Ag/polyaniline/reduced graphene polyester conductive fabric with enhanced electromagnetic shielding performance

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Abstract. The Ag/polyaniline/reduced graphene composite fabric is fabricated via chemical in-situ polymerization to adsorb a layer of polyaniline and graphene on the polyester fabric, and then Ag is plated on the fabric surface using magnetron sputtering. The electromagnetic shielding performance of composite fabrics was studied at different concentrations of aniline and graphene, and the influence of magnetron sputtering power and time on fabric performance was further studied. At the same time, the Ag/polyaniline/reduced graphene polyester composite conductive fabric was characterized by Fourier transform infrared spectroscopy (FTIR) and scanning electron microscope (SEM). It was found that when the concentration of polyaniline was 0.7mol/L and the concentration of graphene was 0.15mol/L, the electrical conductivity and electromagnetic shielding performance of the composite fabric came to the best under controlled sputtering power of 200W and time of 20 minutes.

1. Introduction

With the rapid development of the electronics industry, electromagnetic waves have been widely used in various fields[1][2]. At the same time, electromagnetic pollution is becoming more and more serious, which not only damages electronic instruments, but also can be harmful to our environment[3]. In order to solve these problems, people began to develop electromagnetic shielding products[4].

It can be known from a number of studies that polyaniline (PANI) combined with fabric can achieve the purpose of improving electromagnetic shielding[5][6]. Therefore, in this work, the polyaniline polyester composite fabric was prepared by in-situ polymerization, and the effect of the concentration of polyaniline on the electromagnetic shielding performance was studied. It is found that the use of PANI as a single substance has a low improvement in the electromagnetic shielding performance of the fabric, the mechanical and physical properties are difficult to meet the demand in our daily life. Therefore, the graphene polyaniline polyester composite fabric was prepared, and the effect of the concentration of graphene on the performance of the fabric was studied by changing the graphene concentration. Finally, the Ag/polyaniline/reduced graphene composite fabric is fabricated by using magnetron sputtering to plate Ag on the surface of the fabric under different power and time.

Studies have shown that the electromagnetic shielding performance of the fabric is improved to a certain extent after being compounded with polyaniline, and there is a slight improvement after adding graphene. After silver plating, the electromagnetic shielding performance of the fabric is improved greatly. When the concentration of polyaniline is 0.7mol/L, the concentration of graphene is 0.15mol/L, the magnetron sputtering power is 200W, and the time is 20 minutes, the fabric has the best conductivity and electromagnetic shielding performance.
2. Preparation

2.1 Materials
Polyester yarns were washed with sodium carbonate aqueous solution, water and ethanol before use. Aniline, graphene, dodecylbenzenesulfonic acid (DBSA), Polyvinyl alcohol (PVA); ammonium persulfate (APS) and other chemicals were purchased from Sinopharm Chemical Reagent Co. Ltd (China) and used as received.

2.2 Preparation of Ag/polyaniline/graphene composite fabric
Polyester fabric was alkaline treated before use. The preparation of polyaniline polyester composite fabric is completed by emulsion polymerization[7]. The PVA solution is prepared by putting PVA particles in 90°C water[8]. Graphene is prepared by redox method[9]. First, the polyester fabric is placed in the aniline solution to prepare the polyaniline polyester composite fabric via in-situ polymerization, and then immersed in the PVA/graphene solution to obtain the graphene/polyaniline/polyester composite fabric by chemical methods, and finally Ag/polyaniline/graphene composite fabric was fabricated by magnetron sputtering.

2.3 Characterization
The surface morphologies of the samples were characterized by using scanning electron microscope (SEM, HITACHI/TM-1000, Japan). The FT-IR spectra of the samples were directly recorded by Fourier transform infrared spectrometer (FTIR, Nicolet 6700, America) from 2500 cm\(^{-1}\) to 500 cm\(^{-1}\). The surface conductivity was determined by four point probe resistivity measurement system (Loresta AX Model MCP-T370, Japan).

3. Results and discussion

3.1 SEM picture

Fig.1. SEM images of composite fabric with different polyaniline concentrations (a:0.1mol/L, b:0.3mol/L, c:0.5mol/L, d:0.7mol/L, e:0.9mol/L).

Fig.1 shows the SEM test results of different concentrations of aniline on polyester composite fabrics. From Fig.1 (a), we can see that for the 0.1mol/L polyaniline polyester composite fabric, polyaniline is sparsely distributed on the surface of the fabric, and only a small amount of fine rod-shaped polyaniline is attached to the surface of the fabric. As the concentration increases, Fig.1 (b) shows that granular polyaniline has appeared on the surface. When the concentration increases to 0.5mol/L, it can be seen from Fig.1 (c) that the polyaniline has become rod-shaped and the distribution is more uniform.
As the concentration increases to 0.7mol/L, Fig.1 (d) shows that polyaniline has covered the fabric, the distribution is more uniform, and the thickness of polyaniline is more uniform. Compared with 0.5mol/L aniline, the rod-shaped polyaniline is thicker. It is distributed in a net shape, intertwined in an orderly manner. When the concentration reaches 0.9mol/L, it can be seen from Fig.1 (e) that the polyaniline has obvious agglomeration, which makes it difficult to uniformly connect the polyaniline.

### 3.2 Infrared

![Infrared spectra](image)

**Fig.2.** Infrared spectra of composite fabric with different polyaniline concentrations.

Fig. 2 shows the infrared spectra of polyester composite fabrics with different concentrations of polyaniline. According to the analysis, the characteristic peak of polyaniline at 1103cm⁻¹ represents the C=C stretching vibration peak of the quinone ring and the benzene ring in the polymer chain[10]. The functional group structure at 1400cm⁻¹ represents the quinone ring The upper C=N stretching vibration peak is the main characteristic peak of conductive polyaniline[11]. 3000cm⁻¹ is the C-N stretching vibration absorption peak, which is the main characteristic peak of polyester. From the figure, we can see that although the concentration of polyaniline has changed, the peak shape measured at the end is basically similar, indicating that the concentration of polyaniline has little effect on the structure. The longitudinal movement occurs because different concentrations of polyaniline react with different oxidation degrees, which changes the electron cloud density of the polyaniline main chain.

### 3.3 Resistivity

The resistivity of polyaniline is related to its electromagnetic shielding performance, so it is very important to test the conductivity of polyaniline. In this experiment, SZT-2C four-eye probe tester was used to test the same sample five times, and the average value of the five tests was taken as the resistivity of the sample. Fig. 3 shows the resistivity of polyaniline. It can be seen from the figure that under other conditions unchanged, the conductivity of amine is the best when the concentration of polyphenylene is 0.7mol/L. Combined with the SEM image analysis, when the concentration is low, there is only a small amount of polyaniline on the surface of the fabric, which cannot form a conductive network, so the resistivity is high. When the concentration is higher, polyaniline agglomerates and cannot form a good conductive network. The polyaniline/graphene composite fabric is prepared under different graphene concentrations when the concentration of polyaniline is 0.7 mol/L. It can be seen that when the concentration of graphene is 0.15mol/L, the fabric has the best conductivity. In this case, the fabric has the best conductivity after magnetron sputtering Ag.
3.4 Electromagnetic shielding

It can be seen from Fig. 4 that the 0.7mol/L polyaniline polyester composite fabric has the best electromagnetic shielding performance. Through comparative analysis with resistivity data, it is found that the change trend of electromagnetic shielding performance is the same as the change trend of conductivity. The better the electromagnetic shielding performance, the better the conductivity and the smaller the resistivity. This is determined by the electromagnetic shielding principle of polyaniline. The polyester fabric is compounded with polyaniline, and the polyaniline is linked on the surface of the fabric to form a conductive network. This conductive network reflects and transmits electromagnetic waves to consume them and play an electromagnetic shielding role. Therefore, the electromagnetic shielding performance of the composite fabric will become better as the conductivity increases. Through the analysis of the SEM image, it can be seen that the polyaniline distribution on the surface of the 0.7mol/L polyaniline polyester composite fabric is the most uniform, so the composite fabric at this concentration has the best performance.
Fig. 4. Electromagnetic shielding performance of different composite fabrics. (a) Polyaniline polyester fabric under different aniline concentrations, (b) polyaniline/graphene composite fabric under different graphene concentrations, (c) Ag/graphene/polyaniline composite fabric at different magnetron sputtering power, (d) Ag/graphene/polyaniline composite fabric under different magnetron sputtering time.

The Ag/polyaniline/graphene composite fabric is fabricated at a concentration of 0.7 mol/L of polyaniline. It can be seen that when the concentration of graphene is 0.15 mol/L, the electromagnetic shielding performance of the fabric is the best. On this basis, when the power is 200 W and the sputtering time is 20 minutes, the fabric can obtain the best electromagnetic shielding performance by magnetron sputtering Ag.

4 Conclusion
In this work, polystyrene/polyester composite fabrics with different concentrations were prepared by in-situ polymerization, and it was concluded that 0.7 mol/L of polyaniline and 0.15 mol/L of graphene can get the best electromagnetic shielding effect. Experiments were carried out by changing the power and time of magnetron sputtering, and it was found that silver plating greatly improved the electromagnetic shielding performance of the fabric prepared, and the fabric prepared by 200 W and 20 min had the best electromagnetic shielding performance. The concentration of polyaniline and graphene has little effect on the surface structure of the composite fabric, but has a great impact on the electrical conductivity and electromagnetic shielding performance, and there is a connection between the electrical conductivity and the electromagnetic shielding performance.

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