu et al. synthesized silver/poly(ethylene terephthalate) (PET) fabric through ultrasonic-assisted electroless deposition. The PET fabric was initially treated by (3-aminopropyl) trimethoxysilane and heated at 125 °C for 30 min, and then modified in anhydrous toluene solution containing 1 vol.% 3-mercapto propyl-triethoxysilane for 2 h [12]. Silk fabric with silver coatings was obtained by using tris (2-carboxyethyl) phosphine as reducing reagent [13]. However, the substrates mentioned above are cotton fabrics, PET fabrics, and silk fabrics, which have low mechanical properties and will limit their practical applications in electromagnetic interference shielding area. Furthermore, vast majority of reported work was conducted in the presence of highly toxic organic reagents, causing concerns from an environmental method. Time-costly and extremely complicated pretreatments were also required. The silver coatings would be easily peeled off if the substrates were not well pretreated and the plating rate could not be efficiently controlled. Carbon fabrics are well known for their unique properties including high specific strength, specific modulus, high thermal and electric conductivity, so they were widely used as reinforcements to fabricate composites with excellent performance. Although silver-coated short carbon fibers with excellent conductivity were reported previously [14,15], it is still a challenge to deposit silver layer on carbon fabrics on a large area because that the operation for the deposition of silver on short carbon fibers is easily realized in technique. Additionally, it is of outstanding importance these days to choose a facile, efficient and eco-friendly synthetic process to fabricate conductive composites.

Herein, silver-coated carbon fabric composites were successfully prepared via an electroless deposition process, and glucose was employed as an environmentally friendly reducing reagent.

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The influence of reaction temperature and dosage of glucose on the silver coatings was investigated in details. The composites with uniform silver coatings on the surface of carbon fabric exhibited an optimal volume conductivity of $8.99 \times 10^{-4}\,\Omega\cdot$cm, and such composites offer a high potential in biomedical electronic field and electromagnetic interference shielding.

2. Results and discussion

Fig. 1a exhibited the typical XRD pattern of the obtained Ag-coated carbon fabric composites. It was observed that five characteristic peaks at 2θ = 38.16°, 44.36°, 64.52°, 77.48°, and 81.62° corresponded to the diffraction of (111), (200), (220), (311), and (222) planes of face-centered cubic (FCC) silver (JCPDS 04-0783). No peaks of other impurities for amorphous carbon fabric were detected, suggesting that a layer of pure silver coating was formed on the surface of carbon fabric. The SEM image of the composites was shown in Fig. 1b, which revealed that the silver coating was compact and uniform. Close observation (in the inset of Fig. 1b) would find that the silver coating consisted of many particles, and no peeled position could be observed. It indicated that the sample possessed a strong adherence between the coating and carbon fabric.

Fig. 2 displayed the SEM images of the samples obtained at different reaction temperatures. It could be seen that the silver coatings were compact and continuous when the deposition temperature was lower than 40 °C (Figs. 1b and 2a), and a few clusters were arbitrarily attached on the surface of these coatings. With the reaction temperature increasing, the amount of clusters increased gradually and their related size became larger. These clusters were loosely located, and it seemed that the silver layer below the clusters was still compact (Fig. 2b–d). So it is not beneficial to obtain a uniform silver coating at higher temperature. The reaction rate was greatly accelerated when the temperature increased, and the silver particles had more opportunities to be produced in solution instead of to be deposited on the active site of carbon fabric surface. Thus, more clusters formed in the solution and finally attached on the outer silver layer.

Fig. 3 presents the SEM images of the products obtained with various dosages of reducing agent. When the amount of glucose was low, the silver deposition rate was very low and the silver coating was incomplete, and the coating on the surface of carbon fabric with detached position could be seen (Fig. 3a–c). Because the carbon fabric was initially activated by Pd, the silver nuclei would preferentially form on the activated positions, and then gradually grew into a compact and continuous film. With the dosage of glucose increased to 1.5 g, the coating became perfect

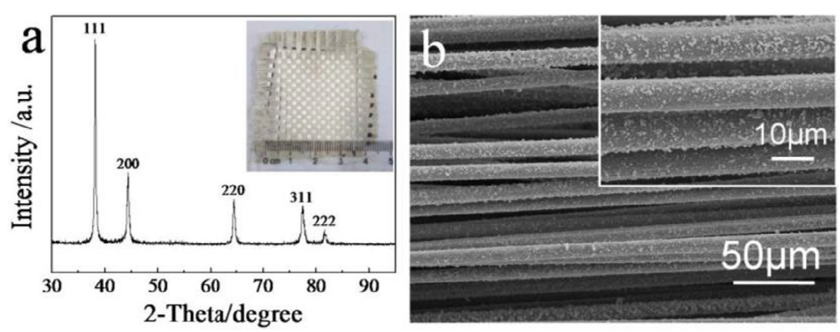

Fig. 1. (a) XRD pattern and (b) SEM image of the sample obtained at 30 °C for 30 min using 1.5 g of glucose, inset of (a) is the digital camera image.

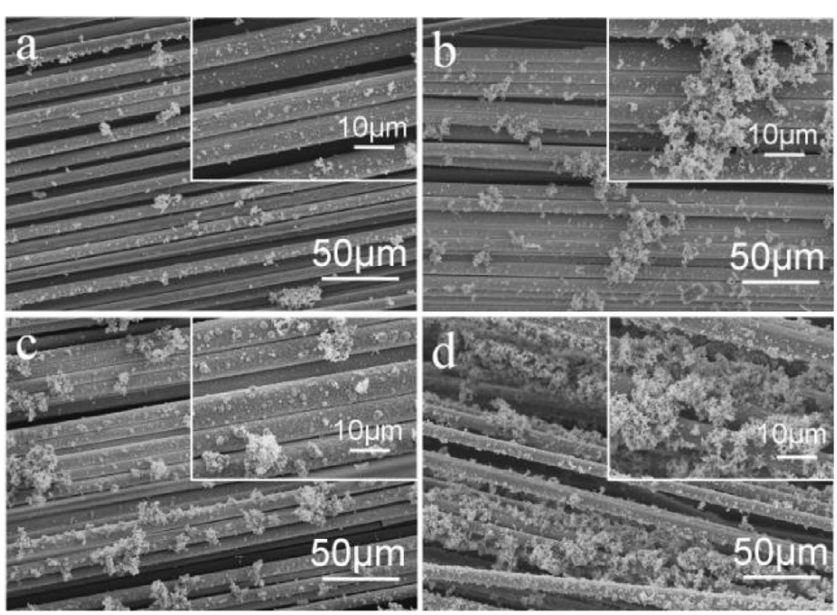

Fig. 2. SEM images of the products prepared at (a) 40, (b) 50, (c) 60, and (d) 70 °C.