Contract Report

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

**NREL contract no. XXL-5-44205-08, UCF/FSEC Account no. 2012 8098**

**Year 4, Quarter 1 Report**

**Report no.** FSEC-CR-1765-08

July 29, 2008

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# 1. DIFFUSION PUMP MAINTENANCE

During the fabrication of CIGSeS thin film solar cells some of the processes are carried out by thermal 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 thermal evaporation chamber is obtained by a combination of mechanical pump and diffusion pump with a liquid nitrogen trap.

During one deposition it was realized that the diffusion pump was not being heated. After checking the electric connections, it was observed that the contacts to heating elements had burnt due to repeated heating and cooling cycles. Therefore, new heating elements were procured. The pump body and the internal vapor-jet elements were thoroughly cleaned with soap water as well as with high pressure water jets and completely dried. As the parts of electrical circuit were corroded, they were thoroughly cleaned and re-painted to reduce further corrosion. As the diffusion pump oil had turned dark, new oil of required grade i.e. DC-704 and required quantity i.e. 800 ml was refilled into the diffusion pump. The new heating elements were then reconnected to the diffusion pump. During this maintenance period, all regular experiments had to be temporarily halted. After re-installation of the new heating elements the diffusion pump was mounted back into the system and the pneumatic, electrical and cooling water connections were carried out. After this the system was tested and it was observed the diffusion pump was heated as in a regular operation. Currently the vacuum evaporation processes are being resumed in a routine manner.

## 2. $Si_xN_y$/Mo DEPOSITION

Molybdenum has emerged as the dominant choice for the back contact layer to CIS and CIGSeS chalcopyrite thin film solar cells because of its relative stability at the processing temperatures, resistance to alloying with Cu and In, and its low contact resistance to the absorber [1]. It is essential to deposit stress-free and relatively inert Mo films in order to achieve well adherent and highly efficient CIGSeS absorber thin film solar cells [2]. This quarterly report gives results regarding the continued experiments with starting layer of molybdenum in tensile stress mode. Figure 1 and 2 shows the sequence of molybdenum layer deposition for these experiments. Molybdenum layer in compressive stress mode layer at top has lower sheet resistance as compared to molybdenum layer in tensile stress mode. This low sheet resistance is desirable for metallized back contact layer for solar cells.

| |
|---|
| Mo Compressive ~ 7000 Å |
| Mo Tensile ~ 2000 Å |
| $Si_xN_y$ ~ 1000 Å |
| Glass |

Figure 1: 2 layers Mo, top layer compressive.

| |
|---|
| Mo Compressive ~ 3500 Å |
| Mo Tensile ~ 1000 Å |
| Mo Compressive ~ 3500 Å |
| Mo Tensile ~ 1000 Å |
| $Si_xN_y$ ~ 1000 Å |
| Glass |

Figure 2: 4 layers Mo, top layer compressive.

The $Si_xN_y$ layer was sputtered using 425 watt sputtering power. Partial pressures of sputtering gases during the $Si_xN_y$ deposition were as follows: argon 8 x $10^{-4}$ Torr and nitrogen 8 x $10^{-4}$ Torr, the total pressure being 1.6 x $10^{-3}$ Torr. The Mo layers having tensile stress were sputtered using low sputtering power 200 watt and high sputtering gas pressure of 5 x $10^{-3}$ Torr. The Mo layers having compressive stress were sputtered using high sputtering power of 300 watt and low sputtering gas pressure of 3 x $10^{-4}$ Torr. In both cases, the sheet resistance measured at various locations of the sputtered molybdenum films was ~0.6 Ω/□.

Three different experiments have been carried out. One experiment was with 2 layer molybdenum, as shown in Figure 1 and the other two were with four layer molybdenum, as shown in Figure 2.

Figure 3 and 4 show cross-sectional transmission electron microscopy (TEM) images of 2-layer and 4-layer molybdenum films respectively.

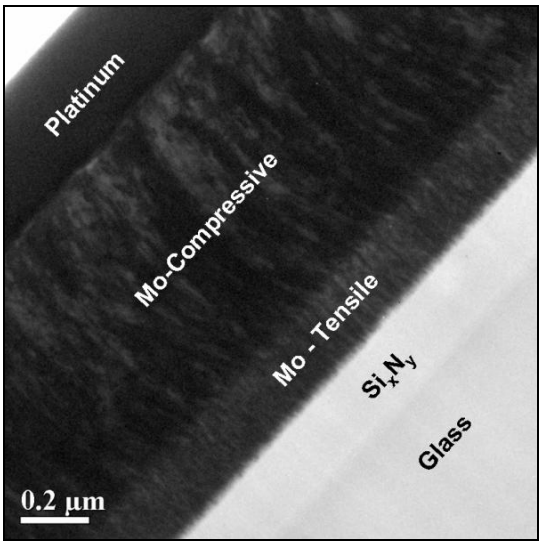


Figure 3: Cross-sectional TEM image of a 2 layer molybdenum film

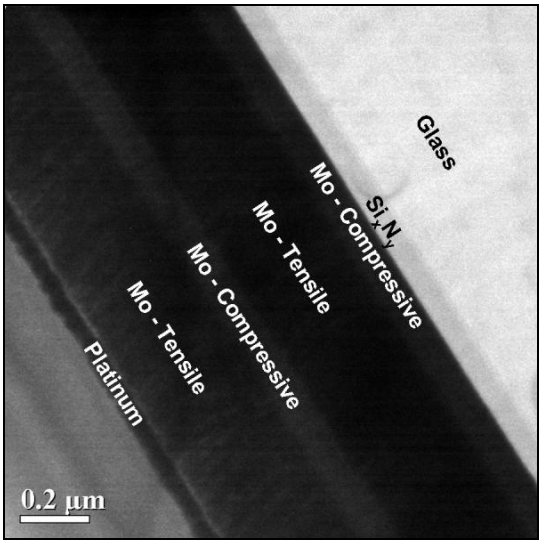


Figure 4: Cross-sectional TEM image of a 4 layer molybdenum film

Molybdenum films having a compressive starting tensile layer on $Si_xN_y$ barrier layer peeled off partially after selenization/sulfurization. The peeling off of the molybdenum has been substantially reduced when molybdenum films had tensile starting layer on $Si_xN_y$ barrier layer.

The CIGSeS thin film solar cells have been completed on these molybdenum films and the current-voltage (I-V) tests are being carried out.

## 3. REFERENCES

[1] K. Granath, A. Rockett, M. Bodegard, C. Nender, and L. Stolt, 13th European Photovoltaic Solar Energy Conference, Nice, France, Oct 23-27 1995, (H.S. Stephens & Associates, Felmersham, 1995), pp. 1983.

[2] Ankur A. Kadam, Neelkanth G. Dhere, Paul Holloway, Evan Law, J. Vac. Sci. Technol. A 23 (4) (Jul/Aug 2005) 1197