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Dielectric Properties and Crystal Structure of Aluminum Oxide (Al_2O_3) at Different Molar

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Abstract: In this work preparing Al_2O_3 samples were prepared by the sol-gel method with different molar (0.1, 0.2 and 0.3M). The optical properties of the (Al_2O_3) samples were investigated. In particular, optical parameters such as the optical band gap, absorption coefficient, refractive index and extinction coefficient, real and imaginary dielectric constant were comprehensively studied. A number of samples were prepared by Sol-gel method. It is found that the optical absorbance wavelength range was (370–390) nm. Also the morphology characteristics of crystal structure of samples have been investigated by XRD and using optical method to investigate the electrical properties; and the results were as follow: the existence of the (022) at 34.87^O, (111) at 38.35^O, (202) at 45.23^O, (020) at 54.53^O, (113) at 58.59^O and (311) at 61.48^O
Major lattice planes in the XRD patterns confirms the formation of spinal Monoclinic, Miller indices provided in the figure and all peaks determine transformation of dried .The results indicate the sample have good characteristics for optoelectronic applications.

Keywords: Aluminum Oxide, Sol-gel method, reail and imajanery dielectric constant, optical and electrical conductivity

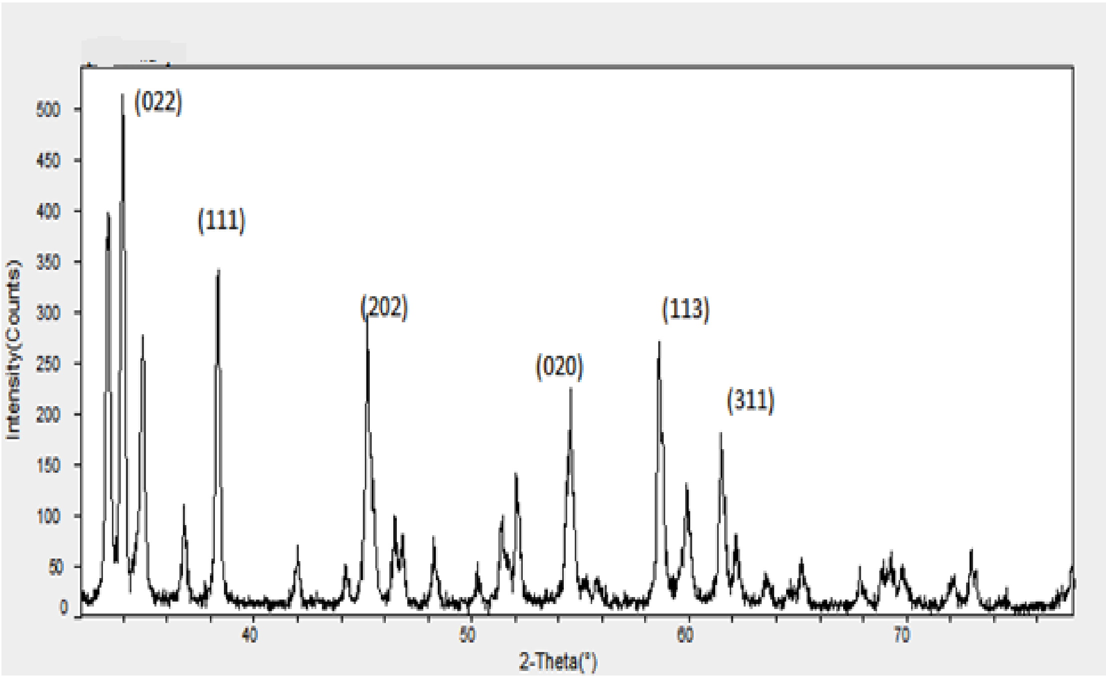
Introduction

Transparent conducting oxides (TCOs) are electrical conductive materials with a comparably low absorption of light. (TCO) samples have emerged as excellent candidates due to interest in their promising applications in next-generation electrode. A wide variety of transparent conductors in terms of new materials are becoming available that could serve as an alternative to ITO [1]. ITO is one of the best transparent conductors, but indium is quite expensive [2]. The electrodes fabricated utilizing TCO samples in optoelectronic devices have excellent physical properties of high visible transmittance, low resistivity, high infrared reflectance, and large absorbance [3]. Because Al_2O_3materials are large-band-gap semiconductors with peculiar physical properties of high chemical stabilities and large excitons binding energies, they are of current interest due to their potential applications in optoelectronic devices, such as photo detectors, solar cells, light-emitting diodes, and laser diodes. Low-resistivity Al_2O_3samples may be realized by using several dopants, such as, Ga, and in of the group III [4]. Aluminum doped zinc oxide (AZO) coatings exhibit high transparency and low resistivity and these materials are suitable for fabricating transparent electrodes in solar cells, gas sensors and ultrasonic oscillators. They are also found in applications such as surface acoustic devices, optical waveguides and micro-machined actuators. They are an alternative material to tin oxide and indium tin oxide, which has been most, used up to date [4]. For the most used (ITO) as a transparent conducting oxide which has transmittance (≥90%), low specific resistance (≤10-3 Ω/cm) in the visible rays area, so it is used as the transparent electrode of the solar cell, display fields widely. But the raw materials of ITO are expensive, and it has weak point of the degradation phenomenon and toxicity when it is exposed in the hydrogen plasma [4-2]. Ohyama reported that the use of 2-methoxyethanol and mono ethanolamine, solvents with high boiling point, resulted in transparent Al_2O_3 samples with strongly preferred orientation and that better electrical and optical properties had been obtained in 0.5 at. % aluminum doped ZnO thin films heated in reducing atmosphere. Nunes found that when the doping concentrations of Al, in and Ga were 1, 1 and 2 at %, respectively, electrical and optical properties of doped ZnO were superior [2]. Various techniques such as molecular beam epitaxial (MBE) [6], pulse laser deposition (PLD) [7], magnetron sputtering [8], chemical vapor deposition (CVD) [9], atomic layer deposition [10], electron beam evaporation [11], hydrothermal method , and sol-gel process have been applied to ZnO thin film preparation[11]. The sol-gel method has distinct potential advantages over these other techniques owing to its lower crystallization temperature, low cost, simple deposition procedure, easier compositional control, ability to tune the microstructure via sol-gel chemistry, and large surface area coating capability.

Material & Method

The precursors used in the synthesis Al_2O_3 by sol-gel process Aluminum nitrate dehydrate Al $(NO_3)_3.9H_2O$. The need for surfactant is fulfilled by the use of 2-methoxyethanol (ME) $CH_3OCH_2CH_2OH$. The stock solution for the samples was prepared using Aluminum nitrate (0.1M, 0.2 M and 0.3 M) dissolved in 300 ml of ethanol in the glass beaker. Then the solution was stirred for 60 min at 80°C until we get milky solution. Drops from 2-methoxyethanol (ME) was added to the solution as stabilizer to get a transparent solution. We get then the Aluminum-oxide solution. And then kept the Aluminum oxide solution at lab's temperature about 24 hours, then we filter it, and we obtained the Sol ready to be used the samples. After prepared the samples, they were ready for characterization. The molar of the (Al_2O_3) sample were about (0.1 M, 0.2 m and 0.3 M) for all samples. The optical transmittance and reflectance of the (Al_2O_3) samples were measured as a function of wavelength by UV-visible spectroscopy, and other optical constant was calculated. The crystal structure of all samples characterized at room temperature using a Philips PW1700 X-ray diffract meter (operated at 40 kV and current of 30 mA) and samples were scanned between 20o and 90o at a scanning speed of 0.06 ^{o}C/s using Cu Kα radiation with λ = 1.5418Å .

Results



Fig(1): The XRD charts of the (Al_2O_3) sample

Table (1) some crystallite lattice parameter
(size , Miller indices and d – spacing) of the (Al_2O_3) sample

2-Theta	X_s (nm)	d(nm)	h	k	L
34.87	32.4	0.257	0	2	2
38.35	42.8	0.235	1	1	1
45.23	33.7	0.200	2	0	2
54.53	31.9	0.168	0	2	0
58.59	33.2	0.157	1	1	3
61.48	38.9	0.151	3	1	1

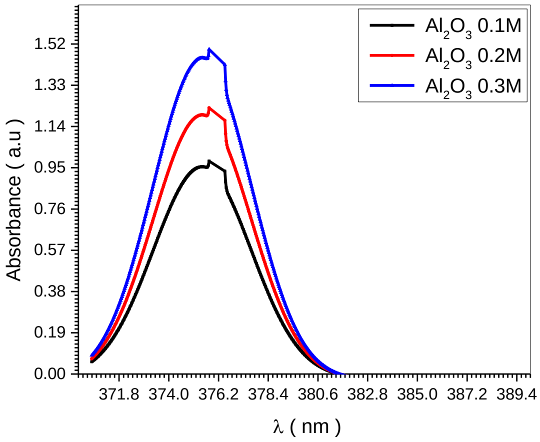


Fig (2):The relation between absorbance and wavelengthsof three (Al_2O_3)samplesin different molar (0.1M,0.2 M and 0.3M)

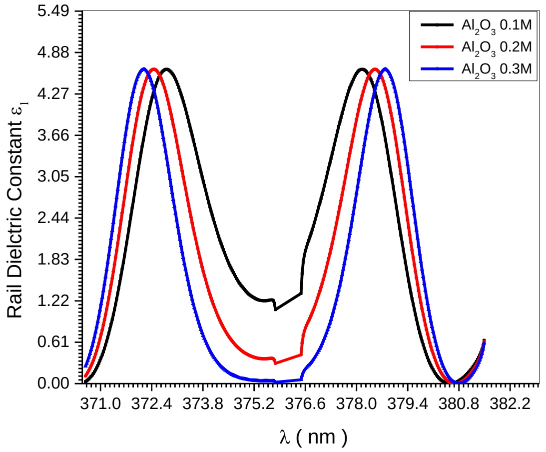


Fig (3):The relation between reail dielectric constant and wavelengthsof three (Al_2O_3)samplesin different molar (0.1M,0.2 M and 0.3M)

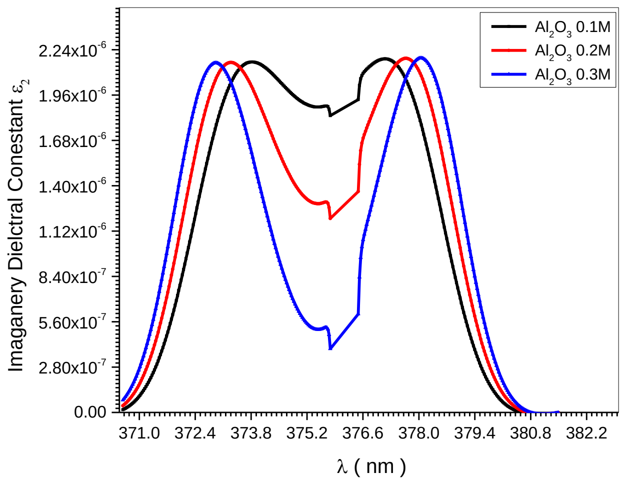


Fig (4):The relation between imagnery dielectric constant and wavelengthsof three (Al_2O_3)samplesin different molar (0.1M,0.2 M and 0.3M)

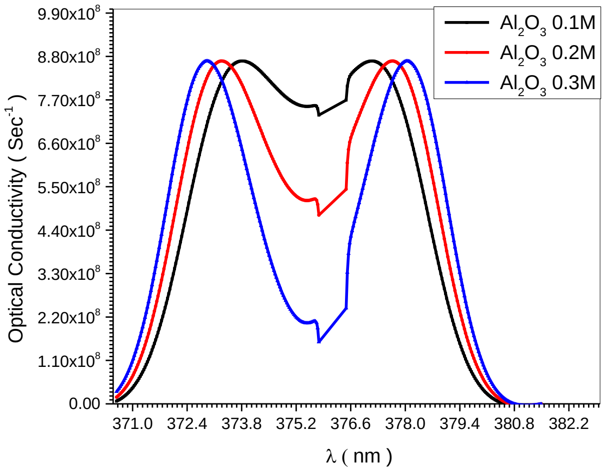


Fig (5):The relation between optical conductivity and wavelengthsof three (Al_2O_3)samplesin different molar (0.1M,0.2 M and 0.3M)

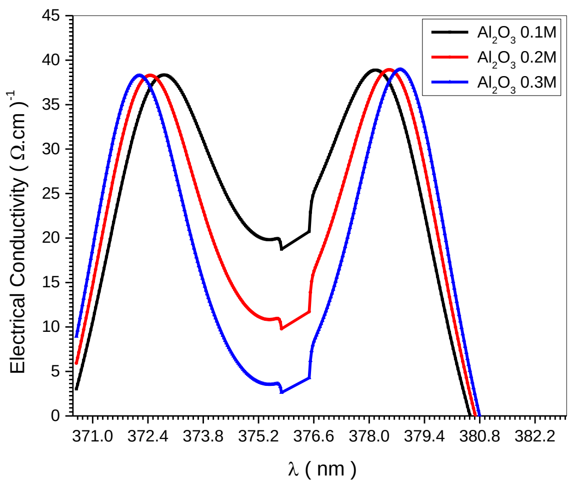


Fig (6):The relation between electrical conductivity and wavelengthsof three (Al_2O_3)samplesin different molar (0.1M,0.2 M and 0.3M)

Conclusion & Discussion

The X-ray diffraction patterns of the synthesized of (Al_2O_3) nano-crystals have been shown in Fig (1). The existence of the (022), (111), (202), (020), (113) and (311) major lattice planes in the XRD patterns confirms the formation of spinal Monoclinic, Miller indices provided in the figure and all peaks determine transformation of dried ((Al_2O_3) crystallites with Monoclinic retile crystal structure. Table (1), shows the XRD parameters of (Al_2O_3) nanocrystals at various crystalline orientations. In fig. (2) Shows the relation between absorbance and wavelengths for three samples of (Al_2O_3), the rapid increase of the absorption at wavelengths ranged (370 -390 nm). The effects of Aluminum Oxide (Al_2O_3)molar in the absorbance value increased when the molar increase, also in fig (2) show that the maximal value at 375 nm wavelength. Real Dielectric Constant (ε_1)shows in fig(3) the variation of the ealdielectric constant (ε_1) with wavelengthof three samplesin different molar (0.1M,0.2 M and 0.3M)thatprepared by Aluminum Oxide (Al_2O_3) which calculatedfrom the relation:

$$\varepsilon_1 = n^2 - k^2$$

Where the real the dielectric (ε_1) is thenormal dielectric constant .From fig (3)the variation of (ε_1) is follow therefractive index, where increased in theregion that λ >371 nmforall Aluminum Oxide (Al_2O_3) and 376 nm , where theabsorption of the samples for thesewavelength is small, but the polarizationwas increase. The maximum value of (ε_1)equal to (4.66) for all samples at diefferant wavelengthnear. The effect of treetetment by (Al_2O_3) molar increased when (ε_1)decreased at wavelength 375.5 nm . But the imaginary dielectric constant (ε_2)vs(λ) was shown in fig(4) this valuecalculated from the relation:

$$\boldsymbol{\varepsilon}_2 = 2Nk$$

(ε_2) represent the absorptionassociated with free carriers.Asshown in fig(4) the shape of (ε_2)is thesame as (ε_1), this means that therefractive index was dominated in thesebehavior . The maximum values of (ε_2)are different according to the tratmentoperation , so The maximum value of (ε_1)equal to (4.66) for all samples at diefferant wavelengthnwhile the maximum value of (ε_2) equal to (2.19×10^{-6}) for all samples at diefferant wavelengthn, these behavior may by related tothe different absorption mechanism forfree carriers.

Electrical and Optical Conductivity :The optical conductivity is a measure of frequency response of material when irradiated with light which is determined using the following relation:

$$\delta_{opt} = \frac{\alpha nc}{4\pi}$$

Where(c) is the light velocity. The electrical conductivity can be estimated using the following relation:

$$\delta_{ele} = \frac{2\lambda\delta_{opt}}{\alpha}$$

The high magnitude of optical conductivity (8.73×10^{8} sec^{-1}) confirms the presence of very high photo-response of three (Al_2O_3)samplesin different molar (0.1M,0.2 M and 0.3M). The increased of optical conductivity at high photonenergies is due to the high absorbance of elevant samples prepared by (Al_2O_3)different molar (0.1M,0.2 M and 0.3M) formand may be due to electron excitation by photon energy as it is shown in Figs (5) and (6) .

So it is obvious that these treatments for thin film give a best optical property to be used for optoelectronic applications.

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