A Study of Electrical Properties Of CdO Thin Films On ITO And Silicon Substrate By Spin Coating Method

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ABSTRACT

Cadmium Oxide (CdO) thin films have been prepared on ITO and Silicon substrates by sol-gel Spin Coating method. CdO is a II–VI semiconductor with a direct, dipole allowed band gap around 2.3 eV. Cadmium oxide is one of the binary oxide having important electronic, structural and optical properties. The films of CdO have been prepared by employing various physical and chemical thin film deposition techniques such as, spray pyrolysis, chemical-vapour deposition, sol-gel process, laser deposition, ion beam sputtering, DC sputtering, RF sputtering etc.. But here, we use sol-gel spin coating method for studying the electrical properties of CdO thin film. The sol -gel spin coating method is basically a chemical deposition technique where the desired material is spread onto the substrates by spin coating. For structural study of thin film, we discuss the two techniques, first is X-RAY Diffraction and second is Scanning Electron Microscopy (SEM), both are famous techniques. For electrical study of CdO thin film we discuss about 4200-SCS (Semiconductor Characterization System). CdO films have been deposited by sol-gel spin coating method on plane glass substrate at different annealing temperatures. There is crystalline nature in the sample. CdO thin film shows the (111) peak is observed as 33.05^0. Electrical study shows that on increasing the annealing temperature, resistance and resistivity increases upto 450^0C. But at further increasing the annealing temperature, both resistance and resistivity are decrease.

Keywords: DC sputtering, RF sputtering, X-RAY Diffraction, SEM, 4200-SCS.

Introduction

Material science is a branch of science that focuses on materials; interdisciplinary field composed of physics and chemistry. The combination of physics, chemistry, and the focus on the relationship between the properties of a material and its microstructure is the domain of Materials Science. The development of this science allowed designing materials and provided a knowledge base for the engineering applications (Materials Engineering). Important components of the subject Materials Science are structure, properties, processing, and performance. Semiconductors are the materials which play an important role in the development in the field of science and technology. The two most important semiconductors are Silicon (Si) and Germanium (Ge). Some important semiconducting materials that compete with Ge and Si in this reference belong to II-VI, group of materials. One of the most important characteristics of semiconductor, which distinguish it from the metals and insulators, is its energy band gap. In the recent years, the group II-VI compounds has been studied very extensively because of their greater potential in the field of optoelectronics. Originally, II-VI compounds were studied and applied in powder form only. Cadmium oxide (CdO) is a II–VI semiconductor with a direct, dipole allowed band gap around 2.3 eV. CdO is naturally an n-type semiconductor partially due to its deviation from stoichiometry. Cadmium Oxide is one of the binary oxide having important electronic, structural and optical properties. Its high electrical conductivity is due to moderate electron mobility and higher carrier concentration due to the contribution from shallow donors resulting from inherent non-stoichiometry. CdO is a transparent conductive material, which was prepared as a transparent conducting film. Cadmium oxide in the form of thin film has been used in applications such as photodiodes, phototransistors, photovoltaic cells, transparent electrodes, liquid crystal displays, IR detector, and anti-reflection coating. Many technique have been employed to prepare CdO thin film on different substrates, such as, spray pyrolysis, chemical-vapour deposition, sol-gel spin coating method, laser deposition, ion beam sputtering, DC sputtering, RF sputtering etc. Among these deposition techniques, sol-gel spin coating technique is a simple, cheap and low-temperature technique that allows for the fine control of the product's chemical composition. It can be used in ceramics processing and manufacturing as an investment casting material, or as a means of producing very thin films of metal oxides for various purposes. X-RAY Diffraction and Scanning Electron Microscopy are the famous techniques for structural study of thin film. Electrical study is done by 4200-SCS (semiconductor characterization system) at room temperature. This study aims at a detailed investigation of the characteristics of CdO thin films that were synthesized by the sol-gel spin coating method and annealed at 450^0C.

SYNTHESIS METHOD OF THIN FILM

There are various method to preparing CdO thin film. Some of them, the most familiar method are given follows:

1. **Spray pyrolysis-** Spray pyrolysis is a process in which a thin film is deposited by spraying a solution onto a heated surface, where the constituents react to form a chemical compound.
2. **Sputtering-** Sputter deposition is a physical vapor deposition process for depositing thin films, sputtering means ejecting material from a target and depositing it on a substrate such as a silicon wafer. There are two types of sputtering – DC sputtering and RF sputtering.
3. **Sol-Gel Method-** In materials science, the sol-gel spin coating method is basically a chemical deposition technique where the desired material is spread onto the substrates by spin coating. Cadmium oxide (CdO) thin films were prepared via sol–gel spin coating method on different substrate. This method is used for the fabrication of metal oxides, especially the oxides of silicon and titanium. The process involves conversion of monomers into a colloidal solution (sol) that acts as the precursor for an integrated network (or gel) of either discrete particles or network polymers. In this chemical procedure, the 'sol' (or solution) gradually evolves towards the formation of a gel-like diphasic system containing both a liquid phase and solid phase whose morphologies range from discrete particles to continuous polymer networks. In the case of the colloid, the volume fraction of particles (or particle density) may be so low that a significant amount of fluid may need to be removed initially for the gel-like properties to be recognized. The rate at which the solvent can be removed is ultimately determined by the distribution of porosity in the gel. The ultimate microstructure of the final component will clearly be strongly influenced by changes imposed upon the structural template during this phase of processing. The precursor sol can be either deposited on a substrate to form a film (e.g., by dip coating or spin coating), cast into a suitable container with the desired shape (e.g., to obtain monolithic ceramics, glasses, fibers, membranes, aerogels), or used to synthesize powders (e.g., microspheres, nanospheres). It can be used in ceramics processing and manufacturing as an investment casting material, or as a means of producing very thin films of metal oxides for various purposes. The interest in sol-gel processing can be traced back in the mid-1800s with the observation that the hydrolysis of tetraethyl orthosilicate (TEOS) under acidic conditions led to the formation of $SiO2$ in the form of fibers and monoliths. The sol-gel approach brought new promise of providing high stationary phase stability and column efficiency in separation.

Structural study

For structural study of thin film two techniques are discuss.

1: X-RAY Diffraction- X-ray diffraction is a powerful tool for materials characterization as well as for detailed structural elucidation. X-ray patterns are used to establish the atomic arrangements of the materials because of the fact that the lattice parameter, d (spacing between different planes) is of the order of x-ray wavelength. Further, X-ray diffraction method can be used to distinguish crystalline materials from non-crystalline (amorphous) materials. The structure identification is made from the x-ray diffraction pattern analysis and comparing it with the internationally recognized database containing the reference pattern (JCPDS).

Determination of crystal size

The X-ray diffraction analysis has been the most popular method for the estimation of crystallite size in nanomaterials. Crystallite size of the deposits is calculated by the X-ray diffraction (XRD) peak broadening. The diffraction patterns are obtained using Cu Kα radiation at a scan rate of 10/min. The full width half maxima (FWHM) of the diffraction peaks were estimated by pseudo-Voigt curve fitting. After subtracting the instrumental line broadening, which was estimated using quartz and silicon standards, the grain size can be estimated the Scherrer equation

$$D=0.9\lambda/(\beta \cos\theta)$$

Where λ is wave length of X-ray, β is FWHM in radian, θ is peak angle.

2: Scanning Electron Microscopy- In this technique, electrons are used instead of light waves to see the microstructure of surface of a specimen. However since electrons are excited to high energy (keV), so wavelength of electron waves are quite small and resolution is quite high. The electromagnetic lenses used in it are not a part of image formation system, but just helps to focus the electron beam on specimen surface. This gives two of the major benefits of SEM: range of magnification and depth of field in the image, giving three dimensional information of image. Backscattered electrons (BSE) may be used to detect contrast between areas with different chemical compositions, especially when the average atomic number of the various regions is different, since the brightness of the BSE image tends to increase with the atomic number. Backscattered electrons can also be used to form electron backscatter diffraction (EBSD) image. This image can be used to determine the crystallographic structure of the specimen.

ELECTRICAL STUDY:

4200-SCS Semiconductor characterization system

The Model 4200-SCS provides a total system solution for DC and pulse characterization and stress-measure/reliability testing of semiconductor devices and test structures. The 4200-SCS combines unprecedented measurement speed and accuracy with an embedded Windows-based PC and the Keithley Interactive Test Environment (KITE) to provide a powerful single-box solution. The Keithley Interactive Test Environment allows users to gain familiarity quickly with tasks such as managing tests and results and generating reports. Sophisticated and simple test sequencing and external instrument drivers simplify performing automated device and wafer testing with combined I-V and C-V measurements. The system supports up to eight Source-Measure Units, including up to eight high power SMUs with 1A/20W capability. An optional Remote PreAmp extends the resolution of any Source-Measure Unit from 100fA to 0.1fA.

RESULT:

Electrical Study

Electrical study is done by 4200-SCS (semiconductor characterization system) at room temperature. The graph is shown in figure. Resistance of thin films were calculated using I-V characteristics and resistivity were calculated using equation (B). Dimension of thin films were 1x1 inch with thickness 200nm.

$$R=V/I \quad (A)$$

$$\rho=RA/l \quad (B)$$

$$\sigma=1/\rho \quad (C)$$

Where A is cross section area, l is length, V is applied voltage, I is measured current.

We found that on increasing temperature resistivity and resistance increase upto 550^0C but at further increasing annealing temperature both the parameters resistivity and resistance decreasing.

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Table- Electrical Parameters of CdO Thin Films.

Substrate	Voltage (V)	Current (I)	Resistance R=V/I(Ω)	Resistivity ρ=RA/l (Ωm)	Conductivity σ=1/ρ(1/Ωm)
ITO	5	$96.4774x10^{-3}$	51.8256	$5.18256e^{-6}$	$1.92954e^{+5}$
Silicon	5	$27.15x10^{-3}$	184.162	$1.84162e^{-5}$	$5.43e^{+4}$

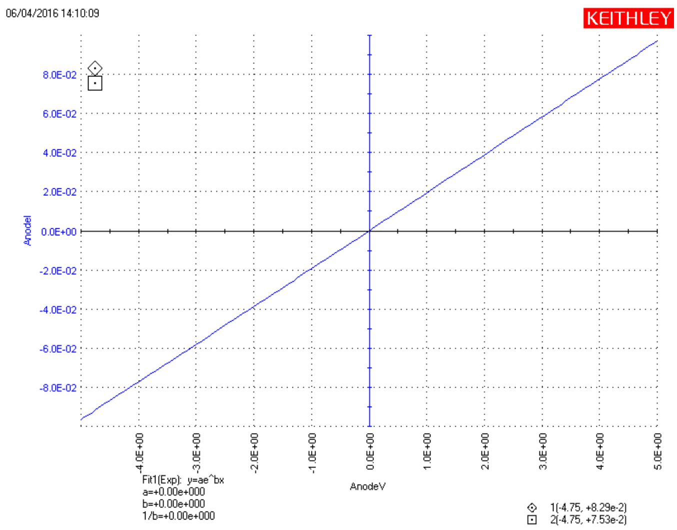

Fig: I-V Characteristics of CdO thin film annealed at temperature 450^{0}C.

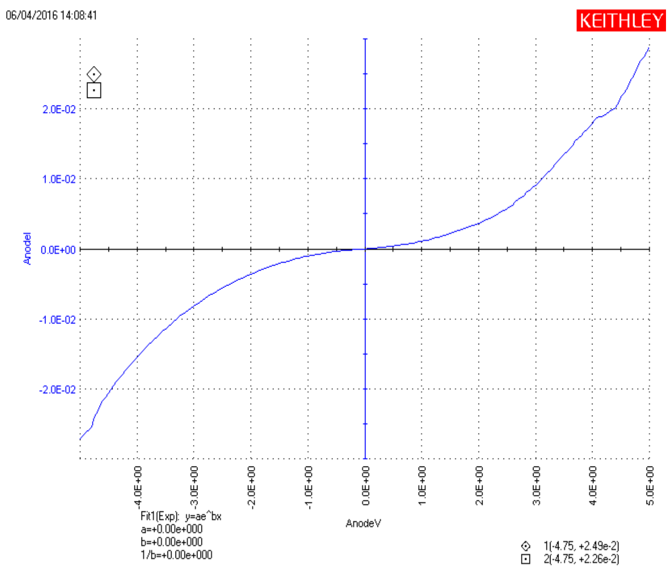

Fig: I-V Characteristics of CdO thin film annealed at temperature 450^{0}C.

CONCLUSION

In summary, CdO films have been deposited by sol-gel spin coating method on plane glass substrate at different annealing temperatures. There is crystalline nature in the sample. CdO thin film shows the (111) peak is observed as 33.05^0. The films have the simple cubic structure. But at annealing temperature 450^{0}C, we did not observed any peak in the diffraction pattern i.e. no crystalline nature of film. As annealing temperature increases crystallinity of CdO thin film decreases. And electrical study shows that on increasing the annealing temperature, resistance and resistivity increases upto 450^{0}C. But at further increasing the annealing temperature, both resistance and resistivity are decrease.

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