



Fabrication and characterization of Au/SiO₂ nanocomposite films

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ABSTRACT

Au/SiO₂ nanocomposite films were prepared by radio frequency sputtering technique and annealing. The above nanocomposite films were characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), and atomic force microscopy (AFM). The surface of the nanocomposite films was uniform with the particle diameter of 100–300 nm. The size of Au crystallites increased on increasing annealing time. The luminescent behavior of the nanocomposite films was characterized by photoluminescence (PL) with different excitation wavelengths. Two emission peaks at around 525 nm and 560 nm were observed with the excitation wavelength at 325 nm. An intensive emission peak at around 325 nm was observed with the excitation wavelength at 250 nm, which is related to the defective structure of the amorphous SiO₂ layer because of oxygen deficiency, and could be applied to many fields, such as ultraviolet laser and ultraviolet detector.

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1. Introduction

Nanocomposite films with metallic clusters or crystals in dielectric matrix have potential applicability for photonics, magnetics and electronics, and single electron devices [1,2]. In order to fabricate new nanoscale devices with excellent properties, we should choose novel materials and improve the ability to synthesize, deposit, and position nanosized building blocks on suitably designed substrates [3]. So, it plays an important role in the actual application of the nanocomposite films so that we adopt novel materials and advanced techniques in the experiment.

To date there have been many studies on nanocomposite films which consist of different materials, such as Au/Al₂O₃ [4], Ag/SiO₂ [5,6], Au/ZnO [7], Au/SiO₂ [8], and ZnO/SiO₂ [9]. The nanocomposites dispersed with noble metal nanoparticles, especially Au nanoparticles, have been extensively studied as they can provide the novel optical materials [10,11] and can be possibly used as photocatalysts and sensor materials [2]. Su et al. studied multiphoton luminescence of Au nanocrystals prepared by radio frequency co-sputtering technique with glancing angles [12]. Kim reported that the Au nanoparticles in the Au/SiO₂ nanocomposite films were aggregated through water treatment [13]. However, shortwave photoluminescence from Au/SiO₂ nanocomposite

films prepared by radio frequency sputtering technique using different targets for different sputtering times was seldom reported.

In this study, we present the preparation and characterization of Au/SiO₂ nanocomposite films with uniform surface and unique shortwave photoluminescence properties by RF magnetron sputtering method. In our experiment, SiO₂ was first deposited on the substrate. Subsequently, Au was deposited on the surface of SiO₂ layer. Different times were chosen in the annealing process. The as-grown Au/SiO₂ nanocomposite films were characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), and atomic force microscopy (AFM). And the aggregation mechanism of the nanoparticles in the nanocomposite films was shortly discussed. As the luminescent behavior of the Au/SiO₂ nanocomposite films was important but rarely studied in other reports, photoluminescence (PL) was also carried out in the experiment, with different excitation wavelengths. We observed the unique shortwave photoluminescence, with an emission peak at around 325 nm with the excitation wavelength at 250 nm. We also discussed the reason for the shortwave emission, which may be applied to many fields, such as ultraviolet laser and ultraviolet detector.

2. Experiment

Au/SiO₂ nanocomposite films were prepared on Si(111) substrates in JCK-500A RF magnetron sputtering system with

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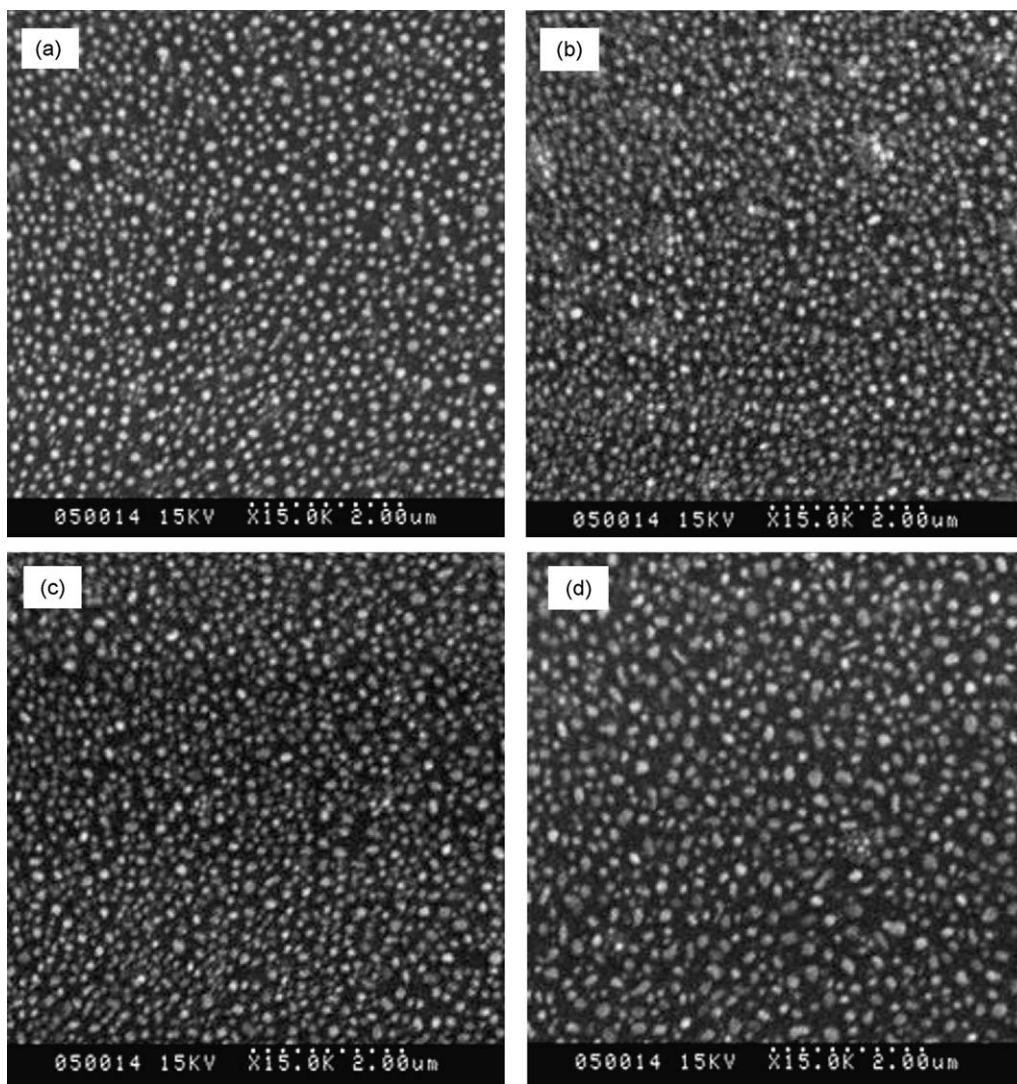


Fig. 1. SEM images of samples annealing at 900 °C for different times: (a) 10 min; (b) 20 min; (c) 30 min; (d) 40 min.

1.9×10^{-3} Pa basic pressure. SiO₂ and Au layers, with the thickness of about 200 nm and 15 nm, respectively, were deposited on the substrates by sputtering high-purity (99.999%) SiO₂ target and Au target in Ar, respectively. The distance between the target and the substrate was 80 mm. The sputtering time of SiO₂ and Au was 30 min and 5 s, respectively. The substrates were ultrasonically cleaned in alcohol for 15 min, and then dried. The RF sputtering power was 150 W. Subsequently, the as-deposited films were annealed in tube furnace in N₂ atmosphere with a flow rate of 500 ml/min at 900 °C for 10, 20, 30 and 40 min. After annealing, it was observed that a weak yellow and transparent thin film had appeared on the surface of the substrate.

The products were characterized using scanning electron microscopy (SEM), X-ray diffraction (XRD), atomic force microscopy (AFM) and photoluminescence (PL).

3. Results and discussion

Fig. 1 shows the typical micrographs of the Au/SiO₂ nanocomposite films annealing at 900 °C for 10, 20, 30 and 40 min. The white dots were Au crystal particles. The Au particles were homogeneously distributed over the entire surface of the substrate, although their distribution was not ordered (Fig. 1a).

As the annealing time increased, the Au particles were slightly aggregated (Fig. 1b) with the increasing interval of the particles, then, grew to bigger particles (Fig. 1c and d). The process of morphological change of the Au/SiO₂ nanocomposite films could be seen in Fig. 2.

As shown in Fig. 2, SiO₂ was first deposited on the substrate. Subsequently, Au was deposited on the surface of the SiO₂ layer. The Au particles were entirely exposed with uniform distribution on the SiO₂. Before annealing, the colors of the films are rainbow-like. After annealing, their colors change to weak yellow and transparent for the films with a thinner Au layer indicating that the Au particles were aggregated during the annealing process [13,14].

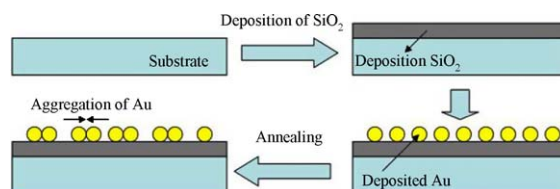


Fig. 2. Schematic drawing for aggregation mechanism.

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