ABSTRACT

Satisfying world's growing energy demand is one of the most significant challenges facing modernization of human life. There is an increasing global energy demand due to the tremendous growth of population and industrialization, and on the other hand the conventional fossil fuels like coal, oil, natural gas, etc., are fast depleting. More consumption of fossil fuels increases the emission of green-house gases such as carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), phosphorus pentoxide (P_2O_5) and etc., and the acidification caused by fossil fuels. Hence there is a need for the development of alternate clean energy sources. Solar energy is one of the potential alternativesource which is inexhaustible, completely natural and provides sustainable energy supply. Today, photovoltaic technologies are dominated by wafer-based crystalline silicon. In an effort to reduce manufacturing costs, thin film technologies that require lesser raw materials using efficient processing technique have been subject to active research and development.

Photovoltaic (PV) devices directly harness solar radiation and convert the light into usable electrical energy. Solar cell is an opto-electronic device which converts solar energy directly into electrical energy through the photovoltaic effect. When light photons with energy greater than its band gap is absorbed by a semiconducting material, free electrons and holes are formed by excitation. Silicon offers innumerable advantages in terms of its abundance, special characteristics such as single-phase behaviour, high degree of chemical stability and extremely low vapour pressure. This has led to its research and utilization on a large scale. However, silicon is certainly not the most efficient semiconducting material for sunlight conversion

because of its indirect band gap. The semiconducting properties of the Cu-chalcopyrite's are popular due to their electronic and structural similarity to the group IV elements likes silicon and germanium. The optical band gap of $CuInSe_2$ (CIS) is 1.04 eV which is considerably lesser than the optimum value to achieve higher efficiency. However, the band gap can be varied from 1.04 eV for CIS to 1.68 eV for $CuGaSe_2$ by the selective incorporation of gallium (Ga).

In the present work, a rotating furnace was employed to prepare the bulk material. The quaternary $CuIn_xGa_{1-x}Se_2$ alloys with two different compositions (x = 0.65 and 0.70) were used in the thin film deposition which were synthesized by direct reaction of high quality elemental copper, indium, gallium and selenium. Stoichiometric $CuIn_{0.7}Ga_{0.3}Se_2$ and $CuIn_{0.65}Ga_{0.35}Se_2$ compounds were synthesized by direct melting method. The tetragonal chalcopyrite structure with preferred orientations along the crystallographic planes (1 1 2), (2 2 0/ 2 0 4) was confirmed by XRD pattern for the prepared CIGS compound powders. TEM images indicated that CIGS exhibits large agglomerate states that are composed of super-lattice nanocrystals.The crystal structure of the powders was further confirmed by HRTEM.

The Cu $(In,Ga)Se_2$ nano-crystals were synthesized using chemical solution method in one pot-route.In this route, acetylacetonate salts and selenium powder were simply refluxed in triethylenetetramine (TETA) in air for 6 hours. The size of the CIGS crystals were characterized by FESEM and it has an average size of 60 nm. EDAX analysis revealed the chemical composition of the stoichiometric $CuIn_xGa_{1-x}Se_2$ nano-crystals as in the bulk compound.

The methods generally used for the deposition of CIGS thin films include co-evaporation, electron beam evaporation, pulsed laser

deposition and electro-deposition. Hot wall deposition technique is one of the physical methods whose main characteristic feature is the formation of epitaxial layers under conditions as close as possible to the thermodynamic equilibrium with minimum loss of materials. Thin films of Cu (In, Ga)Se_2were deposited on a well-cleaned glass substrate by hot wall deposition technique in a base vacuum of 2 x 10^{-6} Torr. The hot wall deposited CIGS thin film exhibits tetragonal crystal structure with lattice parameters a= 5.73 Å, c= 11.66 Å, $\alpha = \beta = \gamma = 90°$. The expected chalcopyrite structure with the preferential orientation along (112), (220/204) and (312) was observed. The transmittance spectra reveal that the films show good transparency exhibiting interference pattern for wavelengths greater than 1000 nm. The AFM image revealed that the average grain size was 20 nm and the surface roughness was about 8 nm.