ITN Energy Systems, Inc.
8130 Shaffer Parkway, Littleton, Colorado 80127-4107

Voice: 303 420 1141 | Fax: 303 420 1551
Email: info@itnes.com | Web: www.itnes.com

July 19, 2004

Dr. Harin Ullal, MS3212
National Center for Photovoltaics
National Renewable Energy Laboratory
1617 Cole Blvd
Golden, CO 80401

Re: Thirty-First Monthly Report #NDJ-2-30630-11

Dear Harin,

This letter comprises the monthly technical status report for ITN's subcontract # NDJ-2-30630-11, "Plasma-Assisted Coevaporation of S and Se for Wide Band Gap Chalcopyrite Photovoltaics", under the Thin Film Partnership Program. The reported work was performed during the seventh month of phase 3 for this contract (thirty-first month overall), which is June 7, 2004 through July 7, 2004. This report describes activities performed by ITN, as well as those performed by lower-tier subcontractor Colorado School of Mines (CSM), under the direction of Dr. Colin Wolden.

1. Program Goals and Approach

Our primary objective under this program is to determine if the chalcogen in CIGS co-evaporation can be delivered more effectively by activation with a plasma. Possible advantages of plasma-assisted co-evaporation (PACE) are

- increased utilization of chalcogens,
- decreased deposition temperatures,
- decreased deposition times, and
- increased ability to tailor S/Se ratio.

University researchers at CSM are developing and testing the fundamental chemistry and engineering principles. Industrial researchers at ITN are adapting PACE technology to CIGSS co-evaporation and validating PACE process for fabrication of thin film PV. In_2Se_3 films, which are used as precursor layers in high-efficiency CIGS depositions, were used as the first test case for the examining the advantages of PACE listed above, and significant advantages were demonstrated. Presently, the examination is being extended to the complete high-efficiency three-stage CIGS co-evaporation process.

2. Incorporation of PACE Sources Into Three-Stage Deposition

Last month, the first operation of a PACE source (without applying RF) during three-stage CIGS deposition was demonstrated.

This month, two major steps toward full incorporation of PACE processing with RF into three-stage CIGS deposition were made. First, the new PACE source was integrated into the fully-automated CIGS control. The automated control in the bell jar was established early in the PACE program. It maximizes reproducibility between different depositions and operators, since all depositions are run from pre-programmed recipes. Furthermore, all measured quantities are logged to the computer for later reference. Incorporating the new PACE source into this control strategy required adding hardware and software to communicate with the PACE source temperature controllers, heat the PACE source according to computer-specified setpoints, log PACE source rates and temperatures, and allow recipe programming of these quantities. Figure 1 shows rates and temperatures from the first fully-automated CIGS run incorporating a PACE source. Because the PACE source has a much larger thermal mass than the traditional Ta boat, some minor oscillations in Se rate are unavoidable. However, these ~15% oscillations are much smaller than the recommended 2 to 10x Se-to-metals ratio envelope that is considered acceptable for high-quality CIGS formation. Figure 2 shows a sample of the recipe program used to run the deposition. A second step made this month is the adaptation of chamber internals to accommodate power to the RF coil on the PACE source. To accommodate feedthroughs for RF power and the source placement, several chamber components had to be moved, including the quartz crystal microbalance, the In source bus bar, the infrared substrate sensor, and the traditional tantalum Se boat. Argon was piped into the source area. Next month, the RF coil will be installed and a plasma struck on the PACE source.

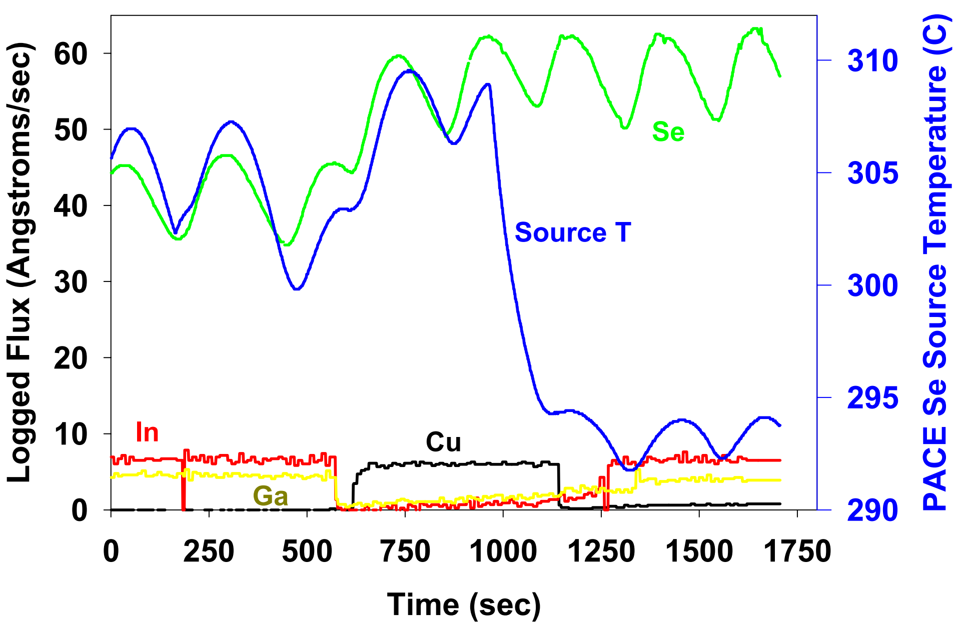
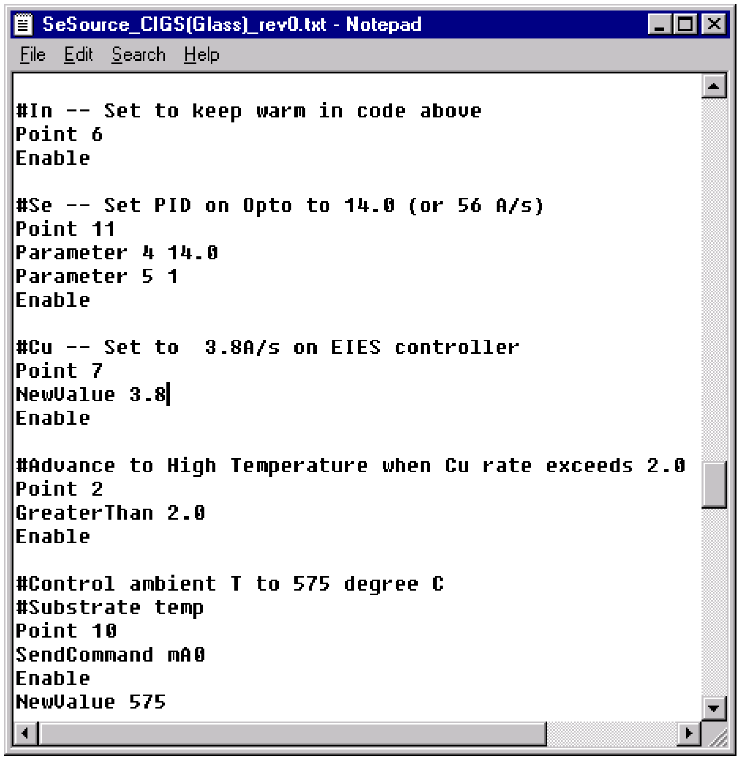


Figure 1: Rates and temperatures from fully-automated CIGS run incorporating PACE source..




```
#In -- Set to keep warm in code above
Point 6
Enable

#Se -- Set PID on Opto to 14.0 (or 56 A/s)
Point 11
Parameter 4 14.0
Parameter 5 1
Enable

#Cu -- Set to  3.8A/s on EIES controller
Point 7
NewValue 3.8
Enable

#Advance to High Temperature when Cu rate exceeds 2.0
Point 2
GreaterThan 2.0
Enable

#Control ambient T to 575 degree C
#Substrate temp
Point 10
SendCommand mA0
Enable
NewValue 575
```

Figure 2: Example portion of recipe used to program the deposition with the PACE source.

3. Team Activities

ITN and CSM participate in CIS team activities. This month, the outline of a publication describing absorber sub-team activities was further revised according to participant comments. Co-authors who will be contributing text over the next month were contacted individually and division of responsibilities was discussed.

Best Wishes,

Ingrid Repins
Principal investigator
ITN Energy Systems

Cc: Ms. Carolyn Lopez; NREL contracts and business services
Dr. Colin Wolden; CSM technical lead