Reaching Grid Parity Using BP Solar Crystalline Silicon Technology

for

DOE Solar Energy Technologies Program Review

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Outline

- **Program goals and objective**
- **Program Tasks**
- **Partners**
- **Progress Highlights**
- **Issues**

Overall Program Objective

- **Accelerated development of multicrystalline silicon technology.**
- **Module designed for use in residential and commercial markets with products designed specifically for these applications.**
- **System components designed to add value to electricity produced.**
- **To achieve parity with the grid and grow to Gigawatt levels of production will require involvement of the entire product chain.**

Specific Objectives

- **Module cost reductions to:**
  - **67% of today's costs by 2010**
  - **50% of today's costs by 2015**
- **System cost reduction to:**
  - **60% of today's costs by 2010**
  - **36% of today's costs by 2015**
- **Levelized cost of electricity in 2015 of**
  - **8 to 10 ¢/kWh for residential**
  - **6 to 8 ¢/kWh for commercial**

Program Tasks

- Silicon Feedstock
- Casting
- Wafering
- Cells and Contacts
- Modules
- Manufacturing
- Inverter
- Monitoring and BOS
- System Engineering and Integration
- Installation and Maintenance
- Deployment
- Collaboration

Partners

- **Subcontracts signed with**
  - **AGC Flat Glass**
  - **ASU**
  - **Ceradyne**
  - **Dow Corning**
  - **FSEC/UCF**
  - **Georgia Tech**
  - **Komax**
  - **NCSU**
  - **PARC**
  - **Recticel**
  - **STR**
  - **Xantrex**
- **Subcontracts under negotiations with**
  - **SMUD**
  - **Fat Spaniel**
  - **ATS**

Silicon Feedstock Highlights – Dow Corning

- **Preliminary designs for the directional solidification pilot plant are complete and a vendor has been selected for building the furnace.**
- **Several materials have shown promise as materials of construction for re-useable crucibles. Longer term studies with each material are in progress.**
- **Initial studies have shown a dependence of segregation effectiveness on crystal growth rates during directional solidification. At segregation rates below ~0.7 mm per minute, near theoretical segregation coefficients have been obtained.**

Casting Highlights

- **Mono^2™**
  - **Demonstrated efficiency gain using Mono^2 technology under PV Manufacturing R&D program.**
  - **Completed internal qualification and external certification to IEC 61215.**
  - **Built 210 kW of modules and delivered to customer for installation in system being monitored.**
  - **Designed and installed equipment for casting process control and template cleaning.**
- **Casting of larger ingots**
  - **Installed new 400 kg stations.**
  - **In process of optimizing casting in these larger stations.**

Casting Highlights (cont)

- **Ceradyne has established the critical operating parameters for *Pre-Coated PV Crucibles* through multiple tests with BP Solar.**
- **NCSU determined that the low minority carrier lifetime region at base of ingot is the result of a complex interaction between impurities (Fe and O) and grown in crystal defects.**
- **NCSU determined that dislocations can be nucleated by precipitates or inclusions that become trapped at the solid/liquid interface. These dislocations can then contribute to the "cascades" observed in the lifetime scans.**

Wafering Highlights

- **Switched production to 200 μm thick wafers using 140 μm diameter wire.**
- **Completed more than 30 runs utilizing 120 μm wire.**
- **Have cut > 5,000 180 μm thick wafers for test.**
- **Wafer singulation machine delivered and qualified for operation.**

Cell and Contacts Highlights

- **Completed internal qualification and external certification to IEC 61215 for low bow Al paste.**
- **Developed Iso-chemical texturing process (ICT) and selected for implementation with Mono^2.**
- **Fabricated solar cells with conventional screen printed front contacts and BSF, with laser-fired Al rear contacts resulting in cell efficiencies as high as 15.8%.**
- **PARC is printing wafers using a 16 nozzle print head, producing lines that are 50 μm by 50 μm $\pm$ 15 μm.**
- **Georgia Tech modeling providing input to roadmap for high efficiency thin Mono^2 cells.**

Modules Highlights

- **Completed internal qualification and external certification to IEC 61215 for AGC AR coated glass. Implemented this glass for all products in Frederick.**
- **Completed internal qualification and external certification to IEC 61215 for STR faster cure EVA.**
- **Completed internal stage gate review (from *select* to *define*) for residential roof integrated product. Recticel assisting in design of part in terms of feasibility to mold.**

Modules Highlights (cont)

- **Demonstrated concept for commercial roof integrated product.**
- **Developed improved reliability test procedure to include dynamic mechanical loading to evaluate breakage of ultra-thin cells.**
- **BP Solar and STR are developing DSC (Differential Scanning Calorimetry) as a QA tool to monitor EVA cure level.**
- **Samples of high voltage/higher power solar modules have been completed and are in test.**
- **BP Solar, FSEC and ASU are setting up outdoor test stations to measure module energy collection.**

Manufacturing Highlights

- **Modified 2 production screen printers to optimize the process for thin wafers.**
- **Completed Measurement System Analyses for Cell Line in-process metrics. New measurement tools on order.**
- **Upgrading the Manufacturing Execution System (MES) in the Casting/Wafering areas.**
- **Have agreed on equipment development details with ATS, but their legal department has held up their subcontract.**

Manufacturing Highlights (Komax)

- **Stringing**
  - **Taking the concept for Robotic cell pick, inspection and placement to a detailed design phase.**
  - **Have taken upgraded closed loop solder control for real time temperature measurement from the lab to the machine.**
  - **The concept design to increase throughput to 1200 cells/hour is ongoing.**
- **Screen Printer**
  - **Added a robot to load and orient cells.**
  - **Adapted new cognex camera and mirrors for better cell images.**
  - **Redesigned glass chuck holders for easier installation and removal of chuck heaters.**
  - **Refined paste detection vision on glass chucks**

Inverter Highlights

- **Xantrex**
  - **Functional Specification for the high voltage charge controller created.**
  - **Proof of concept prototype designed and constructed, validated ability to hit efficiency and voltage range targets.**
  - **Detailed design well underway, for both electronics and mechanical components.**
  - **Starting definition of the digital control architecture.**
  - **Key issue is whether to include a high voltage PV disconnect switch with the base unit, as this will add significant cost.**
- **ASU – Performing detailed modeling of distribution system and power converter for large scale penetration of PV.**

Monitoring and BOS Highlights

- **Arc suppression analysis complete. Planning to develop an arc detector for use in strings.**
- **Cost reduced monitoring system development initiated and integration with advanced smart grid technology being explored.**
- **Both FSEC and ASU have begun long term testing of PV connectors.**

System Integration Highlights

- **Developing mounting system and installation procedures for residential rooftop product.**
- **Optimized single axis tracking system is under development. Shading and performance analyses have been completed.**
- **Documented the third party approvals necessary for deployment of a PV system on a residential rooftop.**

Collaboration

- **Supporting Solar ABCs**
- **Removal of non-technical barriers**
- **Accelerated Aging Workshop**

Issues

- **Progress on demonstrating the use of higher purity raw materials to directly make solar grade silicon has been hampered by the inability to do smelting trials at the NETL Labs in Albany, Oregon. The DOE arc furnace operations is shut down due to an unrelated safety incident in another part of the facility. A full safety review is in progress and will take at least two more months to complete. It now looks like the first smelting trials will occur in June.**
- **Questions about NREL measurements of large size modules and whether they are consistent with international calibration levels.**