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STUDY OF OPTICAL PROPERTIES OF INDIUM OXIDE (In_2O_3) THIN FILMS

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ABSTRACT

Thin films of Indium Oxide (In_2O_3) are prepared by thermal evaporation technique in high vacuum (10^{-6} Torr) onto glass substrate. The films are annealed in open air for half an hour at a temperature 573^0K The optical properties of In_2O_3 for as-deposited and annealed films are studied in the wave length of 300 to 3000 nm. The films are transparent in the visible region. The films have low reflectance, high absorbance and high optical conductivity in the ultraviolet region. The transmittance increase but reflectan absorbance and optical conductivity decrease after annealing. The band gap of the films is about 3.15 eV.

Keywords : Thin films, vacuum deposition, optical properties.

1. INTRODUCTION

The contribution of thin films technology [1-3] make the present world a global village. Thin films technology is an important special branch of physics in which the characteristics of different metals, semiconductors and insulators are investigated in thin films form. It is very important to know the characteristics of metals, semiconductors and insulators in thin films form because the characteristics of thin films are quite different from their bulk values and most of the electronics equipments in the modern world are the contribution of thin films technology. The technological importance of thin films is reflected in the fundamental study of their physical properties. The search for new material to satisfy the practical demand and the use of electronic and optical devices has stimulated considerable interest in the growth and understanding of optical properties of Indium Oxide (In_2O_3) thin films. The study of the optical properties of thin films is in particular interest because of their use in optical devices [4-5] and oxide films have been used for microelectronics applications and surface coating of optical and electrical materials [6-8]. The investigation of the optical properties is useful way of studying the optical induced transition and for providing essential information about the band structure and the energy gap in crystalline and amorphous materials. The aim of the present paper is to study the transmittance, reflectance, absorbance, extinction coefficient, refractive index, dielectric constant, optical conductivity and band gap of In_2O_3 thin films.

2. EXPERIMENTAL

The films of Indium Oxide (In_2O_3) were prepared by thermal evaporation technique using Edwards E-306A high vacuum coating unit [9-11]. Resistively heated Molybdenum (Mo) source in the form of boat was used for evaporation of In_2O_3. Well shaped mask was placed on the substrate of which film was grown and the substrate-mask couple was clamped with the holder about 7 cm apart from the source. When the required vacuum was obtained (~10^{-6} Torr), then the source was heated by passing current of about 18 ampere through the source. The evaporation of In_2O_3 was started after a certain period of time. A shutter was placed between the source and the substrate and it was removed when the evaporation of In_2O_3 seemed to be uniform. Varying the deposition time, chamber pressure, source to substrate distance and source temperature, different thickness of films were prepared. The films were placed on furnace and heated at a constant temperature of 573^0K in open air to investigate annealing effect. Then the films were normally cooled in open air and the optical properties were measured and compared with normally deposited films. PERKIN ELMER LAMBDA-19 UV/VIS/NIR spectrophotometer was used for optical measurement of In_2O_3 thin films. It was a double-beam, double-monochromator optical system. Holographic gratings were used in each monochromator for the ultraviolet/ visible/ near infrared (UV-VIS-NIR) range. The transmittance and reflectance were measured at normal incidence for the $300 \leq \lambda \leq 3000$ nm range with reference to glass using an integrating sphere detecting system. The absolute reflectance was measured by using

UV-3100 spectrophotometer in the range $300 \leq \lambda \leq 3000$ nm. Knowing the film thickness and transmittance at the corresponding wavelength determined absorption coefficient, extinction coefficient, refractive index, dielectric constant and optical conductivity.

3. RESULTS AND DISCUSSION

The films of In_2O_3, thickness 90 nm, 118 nm and 142 nm are prepared onto glass substrate at a pressure of about $6x10^{-6}$ Torr for studying the optical properties of In_2O_3 films. The measurements for both the as-deposited and annealed films are obtained at room temperature in the wavelength of 300 to 3000 nm. The variation of transmittance and reflectance with wavelength for as-deposited and annealed films of different thickness are shown in Figure 1(a & b) and 2(a & b) respectively.

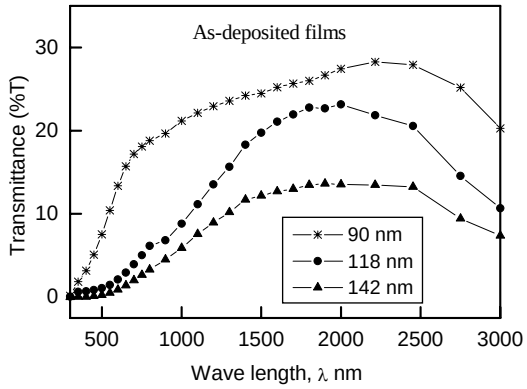

Fig 1(a). Variation of transmittance with wave length for as-deposited films of different thickness.

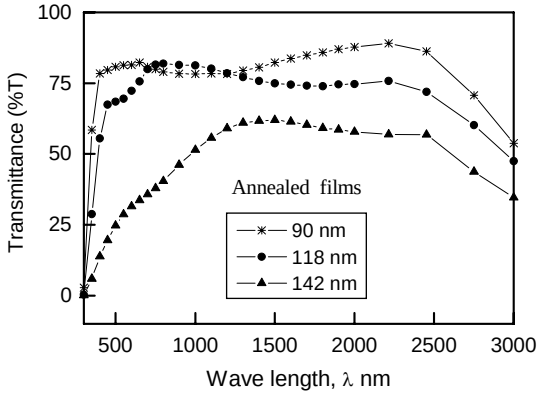

Fig 1(b). Variation of transmittance with wave length for annealed films of different thickness.

It is seen from the graph of Figure 1 that the value of transmittance is low in the ultraviolet region. In the visible region, the transmittance is high whereas it decrease in the near-infrared region. It is also observed from the graph of Figure 2 that the value of reflectance is low in the ultraviolet region and increase in the visible region. After annealing, the transmittance increase but the reflectance decrease. Also the transmittance and reflectance decrease with the increase of films thickness.

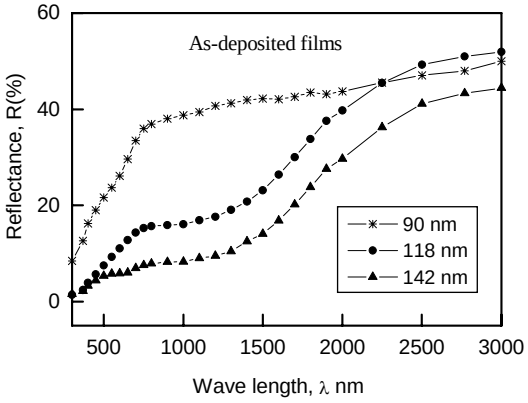

Fig 2(a). Variation of reflectance with wave length for as-deposited films of different thickness.

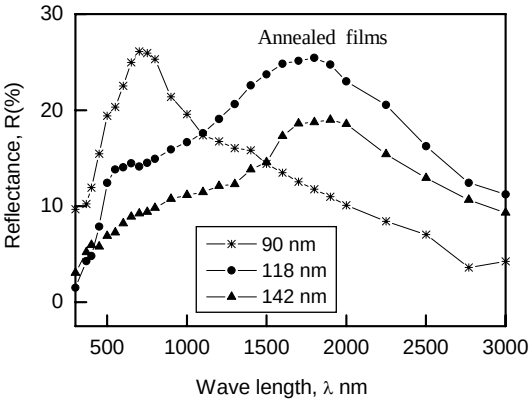

Fig 2(b). Variation of reflectance with wave length for annealed films of different thickness.

The variation of absorbance and extinction coefficient with wavelength for as-deposited films of different thickness are shown in Figure 3 and 4 respectively. The absorbance is very high in the ultraviolet region whereas its value decrease in the visible and near-infrared region as shown in Figure 3. It is also observed from the graph of Figure 4 that the value of extinction co-efficient is low in the ultraviolet region and high in the near-infrared region. The absorbance and extinction co-efficient decrease after annealing. Figure 5 and 6 show the variation of refractive index and dielectric constant with wavelength for as-deposited films of different thickness. The value of refractive index and dielectric constant are low in the ultraviolet region and gradually increase with wavelength from the visible region to the near-infrared region. These values decrease after annealing.

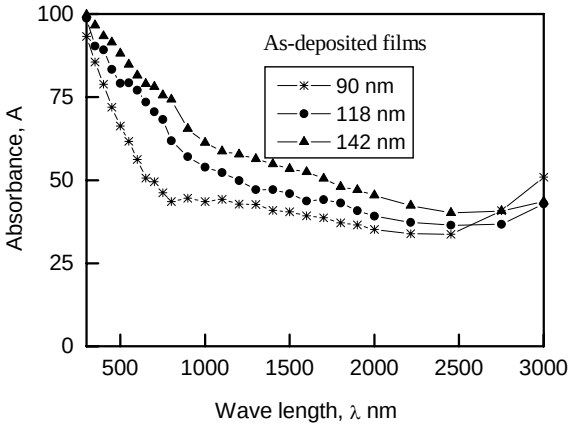

Fig 3. Variation of absorbance with wave length for as-deposited films of different thickness.

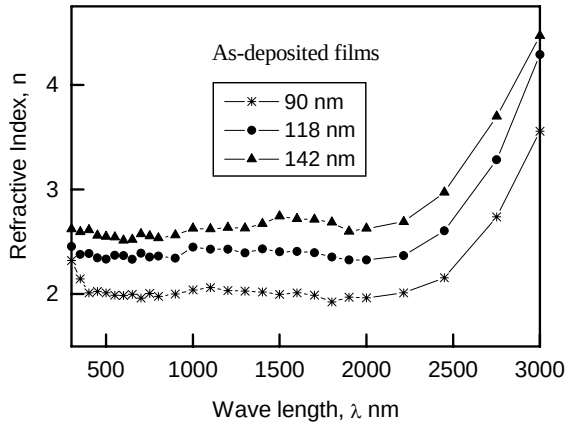

Fig 4. Variation of extinction coefficient with wave length for as-deposited films of different thickness.

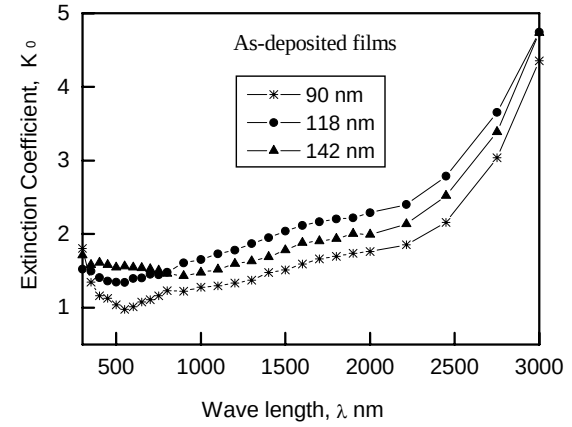

Fig 5. Variation of refractive index with wave length for as-deposited films of different thickness.

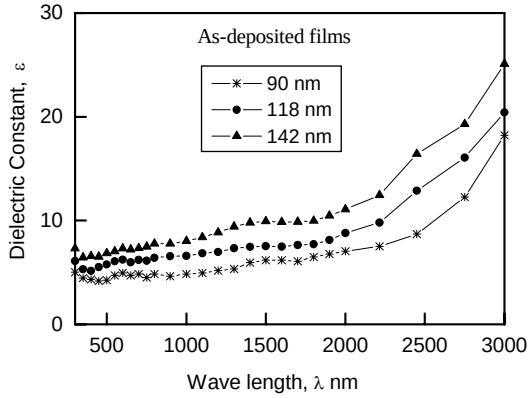

Fig 6. Variation of dielectric constant with wave length for as-deposited films of different thickness.

The variation of optical conductivity with wavelength for as-deposited films of different thickness is shown in Figure 7. It is observed that the value of optical conductivity is very high in the ultraviolet region, almost constant in the visible region and increased in the near-infrared region. Optical conductivity decrease after annealing. The plot of $(Kh\nu)^2$ vs. $(h\nu)$ for direct allowed transition of different films thickness is shown in Figure 8. The value of energy gap is evaluated from the graph of Figure 8 and is found to be ~3.15 eV. This suggest that In_2O_3 is a direct band gap material. The band gap increase after annealing.

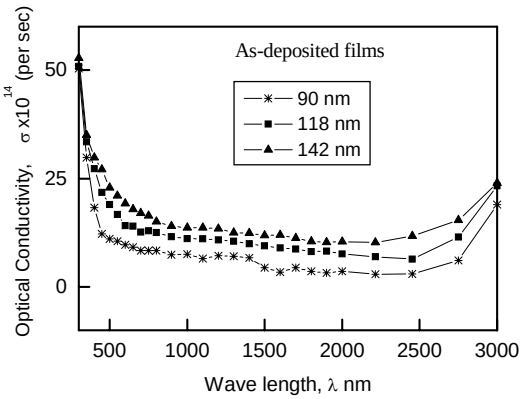

Fig 7. Variation of optical conductivity with wave length for as-deposited films of different thickness.

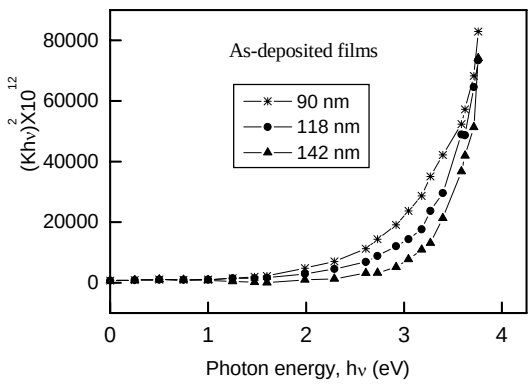

Fig 8. Variation of $(Kh\nu)^2$ with photon energy for as-deposited films of different thickness.

4. CONCLUSIONS

The film of In_2O_3 is transparent in the visible region. It has a low reflectance and extinction co-efficient but a high absorbance in the ultraviolet region. The value of refractive index lies between 2.52 to 4.75 and dielectric constant lies in the range 5.51 to 25.52 for as-deposited films. The optical band gap of the film is direct. The optical conductivity is very high in the ultraviolet region. This value is found to be 10^{14} per sec. The transmittance and optical band gap increase but reflectance, absorbance, extinction coefficient, refractive index, dielectric constant and optical conductivity decrease after annealing. Also these values vary with thickness.

5. ACKNOWLEDGEMENT

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