Market-Driven Modules Based on Edge-Defined, Film-Fed Growth

Highlights

- New invention enables modules to collect light 20% more efficiently
- Cost of diode housing and electrical protection circuits has been cut in half
- New etching process eliminates fluorine ion waste stream while cutting costs
- Record crystal-growth run length produces enough material for 35,000 wafers

This ASE Americas project is part of the 1995 solicitation of PVMaT—a cost-shared partnership between the U.S. Department of Energy and the U.S. PV industry to improve the worldwide competitiveness of U.S. commercial PV manufacturing.

PVMaT Fact Sheet

Photovoltaic Manufacturing Technology

ASE Americas, Inc.

Goal

ASE Americas has completed its 1995 PVMaT solicitation project, whose overall goal was to reduce module manufacturing costs by 25%. Specific objectives were to:

- reduce wafer thickness from 300 microns to 250 microns
- improve silicon feedstock use
- increase the number of wafers produced from one crucible
- improve the laser-cutting process to reduce cut damage and increase yield
- develop a new glass etch process to reduce fluorine ion effluents and provide environmental benefits, and
- develop new encapsulants for high throughput and yield for new module designs.

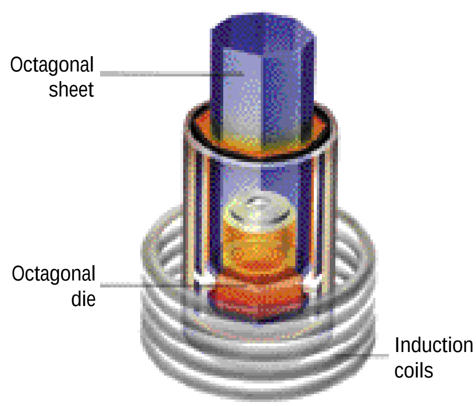
Technical Approach

ASE Americas uses its patented edge-defined, film-fed-growth (EFG) method to grow silicon crystals. In this process, pellets of pure silicon are mixed with boron and melted at 1410°C in an 8-sided crucible with capillary slots built into the walls. Molten silicon rises in the slots to form a thin-walled, hollow octagonal tube about 5 m long. Conventional crystal-growth technologies produce silicon blocks that must be sawn into wafers, which results in a sawdust-like waste of expensive silicon. In EFG, by contrast, the octagonal tube that emerges directly from the molten silicon requires no sawing—hence, there are no sawing losses.

When the tubes are removed from the crucible, they are conveyed on a monorail to a laser-cutting station, where they are cut into square wafers that are 10 cm on a side. This process uses silicon material far more efficiently than conventional growth and sawing methods.

After cutting, the wafers are transferred to the cell processing line, where they undergo proprietary processing in which phosphorous is diffused into the boron-doped wafers to make electrically active cells. These cells are then moved to the module fabrication line, where they are assembled into modules.

To protect cells from corrosion and to prevent moisture from getting inside the module, ASE developed an encapsulant that is superior to the ethylene vinyl acetate used by conventional modules. To protect against environmental damage, the front and back of the module are laminated with glass.



ASE Americas, Inc./PIX06234

In the EFG process, long, thin sheets of silicon are grown in an octagonal crucible.

Results

To reach its objectives, ASE Americas explored technological advances in all three stages of production: wafer production, cell processing, and module manufacturing.

Wafer Production

To boost wafer quality and reduce wafer thickness while maintaining yield, ASE Americas did several things. It designed and built a new enclosure for the crystal-growth furnaces, to reduce contamination from oxygen and dust and to increase the run length of crystal growth. (A “run” is a period of continuous production from a growth furnace, using a single graphite die. The die must be replaced when the run ends, which requires the furnace to be cooled down and then reheated.) ASE redesigned furnace components to improve the purification process and modified and tested an automated system for handling silicon feedstock.

These efforts enabled ASE to improve the quality of its crystal growth, reduce wafer thickness from 300 µm to 275 µm, reduce silicon-feedstock losses by 50%, increase cell conversion efficiencies by an absolute 0.1%, and increase the average length of crystal-growth runs. Also achieved was a record run length, using a single graphite die, of 98 tubes—enough material for about 35,000 wafers.

ASE Americas, Inc./PIX08292

An ASE advance based on this PVMaT contract grows EFG tubes that are circular, rather than octagon-shaped.

There are a couple of concerns, however. First, thin wafers are fragile. Despite achieving good yields with 275-µm wafers, 250-µm wafers suffer excessive breakage during laser cutting. Although the company has already improved its laser cutting to reduce wafer damage and has found ways to double cutting speeds, there is still room for improvement.Reducing the force exerted by the gas nozzle could reduce damage to 250-µm wafers and increase yields to an acceptable level.

Second, cells made from wafers produced late in a crystal-growth run generally have lower efficiencies than those produced early in the run. But this problem holds reason for optimism—discovering and eliminating the cause of this characteristic could raise the overall absolute efficiency of cells by about 0.2%.

Cell Processing

To increase the conversion efficiency of its cells and to reduce cell processing and material costs, ASE Americas tested a new prototype system for etching away the phosphorous glass that forms on wafers during the process of adding phosphorous dopant. Rather than relying on a typical batch process, in which an acid bath is used to etch away the glass, the new system employs a continuous process that uses hydrogen fluoride vapor for etching. This reduces fluorine ion effluent by 99% and eliminates an entire waste stream.

To further improve cell processing, ASE Americas studied the use of Rapid Thermal Processing for more efficient and better dopant diffusion. Researchers also designed and fabricated new equipment for increasing the number of contact fingers on cells, and hence, increasing the collection efficiency of charge carriers. Also instituted was Statistical Process Control, a computer-based manufacturing method that provides engineers with quick information from the production floor for greater quality control and for enhanced product reliability.

Module Manufacturing

During this project, ASE improved interconnection throughput and module yield, reducing module costs by 2.5%. But the company has explored several additional avenues that promise to further decrease costs while increasing module quality and reliability. For example, it redesigned and tested the module diode housing and electrical protection circuits—a move that cut in half the cost of these circuits and that reduced the cost of an average module by $6 to $7.

The company also tested several new encapsulants, trying to find long-lived materials that resist yellowing. One of these materials not only outperformed all other known encapsulants used in the PV industry, but also promises to improve lamination throughput.

Inventions/Patents

ASE Americas developed a new approach for collecting light between cells in a module, an approach that is about 20% more efficient than the approach the company uses for its current modules. This means that the company will be able to use about 20% fewer cells, packed less densely, while maintaining the same high module efficiency. This not only reduces material and production costs, but also effectively increases plant capacity from its current 4 MW per year to nearly 5 MW per year.

Company Profile

The EFG technology that is the basis of this PVMaT project was developed more than 20 years ago and was moved to production by Mobil Tyco, which later became Mobil Solar Energy Corporation (MSEC). MSEC, in turn, was purchased by ASE GmbH and was renamed ASE Americas. ASE GmbH itself is a joint venture of Deutsche Aerospace AG (DASA), which is a subsidiary of Daimler-Benz AG, and NUKEM GmbH, which is owned by Germany's largest electric utility company, RWE AG. Both DASA and NUKEM have a long history of developing and applying photovoltaic technologies. ASE Americas manufacturing operations remain in the Billerica, Massachusetts, facility formerly owned by Mobil Solar.

Today, the company employs more than 160 people, many of whom worked for Mobil Solar. In 1995, ASE Americas shattered the 1-MW barrier by increasing its module shipments from 600 kW to 2 MW in a single year. Over the last two years, the company continued its phenomenal growth, shipping 4 MW in 1997.

References

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