Thrust Area 4: Solar (Low Cost PV Manufacturing)

Development of High Throughput CIGS Manufacturing Process

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Description: A reduction in the cost of CIGS and other thin film PV modules is required for broad PV applications. The project objective is to develop a high-rate deposition process for synthesis of CIGS absorbers and other layers by employing in-line and batch deposition techniques. The goal is finally to attract a PV manufacturing company to Florida by developing a high-rate manufacturing process for $CuIn_xGa_{1-x}Se_2$ (CIGS) solar cells.

Budget: $141,620
Universities: UCF/FSEC

Progress Summary

The back contact for the CIGS thin film solar cells comprises of molybdenum film that is approximately 1um thick. Typically the film is deposited in a stacking sequence to form a composite structure that has good adhesion and at the same time low resistivity. A thorough study has been carried out recently to understand the effect of processing parameters on the properties of molybdenum back contact. Back contact deposition is a bottleneck in high volume manufacturing due to the current state of art where molybdenum back-contact film consisting of multiple layers must be deposited to achieve the required properties. Experiments were carried out in order to understand and solve this problem.

The effect of working distance (distance between the target and the substrate) on film properties was studied and is being presented here. The main goal in reducing the working distance was to determine the increase in the deposition rate that would be very essential in order to reduce the deposition time and eventually the manufacturing cost. Earlier work carried out on molybdenum films reflected on the effect of the sputtering power and working gas pressure on the film properties. This work is a continuation of that effort in understanding effects of various sputtering parameters and determining the route to develop a composite molybdenum film that possess the required properties of near zero stress, low resistivity and good adhesion to substrate. Further effort has also been made on the development of CIGS solar cells with higher efficiencies.

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The effect of varying the sputtering power on the residual stress in the films deposited at working gas pressure of 1 mTorr was studied. Also, the effect of working gas pressure on the residual stress in the films deposited while keeping sputtering power constant at 200 W was also investigated. It was found that lower sputtering power of 200 W yielded tensile stresses in the molybdenum films. At higher sputtering power of 275 W some compressive stresses were developed in the molybdenum film.

Variation of residual stress with varying working gas pressure suggests an inverted U shaped curve where the tensile stress reaches maximum and then the tensile stress is reduced with the increase of working pressure. Beyond a certain higher pressure, the residual stress crosses into the compressive stress regime. As compared to earlier work, at working distance of 6.5 cm, the dependence of residual stress on the processing conditions is significantly different. It is noted that the properties of the plasma change with varying working distance. Moreover, the discharge voltage required to achieve the same sputtering conditions of power and pressure for working distance of 6.5 cm was higher as compared to that required for working distance of 9 cm. This higher discharge voltage results in higher kinetic energy of the sputtered atoms as well as of the back-scattered and neutralized argon atoms. A four point probe technique was used to measure the sheet resistance of the films and the resistivity of the films was calculated. Figure 1 and 2 shows the variation of resistivity with varying sputtering power and working gas pressure respectively.

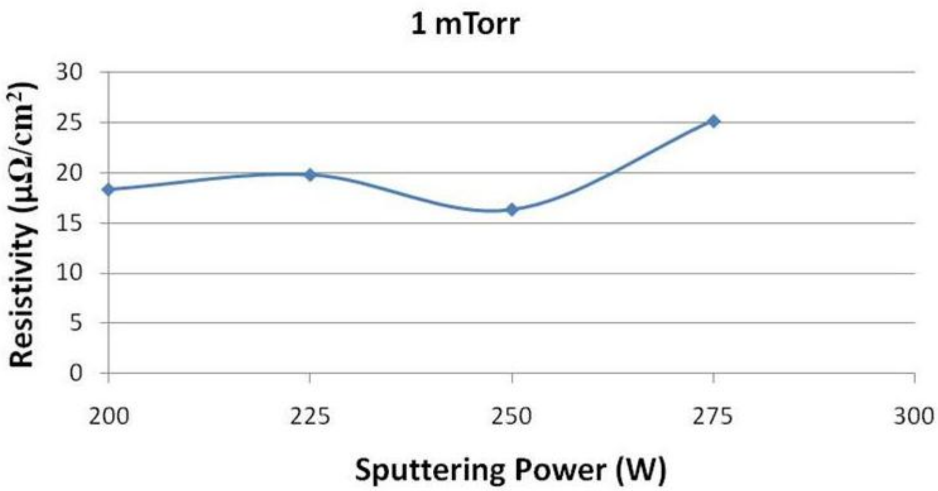

Figure 1: Variation of Resistivity with varying sputtering power for working distance of 6.5 cm

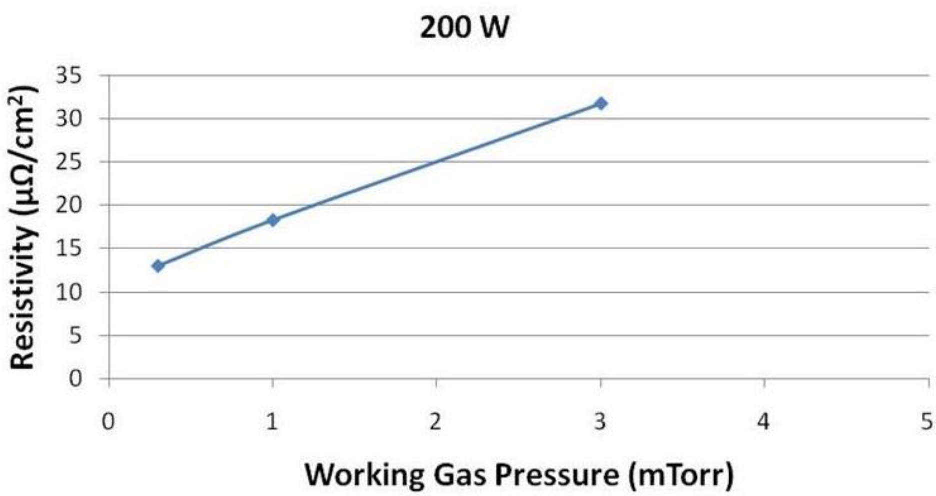

Figure 2: Variation of Resistivity with varying working gas pressure for working distance of 6.5 cm

In Figure 1, the variation in the resistivity of the molybdenum films with sputtering power is not significant. In Figure 2, the resistivity increases with increasing gas pressure because as the pressure increases the scattering of sputtered atoms and the neutralized argon atoms take place. Therefore, the incident kinetic energy of the sputtered atoms and the neutralized argon atoms is reduced which in turn can lead to a slightly more open structure causing an increase in resistivity.

CIGS Solar Cells Development:

Currently research is also being carried out on the development of $CuIn_xGa_{1-x}Se_2$ (CIGS), $CuIn_xGa_{1-x}Se_2S_{2-y}$ (CIGSeS), $CuIn_xGa_{1-x}S_2$ (CIGS2) thin-film solar cells on the soda-lime glass substrate with the molybdenum back contact. The goal is to correlate the processing parameters with materials and electronic properties of solar cells. Efficiencies close to the previously achieved record numbers have been obtained at PV materials lab at FSEC. Official results are pending characterization at the NREL facility.

Human Resources:

Shirish Pethe (PhD in Electrical Engineering) graduated in fall 2010 and Ashwani Kaul (PhD in Material Science) will be graduating in spring 2012. Eric Schneller (M.S in Material Science) will be graduating in fall 2012. Narendra Shiradkar (PhD) and Sagarnil Das (PhD) joined the group during fall 2011.

Publications:

3. S. A. Pethe, A. Kaul and N. G. Dhere, "Effect of working distance on properties of sputtered molybdenum films", submitted for the upcoming MRS- Spring 2011 conference.
4. N. G. Dhere, A. Kaul, S. A. Pethe, and, H.R. Moutinho, "Structural study of CIGS and CIGS2 thin-film solar cells using EBSD technique", 26^{th} European Photovoltaic Solar Energy conference, Hamburg, Germany, September 2011.