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Effects of Ar gas pressure on characterization of nano-structured silver films deposited on the surface of polyester fabric

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Abstract The silver films of nano-structured are prepared by magnetron sputtering on the surface of polyester plain weave fabric,The effect of vacuum pressure on the morphology of the nano-structured silver films,anti-UV and the conductivity of samples deposited with silver films is investigated.Results of experiments show that the surface roughness of silver film with substrate for plain weave fabric is biggest, particle size is largest and particles formed on the surface of films is distinctest when pressure is 0.6Pa,but the conductivity of silver film is optimum when pressure is 0.3Pa; The samples deposited with silver films show better UV absorption, Ar gas pressure has no obvious influence on the samples shielding UV radiation.

Introduction

Nano-structured silver is a kind of new functional material for small particle size and large effective area,which has broad application in chemical, textile, medicine, optical, electronic and other industries due to its surface effect, quantum effects and other unique properties [1]. Silver film of nano-structured is an ideal functional material as the substrate of textile materials that can be used to develop UV-shielding materials, fiber solar cells, medical antibacterial material etc.

At present, scholars deposited metallic films of nano-structured by magnetron sputtering with substrate for nonwoven fabric and have investigated surface morphology of thin films,the relationship of thickness and electrical conductivity of thin films,transmittance of ultra-violet (UV) rays [2,3]. Magnetron sputtering is considered a better technique for preparing functional nanofilms in an ideal vacuum conditions and the process is sputtering alone,which can offer better adhesion between substrate and thin films.In this study,silver films of nano-structured were deposited onto the surface of polyester plain fabric by the radio frequency(RF) magnetron sputtering at room temperature. The sputtering process parameters, such as gas pressure, sputtering power, sputtering time ,temperature of substrates and others have an important impact on performance of thin film [4].Thus, in this article, the morphology of nanoscale silver films prepared under different gas pressure was characterized by atomic force microscopy (AFM) and the optical and electrical properties of the silver-deposited materials were also investigated.

Experimental

Materials preparation

The substrate used in this study was polyester plain fabric with warp density of 332 root/ 10 cm and weft density of 206 root/ 10 cm. The samples were cut into 10cm × 8cm ,first immersed in acetone solution for 30 min with ultrasonic washer to remove the organic solvents and dust on the surface of fabric .Then they were washed twice with de-ionized water and dried at 50℃in a drying oven.

Silver deposition

The equipment of silver thin films deposited in this study was a lab radio frequency (RF) sputtering system JZCK-420B supplied by Shenyang Juzhi Co., Ltd. The target was silver with a high purity of about 99.999% and fixed on the cathode, the substrate was placed on the anode with a side facing the target.The distance between the target and substrate was 60 mm, Prior to the deposition process, the target was discharged in argon gas for about 5 min to remove impurities on its surface and sputtering chamber was pumped to a base pressure of 5.0×10^{-4}Pa before the introduction of high-purity argon gas as sputtering gas to a certain pressure at the flow rate of 20 sccm. The sputtering time was set at 10 min and sputtering power of 120 W. The coating pressure was set at 0.3Pa, 0.6Pa and 0.9Pa respectively in this work.

To avoid the deformation of substrate caused by high temperature,water-cooling was used to control the temperature of the substrate during the sputtering process.During the sputtering ,the sample holder was rotating at a speed of 100 rpm to ensure silver particles uniformly deposited on the substrate.

Surface Characterization

The surface morphology and grain size of nano-structured silver films after sputtering were scanned by atomic force microscopy (AFM). The AFM used in this study was CSPM 4000 in contact mode provided by Benyuan Co.,LTD.Scanning was carried out and all samples were scanned at room temperature in the atmosphere. The scanning scope was set at a size of 5,000nm×5,000 nm and the scanning frequency was set at 1.0 Hz.

Optical properties

The optical properties of the samples deposited with silver thin films were analyzed with the transmittance of Ultra-violet (UV) and visible (vis) light through samples.The SP-1700 UV–visible (UV/Vis) spectroscopy with a deuterium lamp was obstained to scan the transmittance of samples in the wavelength ranging from 200nm to 600 nm.

Electrical property

The electrical property of samples was characterized by resistivity measurement. The resistivity was measured by SX1934 four-point probe tester made by Baishen Technology.In order to minimize the deviations brought by the unevenness of sample surface, the resistivity of each sample was measured several times then the average values were obstained.

Results and discussion

Surface morphology

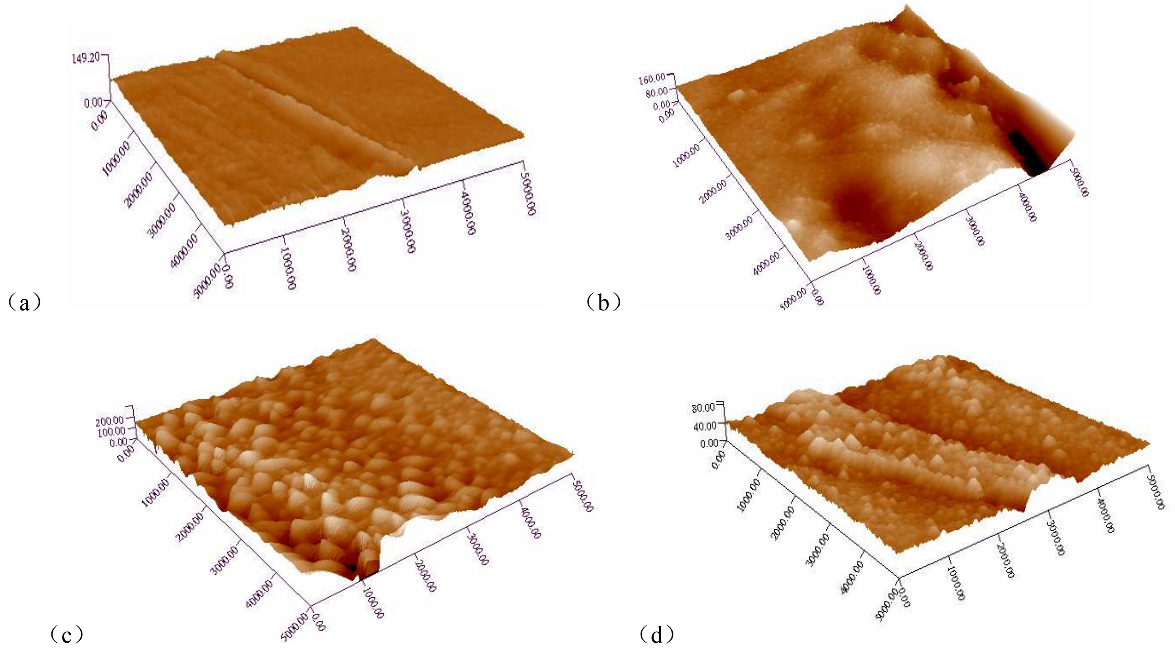

Fig.1: Surface morphology at different pressure: (a) original sample; (b)0.3Pa; (c) 0.6Pa; (d) 0.9Pa

The surface morphology of polyester plain fabric is presented in Fig. 1a. It appears that the surface of original sample is relatively smooth as presented in Fig. 1a .The surface has an average roughness of 2.75nm as analyzed by Imager Software.The silver coating obviously modifies the surface characteristics of the fibers as illustrated in Fig. 1b. The AFM images clearly show the sputtered particles covering the fiber surface as the pressure is 0.3Pa.The average diameter of the sputtered silver clusters is about 56.5 nm and the surface roughness is increased to 15.5 nm.It is found that more nanoparticles are covered up the nanofiber surface as the sputtering pressure is increased to 0.6 Pa. The average diameter of the silver grain is increased to 92.7nm and the surface roughness is also further increased,as revealed in Fig. 1c. The increase in deposition pressure leads to the formation of larger grain for the collision of the sputtered silver particles.Figure.1d clearly shows that the deposited clusters are much denser compared to those shown in Figs. 1b and 1c. The average diameter of the silver cluster is reduced to 70.2 nm and the surface roughness is also reduced to 6.25 nm,as presented in Fig. 1d. The growth of the deposited silver cluster is also observed.

Optical properties

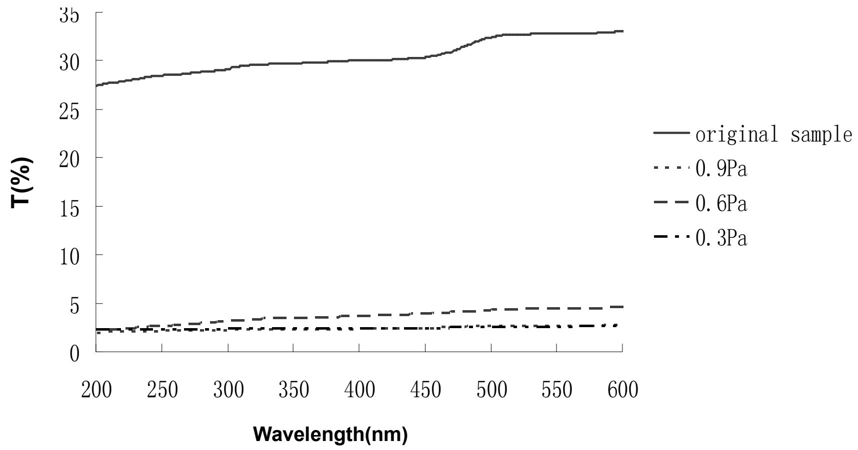

Fig.2:Transmittance spectra of polyester plain fabric samples

The optical transmittance of polyester plain fabric with and without silver films deposition under different Ar gas pressure is showed in Fig. 2. It shows that the original sample has the transmittance of about 30% in the range from 400 to 600 nm, indicating a good transmittance of visible light. The transmittance drops a little in the range between 400nm and 200nm, indicating the UV shielding effect of the sample.The increase in coating pressure first leads to a little further increase and then decrease in transmittance in both UV and visible light range, as revealed in Fig. 2.The silver-deposited polyester plain fabric have the transmittance obviously lower than that of uncoated polyester plain fabric over the wavelength range between 200 and 600 nm.The silver sputter coating significantly alters the optical properties of polyester plain fabric, as displayed in Fig. 2. The transmittance of UV light and visible light in the range of 200–600 nm is considerably reduced to about 5% when sputter coating pressure is between 0.3Pa and 0.9Pa,revealing the light-shielding effect of silver coating. The change in Ar gas pressure of the silver deposition does not show any obvious effects on the transmittance of UV light through the samples.

Electrical property

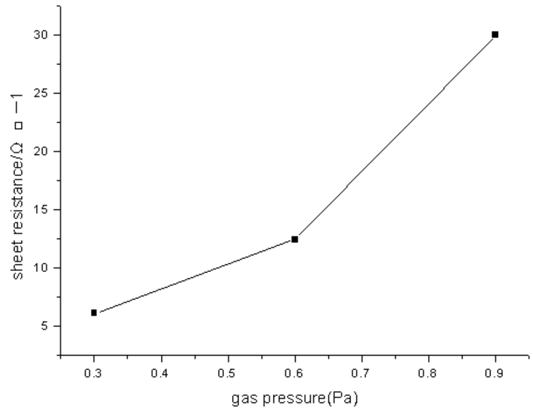

Fig.3: The relationship between Ag film sheet resistance and Ar gas pressure

The results of resistance measurements of the samples are indicated in Fig.3 ,which showed the relationship between Ar gas pressure and sheet resistance of nanoscale silver films. The sheet resistance of thin film also increased with the increasing of argon pressure ,which indicated the electricity of thin films weakened significantly. When the gas pressure was more than 0.6Pa, sheet resistance increased more quickly, conductivity of thin films also decreased rapidly.It showed the opportunity of collision between energetic particles and argon gas molecules enhanced with the increasing of Ar gas pressure in vacuum,which caused free path of charged particles short, the kinetic energy of silver particles sputtered out also reduced.So silver particles is not easily deposited on the fiber surface, conductive performance of thin film also reduced[5].

Conclusion

In this study, silver thin films have been deposited on the surface of polyester plain fabrics using sputter coating of silver under different Ar gas pressure.The silver coating significantly altered the surface morphology of the fabrics. The surface conductivity of the material was also significantly reduced. The results showed that Ar gas pressure could not only influence the morphology of fiber surface,but also conductivity of these coated fabrics. The surface functionalization of fabrics will improve the surface properties of the materials and expand the potential applications of these materials.

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