

## Structural and Optical Properties of TiO<sub>2</sub>/Ag/TiO<sub>2</sub> Multi Layers

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### ABSTRACT

Titanium dioxide nano layers of same thicknesses, and near normal deposition angle, and same deposition rate were deposited on glass substrates, at room temperature, under UHV conditions. Silver nano particles of different thicknesses also near normal deposition angle and same deposition rates were post deposited on Titanium dioxide nano layers at room temperature under UHV conditions. At least again Titanium dioxide nano layers as third nano layer of same thicknesses with near normal deposition rate, same deposition angle at room temperature under UHV conditions, were deposited by thermal evaporation. nano structure of these multi layers were determined by AFM and XRD methods. Roughness of the films changed due to different thicknesses of silver nano particles. . Optical Reflectance were studied by spectrophotometer method. Correlation between nano-structures and optical reflectance studied. Thickness of titanium dioxide and silver nano particles can play an important role in the nano-structure of the films.

**Keywords:** Titanium dioxide; AFM; XRD.

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### INTRODUCTION

It is well known that the optical and electrical properties of very thin metal films depend considerably on their structures [1]. Titanium Dioxide is used extensively in thin film optical-interference coatings. For most applications films with indices as high or as low as possible are required. Titanium dioxide has the highest index of all oxides [2]. Titanium dioxide layers have been attracting much attention because of photo catalytic reactions at the surface in view of their practical applications to environmental cleaning such as self cleaning of tiles, glasses, and windows [3]. The highly transparent TiO<sub>2</sub> films can be used as anti-reflection coatings for increasing the visible transmittance in the photo catalytic heat mirrors. One of the important optical requirements for the heat mirror is high transmittance in the visible region [4]. heat mirrors are transparent for visible light and reflecting for infrared (IR) solar radiation. These mirrors are used for obtaining energy efficiency when overheating from excessive solar input is a problem. Dielectric / metal / dielectric (D/M/D) layers on a glass substrate could be used as a filter that reflects IR radiation and transmits most of the visible spectrum [5]. Heat mirrors have also been constructed for cold climates; these include (D-M-D) layers on glass TiO<sub>2</sub>-Ag-TiO<sub>2</sub>, ZnS-Ag-ZnS, and tin-doped indium oxide, coatings on glass [6]. Extensive work has been done in understanding the growth mechanism of the Ag film on various substrates using different deposition processes [7]. Because of their unique physical properties such as the high reflectance in visible region and low resistivity Ag films have many applications in various modern technologies. They are widely used as optical mirror and electrode in electronic device [8]. Transparent heat mirror films can be obtained via three methods:

1. Using multi-layer dielectric/metal or dielectric/metal/dielectric films.
2. Using metal thin films with high infrared reflectance, such as silver, gold, copper, etc...
3. Using semiconductor materials with high infrared reflectance [9]. The aim of this work is to produce TiO<sub>2</sub>/Ag/TiO<sub>2</sub> multi nano layers and investigate about Nano structure, morphology, roughness, optical reflectance and correlation between these Properties.

### Experimental details

Titanium dioxide nano layers of 10 nm thickness, silver nano particles of 13 nm and 23 nano meters and at least Titanium dioxide nano layers of same 10 nm thicknesses, were deposited on glass substrates at room temperature. The residual gas was composed mainly of H<sub>2</sub>, H<sub>2</sub>O, CO and CO<sub>2</sub> as detected by the quad ro pole mass spectrometer. The substrate normal was at 8.5 degree to the direction of the evaporated beam (near normal) and the distance between the evaporation crucible and substrate was 40 cm.

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Just before use all glass substrates were ultrasonically cleaned in heated acetone, then ethanol. Other deposition conditions were same during coating. Vacuum pressure was about  $10^{-6}$  torr and deposition rates were 0.7 A/sec for titanium dioxide and 1.2 A/sec for silver nano particles. Thickness of the layers was determined by quartz crystal technique. Nanostructure of these films was obtained by using a Philips XRD X'pert MPD Diffractometer ( $\text{CuK}_\alpha$  radiation) with a step size of 0.03 and count time of 1 s per step, while the surface physical morphology and roughness was obtained by means of AFM (Dual Scope™ DS 95-200/50) analysis. Reflectance of the films were measured by using UV-VIS spectrophotometer (Hitachi U – 3310) instrument. Table I shows details of multi  $\text{TiO}_2/\text{Ag}/\text{TiO}_2$  thin layers.

Table 1: Details of  $\text{TiO}_2/\text{Ag}/\text{TiO}_2$  Multi Layers.

| sample | Thickness $\text{TiO}_2$ | Thickness Ag | Deposition rate $\text{TiO}_2$ | Deposition rate Ag | Temperature Celsius degree |
|--------|--------------------------|--------------|--------------------------------|--------------------|----------------------------|
| I      | 10 nm                    | 13 nm        | 0.7 A/sec                      | 1.2 A/sec          | 28                         |
| II     | 10 nm                    | 23 nm        | 0.7 A/sec                      | 1.2 A/sec          | 28                         |

## RESULT AND DISCUSSION

Figure 1 shows AFM images, of  $\text{TiO}_2/\text{Ag}/\text{TiO}_2$  nano layer with 10 nm, 13 nm and 10 nm thicknesses respectively for  $5\mu\text{m} \times 5\mu\text{m}$  area. Figure 1(a) shows two dimensional AFM image and figure 1(b) shows three dimensional AFM image of mentioned nano layer. As it can be seen from figure 1 surface is full of titanium dioxide grains with conic silver nano particles between them, silver has sandwiched by titanium dioxide nano layers and because of the nano metric thickness of complete multi layer and glass substrate (very smooth surface) surface is almost smooth and seems homogeneous.

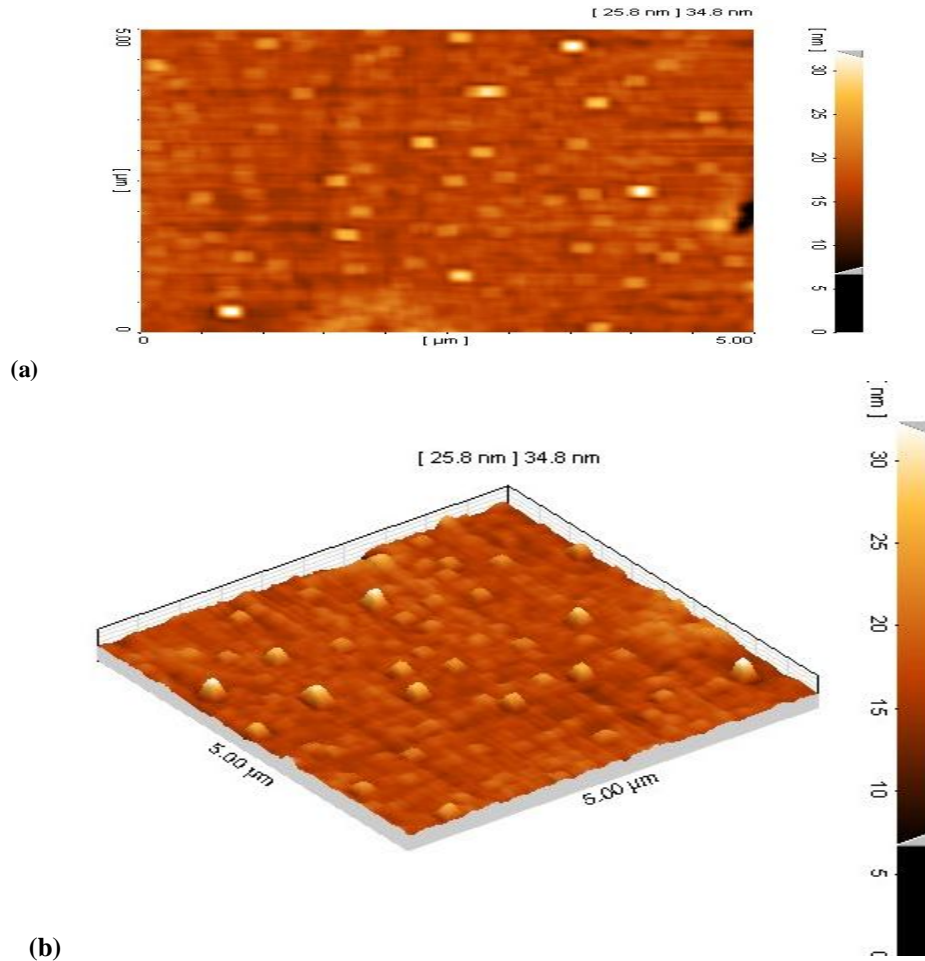


Figure 1. (a) two dimensional and (b) three dimensional, AFM images for sample I.

Figure 2 shows AFM images, of  $\text{TiO}_2/\text{Ag}/\text{TiO}_2$  nano layer with 10 nm, 23 nm and 10 nm thicknesses respectively for  $5\mu\text{m} \times 5\mu\text{m}$  area. Figure 2(a) shows two dimensional AFM image and figure 2(b) shows three dimensional AFM image of mentioned nano layer. As it can be seen from figure 2 by increasing thickness of silver nano particles surface is full of conic silver nano particles that sandwiched between titanium dioxide nano layers and surface shows heterogeneous topography.

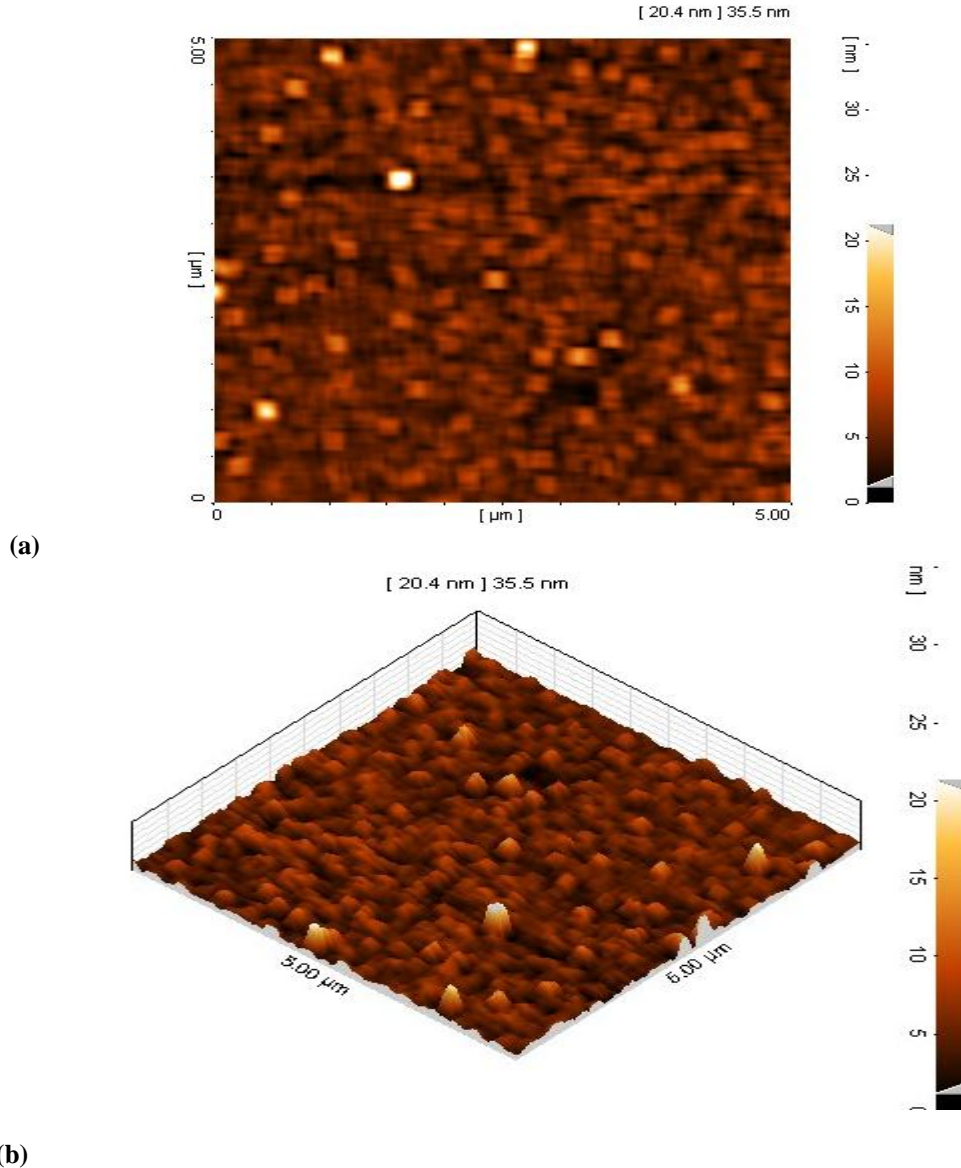


Figure 2.(a) two dimensional and (b) three dimensional, AFM images for sample II.

Figure 3 and figure 4 also show AFM images of produced multi layers in two times bigger area ( $10\mu\text{m} \times 10\mu\text{m}$ ). Figures 3(a) and 4(a) depend to two dimensional AFM images of samples I and II respectively also figures 3(b) and 4(b) depend to three dimensional AFM images of samples I and II respectively. As it can be seen from figures 3(b) and 4(b), by increasing thickness of silver middle layer the morphology of the layer completely changes and there are much more conic grains on surface (fig 4(b)).

Figure 5 shows roughness diagram for the layers produced in this work (samples I and II) in two different areas,  $5\mu\text{m} \times 5\mu\text{m}$  and  $10\mu\text{m} \times 10\mu\text{m}$ . By increasing thickness of silver middle layer in sample II, more voids fill up with silver nano particles that tends to decreasing the roughness of sample II. Figure 6 shows XRD patterns of two produced multi layers in this work. Figure 6(a) depends to XRD pattern of sample I and figure 6(b) depends to XRD pattern of sample II. As it can be seen both of these multi layers

are amorphous and that is because of low temperature of deposition (room temperature) and low thickness of the layers. A wide peak at about 15 degree and noisy patterns depend to amorphous glass substrate. Because of lower thickness of sample I, wide peak at 15 degree that depend to glass substrate is higher and more clear.

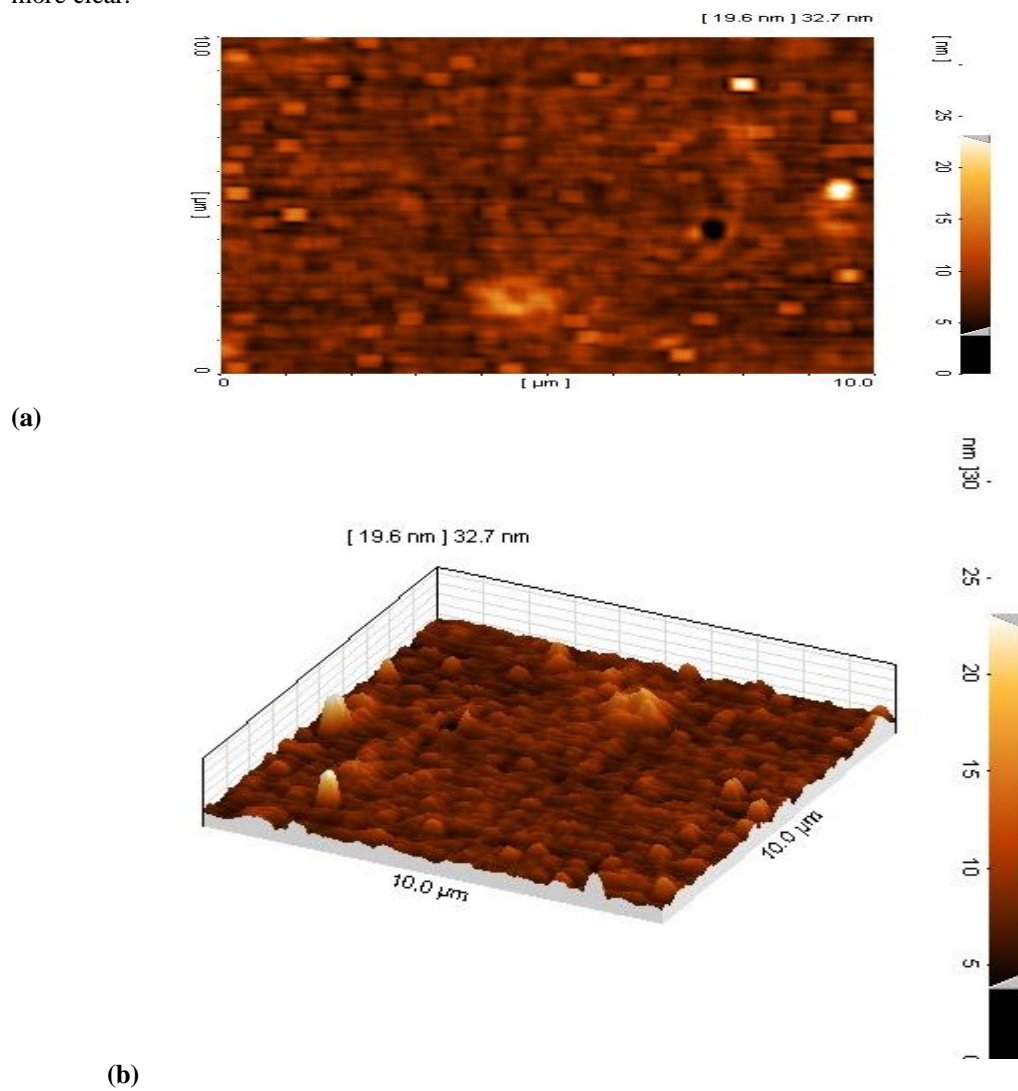
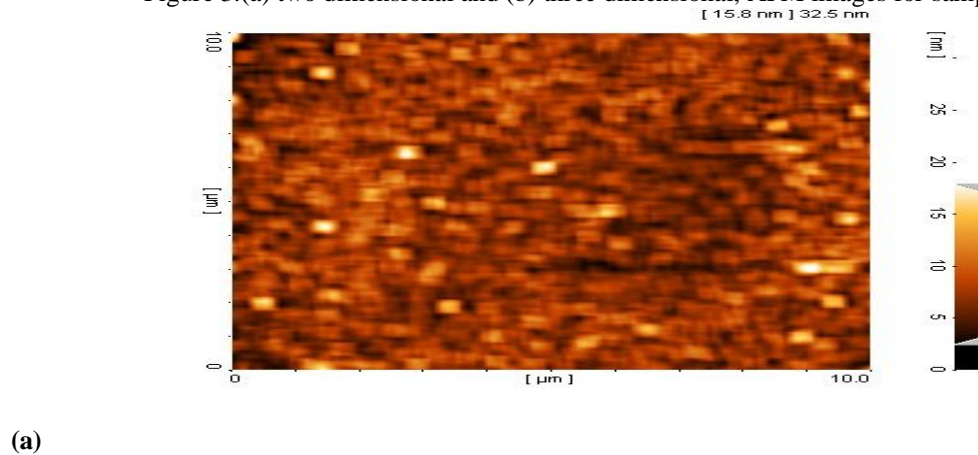


Figure 3.(a) two dimensional and (b) three dimensional, AFM images for sample I.



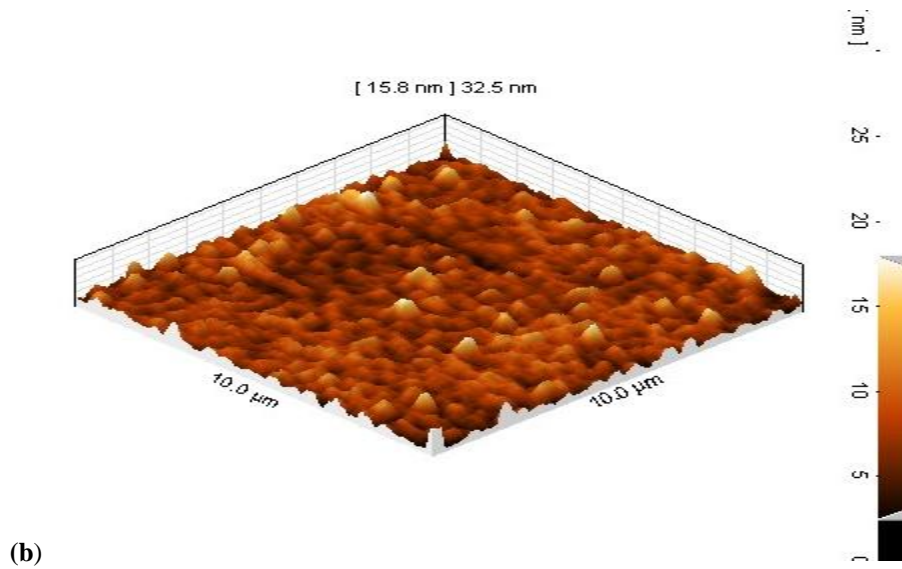


Figure 4.(a) two dimensional and (b) three dimensional, AFM images for sample II.

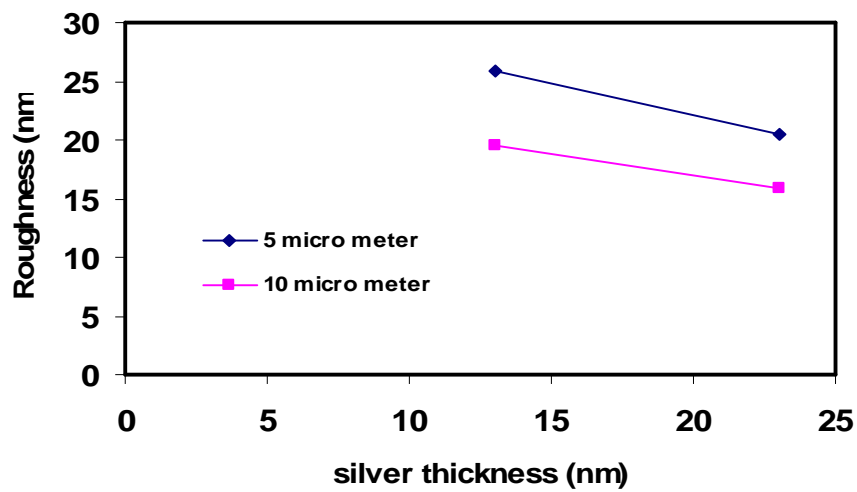


Fig 5. Roughness of samples I and II on two different areas.

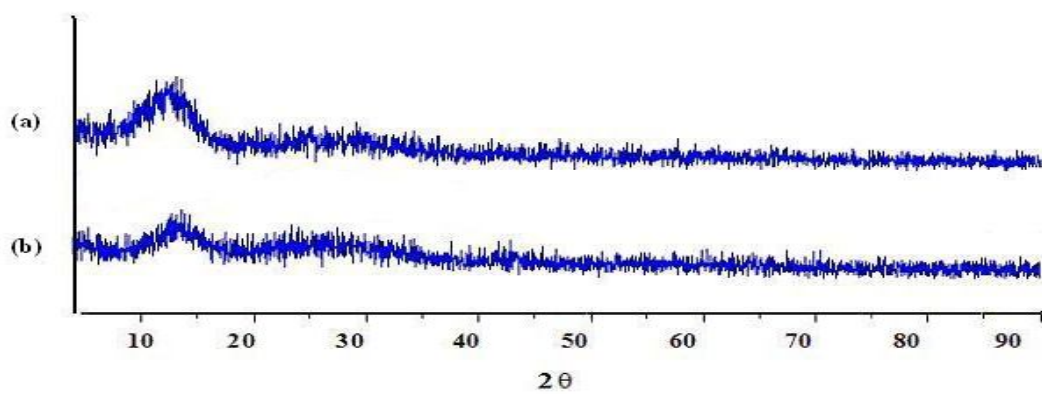


Fig 6. X-Ray diffraction for, (a) sample I and (b) sample II.



Figure 7 shows reflectivity curves of produced multi layers in UV-VIS wave length range. By increasing thickness of silver middle nano layer in sample II, reflectivity curve increases that is because of filling up the voids by more silver nano particles and tends to decreasing transmittance of sample II.

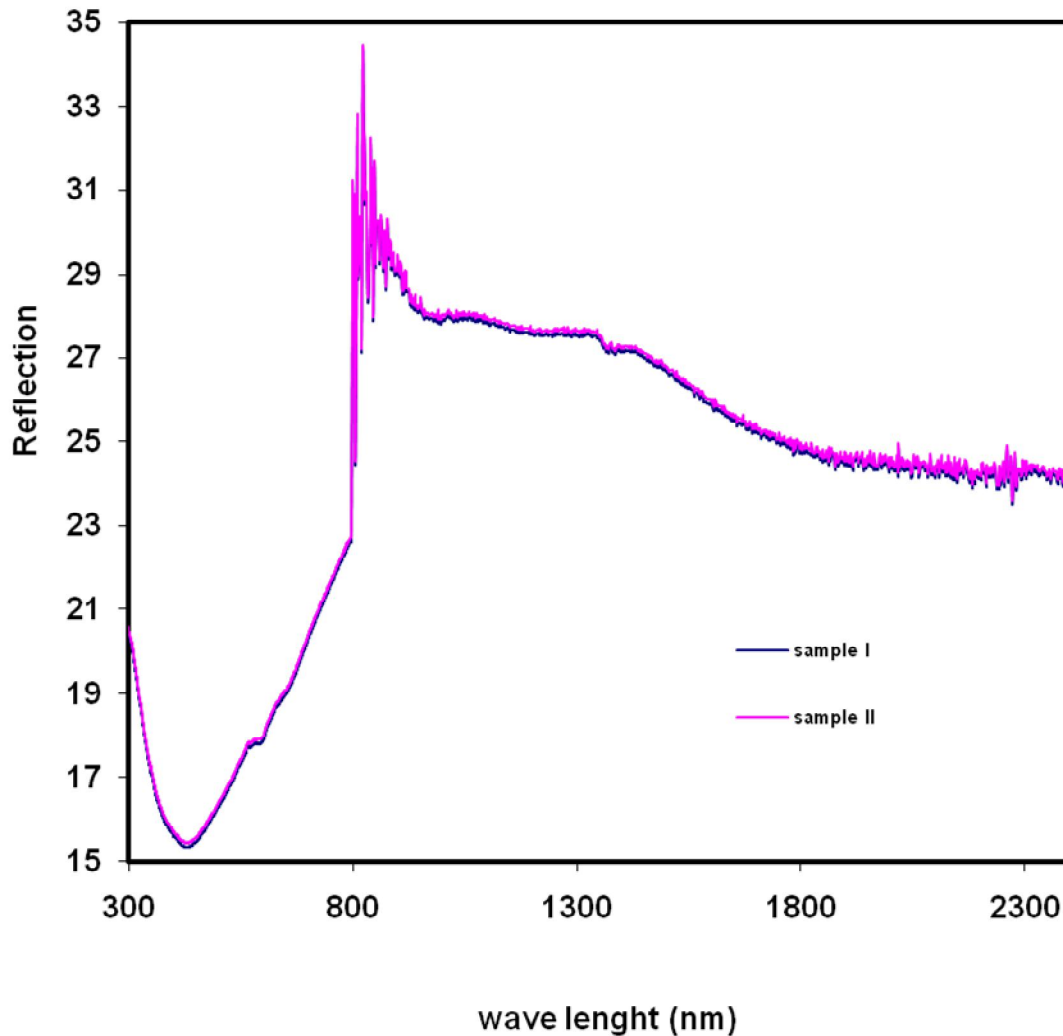


Fig 7. Reflectivity curves for sample I and II.

### Summery

TiO<sub>2</sub>/Ag/TiO<sub>2</sub> nano layers produced in this work, with two different thicknesses of silver middle nano layer ( 13 nm and 23 nm ). TiO<sub>2</sub>/Ag/TiO<sub>2</sub> layers are transparent heat windows with high efficiency to reduce the waste of energy. Two and three dimensional AFM images in two different areas were obtained. By increasing thickness of silver nano particles topography of heat window completely changes and there are more conic grains on surface. Because of filling up the voids by increasing thickness of silver middle nano layers, roughness decreases because of the same reason reflection increases and as it can be seen, heat windows have high transmittance in the visible region. TiO<sub>2</sub>/Ag/TiO<sub>2</sub> nano layers produced at room temperature in this work are amorphous.

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