p-Type CuI Window by SILAR on n-Type CISCuT Absorber Layers: Preparation, Characterization and its Device Performance

B. R. Sankapal and A. Ennaoui
Division Solar Energy Research,
Dept. Heterogeneous Material Systems
Hahn-Meitner Institut, Glienicker Strasse 100, D-14109, Berlin, Germany

SILAR (Successive Ionic Layer Adsorption and Reaction) method is simple, low cost and suitable for the deposition of thin films on roll-to-roll process. The method is based on immersion of the substrate in separately placed cationic precursor for adsorption and anionic precursor for chemical reaction. Rinsing between each immersion with highly purified water to avoid homogeneous precipitation is necessary. The adsorption of the precursor ions controls the SILAR process and the thickness as well.

CuI is a p-type semiconducting material with large band gap and high conductivity. The aim of this research work is to deposit p-CuI (buffer layer) on n-$CuInS_2$ (CISCuT-absorber) and to complete the device (solar cell) with ZnO-TCO layer. The deposition of CuI was carried out on glass and n-$CuInS_2$ substrates by SILAR method at room temperature (25^{o}C). The cationic and anionic precursors were optimized in aqueous solution as 0.1M $CuSO_4$ complexed with $Na_2S_2O_3$ adjusted to pH~5 and 0.025M KI, respectively. A single SILAR cycle consisted of 5sec adsorption, 10 sec rinsing and 20 sec reaction and 10 sec rinsing. Such SILAR cycles were repeated to get desired film thickness. Structural and surface morphological studies such as XRD and SEM are carried for CuI on CIS and on glass substrates. Transmission measurement for CuI was performed on glass substrate. J-V measurement was used for the device performance.

Fig.1 (a-d) show the XRD patterns of CIS (reference), CIS/CuI, CIS/CuI (with I_2-treatment) and CuI on glass, respectively. Strong orientation is observed along (111) direction at 25.56° corresponding to γ-CuI with zinkblende structure. SEM image of CuI on glass was found almost uniform with the crystallite size in the range of 50-100nm. Surface morphology of CuI on CIS shows fibrous structure (fig.2). After I_2-treatment of CuI on CIS, small crystallites appeared and cover the fibrous structure (fig. 3). This is also supported by XRD studies which shows enhancement in peak intensity along (111) direction. Optical transmission was found to be more than 70% in the visible region of solar spectrum. By plotting the square of the absorption coefficient (α), vs. energy (hν), the direct band gap value was estimated to be 2.97 eV. The output characteristic of the device (CIS/CuI/ZnO) was measured (fig.4) under AM 1.5 conditions (100mWcm^{-2}) as total area to include grid loss. The efficiency was found to be 2.48% for as-deposited CuI on CIS. Enhancement of the efficiency to 4.0% was observed after iodine treatment.

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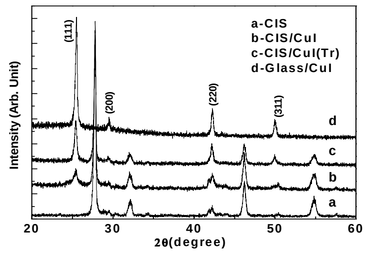

Fig.1 X-ray diffraction patterns of CuI

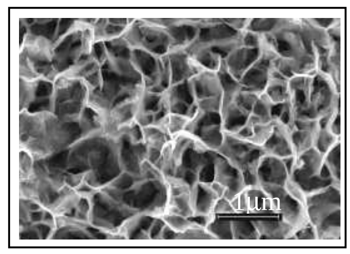

Fig.2 Scanning electron microscopy image of CuI on $CuInS_2$

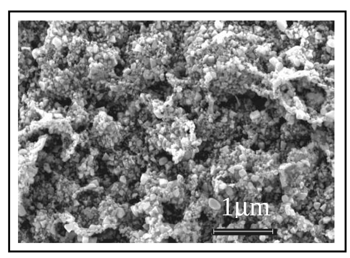

Fig.3 Scanning electron microscopy image of CuI on $CuInS_2$ after iodine treatment

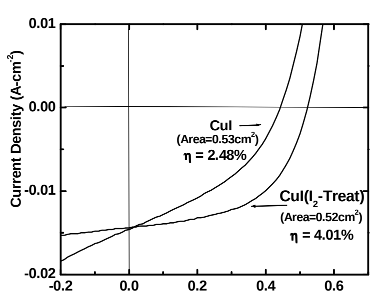

Fig.4 J-V characteristics of CIS/CuI with and without iodine treatment under AM 1.5conditions