ABSTRACT

A solar cell is an electrical device that converts optical energy directly into electrical energy by photovoltaic effect. As of now, the single or multi crystalline silicon solar cells dominate the solar cell manufacturing industry. But the cost of these solar cells is high. It has decreased significantly with the progress of thin film technology. The promising second generation solar cells such as amorphous silicon and thin-film solar cells like Gallium Arsenide (GaAs), Cadmium Telluride (CdTe) and Copper Indium Gallium di-Selenide (CIGS) hold minimum market share along with crystalline silicon. Among the non-silicon solar cells, thin film solar cells based on CdTe and CIGS look promising in terms of efficiency and manufacturing process.

In the present work the characteristics of CIGS thin films and Cadmium Zinc Telluride (CdZnTe) thin films which are used as absorber layers in solar cells have been investigated. Further, characteristics of Gallium doped Zinc Oxide (GZO) thin films - which are used as window layers and transparent conducting oxide in solar cells has been studied.

The first objective is to prepare CIGS thin films by RF magnetron sputtering and study its characteristics. Thin film CIGS absorber layers were deposited onto well cleaned glass/quartz substrates using three step processes. Initially, $Cu_{0.5}In_{0.1}Ga_{0.4}$ (Ga rich) thin film was coated onto glass substrates and quartz plates using RF magnetron sputtering .In the second step, the same chamber was used to deposit $Cu_{0.5}In_{0.4}Ga_{0.1}$(In rich) precursors over CIG (Ga rich) coated substrate. In both cases, a single two inch CIG target was used for CIG film deposition. The RF power density used in the growth process of both CIG (Ga rich) and CIG (In rich) thin film was 2.54 W/cm^2, and the target to substrate distance was optimized at 4.5 cm after several trials. Subsequently, selenisation process was carried out by close space sublimation (CSS) method

using elemental selenium. The prepared films have been post annealed in vacuum at 300°C and 600°C.

The X-ray diffraction pattern of the as deposited CIGS thin films and the films post annealed at 300°C show very small peaks. The diffraction pattern of the film annealed at 600°C exhibits sharp peaks corresponding to the planes of chalcopyrite structure. The grain size of the crystallites increases from 14 nm to 56 nm with annealing temperature. The SAED pattern of HRTEM image of the CIGS sample had distribution of spots which correspond to the planes of chalcopyrite structure of CIGS. The chemical constituents present in the CIGS film have been identified from XPS survey spectra. The CIGS samples were annealed at 600°C and have been studied at different time of etching (0min, 3 min and 20 min) using XPS analysis. The optical properties of the deposited CIGS films have been studied using a UV-VIS-NIR spectrophotometer. The absorption coefficient (α) has been calculated and it is found to be in the order of 10^5 -10^6cm^{-1}. The CIGS films exhibited direct band gap and the band gap values are 0.96 eV, 1.04 eV and 1.15 eV for the as deposited, 300°C annealed and 600°C annealed films, respectively. The measured Hall coefficient of the films indicates that the CIGS films are of p-type nature. The electrical conductivity has been observed to increase with increase in annealing temperature. The mobility of the charge carriers has been found to be 6.84, 5.34 and 1.67 cm^2/Vs for the as deposited, 300°C annealed and 600°C annealed films, respectively.

The second objective of the present work is to prepare CZT thin films by RF magnetron sputtering and study its characteristics. A two inch diameter ternary $Cd_{0.4}Zn_{0.1}Te_{0.5}$ (99.99%) target was used. Cadmium Zinc Telluride (CZT) films were deposited onto well cleaned glass substrates at room temperature (RT), 200°C and 400°C for 30 min in an RF magnetron sputtering system.

The X-ray diffraction pattern of room temperature deposited (RT) and substrate heated (200°C & 400°C) CZT thin films shows the presence of diffraction peaks along (111), (220) and (311) directions, confirm the presence of stoichiometric CZT films with zinc blende structure. From the EDAX spectrum, the composition of the CZT is determined using Vegard's law. A TEM plane view of heat treated CZT thin film at 400°C showed interference fringes which indicate a high degree of material perfection. The presence of the (111), (220) and (311) plane in the SAED pattern substantiates the XRD results and confirms the crystallization of the films with zinc blende structure. From the transmission spectra for the as deposited and substrate heated CZT thin film, the % transmittance value was found to be 0.1-0.2 in the visible region. The optical band gap values have been determined as 1.39 and 1.45eV for the as-deposited and 400°C annealed samples, respectively. The band gap values increase with substrate temperature. Hall effect studies were carried out for the CZT film deposited at 400ºC. The carrier type and sheet resistance of the film was found as p-type and 3.285×10^{8} Ohm/sq, respectively.

The third objective of the present work is to prepare GZO thin films by RF magnetron sputtering and study its characteristics. In the present work, GZO films were prepared using RF power densities < 5 W/cm^2 and at a substrate temperature of 400ºC to obtain GZO films with high figure of merit. Gallium doped Zinc Oxide(GZO) thin films were deposited onto well-cleaned soda-lime glass substrates held at a substrate temperature of 400°C by a sputtering target.

The XRD pattern of GZO films indicates the polycrystalline nature of the films with a hexagonal wurtzite structure. All the films exhibited a strong ZnO peak. As the film thickness increases from 132 nm to 495 nm, the peak height corresponding to the [002] plane increases significantly. This was related to an improvement in the crystallinity or an increase in the crystallite size. The HRTEM bright field image and the respective Selected Area Electron Diffraction (SAED) pattern of the film having a thickness of 495 nm deposited at a substrate temperature of 400°C indicate the polycrystalline nature of the films separated by grain boundaries. The presence of the (002), (102) and (004) plane in the SAED pattern substantiates the XRD results and confirms the crystallization of the films with hexagonal wurtzite structure. All the films deposited at 400ºC, the average transmittance values were higher than 90%. It was found that the conductivity of GZO film increases with increase in crystallite size. The carrier density and mobility of the GZO thin films were estimated from Hall effect measurements carried out at room temperature. The Hall coefficient was found to correlate with GZO film thickness and the negative sign indicates the n-type nature of GZO thin films.

Using the above results, Solar cells with the structure glass/Mo/p-CIGS/n-CdS/i-ZnO/GZO and glass/Mo/p-CZT/n-CdS/GZO have been fabricated and found to have low efficiencies. Improvement in solar cell parameters is taken as a futuristic work. Most of the cells indicate ohmic behaviour indicating that there is a large leakage current. Few cells have indicated rectification behaviour but current values are very less in the order of micro amperes. CZT based cell has shown moderate optical response .Therefore, future scope of the work will be to focus on the improvement in solar cell parameters as well as efficiency.