SPECIFIC PVMAT R&D ON SIEMENS CZ SILICON PRODUCT MANUFACTURING

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Recent work at Siemens Solar Industries in manufacturing cost reduction has shown highly leveraging benefits in producing thinner solar cells, larger area solar cells, and introducing back surface field processes which increase efficiency. The cost to produce silicon wafers makes the reduction in wafer thickness and increase in wafer size an important development program. Siemens Solar Industries has developed and piloted processes for 250 micron thickness cells, in both 103 mm and 150 mm sizes. SSI has also started the development efforts for increasing cell size to 200 mm in diameter. The cost reduction benefit is as high as 25-30% on the $/Watt production level.

INTRODUCTION

The objective of the DOE/NREL PVMat subcontract with Siemens Solar Industries (SSI) is to continue the advancement of Siemens Solar Industries' photovoltaic manufacturing technology in order to achieve a 30% reduction in module cost per watt. A three phase program which focuses on wafer thickness reduction, wafer size increase, and waste reduction has proven effective.

METHODOLOGY

The first step toward reducing cost in the PVMat 5 program at SSI was to reduce wafer thickness. About half of the cost to produce a solar module is incurred by the time a wafer is produced, and another 20% is added in the cell processing steps. In wafer and cell production, the manufacturing costs are reduced by making the wafers thinner. Siemens Solar Industries has studied, developed and piloted processes for 250 micron thickness cells in both 103 mm and 150 mm sizes. The thinner the wafers are made, the lower the potential cost, however the thinner cells are made, the higher the yield loss, and a competing drop in electrical efficiency will take place necessitating the use of a Back Surface Field (BSF). For this reason, the approach has been a two step reduction in thickness, from 400 microns to 250 microns with the introduction of a BSF process, and then a wafer thickness reduction from 250 microns to 195 microns.

The larger cells are made, the lower the potential dollar per watt. SSI has initiated the development of 200 mm ingot, wafers, and cells to be fabricated into modules. These larger cell designs continue to show the best cost structure as they optimize the watts per kilogram of silicon consumed. Module designs for lower cost contribution have been developed.

Additional manufacturing cost reduction is gained in reducing chemicals used in the process. Silicon Carbide used in wafering and caustic etchants used in cell processing are two large cost drivers. SSI has made significant gains under this PVMat program in reducing both SiC consumption and caustic etchant waste.

These areas of focus: thinner cells, more efficient cells, larger cells and modules, and chemical cost reduction have the potential of reducing cost by approximately 30% per watt.

RESULTS

Thin Cells

The thinner cells are made, the higher the yield loss, and the larger cell are made, the higher the yield loss. These effects are shown in Figure 1 and 2 where yield is contrasted to wafer thickness and size, and Figure 3 where electrical performance vs. thickness is shown for two different Back Surface Field (BSF) processes, a Boron BSF process, and an Aluminum BSF process. The Boron process clearly produces more power per cell than the Aluminum process. Siemens Solar has introduced the Boron BSF process on a 250 micron, 150 mm diameter cell in production. Figure 4 shows improved distribution of cells made with a Boron BSF process.

200 mm Product Development

The crystal growth cost component can be highly leveraged by increasing the ingot and wafer size. Currently SSI produces wafers 150 mm in diameter as its largest size cell. By increasing to 200 mm diameter crystals, the watts produced are increased by over 30% in one crystal growth run. A crystal growth production run costs the same for a given amount of polysilicon solidified. The cost for a 40 kg charge producing 103 mm ingots vs. 200 mm ingots is approximately the same. The 103 mm ingot produces 2600 watts per run, while the 200 mm ingot produces 3350 watts per run. This increase of watts produced represents a greater than 10% reduction in the $/watt contribution at the ingot level.

Larger area cells have shown great potential for cost reduction as each process step produces more watts,

lowering the labor and overhead contributions directly. Siemens Solar Industries has begun the pilot effort of producing 200 mm ingot, wafers and cells.

Recycling and Reduction of Chemicals

The work on recycling Silicon Carbide under the contract has proceeded well. As background for the work, Silicon Carbide is the second highest cost driver in the manufacturing process SSI has deployed (Silicon feedstock is number one). SSI has found that a "blended" SiC process using recycled and "new" SiC produces the best results both financially and from a process capability metric. An added benefit to this work has been a significant process improvement in wafer thickness control.

The work on reducing caustic waste has also proceeded well. Caustic waste is a large cost driver in the manufacturing process SSI has deployed. Reduction in waste volumes have been achieved by extending the bath life in the caustic damage removal steps and the caustic texture etch steps in the wet etching processes. The net benefit since the beginning of the program is over 20,000 gallons saved per megawatt produced.

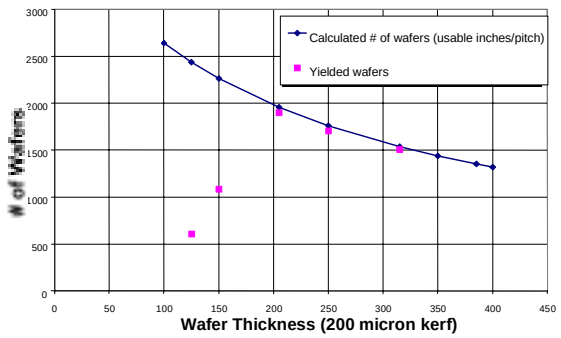

Figure 1. Wafer Thickness vs. Yield

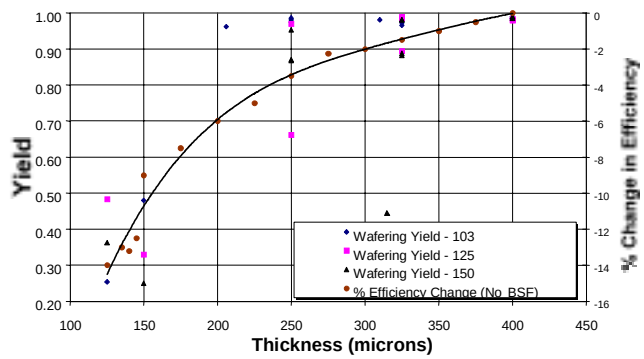

Figure 2. Experimental Data

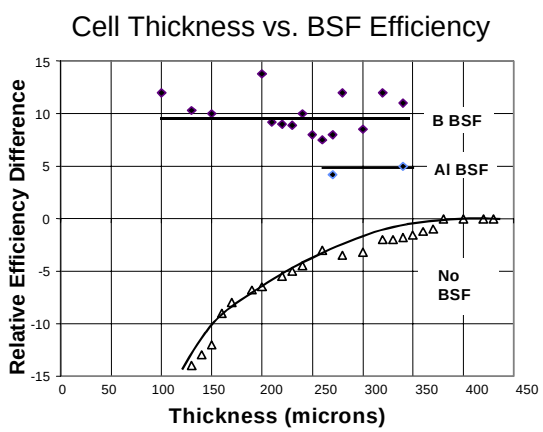

Figure 3. Cell Thickness vs. Electrical Performance

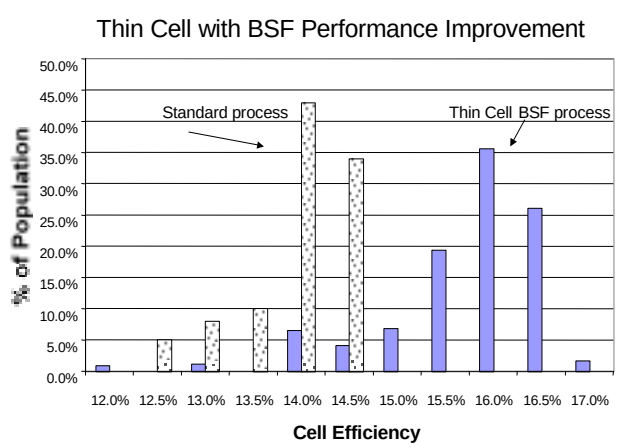

Figure 4. BSF Improvement in Efficiency