Abstract

Consumption of energy across the world has perturbed the human-being. Availability, accessibility, and regeneration of energy resources are a perpetual matter of concern. Renewable energy is the best alternative to non-renewable energy. Solar energy is clean, reliable, and sustainable form of renewable energy available globally. Harvesting solar energy for consumption can be done by converting light energy into electrical energy. Innumerable research work has been carried out with several chemical compositions that are capable of harvesting solar energy. Copper Indium Gallium Diselenide (CIGS) chalcopyrite is a commendable candidate for low cost, highly stable, reliable, and efficient solar cell modules. Solar Frontier has marked 23.35 ± 0.5 % efficiency of CIGS solar cell of area 1 cm^2. In the present research work, the fabrication and development of the CIGS solar cell module on 50 x 50 mm soda-lime glass substrate have been discussed.

Multilayer SLG/Mo/CIGS/CdS/i-ZnO/AZO was deposited sequentially on 60 x 60 x 1 mm SLG substrate to develop CIGS solar cell module. Deposition techniques such as DC sputtering, RF sputtering, and Chemical Bath deposition was used for depositing all functional layer. Bilayer Mo layer deposited by DC sputtering at substrate temperature 215 °C of thickness 1 µm at deposition pressure 10 mTorr (bottom) and 1 mTorr (top) at 150 W power is suitable for Mo layer to act as ohmic back contact. It has a dense columnar structure with a sheet resistance of 0.332 Ω/□, and optical reflectivity of 72 %. Adhesion test was performed using Laser (Nd:YAG 1064 nm) and ammonia solution bath.

CIGS layer as a p-type absorber for photocarrier generation in CIGS solar cell. For depositing the CIGS layer, a vacuum sintered sputter target was prepared. CIGS thin-film layer was deposited using RF sputtering technique, CIGS thin-film deposited at 150 W RF power, 15 mTorr working pressure and further annealed in a vacuum furnace in two steps i.e., first at 400 °C and hold for 2 mins and then at 550 °C holds for 8 mins. This process confirms the tetragonal chalcopyrite phase of the CIGS layer.

For the n-type junction partner of the CIGS absorber, cadmium sulphide (CdS) is a prominent choice. Three different deposition techniques i. e., thermal

evaporation, chemical bath deposition, and RF-sputtering were optimized. From the results, it was found CBD deposition is favorable for depositing the buffer layer. It has low Urbach energy 54.46 meV and the layer has conformal coverage without pinholes.

High resistive transparent layer (i-ZnO) intrinsic-Zinc Oxide and top window contact (AZO) Aluminium doped Zinc-Oxide layers were optimized. i-ZnO layer deposited by RF sputtering with thickness 50 nm at 1 mTorr working pressure and 150 W RF power possess optimum electrical resistivity in order of 10^5 as well highly transparent layer. This layer protects the buffer and absorber layer from the high energetic impact of sputtered AZO atoms. AZO layer was deposited using RF sputtering at 100 W RF power and 10 mTorr working pressure with a thickness of 400 nm. It has optical transmittance of 85-90 % and a resistivity of 6.26×10^{-4} **Ω**-cm.

From cell to module fabrication, monolithic integration of CIGS solar cell module was carried out. P1 with laser (Nd: YAG 1064 nm) and P2 and P3 with mechanical scribing technique was optimized. Performance CIGS solar cell and module fabricated on 50 x 50 mm of SLG substrate was estimated. The I-V characteristics revealed that CIGS solar cell module draws I_{sc} = 0.11 mA, V_{oc} = 410 mV, efficiency-η = 0.26 %, R_s = 1879.22 Ω-cm^2, and R_{sh} = 9062.69 Ω-cm^2. The performance of the CIGS module can be enhanced by tuning fine properties of the functional layers, optimizing better monolithic integration process parameters, and reducing the recombinations in bulk and the interface by light trapping management.