Applied Surface Science 273 (2013) 215–219

Contents lists available at SciVerse ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Effect of wettability on surface morphologies and optical properties of Ag thin films grown on glass and polymer substrates by thermal evaporation

Jing Lv*

School of Physics and Mechanical & Electrical Engineering, Longyan University, Longyan 364000, PR China

ARTICLE INFO

Article history:
Received 9 October 2012
Received in revised form 28 January 2013
Accepted 2 February 2013
Available online 18 February 2013

PACS:
68.37.Ps
68.55.−a
78.68.+m

Keywords:
Wettability
Ag thin films
Substrate material
Surface morphologies
Optical properties

ABSTRACT

A series of Ag films with different thicknesses were deposited on BK-7 glass, PET and PC substrates under identical conditions by thermal evaporation. The effect of the wettability on the morphology and optical properties of Ag/glass and Ag/polymer films was studied by atomic force microscopy and spectrophotometry. The experimental results show that the wettability of Ag grains with polymer is stronger than with glass, which results in the aggregation of bigger grains in initial layer. During deposition the interaction of interlayer plays an important role for the formation of the surface morphology. The strong wettability activates the nonlinear optical properties of Ag grains grown on polymer substrates, which result in the strong absorbance in short wavelength. The effect of the bare substrate on the transmittance of Ag films is more obvious than the reflectance. With the increasing of the thickness, the effect of the wettability on the morphology and optical properties of Ag films decline. In this experiment when the thickness is above 50 nm, the effect almost vanished.

1. Introduction

Ag thin films have attracted much attention owing to their peculiar optical properties [1–3]. In previous investigations, it is found that the size and shape of silver nanoparticles, the surface roughness of the thin films will affect the optical properties of Ag films [4,5]. So, many efforts have been devoted to the preparation and stabilization of Ag nanoparticles in order to control their sizes, shapes and distribution [6–8]. In recent years, it is found that, excluding preparation technology, substrate material also affect the sizes, shapes and distribution of Ag nanoparticle. The dependence of Ag wettability between Ag and substrate material controls the aggregation of grain during deposition is a well known fact. But people fasten their attention upon how to improve adhesion of Ag films and substrate materials. Gadre and Alford found the annealing and plasma treatment are effective [9]. The effect of wettability on surface morphologies and optical properties of Ag thin films is few investigated. With the development of better organic semiconductor materials and fabrication procedures, organic solar cells, light emitting diodes and so on have been of considerable interests. So that it is important to investigate comparatively the influences of inorganic and organic substrates on the properties of Ag thin films.

In this work, we studied the effect of the wettability on surface morphology and optical properties of the Ag/glass and Ag/polymer films. It is found that the wettability of Ag grains with polymer is stronger than with glass. The strong wettability activates the nonlinear optical properties of Ag grains grown on polymer substrates, which results in the strong absorbance in short wavelength. When the thickness is above 50 nm, the effect of the wettability nearly disappeared.

2. Experimental details

A series of Ag films with different thicknesses were deposited on BK-7 glass, polyethylene terephthalate (PET) and polycarbonate (PC) substrates under identical conditions using silver (99.99% purity) wires by thermal evaporation. Electric current for evaporation was about 110 A and deposition pressure was 5.0×10^{-3} Pa. The deposition rate (about 1.0 nm/s) and the thickness ware measured with a quartz crystal micro balance.

The surface morphology of the samples was examined by atomic force microscopy (AFM) (CSPM 5500, Ben Yuan Ltd., China)

* Corresponding author. Tel.: +86 597 13110626038.
E-mail address: lvjing7580433@yahoo.cn

0169-4332/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.apsusc.2013.02.015

Table 1
RMS roughness and SAGS of Ag films grown on different substrates.

Thickness (nm)	Ag/BK-7		Ag/PET		Ag/PC	
	RMS/nm	ASGS/nm	RMS/nm	ASGS/nm	RMS/nm	ASGS/nm
20	3.33	40.2	4.02	62.8	5.52	70.3
30	3.01	35.3	3.35	51.3	5.01	60.2
50	2.42	25.8	2.63	30.5	4.38	40.5

equipped with a microscope and a CCD detection system. Scans were taken under a contact force of 10^{-9} N and over areas of $2.0 \times 2.0\ \mu m^2$. The average surface grain size (ASGS), the root mean square (RMS) surface roughness, surface grain sizes and height distribution were obtained by the corresponding software in CSPM 5500. The reflectance and transmittance were measured in the $200 < \lambda < 800$ nm wavelength range by use of a double beam spectrophotometer (UV-2550).

3. Results and discussion

3.1. The surface morphology

The RMS surface roughness and ASGS of the films calculated from AFM images data are listed in Table 1. The data revealed that in the same thickness, the RMS surface roughness and ASGS of the films grown on BK-7 glass were smaller than the other two. With the increasing of the thickness, the data decreased. When thickness was above 50 nm, the data changed slightly (not be listed about above 50 nm). Fig. 1 shows the surface morphology of the Ag 50 nm films. It was clear that the surface grains were spherical (Fig. 1(a1)), elliptical (Fig. 1(b1)) and flattened elliptical (Fig. 1(c1)) grown on BK-7 glass, PET and PC substrates.

According to the data listed in Table 1, we can conclude that the wettability grown on polymer (PC and PET) substrates is stronger than grown on BK-7 glass. In the first layers, the aggregation of big Ag grains is shaped because of the strong wettability grown on polymer (PC and PET) substrates. During deposition the interaction of interlayer plays an important role. So, the surface grain sizes and morphology are formed as shown in Table 1 and Fig. 1.

3.2. Height and grain sizes distribution

In order to further examine the grain stack during deposition, a height distribution along line in Fig. 1 is performed in Fig. 2. Comparing these three curves in Fig. 2, it was clear that the aggregation of grains, Ag 50 nm film grown on PC substrate, was strongest in the there films, forming a widest rugged profile shown in Fig. 2(c2). While for the film grown on BK-7 glass substrate there were some dispersed finely ravines, which indicated clearly that the aggregation of spherical grains was very weak (Fig. 2(a2)). The different of the grain stack has an important effect on the surface morphology.

The distribution graphs of surface grain sizes with 50 nm thickness are provided in Fig. 3. It was found that the distributions grown on BK-7 glass and PET substrates were similar (Fig. 3(a and b)). The grain sizes are convergence, and the large-sized grains are few. The max size grown on BK-7 glass and PET substrates are about 62 nm (ratio about 0.01%) and 76 nm (ratio about 0.1%), respectively. It is clear that the effect of the wettability on the morphology has no real distinction made between the grown on BK-7 glass and PET substrates when thickness is 50 nm. While for the film grown on PC substrate (Fig. 3(c)), the size scope is wide (6–120 nm), but there is on concentrative distribution area. The ratio of the small grain size between 6 and 10 nm is appreciable, and the total ratio of the large grain size between 80 and 120 nm is about 1%, which reflects the existence of the effect of the wettability on the morphology of Ag 50 nm film grown on PC substrate.

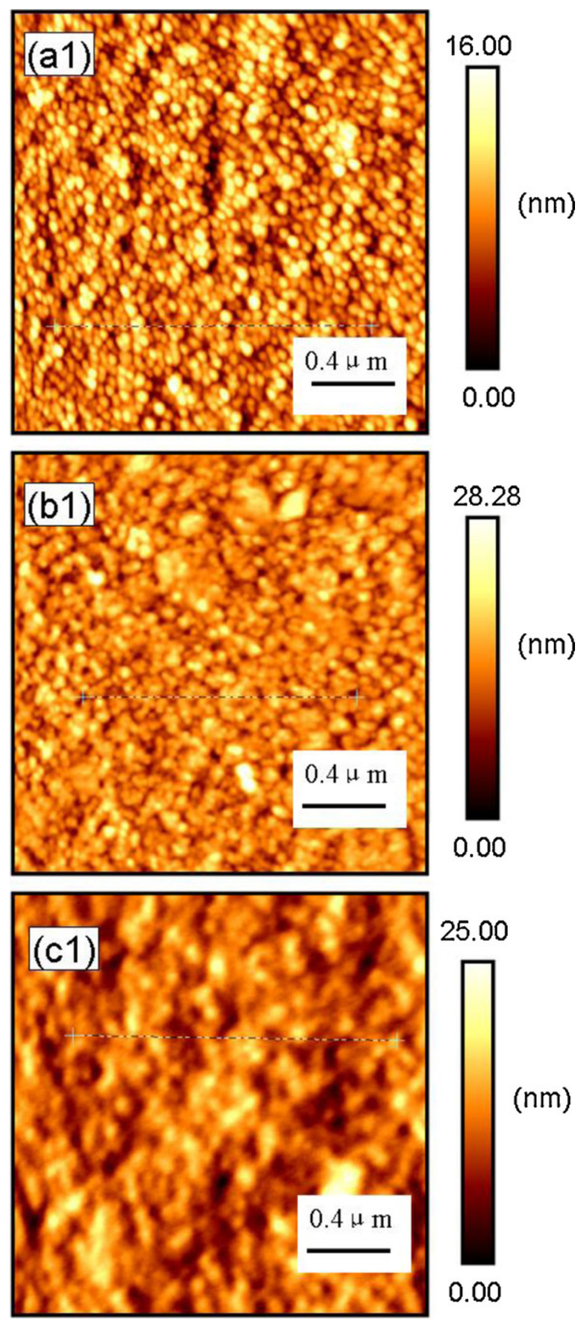

Fig. 1. AFM images of Ag 50 nm films grown on different substrates: (a1) BK-7 glass, (b1) PET and (c1) PC.