Abstract

The generation of electrical current from the solar radiation is known as the photovoltaic effect. Solar cell, also known as photovoltaic (PV) cell, is a device that works on the principle of photovoltaic effect, and is widely used for the generation of electricity. Thin film polycrystalline solar cells based on copper indium gallium diselenide (CIGS) are admirable candidates for clean energy production with competitive prices in the near future. CIGS based polycrystalline thin film solar cells with efficiencies of 20.3 % and excellent temperature stability have already been reported at the laboratory level. The present study discusses about the fabrication of CIGS solar cell. Before the fabrication part of CIGS solar cell, a numerical simulation is carried out using One-Dimensional Analysis of Microelectronic and Photonic Structures (AMPS-1D) for understanding the physics of a solar cell device, so that an optimal structure is analyzed.

In the fabrication part of CIGS solar cell, Molybdenum (Mo) thin film, which acts as a ‘low’ resistance metallic back contact, is deposited by RF magnetron sputtering on organically cleaned soda lime glass substrate. The major advantages for using Mo are high temperature, (greater than 600 °C), stability and inertness to CIGS layer (i.e., no diffusion of CIGS into Mo). Mo thin film is deposited at room temperature (RT) by varying the RF power and the working pressure. The Mo thin films deposited with 100 W RF power and 1 mTorr working pressure show a reflectivity of above average 50 % and the low sheet resistance of about 1 Ω/□.

The p-type CIGS layer is deposited on Mo. Before making thin films of CIGS, a powder of CIGS material is synthesized using melt-quenching method. Thin films of CIGS are prepared by a single-stage flash evaporation process on glass substrates, initially, for optimization of deposition parameters and then on Mo coated glass substrates for device fabrication. CIGS thin film is deposited at 250 °C at a pressure of $10^{-5}$ mbar. The thickness of the film was kept 1 μm for the solar cell device preparation. Rapid Thermal Annealing (RTA) is carried out of CIGS thin film at 500 °C for 2 minutes in the argon atmosphere. Annealing process mainly improves the grain growth of the CIGS and, hence the surface roughness, which is essential for a multilayered semiconductor structure.
Thin layer of n-type highly resistive cadmium sulphide (CdS), generally known as a “buffer” layer, is deposited on CIGS layer by thermal and flash evaporation method at the substrate temperature of 100 °C. The CdS thin film plays a crucial role in the formation of the p-n junction and thus the solar cell device performance. The effect of CdS film substrate temperature ranging from 50 °C to 200 °C is observed. At the 100 °C substrate temperature, CdS thin film shows the near to 85 % of transmission in the visible region and resistivity of the order of greater then $20 \times 10^9 \Omega \text{cm}$, which are the essential characteristics of buffer layer.

The bi-layer structure of ZnO, containing 70 nm i-ZnO and 500 nm aluminum (Al) doped ZnO, act as a transparent front-contact for CIGS thin film solar cell. These layers were deposited using RF magnetron sputtering. i-ZnO thin film acts as an insulating layer, which prevents the recombination of the photo-generated carries and also minimizes the lattice miss match defects between CdS and Al-ZnO. The resistivity of i-ZnO and Al-ZnO is of the order of $10^{12} \Omega \text{cm}$ and $10^{4} \Omega \text{cm}$, respectively. Al-ZnO thin films act as transparent conducting top electrode having transparency of about 85 % in the visible region. On Al-ZnO layer the finger-type grid pattern of silver (Ag), 200 nm thick, is deposited for the collection of photo-generated carriers.

The thin film based multilayered structure Mo / CIGS / CdS / i-ZnO / Al-ZnO / Ag grid of CIGS solar cell is grown one by one on a single glass substrate. As-prepared CIGS solar cell device shows a minute photovoltaic effect. For the further improvement of the cell we have varied the thickness of the buffer layer i.e. CdS. In addition, the deposition of CdS is carried out using flash evaporation method to improve the CIGS/CdS junction. Heat soak pulses of about 200 °C are also applied for 20 sec for the further upgrading the junction. To protect the CIGS/CdS junction from the high-energy sputtered particles of ZnO, a fine mesh of stainless steel is placed just before the sample holder to enhance the performance of the solar cell. The influence of the thickness of i-ZnO and CdS has been checked. The maximum $V_{oc}$ and $J_{sc}$ of about 138 mV and 1.3 mA/cm$^2$, respectively, are achieved using flash evaporated CIGS layer and flash evaporated CdS thin film. Further improvement of current performance can be done either by adopting some other fabrication method to obtain a denser CIGS absorber layer or replacing the CdS layer with some other efficient buffer layer.