A Brief Review and Investigations on CDO, In2O3 and Cadmium Indate Films

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Abstract: — This paper deals with the brief investigations on cdo, indium oxide, cadmium indicate films formed at different Oxygen partial pressures, different substrate temperatures and different substrate bias voltages and its significant impact on physical characters tics were studied and also examined their optical, Electrical properties ,chemical composition using XPS and their crystallographic structure using X -ray diffraction were studied.

Introduction:

The current experiment used dc magnetron sputtering techniques to try to make cadmium indate ($CdIn_2O_4$) films as well as binary indium oxide (In_2O_3) and cadmium oxide (CdO) films. Other sputtering factors, such as oxygen partial pressure, substrate temperature, and substrate bias voltage, have a significant impact on the physical characteristics of the formed films in addition to sputtering pressure and power. The experimental films were deposited at different substrate temperatures, partial pressures of oxygen, and bias voltages. X-ray photoelectron spectroscopy and energy dispersive X-ray analysis were used to investigate the chemical composition of the deposited films. The crystallographic structure of the film was investigated using X-ray diffraction. The electrical resistance and Hall mobility of the films were measured using standard techniques. The optical properties of the films, such as optical absorption coefficient, optical band gap refractive index, and optical transmittance and reflectance, were investigated using the spectrophotometric method.

Indium oxide films:

By sputtering an indium target in the presence of reactive oxygen and argon sputtering gas, indium oxide (In_2O_3) films were deposited on gas substrates. The sputter parameters used during the film deposition were an oxygen partial pressure of 5×10^{-5} - 5×10^{-4} mbar, substrate temperatures of 303 and 473, and a substrate bias voltage of 0 to -100V.

The deposition rate of the films decreased from 20 to 8 nm/min as the oxygen partial pressure increased from 5 10-5 to 2 10-4 mbar, while at higher pressures it remained nearly constant. The films formed at an oxygen partial pressure of 2×10^{-4} mbar were stoichiometric, with an atomic ratio of oxygen to indium of 1.49, according to X-ray photoelectron spectroscopy studies. Further research was conducted on films formed at an oxygen partial pressure of 2×10^{-4} mbar and various substrate voltages ranging from 0 to -100 V. The iron bombardment on the substances had a significant impact on the growth of the films. The films formed without any bias at room temperature (303 K) were amorphous in nature. As the substrate voltage increased the crystallinity of the films also improved.

Ion collisions on the substrate caused by negative bias voltage had the same effect as substrate heating. Substrate heating and biassing significantly improved the physical properties. In contrast to the amorphous phase present in the room temperature deposited films, the films formed at 473 k and without any bias voltage were polycrystalline with bixbyite structure and the presence of (220), (400), and (622) orientations. The films' lattice parameters increased from 1 0080 to 1 0122 nm, and the grain size increased from 15 to 23 nm as the substrate bias voltage increased from 0 to -80 V. With increasing substrate bias voltage from 0 to - 100 V, the electrical resistivity of the films decreased from 6 × 10-3 to 108 $\times 10^{-3}$ cm, Hall mobility increased from 8 to 12 cm^2/V. sec, and electron density increased from 1.3 1020 to 2.9 1020 cm^{-3}. The electrical properties improved significantly as a result of biasing and heating the substrate.

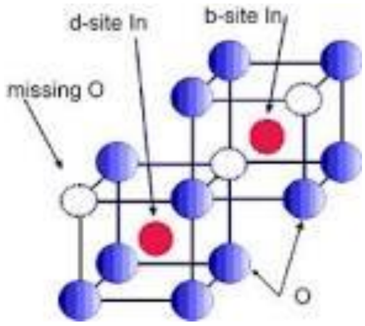

Fig. 1. Indium oxide structure

The optical transmittance of films formed at 473 K increased from 77 to 85% as the substrate bias voltage was increased from 0 to - 100 V. The optical absorption Edge of the films shifted to the shorter wavelength side as the substrate bias voltage increased. The optical band gap of the films increased from 3.70 to 3.78 eV as the substrate bias voltage was increased from 0 to - 100 V. The figure of merit is a quantity used to assess the quality of transparent conducting oxide films, which is determined by the deposited film's sheet resistance and optical transmittance.

The figure of merit of the films increased from 1.2×10^{-4} to $1.1\times10^{-3}\Omega^{-1}$ as the substrate bias voltage increased from 0 to -10 V.

Finally, indium oxide films were deposited using dc magnetron puttering at various oxygen concentrations. Voltages at the bias of the substrate and partial pressure. When the partial pressure of oxygen was 2×10^{-4} mbar, nearly stoichiometric films were produced. According to the dependence of substrate bias voltage, the indium oxide films generated at -100 V showed electrical resistivity of 1.8×10^{-3} cm, optical transmittance of 85% in the visible region, optical band gap of 3.78 eV, and figure of merit of 1×10^{-3}.

Cadmium oxide films

Thin films of CdO were formed on glass substrates using dc reactive magnetron sputtering from a metallic cadmium target at various oxygen partial pressures ranging from 2×10^4 to 5×10^3 mbar, substrate temperatures ranging from 303 to 473 k, and substrate bias voltages ranging from 0 to - 100 V. The chemical composition of the films formed under various oxygen partial pressures revealed that the atomic ratio of oxygen to cadmium increased from 0.80 to 1.02 as the oxygen partial pressure increased from 0.80 to 1.0, 2.2×10^{-4} to 3×10^{-3} mbar. The oxygen partial pressure of 1×10^{3} mbar was an optimum to generate nearly stoichiometric films of CdO.

The attraction of positively charged molecules and clusters of sputtered species towards the substrate was attributed to the high value of deposition rate at low substrate bias voltages. At higher substrate bias voltages, greater than 60 V, the bombarded positively charged molecule causes a decrease in the number of molecules resputtering from the film, resulting in a decrease in the deposition rate. Amorphous CdO films were formed at 303 k in the absence of a substrate bias voltage. The films became polycrystalline with a cubic structure as the substrate bias voltage increased. The electrical resistivity of films decreased from 6.8×10^{2} to 3.3×10^{2} Ω cm as the substrate bias voltage increased from 0 to - 80 V, then reached 2.9102 cm at - 100 V.

The effect of substrate bias voltage and substrate heating on films formed at 473 K under various substrate bias voltages was also investigated. The films formed without bias voltage were polycrystalline, with (111), (200), and (220) peaks present. When the bias voltage on the substrate was increased to - 100 V, the films were preferentially oriented in the direction of (200). Because of the improved crystallinity of the films, the gran size of the films increased from 60 to 125 nm as the substrate bias voltage increased from 0 to -100 V. The electrical resistivity of the deposited films decreased from 4.3×10^{3} to 8×10^{-4} Ω cm, Hall mobility increased from 45 to 62 cm2/V. sec, and electron concentration increased from 3×10^{19} to 1.26×10^{20} cm^{3} as the substrate bias voltage increased from 0 to - 100 V due to improvements in the crystallinity of the grain size and alignment of the grains at the grain boundaries, which minimises grapping and scattering of the charge carried at the grain boundaries.

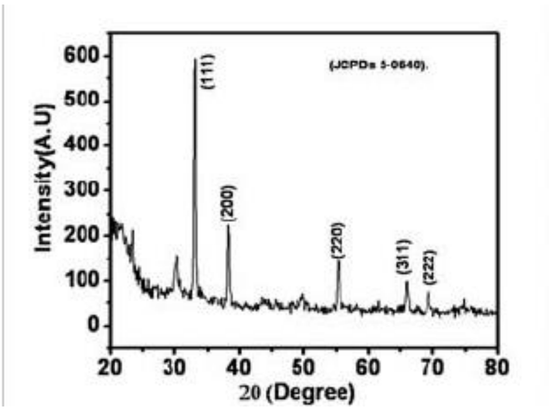

Fig:2. XRD pattern of Cdo.

The temperature dependence of Hall mobility measurements revealed that electrical conduction was more prominent in these films due to grain boundary scattering of charge carriers. The calculated potential barrier height decreased from 22 to 18 me V as the substrate bias voltage increased from 0 to - 100 V based on temperature dependence of Hall mobility measurements. The trapping of charge carriers at the grain boundaries was significantly reduced as the substrate bias voltage increased, resulting in a decrease in the grain boundaries potential. The films' optical band gap increased from 2.44 to 2.48 eV. As the substrate bias voltage is increased from 0 to - 100 V.

Finally, cadmium oxide films were formed using dc magnetron sputtering at various oxygen partial pressures and substrate bias voltages. At an optimised oxygen partial pressure of 1×10^{3} mbar, stoichiometric cadmium oxide films were achieved. The investigations into the dependence of substrate bias voltage on physical properties revealed that the films formed at an oxygen partial pressure and substrate bias voltage of -80 V had an electrical resistivity of 1×10^{-3} cm, an optical transmittance of 86%, and an optical band gap of 2.47 eV, with a figure of merit of 7×10^{-3} Ω^{-1}.

In conclusion cadmium oxide films were formed at different oxygen partial pressures and substrate bias voltages using dc magnetron sputtering technique. The stoichiometric films of cadmium oxide were achieved at an optimized oxygen partial pressure of 1×10^{3} mbar. The investigations on the dependence of substrate bias voltage on the physical properties revealed that the films formed at an oxygen partial pressure and substrate bias voltage of -80 V exhibited the electrical resistivity of 1×10^{-3} Ω cm, optical transmittance of 86 %, and optical band gap of 2.47 eV figure of merit of 7×10^{-3} Ω^{-1}.

Cadmium indate films:

The metallic cadmium indium alloy target was sputtered by a dc magnetron onto a glass substrate at temperatures between 303 and 673 K while being subjected to a variety of oxygen partial pressures between 2×10^{-4} and 5×10^{-3} mbar and substrate bias voltages between 0 and - 100 V. The cathode oxidation (toxic) effect was used to explain the relationship of cathode potential on oxygen partial pressure. The films' energy dispersive X-ray examination showed that they were nearly stoichiometric with a ratio of 0.76 for cadmium and indium to oxygen when they were created at 523 K and an oxygen partial pressure of 5×10^{-4} mbar. The films formed at oxygen partial pressure, according to x-ray diffraction analysis. These polycrystalline films had a cubic spinel structure, an electrical resistivity of 1.2×10^{-3} Ω^{-1}cm, an optical transmittance of 87% in the visible region, and an optical band gap of 3.23 eV.

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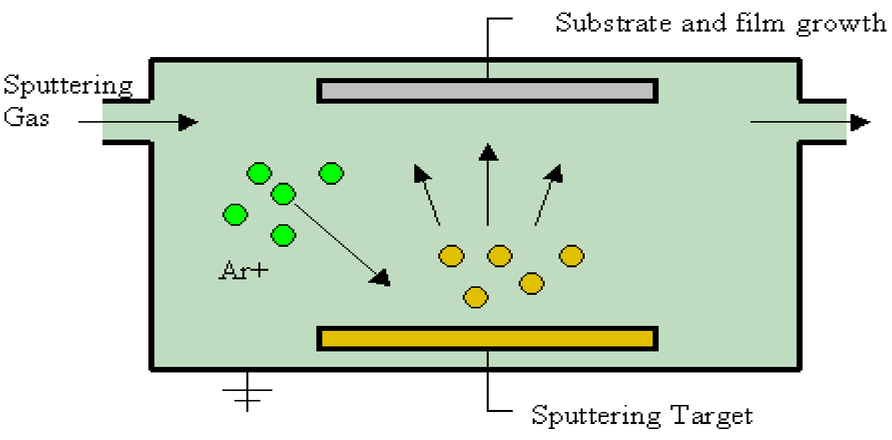

Fig:3 preparation of $CdIn_2O_4$ thin films using sputtering method in lab

$CdIn_2O_4$ films were formed at various substrate temperatures ranging from 373 to 673 K and an optimized oxygen partial pressure of 5×10^{-4} mbar to investigate the effect of substrate temperature on physical properties.

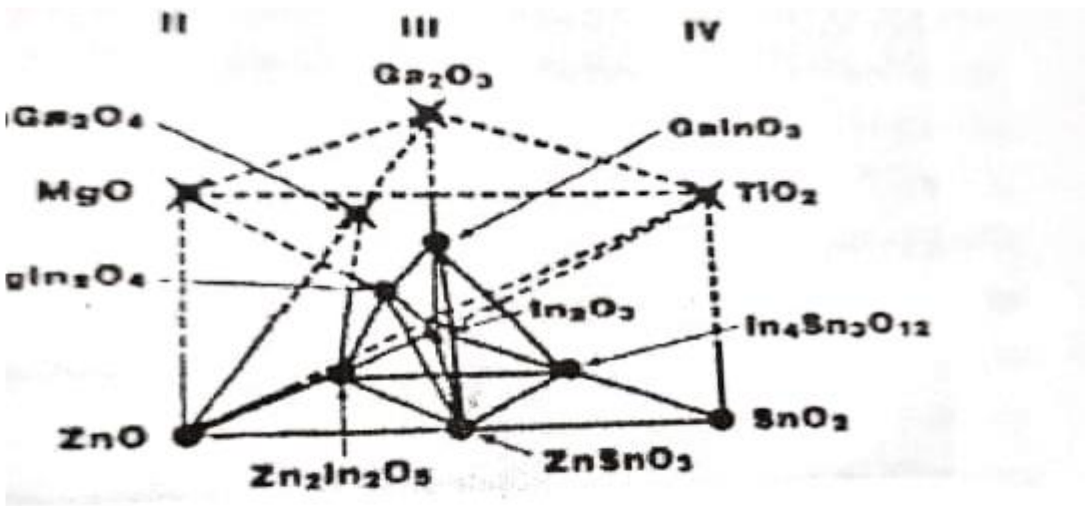

Fig: 4. Composition limitations of ternary /quaternary alloy or compound to deposit the transparent conducting oxide or insulating oxide films

X-ray diffraction studies revealed that films formed at 423 K substrate temperature were amorphous in nature, whereas those formed at 423 K substrate temperature were polycrystalline with cubic spinal structure. The peaks (111), (220), (221), (400), and (511/333) of $CdIn_2O_4$ were visible in the films formed at 523 K. After increasing the substrate temperature to 673 K, the films were oriented in the (220) direction. The lattice parameter of the films decreased from 0.921 to 0.916 nm as the substrate temperature increased from 423 to 673 K..

Due to the crystallinity of the films, the films formed at 373 K had a high resistivity of 1×10^{-2} cm. The films' Hall mobility indicated that they were n-type in electrical conduction. When the substrate temperature increased from 373 to 673 K, the Hall mobility of the films increased from 13 to 29 cm^2/V.Sec and the carrier concentration increased from 7×10^{19} to 6×10^{20} $cm^{-3.}$

.The optical band gap was thought to expand as substrate temperature increased due to the partial filling of the conduction band by free carriers caused by the blockage of the lower states in the conduction band. As the substrate temperature increased from 373 to 673 K, the refractive index (at = 500 nm) of the films increased from 1.98 to 2.06 due to an increase in packing density and crystallinity. The figure of merit of the films increased from 8×10^{-4} to 5×10^{-2} as the substrate temperature increased from 373 to 373 K.

The CdIn2O4 films were formed under various substrate bias voltages ranging from 0 to -100 V and at a substrate temperature of 523 K to investigate the effect of substrate bias voltage on physical properties.

The films formed under unbiased condition were polycrystalline with the pressure of (111), (220), (221), (400) and (511), (333) peaks. When the substrate bias voltage increased to -45 V the intensity of (111), voltage (221) and (511/333) decreased with the increase of intensity of (220) and (400) while those Formed about -80 V the only orientation of (220) and (400) were observed. The atom size of the films was Increased from 40 to 65 nm with the increase of substrate bias voltage from 0 to -5 V respectively. The Electrical Resistivity of the films was decreased from 1.2×10^{-3} to 5.6×10^{-4} Ω cm with the increase of bias Voltage from o V to – 45 V. The Hall mobility of the films increased from 23 to 34 cm^2/V. sec and the Electron concentration increased from 2.3×10^{20} to 3.4×10^{20} cm^{-3} with the increase of substrate bias voltage from 0 to – 100. The optical band gap of the films increased from 3.23 to 3.27 eV and figure of merit Increased from 3.23 to 3.27 eV and the figure of merit increased from 5.5×10^{-3} to $1.5\times10^{-2}\Omega^{-1}$ with the Increase of substrate bias voltage from 0 to – 10 V.

Applications:

Fundamental understanding of the chemical and structural origins of transparent conducting oxides (TCOs) has allowed TCOs (thus we prepared cdo, in2o3, cadmium indate films) to evolve into important materials for photovoltaic devices and optoelectronic applications. Transparent oxide semiconductors (TOSs) are currently being explored as thin film transistor (TFT) materials, as an enabling technology for the next generation of computing, communication, and identification devices. Initially, the technological application of TCOs and TOSs employed these materials in their crystalline form. The materials also played a vital role in flat panel displays and making of solar cell devices.

Advantages and disadvantages of TCOS:

Indium oxide and cadmium oxide, cadmium indate films is very costly materials and the production rate of the material is very low. When the materials are exposed to higher Annealing temperature its resistivity increased and it affects its conductivity property.

It is also revealed that CdO: INO (60:40) multi-component thin films possess moderate toxicity to non-target species and can be considered as a potential TCO with less effective bactericidal properties this is one of the disadvantage.

Conclusions.

In conclusion cadmium indate films were prepared by dc magnetron sputtering under different Oxygen partial pressures, substrate temperatures and substrate bias voltages. Cadmium indate films with Low electrical resistivity of 6×10^{-4} Ω cm, optical transmittance of 88 %, optical band gap of 3.26 eV and Figure of merit of 1.4×10^{2} Ω^{-1} at an optimum oxygen partial pressure of 5×10^{-4} mbar, substrate Temperature of 523 K and substrate bias voltage of – 80 V. From the studies it revealed that the cadmium indate films formed under optimum deposition Conditions are suitable for the use as transparent conducting coatings in solar cells. Recently much Interest is focused on $(CdO)_{1-X}$ $(In_2O_3)_X$ films for the applications in gas sensors and transparent conducting Coating with varied optical band gaps. Based on the experience gained form the present investigations, It is proposed to deposit the $(CdO)_{1-X}$ $(In_2O_3)_X$ films by varying the composition employing dual target of pure cadmium and indium using dc reactive magnetron sputtering where precise Control on the depositing species will be achieved, and the deposited films will be characterized for the Application in the gas sensor as well as transparent conducting coatings.

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