Barrier Coatings and Stability of Thin Film Solar Cells

4th Quarterly Report - Phase III:
June 1, 2007 -- August 31, 2007

NREL Subcontract: 48027

Subcontractor:	**Pacific Northwest National Laboratory**
Principal Investigator:	**Larry C. Olsen**

1. OBJECTIVES/APPROACH

The key objectives of the program are to develop low cost barrier coatings for CIS and CdTe solar cells and to develop an improved understanding of the effects of water on the stability of these types of cells. The scope of this work entails investigations of multilayer, barrier coatings for CIS and CdTe thin film solar cells, and studies of stability issues, particularly those related to moisture ingress. Investigation of barrier coatings on SSI and CSU devices will continue in an effort to establish effective approaches to encapsulate CIS and CdTe modules. Studies will also be directed towards issues concerning cost of the coating process. The program will be structured into three major tasks: (1) Barrier coatings and stability studies for CIS Solar Cells; (2) Barrier coatings and stability studies for CdTe solar cells; (3) Low cost coating process development.

2. PROGRESS FOR THIS REPORTING PERIOD

Work this past quarter concentrated on environmental testing of Shell Solar, Industries (SSI) cells. This work involved coating 2 in. x 2 in. SSI mini-modules (previously provided for our studies) with a PNNL PML barrier coating based on the use of a new polymer that can withstand an 85C/85%RH environment.

2.1 SSI Mini-Modules

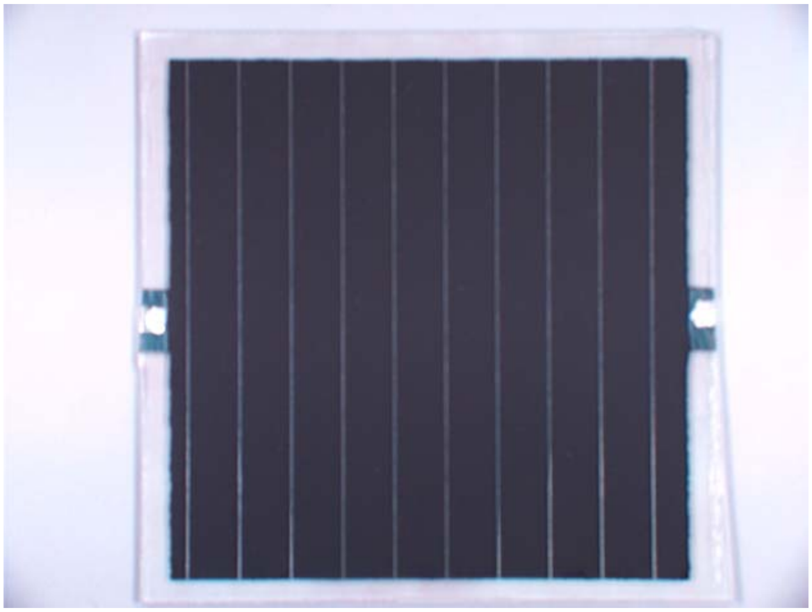
Since our main interest is currently in barrier coatings for CIGS cells, we have attempted to acquire cells from various sources. We will be receiving cells from IEC for activities next quarter. For studies this past quarter, we decided to utilize 2 in. x 2 in. mini-modules provided by SSI two to three years ago. They were stored under ambient conditions, and had degraded to some extent. Nevertheless, we thought it would be useful to acquire data under 85C/85%RH (85/85) environmental conditions, since all of our previous studies have been carried out at 60ºC/90%RH conditions. We were particularly interested in carrying out studies using PNNL coatings based on a newly developed polymer. Specifically, the multi-layer coatings still consist of alternating layers of Al_2O_3 and polymer, but the polymer layers are deposited using a new blend and have been shown to tolerate the 85/85 condition..

Three types of tests were carried out:

(1) Bare modules subjected to 85/85 conditions;

(2) Coated modules subjected to 85ºC and dry conditions;

(3) Coated modules subjected to an 85/85 environment.



2 in.

Figure 1. SSI mini-module provided to PNNL in 2004.

A picture of a coated 2 in. x 2 in., SSI mini-module is shown in Figure 1. The min-module consists of 9 rectangular cells connected in series. They were provided by SSI to PNNL in 2004. Originally, the efficiency of these modules were in the range of 9 to 10 %. After being stored under ambient conditions since 2004, the efficiency of the remaining modules is typically in the range of 5 to 6 %. The degradation is apparently due to effects of moisture.

2.2 Results for Stressed Bare (Uncoated) Mini-Modules

Figure 2 describes results for a bare (uncoated) module. The relative efficiency is plotted versus time for the module subjected to 85/85 stress. The efficiency decreases rapidly in the first 20 to 40 hours, and then begins to decrease more slowly. Table 1 gives tabulated results for the bare cell. It is interesting to consider which cell properties account for the decrease in efficiency. The rather abrupt decrease in efficiency during the first 10 hours is primarily due to the fill factor being reduced by >40%, and to some extent as a result of Voc being reduced. Between 10 and 70 hours, FF and Voc do not change significantly, but Jsc is reduced by 50%. We find that the cells do not degrade significantly due to the 85ºC/dry environment. Thus the degradation is clearly a result of water penetrating the cell structure.

It appears that in the first 10 hours, the sheet conductance of the ZnO TCO is greatly reduced. Beyond 10 hours, the main effect is the reduction of Jsc. Apparently, water

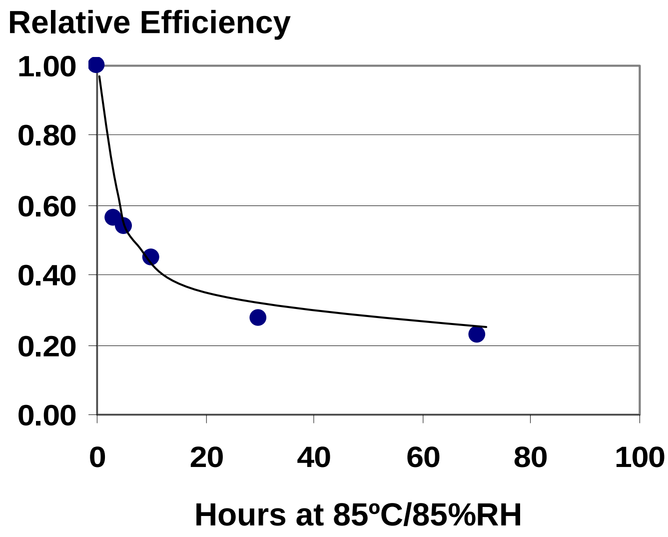


Figure 2. Relative efficiency versus time for a bare min-module subjected to 85/85.

Table 1 -- J-V Parameters vs Time for a Bare Module Subjected to 85/85*

Hours	Jsc (mA/cm2)	Voc (Volts)	FF (%)	Efficiency (%)
0	22.46	.510	45.6	5.23
3	21.0	.433	26.4	2.93
5	20.8	.433	30.6	2.81
10	20.1	.424	27.5	2.33
30	16.0	.390	23.0	1.44
70	10.6	.439	25.0	1.18

* Jsc is computed by dividing the Isc value by the area of one of the rectangular cells, namely, 2.75 cm^2. The Voc and Efficiency numbers are the average value for an individual cell.

diffuses into the depletion region causing a significant increase in recombination centers and thus reduced photocurrent.

2.3 Environmental Testing of Mini-Modules with Barrier Coatings

Data were acquired for SSI mini-modules that were coated with PNNL barrier coatings based on the new polymer blend. Results were obtained for coated modules subjected to 85ºC and dry conditions, and modules with barrier coatings of thicknesses ranging from 3 microns to 10 microns. The 85ºC/Dry testing was done to determine if

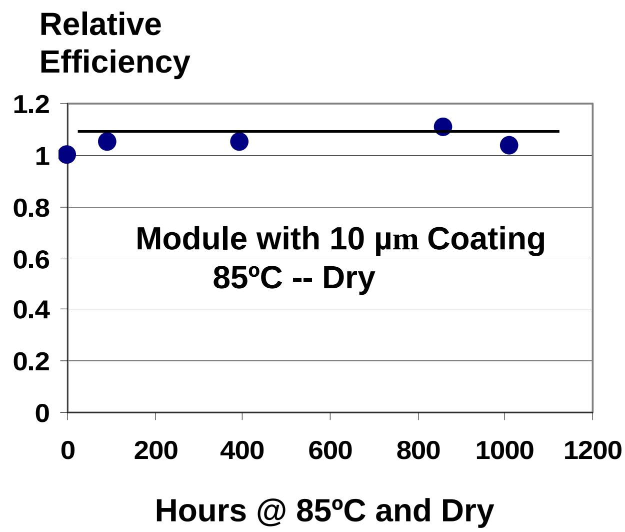


Figure 3. Relative efficiency versus time for a mini-module stressed at 85C and 0%RH.

the coatings react in a negative way with the devices. We found that all coated modules were stable in the 85ºC/Dry conditions. Figure 3 gives results for a module with a coating 10 microns thick. Basically, the module is stable. Thus, it is very clear that the SSI mini-module can tolerate 85ºC and dry conditions, but not a stress of 86ºC/85%RH.

Figure 4 gives results for coated mini-modules with the results for a bare module shown for contrast. Although the PNNL barrier coatings have made a tremendous difference, degradation still occurs. The fact that all modules degrade at the same rate, regardless of coating thickness, provides an important clue as to the cause of the degradation. Based on our overall experience, the effectiveness of the barrier coatings should improve with thickness. In general, we find that there are three cell features that can lead to defects in the multi-layer coatings which in turn provide a path for water diffusion:

(i) Surface roughness;

(*ii*) Inadequate edge seal;

(*iii*) Cuts separating individual cells.

Since the rate of degradation of efficiency is independent of the coating thickness, we suspect that features (ii) and (iii) are most likely responsible for causing pathways of moisture diffusion. Further studies are required before this problem(s) can be clearly identified. However, the results achieved with the new polymer blends in an 85/85 environment are very encouraging.

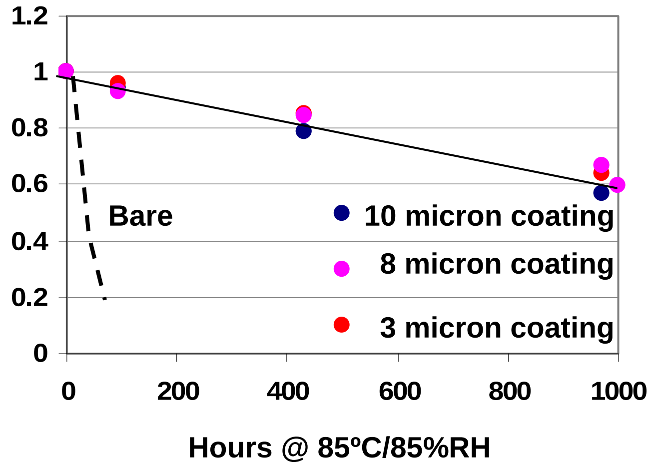


Figure 4. Relative efficiency versus hours for coated modules subjected to 85ºC/85%RH

3. FUTURE WORK

Dr. Shafarman has agreed to prode some IEC CIGS cells for stress studies. These studies will be discussed in the next quarterly report.