OPTICAL TRANSMISSION OF A SILVER DOT ARRAY DEPOSITED ON A GLASS PLATE

AUTHORS

José G. Murillo*[a,b], Saira Aranda[b], Andrea Márquez[b], Manuel Roman[a], and Mario Miki-Yoshida[a]

[a]Centro de Investigación en Materiales Avanzados S.C., Miguel de Cervantes 120, Complejo Industrial Chihuahua, C. P. 31136, Chihuahua, Chihuahua, México;
[b]Universidad Autónoma de Chihuahua, Facultad de Ingeniería, Circuito Universitario, Campus II Chihuahua, Chihuahua, México.

ABSTRACT

Silver besides being a good electrical conductor has important optical properties. The very high optical reflectance of silver in the visible and near infrared ranges makes it one of the most employed materials in applications which go since mirrors of home-use until thin films for applications in the solar control area. Encouraged by this fact in this work we report a study which goal was to investigate the photonic properties of a periodic structure of silver dots deposited on a glass substrate. The silver dots array was deposited using a materials printer with an ink cartridge containing suspensions of silver nanoparticles. By using this method it was possible to obtain a typical silver dot with a diameter of the order of 30 µm and an average thickness of 400 nm. The photonic structure considered was a two-dimensional square array of silver islands with a periodicity parameter of 45 µm covering an area of (1.2 x1.2) mm^2. On the other hand also was deposited a silver continuous thin film using the same method employed to deposit the silver dots array in order to evaluate and compare the optical properties of both systems.

The optical properties of both, the photonic structure and the continuous thin film, were evaluated measuring the optical transmittance as a function of wavelength from 350 to 2400 nm using a spectrophotometer.

The results show an enhancement of the magnitude of the optical transmittance in the UV-VIS range of the photonic structure regarding to the continuous thin film. The array of silver islands with characteristic dimensions of some tens of micrometers has photonic properties that allow it to increase and modify its optical transmittance, essentially only in the optical range from 350-800 nm in a similar way as occurs in a photonic crystal in the sub-micrometric scale

Keywords: Photonic structure of silver islands, thin silver film, optical transmission.

1. INTRODUCTION

Thin metal films have attracted since many years ago an intense interest due to their wide application gamma based on its optical and electrical properties, such as their use as transparent conductive coatings for UV-Visible optical range, transparent electrodes for solar cells, coatings for solar control in glass windows, and active components of surface plasmon resonance, just to mention some of them. In fact in the literature it have been reported the optical and electrical properties of different types of metallic films, including noble metals like Au, Ag, and Cu, transition metals like Ti, V, and Ni, and semimetals like Al and Sn [1]. However, because some technological applications of thin films have additional requirements such as resistance to oxidation and other chemical reactions, the noble metals are usually more studied. In particular, among the noble metals, silver is of great interest because of its high electrical conductivity and its very high optical reflectivity in the VIS-NIR range. In fact there are a good quantity of reports about the electrical and optical properties of silver continuous thin films and very thin films where has been studied the optical absorption in order to obtain localized surface plasmons [2]. Even also has been studied the microstructural and optical properties of silver island films deposited on different substrates by thermal evaporation or by using a DC plasma sputtering method

[2]. In these reports has been obtained interesting results including plasmonic resonances and large nonlinear absorption effects observed after to carry out a thermal annealing process to the discontinuous film composed of silver islands [2].

In this work we report the optical properties of an organized periodic structure of silver dots or circular islands with micrometric sizes deposited on a glass substrate. We have developed this study in order to investigate if even when the array of circular silver islands with sizes of several then of microns kept in some sense a similar behavior to a photonic structure with sub-micrometric dimensions.

2. EXPERIMENTAL DETAILS

The silver dots array was deposited onto a borosilicate glass plate with a thickness of 2 mm using a Fujifilm Dimatrix materials printer with an ink cartridge containing suspensions of silver nanoparticles. The deposition of the photonic structure was carried out at room temperature, although the glass substrate previously cleaned using an ultrasound bath in isopropyl alcohol, was heated at 300 K in order to optimize the deposition conditions. By using this method it was possible to obtain a typical silver island of circular shape with a diameter of the order of 30 µm and an average thickness of 400 nm determined by observing the cross section of the film. The photonic structure considered was a two-dimensional square array of silver islands with a periodicity parameter of 45 µm covering an area of (1.2 x1.2) mm^2. On the other hand also was deposited a continuous thin film of silver using the same method employed to deposit the silver dots array in order to evaluate and compare the optical properties of both systems. After completed the deposition process, both samples were annealed during 30 min at 673 K in order to stabilize their microstructure and enhance the adhesion of film to the substrate.

The microstructure of both, the photonic structure and the continuous thin film of silver was characterized by field emission scanning electron microscopy (FESEM) using a JEOL JSM-7401F operated at 2 kV. The optical properties of both samples were obtained measuring the transmittance spectra using a Varian Cary 5000 UV-Vis-NIR spectrophotometer.

3. RESULTS

In order to determine the optimum conditions such as the temperature of the substrate and the speed of deposition to synthetize the photonic structure and the continuous thin film of silver, a large number of deposition cycles were carried out by using the materials printer. Fig. 1(a) shows a secondary electron SEM micrograph of the surface of one of the best representative two-dimensional photonic structure describing a square lattice of silver islands with a periodicity parameter of 45 µm. An amplification of the photonic structure showing some details about the silver islands is shown in Fig. 1(b). Fig. 1 (c) shows a representative section of the surface of the continuous thin film of silver.

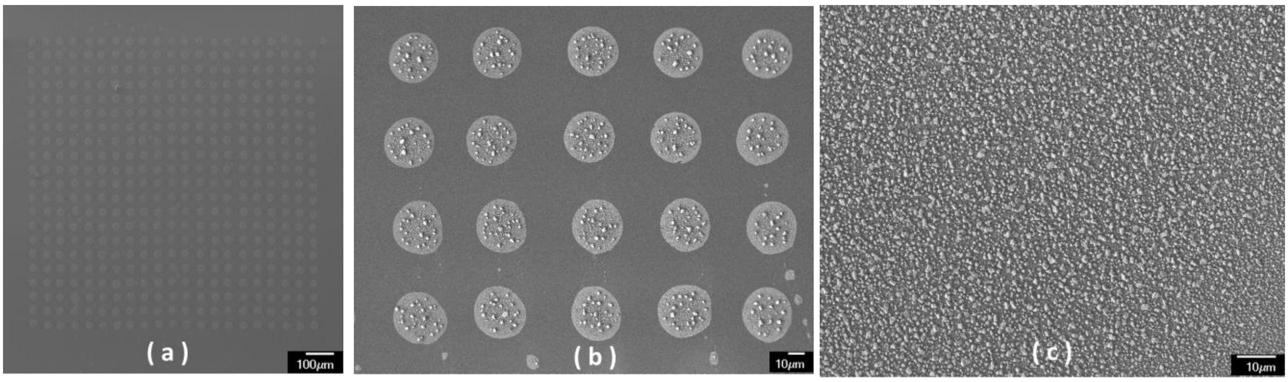

Fig. 1. Secondary electron SEM micrograph of the surface of: (a) two-dimensional photonic structure describing a square array of silver islands; (b) an amplification of the photonic structure showing some details about the silver islands; (c) a representative section of the surface of the continuous thin film of silver.

The optical properties of the photonic structure defined by a square lattice of silver islands and the continuous thin film of silver were obtained measuring the optical transmittance spectra in the wavelength range from 350 to 2400 nm as shown in Fig. 2. The absorption edge at 300 nm for both samples is due to absorption of the glass substrate. As can be seen in Fig 2 the optical transmittance of the square array of silver islands shows a significant difference especially in the UV-Vis electromagnetic range regarding to the transmittance spectra of the continuous thin film.

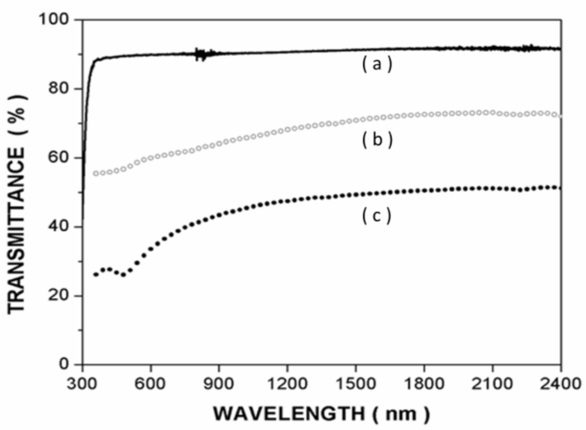

Fig. 2. Transmittance spectra as a function of wavelength of radiation of: (a) ━━━ borosilicate glass substrate; (b) ○○○○ photonic structure of silver circular islands with a square lattice of micrometric size deposited on a borosilicate glass substrate; and (c) ●●●● continuous thin film of silver deposited at room temperature on a borosilicate glass substrate.

4. DISCUSSION AND CONCLUSION

A comparison between the optical transmittance of the silver islands structure and that obtained for the continuous thin film of silver deposited on borosilicate glass substrates shows significant differences in their optical properties. The results show an enhancement of the magnitude of the optical transmittance in the UV-Vis range for the photonic structure regarding to the transmittance spectra of the continuous thin film. Thus the array of silver islands with characteristic dimensions of some tens of micrometers has photonic properties that have allowed it to increase and modify its optical transmittance, essentially only in the optical range from 350-800 nm in a similar way as occurs in a photonic crystal in the sub-micrometric scale. This can be confirmed from the optical transmittance measurements because both systems follow a very similar behavior but only in the near-infrared electromagnetic range.

5. AKNOWLEDGEMENT

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