

OPTICAL PROPERTIES OF BIO-NANO-COMPOSITES OF ALUMINUM OXIDE

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ABSTRACT

Thin layers of Aluminum oxide have been prepared by chemical bath deposition technique from different metallic ion concentrations. The layers were grown on glass substrates. The deposition was performed in alkaline media at 85 °C and pH fixed on 4-5 constant value. optical properties of Nano layers were studied by spectrophotometer analysis in VIS wavelength range. Natural optical properties were obtained by applying Kramers-Kronig relations on reflectivity curves. The optical band gap (E_g), was evaluated from VIS absorption spectra and found to have a mean value of 1.733 eV. Changing ion concentrations affect on all optical properties.

Keywords: Aluminum oxide; spectrophotometer; thin layer; optical properties.

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INTRODUCTION

Alumina thin films have attracted much interest in recent years due to their interesting mechanical and electrical properties and possible applications in several engineering fields [1, 2]. These properties are strongly influenced by the phase composition [3,4]. In most cases, amorphous films are deposited at low temperatures, while metastable and stable crystalline phases require higher deposition temperatures. Usually, crystalline

alumina films tend to be harder than amorphous films therefore the crystalline phases are favored for the application as hard coating [5]. The hardest phase (corundum) is α -Al₂O₃, which has an excellent thermal stability. Chemical bath deposition has become one of the most widely used methods to deposit Al₂O₃ films [6]. Optical properties of thin metal films are determined by spectrophotometric, interferometric, and

spectro ellipsometric methods. Optical constants determined in such calculations are significantly different in various works and, in addition, differ essentially from the corresponding optical constants of massive metals by their values. In this work we used Kramers- Kronig relations applying on reflectivity curve to calculate natural optical properties of Aluminum oxide thin layers.

Experimental details

Aluminum oxide layers were produced by chemical bath deposited on glass substrates. Prior to deposition, the platelets (50mm x 25mm x 1mm) were ultrasonically cleaned with acetone and then alcohol and dried. The details of the procedure are: three different amounts of Aluminum chloride solution and NH₃ were separately prepared. Formed mixtures are thoroughly stirring for several minutes in order to dissolve the formed

precipitate and solutions to become homogeneous. Then in obtaining solutions were added distilled water. These solutions were mixed in a beaker and stirred well for a few minutes. The deposition bath was continuously stirred and heated at 85°C for 1 hour. The substrates were immersed into the deposition bath, by vertically suspending them around the stirrer. The substrates were taken out after 1hour as deposition time. Deposition parameters were: [Aluminum chloride] = 0.01M, 0.015 M and 0.02M; [NH₃] = 0.01 M; pH = 4-5; All samples were annealed in air, at 250°C for half hour. Table I shows the detail of deposited layers produced in this work. The optical constants of our samples were derived on the basis of standard Kramers–Kronig relations using computer techniques.

Table I: Details of produced Al₂O₃ layers by CBD method.

Sample name	[AlCl ₃] Molar Value
1	0.01 M
2	0.015 M
3	0.02 M

RESULTS AND DISCUSSION

In this work Kramers-Kronig relations were used to calculate the phase angle $\theta(E)$ [7]:

$$\theta(E) = -\frac{E}{\pi} \int_0^{E_2} \frac{\ln R(E) - \ln R(E_0)}{E^2 - E_0^2} dE + \frac{1}{2\pi} \ln \left[\frac{R(E)}{R(E_2)} \right] \ln \frac{E_2 + E}{|E_2 - E|} + \frac{1}{\pi} \sum_{n=0}^{\infty} \left[4 \left(\frac{E}{E_2} \right)^{2n+1} \right] (2n+1) \quad (1)$$

where E denotes the photon energy, E_2 the asymptotic limitation of the free-electron

energy, and $R(E)$ the reflectance. Hence, if E_2 is known, the $\theta(E)$ can be calculated.

Then the real and imaginary parts of the refractive index were calculated, from which other parameters were obtained. Figure 1 show Reflectance curves of Aluminum oxide thin layers produced in this work. Gomez optical curves as a reference are added to all optical curves for comparison. The general trend between our data and Gomez data are the same. As it can be seen from figure 1 by increasing Al ion concentration reflectivity has a decreasing trend. That is because of formation more aluminum oxide compounds on substrate. By increasing ion concentration the ratio of oxygen atom to Aluminum atom gets bigger than one, that is because of super saturation property and desorption of Al atoms to chemical solution. There for by increasing ion concentration dilute layers form on substrate. In lower concentrations most area of substrate is covered with Al atoms plus Aluminum oxide compounds, super saturation property tends to desorption of Al atoms.

Figure 2 shows the real part of refractive index for layers produced in this work. As we discussed above by increasing metallic ion

concentration dilute layers configure this tends to decreasing trend for n curves.

In figure 3 we depict the imaginary part of refractive index (k) for the layers produced in this work. By desorbing Al atoms in high concentrations fraction of voids increases there for transmittance increases and extinction coefficient decreases.

Figures 4 and 5 show the real and imaginary parts of conductivity respectively. There are decreasing trend for σ_1 and σ_2 by increasing metallic ion concentration. That is because of high ratio of oxygen and more fraction of voids by on sample 3.

We depict the natural optical band gap in figure 6. By increasing metallic ion concentration, super saturation property and desorption of Aluminum atoms to chemical solution, fraction of voids increases there for absorption coefficient decreases. Also conductivity decreases and dielectric property increases that tends to increasing natural value of band gap. The value of band gap calculated 1.6 eV, 1.7 eV and 1.9 eV for samples 1, 2 and 3 respectively.

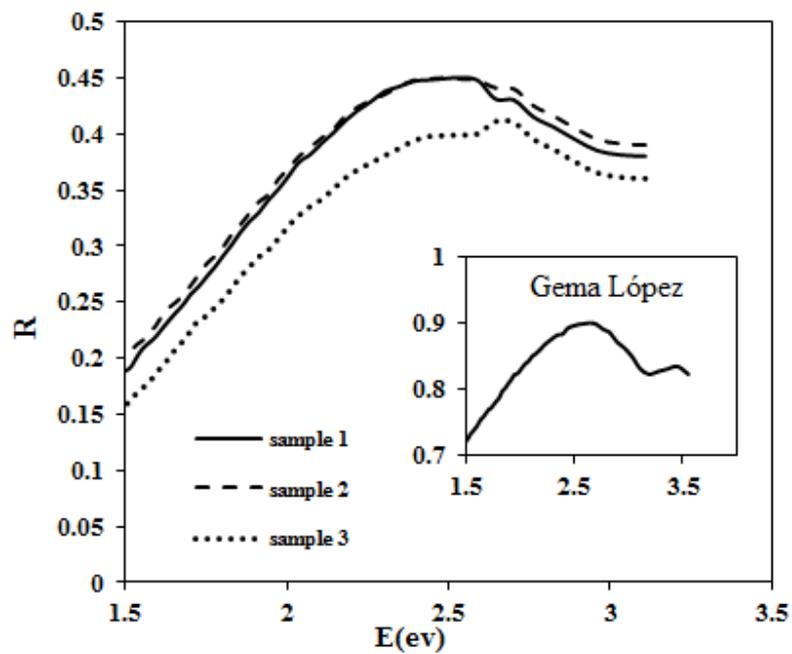


Figure 1: The reflectance of aluminum oxide layers produced by CBD method at different metallic ion concentrations.

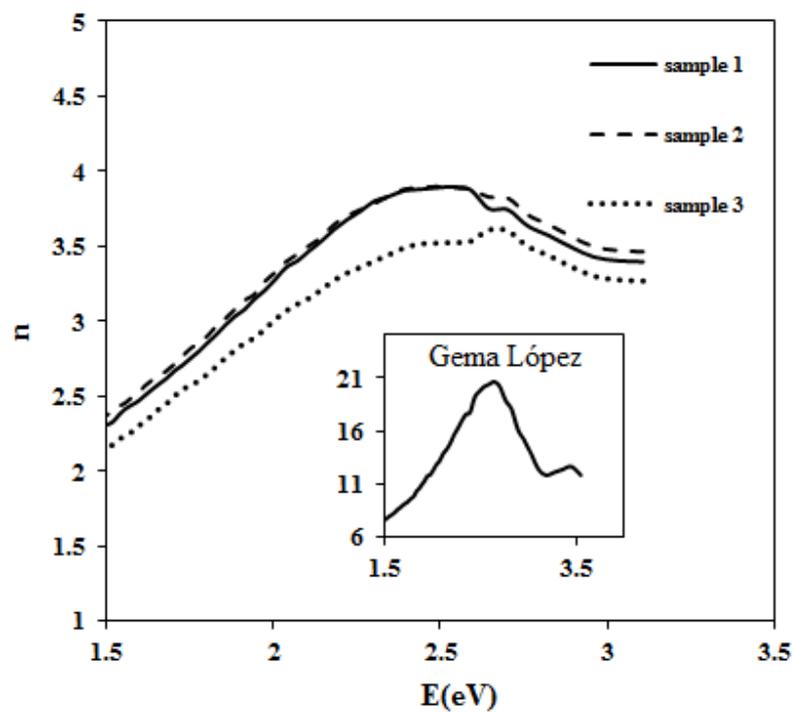


Figure 2: The real part of refractive index of aluminum oxide layers produced by CBD method at different metallic ion concentrations

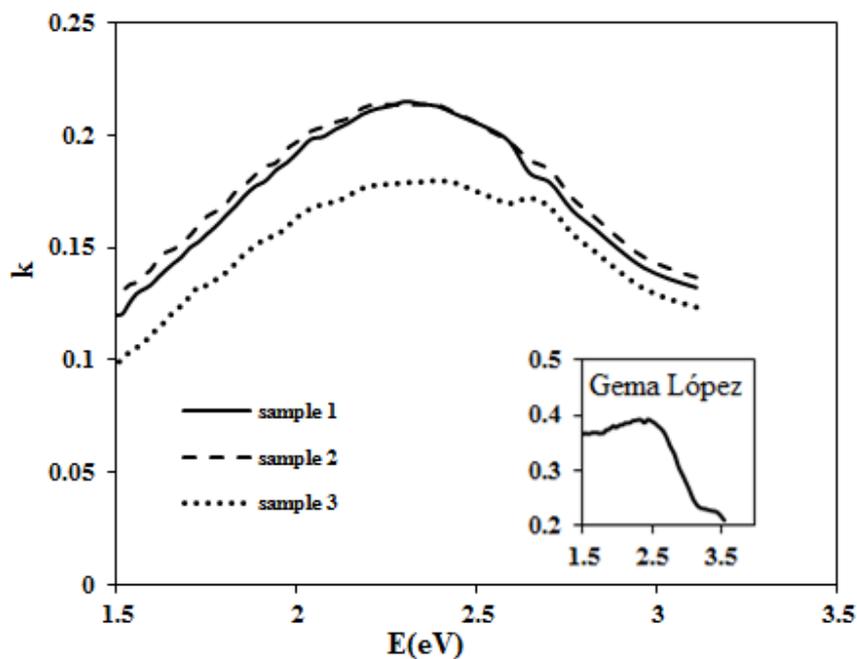


Figure 3: The imaginary part of refractive index of aluminum oxide layers produced by CBD method at different metallic ion concentrations

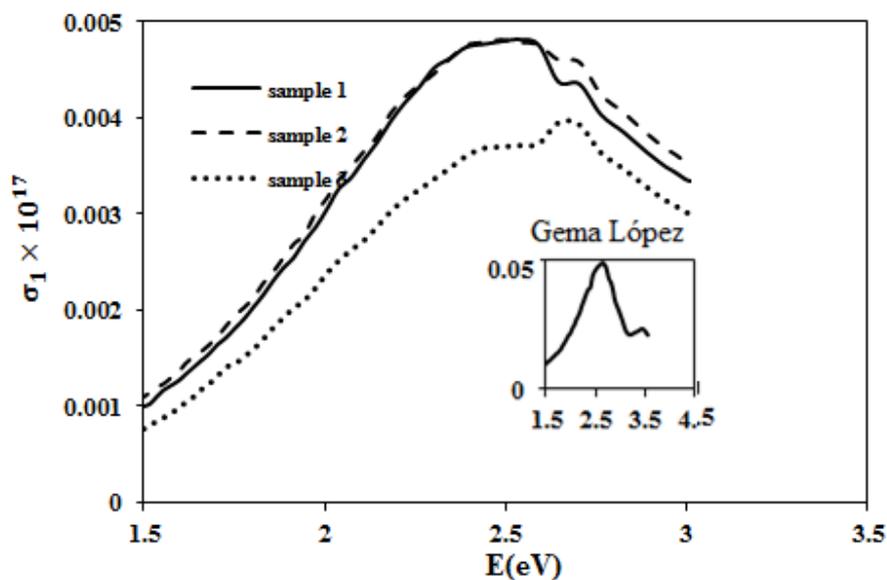


Figure 4: The real part of conductivity index of aluminum oxide layers produced by CBD method at different metallic ion concentrations.

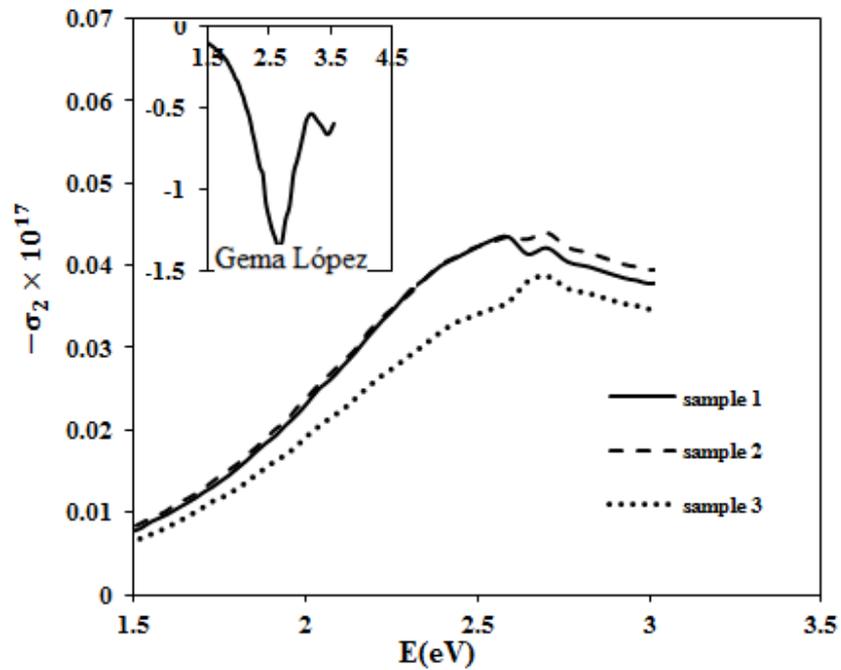


Figure 5: The imaginary part of conductivity index of aluminum oxide layers produced by CBD method at different metallic ion concentrations

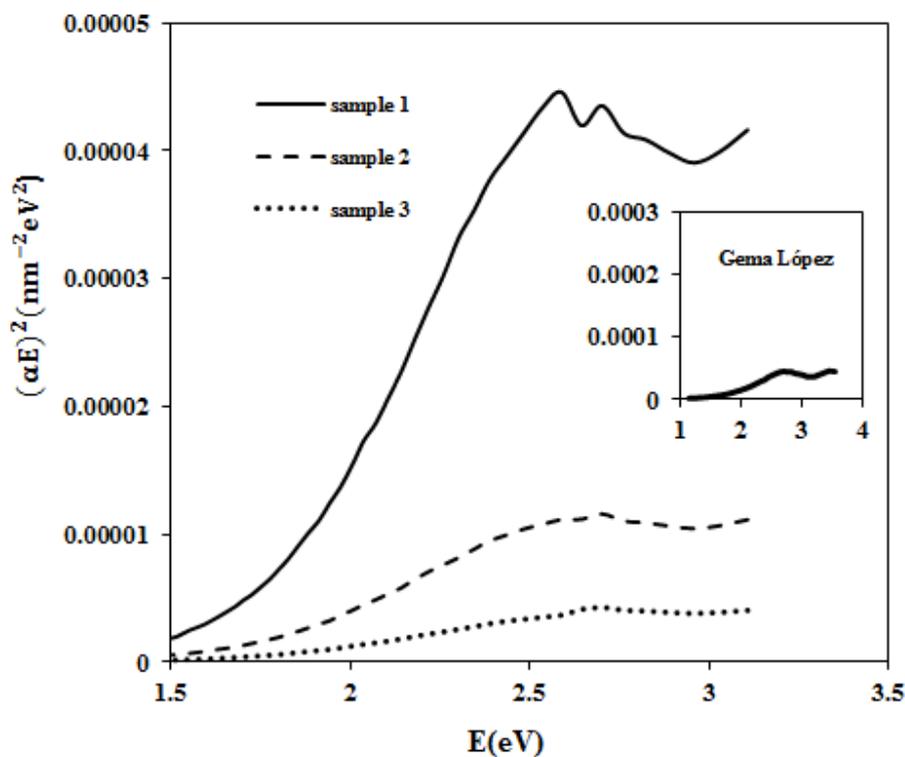


Figure 6: The values of band gap energy of aluminum oxide layers produced by CBD method at different metallic ion concentrations

CONCLUSION

Thin layers of Aluminum oxide have been prepared by chemical bath deposition technique from different metallic ion concentrations. The layers were grown on glass substrates. The deposition was performed in alkaline media at 85 °C and pH fixed on 4-5 constant value. Optical properties of Nano layers were studied by spectrophotometer analysis in VIS wavelength range. Natural optical properties were obtained by applying Kramers-Kronig relations on reflectivity curves. By increasing ion concentration the ratio of oxygen atom to Aluminum atom gets bigger than one, that is

because of super saturation property and desorption of Al atoms to chemical solution. There for by increasing ion concentration dilute layers form on substrate. In lower concentrations most area of substrate is covered with Al atoms plus Aluminum oxide compounds, super saturation property tends to desorption of Al atoms. Reflectivity, n , k , $\bar{\sigma}_1$ and $\bar{\sigma}_2$ decreases. The optical band gap (E_g), was evaluated from VIS absorption spectra and found to have a mean value of 1.733 eV. Changing ion concentrations affect on all optical properties.

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