Contract Report

High Throughput, Low Toxic Processing of Very Thin, High Efficiency CIGSS Solar Cells

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1: INTRODUCTION

The major concern in the photovoltaic industry is to find a way to reduce the cost below $1.00/peak watt to make the technology economically viable. Keeping this goal in mind the research activities are focused on developing highly efficient thin-film solar cells capable of being produced using an economical process. $CuIn_{1-x}Ga_xSe_{2-y}S_y$ (CIGSeS) is a potential candidate for this purpose. Efficiency of 19.5% [1] has been achieved on $CuIn_{1-x}Ga_xSe_2$ (CIGS) deposited using co-evaporation. Sputtering is the technique capable of providing high yield and higher production rates. Research activities presented here focuses on developing CIGSeS thin films by depositing elemental precursor Cu-In-Ga by sputtering technique followed by selenization/sulfurization in either conventional furnace or by rapid thermal processing. During the first year, experiments were carried out to optimize conditions for both conventional and rapid thermal processing approaches. Also experiments were conducted on very thin absorber layers with both the conventional and rapid thermal processing approaches. These initial experiments towards optimizing the selenization parameters were discussed in detail in earlier reports.

During this quarter, experiments were carried out to optimize the metallic precursor deposition for standard and very thin absorber preparation and selenization/sulfurization parameters for the conventional furnace and rapid thermal processing. Also maintenance of two cryopumps was completed and maintenance of diffusion pump was carried out. The two cryopumps are used to obtain high vacuum in sputtering systems while the diffusion pump is used for obtaining high vacuum in the vacuum evaporation system.

2: OPTIMIZATION OF METALLIC PRECURSOR DEPOSITION AND SELENIZATION/SULFURIZATION IN THE CONVENTIONAL FURNACE

Experiments are being carried out to optimize the Cu/In+Ga ratio and also to analyze the effect of variation of NaF. The selenization and sulfurization process parameters are also being optimized. The composition is being analyzed by electron probe microanalysis (EPMA) and X-ray energy dispersive spectroscopy (XEDS), the crystallographic structure is being studied by X-ray diffraction (XRD) and the morphology is analyzed by scanning electron microscopy (SEM). The photovoltaic characteristics are being studied by current-voltage (I-V) and quantum efficiency (QE) measurements.

3: RAPID THERMAL PROCESSING

Rapid thermal processing (RTP) provides a way to rapidly heat substrates to an elevated temper After getting encouraging results during research carried out in year one, (efficiencies approaching 13%) [2] further optimization of the RTP process is being carried out. Currently experiments are done to optimize the Cu/In+Ga ratio. As described above the detailed material and photovoltaic characterization is being carried out by EPMA, XEDS, XRD, SEM, TEM, I-V and QE techniques.

4: ULTRA THIN CIGSeS THIN FILM SOLAR CELLS

Experiments are being carried out to further optimize the process for very thin absorbers by selenization/sulfurization in conventional furnace and by rapid thermal processing (RTP). Earlier very thin (0.9 μm) CIGSeS thin film solar cell by rapid thermal processing approach have shown an efficiency of 8.65% measured at NREL. Optimization of Sulfur content is being carried out for RTP approach because of the lower Jsc values of earlier cells [2].

5: MAINTENANCE

5.1 Cryopumps Maintenance

The CIGSeS thin films are prepared by depositing CuGa-In metallic precursors on molybdenum coated glass substrates by using DC magnetron sputtering, after selenization/sulfurization and CdS hetrojunction partner layer deposition on CIGSeS layer, the next step is to carry out ZnO/ZnO:Al window bilayer deposition by RF magnetron sputtering. Cryopumps are used to obtain vacuum in these sputtering chambers. Two cryopumps are used for obtaining high vacuum in CuGa and In, DC magnetron sputtering chamber and i-ZnO and ZnO:Al RF magnetron sputtering chamber.

Maintenance of these pumps became essential because the ultimate vacuum level obtained in the chambers was deteriorating and it was necessary to carry out frequent regeneration for these cryopumps. Therefore, maintenance kits for both the cryopumps were purchased. After this, one of the pumps was dis-assembled for inspection and thoroughly cleaned. Coldhead and displacer assembly O-rings and gaskets that were subjected to wear during service were replaced with new O-rings and gaskets from the service-kit. After replacing the worn-out components and reassembling the displacer, the displacer assmebly was kept in oven for baking at 80°C for 24 hours. After this step, the displacer assembly was reassembled into the cryopump.

It was decided to replace absorber in the cryocompressor, since it was nearing the completion of service life period of 15000 hours. A new cryocompressor absorber unit was procured was installed. A crypcompressor was re-charged with helium to obtain earlier level helium pressure of 16.5±1.0 bar.

The smaller cryopump was connected to the cryocompressor using helium lines and the pump down was initiated. A low temperature of ~20 K was obtained in the cold head.

The same maintenance procedure was repeated for the larger cryopump and after successfully completing the maintenance procedure, both the cryompumps were connected in parallel to the cryocompressor. Now the cryopumps are being used for obtaining vacuum of the order of 10^{-6} Torr in CuGa and In DC magnetron sputtering chamber and the i-ZnO/ZnO:Al RF magnetron sputtering chamber. With the completion of maintenance of the cryopumps and cryocompressor, sputtering of CuGa and In metallic precursors and i-ZnO/ZnO:Al window bilayer is being carried out routinely.

5.2 Diffusion Pump Maintenance

During the fabrication of CIGSeS thin film solar cells some of the processes are carried out by vacuum evaporation. These processes include sodium fluoride (NaF) deposition for incorporation of controlled amount of sodium in the CIGSeS film, elemental selenium deposition during CIGSeS formation by rapid thermal processing (RTP) and, deposition of chromium and silver contact fingers.

Vacuum in the evaporation chamber is obtained by mechanical pump and diffusion pump. Initial vacuum in diffusion pump is obtained by mechanical pump using backing valve. This backing valve is in turn activated with the help of pneumatic driven solenoid valve actuator. During a deposition process, the solenoids valve actuator malfunctioned and the backing valve did not open. Due to this the diffusion pump oil backstreamed into the vacuum evaporation chamber. During the maintenance period, all regular experiments were temporarily halted, a new pneumatic driven solenoid valve was procured and all the vacuum evaporation systems components were disassembled for thorough cleaning.

The system components that were disassembled for cleaning included diffusion pump, liquid nitrogen trap, gate valve, backing and roughing valves and, vacuum evaporation chamber components e.g. electrodes and substrate mounting mechanism parts. These components were individually dismantled, so that all the inside surfaces could be cleaned properly. The initial cleaning was carried out by lint free cloth to wipe out the oil. Then these parts were thoroughly cleaned with the help of soap and high pressure water jet. Afterwards these parts were degreased to insure that no traces of oil remained. The inside surface of the vacuum evaporation chamber was also thoroughly cleaned using the same procedure. All the components were thoroughly dried for 24 hours in air to insure effective moisture removal. For intricate parts the drying was also facilitated using a hot air blower.

The individual components e.g. liquid nitrogen trap, gate valve, backing and roughing valves were then reassembled. As the diffusion pump oil has backstreamed into the chamber, the quantity of the oil in the diffusion pump was reduced. New diffusion pump oil was refilled to ensure that the oil quantity was back to normal level i.e. 800 ml. These components were mounted back into the system and their pneumatic, electrical and cooling water connections were carried out. After this the system was tested and normal operation was observed. Currently the vacuum evaporation processes are resumed in a routine manner.

6: REFERENCES

[1] Miguel A. Contreras, K. Ramanathan, J. AbuShama, F. Hasoon, D. L. Young, B. Egaas and R. Noufi, Prog. Photovolt: Res. Appl. 2005; 13:209–216.
[2] High Throughput, Low Toxic Processing of Very Thin, High Efficiency CIGSS Solar Cells, Year 1, Final Report.