SURFACE AND OPTICAL PROPERTIES OF $Cu_2InGaSe_2$THIN FILM ABSORBER LAYER FOR HIGH EFFICIENCY SOLAR CELLS

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Copper Indium Gallium diselenide $Cu_2InGaSe_2$ (CIGS) thin film was fabricated on molybdenum (Mo) coated soda lime glass substrate. The surface morphology, optical properties and carrier life time measurements were investigated and measured by atomic force microscopy (AFM), Raman spectroscopy, UV-Vis spectroscopy and time resolved photoluminescence (TRPL) measurement. The observed noteworthy results were presented and discussed.

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Keywords: CIGS, Thin film, Absorber layer, Solar cells, Carrier life time

1. Introduction

CIGS is one of the important direct band gap I-III-VI_2thin film absorber material composed of copper, indium, gallium, and selenium. Band gap of the CIGS thin film can modified from 1.1 to 1.6 eV by tuning the gallium and Indium composition. High energy conversion efficiency of $CuInGaSe_2$ (CIGS) solar cell devices has been largely issued for the last decades. The CIGS devices have proved superior laboratory scale photo power conversion efficiency (*PCE*) over 18% and a successful installation of plant scale level with megawatt power conversion for the past decades [1-7]. However, an in-depth research is still ongoing to reach the theoretical efficiency limitation using many ways, such as controlling the In and Ga ratio, suitable n-type buffer layer modifications, molybdenum (Mo) back metal surface texturing and controlling the sodium participation, ultra-thin quasi-ohmic layer formation and selenium flux controlling [8-27], reducing the resistance and increasing the transparency of transparent conducting oxide (TCO) layer, grid pattern designing, antireflection coating and texturing, and suitable protection over layer [28-32].

The CIGS solar cells have demonstrated high power conversion efficiencies exceeding 20% in laboratory scale (0.45 cm^2) and 13-16% in case of sub-module or mini-module level was reported by industries and few research groups which stems from the defect-free absorber layer. Mo-CIGS interface and the effect of Na diffusion through the Mo back contact metal on the performance of CIGS solar cells have been reported by many research groups and they are well understood.

In the present work, a good quality CIGS absorber layer fabrication with large grain boundary and its surface morphology were investigated. CIGS absorber layer defect related things were analyzed by Raman spectroscopy. Carrier life time measurement was carried out to analyze the carrier generation capability and the optical reflectance was measured to find out the CIGS absorbance.

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2. Experimental

p-type CIGS thin film absorber layer was fabricated with the following procedures. The 2.8-3.0 cm^2 CIGS absorber layers were deposited on the Mo-coated soda-lime glass (SLG) substrates through a conventional three-stage co-evaporation. CIGS layer was grown at the Mo/soda lime glass substrate temperature of 530 (±3) °C. To obtain the high uniformity, the Mo substrate was rotated at an RPM of 5 throughout the deposition.

3. Results and discussion

Fig (1) shows the AFM image of our fabricated CIGS thin film absorber layer. AFM analysis on the fabricated CIGS absorber layer showed relatively smooth surface morphology and also exhibits the larger grains. One can control the charge carrier loss due to surface defects by making the CIGS layer with large grain boundaries. The present smooth surface morphology will lead to achieve high photo-conversion efficiency.

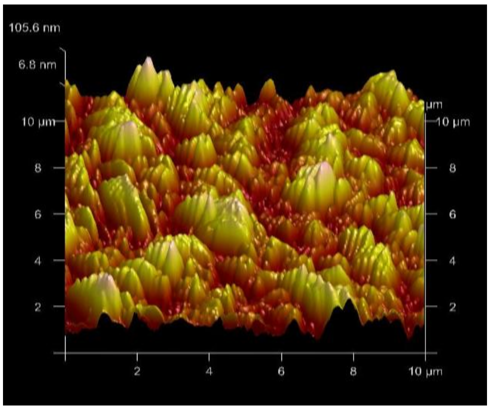

Fig (1) AFM image of the fabricated CIGS thin film absorber layer

Fig (2) showed a Raman spectrum of the fabricated CIGS absorber layer and the spectra were recorded at the room temperature. Raman spectra on the fabricated CIGS absorber layer was recorded from 20 to 500 cm^{-1} and the obtained result showed an intense single peak Raman shift. One small defect peak at 220 cm^{-1} was also observed which confirms a small negligible amount of CIS or CIGS with impurity related defect formation.

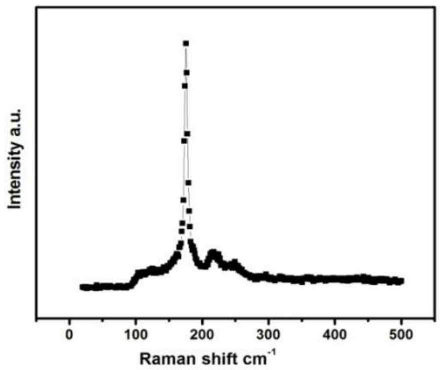

Fig 2. Raman spectrum of the fabricated CIGS absorber layer

Fig (3) showed the UV-Vis reflectance spectra of the CIGS absorber layer. UV-Vis spectrum of the fabricated CIGS absorber layer showed the optical reflectance of less than 12% in the wavelength range of 300-1100 nm and the optical reflectance exceed 12% over the wavelength range of 1100 nm. The total optical absorbance was over 85% in the wavelength range of 300-1100 nm which is important to generate more photo carriers.

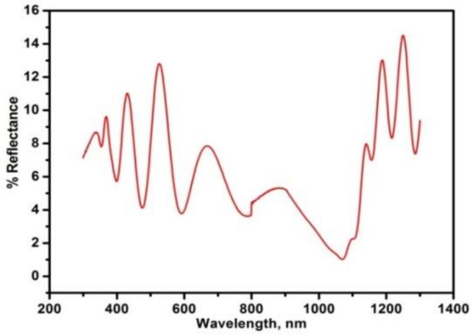

Fig 3. UV-Vis reflectance spectrum of the fabricated CIGS absorber layer

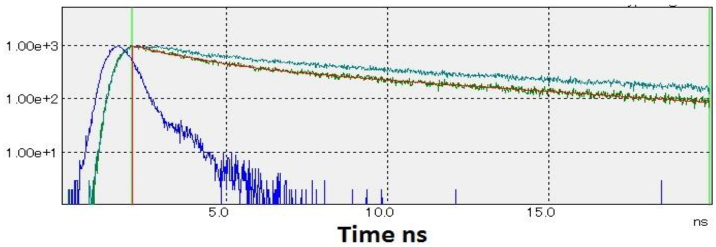

Fig 4. Carrier life time of CIGS absorber layer

Fig (4) showed the carrier life time of the CIGS absorber layer with third order fitting. Room temperature TRPL measurement of the fabricated CIGS absorber layer showed a greater carrier life time of 7 ns which evidences the grown CIGS layer has defect free crystalline quality and less surface defects. These longer carrier life times are important to prevent the immediate recombination near to the space charge region and which promote the output current uninterruptedly.

4. Conclusions

The fabricated CIGS thin film absorber layer at the Mo/soda lime glass substrate temperature of 530 (±3) °C showed a better surface and optical properties. The AFM image of the CIGS layer showed larger grains with lower surface defects and has relatively smooth surface morphology. The intense single Raman shift peak exhibits the grown CIGS has less defects and one small Raman shift shoulder peak might originate from the impurity oriented CIGS or CIS phase formation. The lower optical reflectance (less than 12%) showed the fabricated CIGS layer has good optical absorption which is important to generate more number of photo-carriers. The TRPL measurement showed the photo-carriers generated from the CIGS layer has a longer carrier life time of 7 ns which can produce high photo-conversion efficiency.

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