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Conductive glass fabrics@nickel composites prepared by a facile electroless deposition method

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ABSTRACT

In this work, glass fabrics with uniform nickel layers on the surface were successfully synthesized via a simple electroless deposition method. The optimal electroless deposition parameters were obtained by orthogonal test. The morphology and chemical composition of nickel-coated glass fabrics were investigated by scanning electron microscopy (SEM) and X-ray diffraction (XRD), respectively. It was found that the volume of the ammonia water and reaction time played important roles for the formation of uniform nickel coatings. The optimal volume resistivity of the composites with compact nickel layers could reach $6.25 \times 10^{-3}\ \Omega$ cm. Such composites with excellent conductivity would broaden the application range of glass fabrics and this method could be scaled up for mass production.

1. Introduction

As the use of communication instruments and electronic products grows rapidly, more radio-frequency energies are released from telephones, computers, digital circuitry, and so on, and so there are potential health hazards associated with the exposure to electromagnetic fields [1–6]. A growing and urgent need exists for suitable materials that can possess shielding effect and reduce the hazards from electromagnetic energies. Recently, some conductive textiles coated with metal films were reported for this purpose, which could replace the traditional metals and alloys [7]. Such composites are expected to be a new and important electromagnetic interference (EMI) shielding materials [8]. Cheng et al. fabricated a conductive knitted fabric composite material, polypropylene as the matrix phase, glass fibers as the reinforcement phase and copper wires as conductive fillers, and the results showed that knitted fabrics reinforced polymer composites are suitable for making complex shaped components and application in electromagnetic shielding [9].

Many techniques including electroplating, electrospinning, electroless deposition, sputtering, and etc. [10,11], have been developed to deposit metal coatings. Among them, electroless plating is a promising way to produce metal-coated fabric due to its advantages including low cost, fine coverage, and environmental friendliness [12]. Zhao et al. fabricated flexible and sensitive substrates for surface-enhanced Raman scattering (SERS) via electroless plating of Ag nanoparticles (NPs) on the surface of carbon cloth [13]. Rahaman and coworker studied the effect of coating time and temperature on electroless deposition of cobalt-phosphorous on the surface of E-glass fibers/fabrics, and demonstrated that a uniform Co film formed on the glass fibers when the pH and temperature were 8.5 and 75 °C, respectively, [14]. Ersoy et al. adopted the electroless coating to synthesis of silver nanoparticles onto glass-stitched fabrics, and the results showed that a compact fabric surface promoted the EMI and that a critical threshold of surface conductivity of $0.3\ \mathrm{s\ cm^{-1}}$ was required to obtain EMI effectiveness above 50 dB in the frequency range 300 MHz to 1.5 GHz [15]. Of course, some other matrix materials including cotton, polyester fabric, bamboo fabric, and etc were reported [16–18].

In this work, conductive glass fabrics with nickel coatings on their surface were successfully prepared via an electroless deposition approach. The deposition time and volume of ammonia water had a major impact on the deposited coatings. The results showed that the resistivity of the composites with compact and continuous nickel coatings could reach $6.25 \times 10^{-3}\ \Omega$ cm.

2. Experimental

2.1. Materials and method

All chemical reagents were in analytic grade and used without further purification. The plain weave glass fabrics (density of $140\ \mathrm{g/m^2}$ and thickness of 0.15 mm) in white color were orderly degreased in 50 mL acetone solution and coarsened in NaOH

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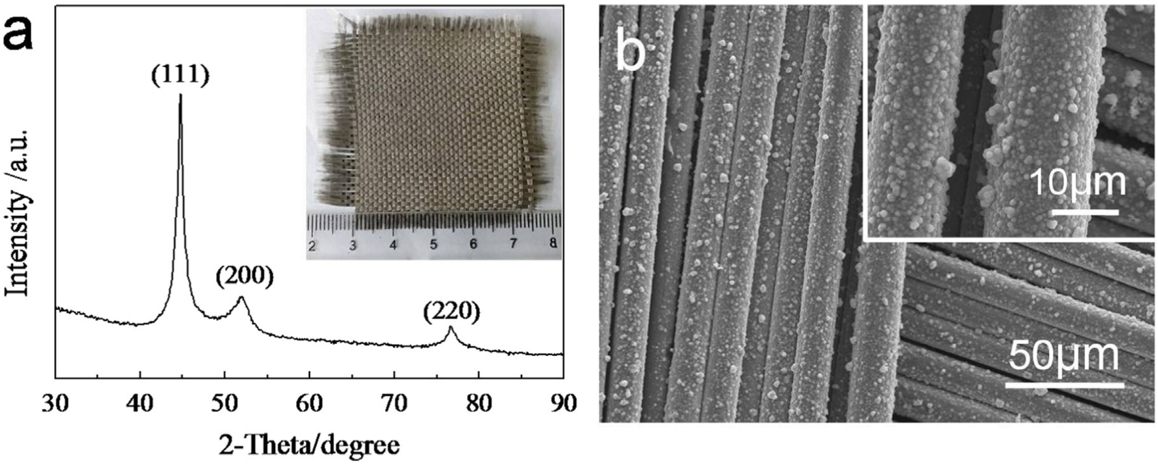

Fig. 1. (a) XRD pattern and (b) SEM image of the optimal sample, inset is the digital image.

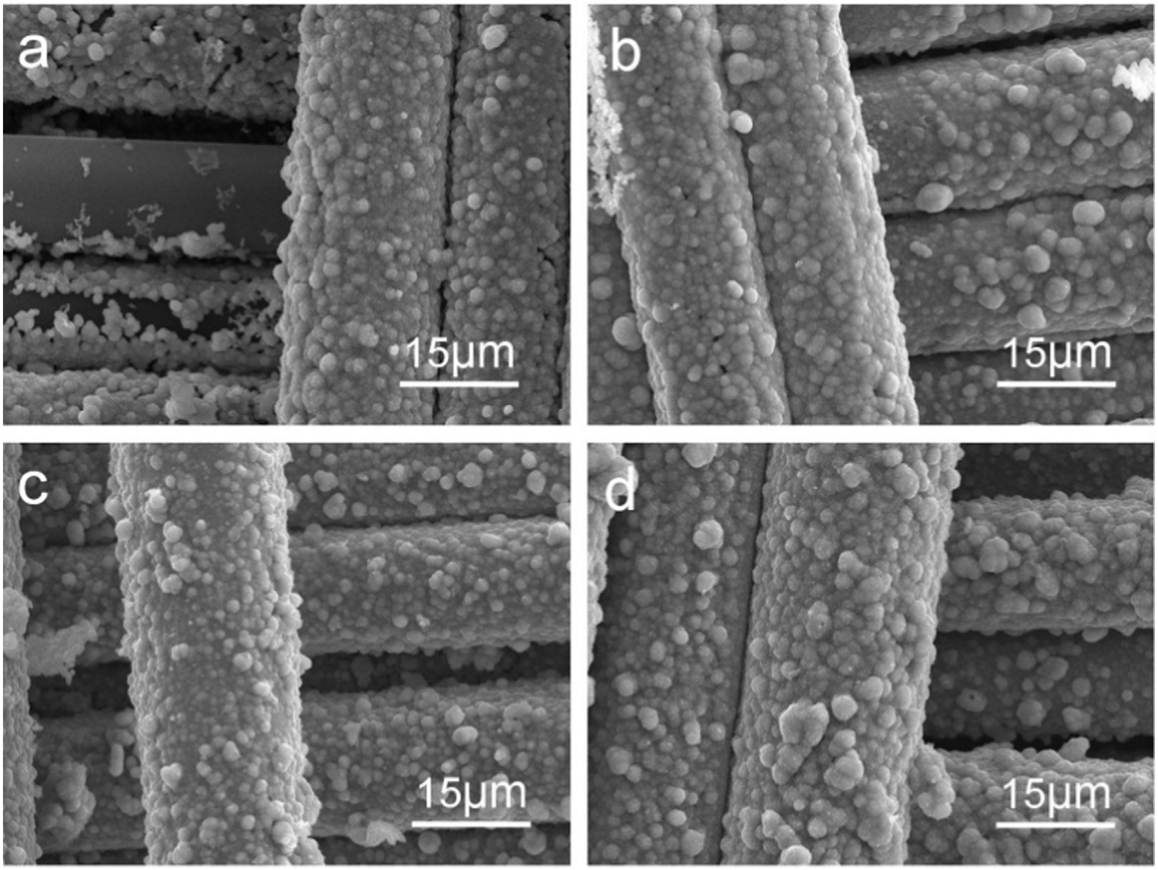

Fig. 2. SEM images of samples obtained with $NH_3 \cdot H_2O$ of (a) 0.5, (b) 1.0, (c) 2.0, and (d) 2.5 mL.

solution (40 g/L) at 60 °C for 30 min. Subsequently, the glass fabrics were sensitized by $SnCl_2$ (30 g/L) and activated by $PdCl_2$ (0.1 g/L) at 30 °C for 20 min, respectively. In a typical deposition procedure, the pretreated glass fabrics were immersed in the solution with water bath shaker. The orthogonal experiments were designed to determinate the optimum electroless deposition parameters. Typically, the glass fabrics were immersed in a 30 mL of water solution containing 30 g/L of $NiSO_4 \cdot 6H_2O$ and 30 g/L of $Na_3C_6H_5O_7 \cdot 2H_2O$, and the pH value was adjusted to 11 by adding 1.5 mL of $NH_3 \cdot H_2O$. Later on, 10 mL of water solution containing reducing reagent of $NaH_2PO_2 \cdot H_2O$ (35 g/L) was introduced dropwise. After reaction at 80 °C for 40 min, the product was collected, rinsed with distilled water and dried.

2.2. Characterizations

The surface morphology of the samples was investigated by scanning electron microscopy (SEM, Hitachi SU-1500). XRD pattern was recorded on a Bruker D8 focus diffractometer with Cu kα radiation. The volume resistivity values were determined by a SB120 four-point-probe instrument.

3. Results and discussion

XRD was used to characterize the crystal structure and composition of the obtained sample. It could be seen in Fig. 1a that