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Cast-Mono Wafers Revisited: Re-Emergence Of Mono Tech Driving Wafering Innovations

Renewed interest in cast-mono PV cells has expanded the wafering debate beyond the standard slurry-versus-diamond-wire discussion.

Nora Caley

Crystalline solar cells are no longer simply monocrystalline or multicrystalline. Now, cast-mono - or mono-like cells - are getting attention, and the methods used to develop these new cells could affect the wafering process.

BP Solar first began experimenting with a new process for ingot growth in 2006, through a grant from the U.S. Department of Energy's Technologies Pathways Partnership and with researchers from IMEC, a research center in Belgium. The result was Mono 2, which, according to a paper presented at the 2009 European Photovoltaic Solar Energy Conference, is a "novel type of [silicon] material for solar cell application and is obtained using a seeded directional solidification technique."

Because the new technique was proprietary, BP Solar did not divulge many details of the process. In general, the processes used to create Mono 2 technology differ from the continuous Czochralski (CZ) monocrystalline process. For the CZ method, single crystals are grown using a method that involves a rod-mounted seed crystal dipped into molten silicon, and a cylindrical ingot is formed when the rod is pulled.

The Mono 2 process is a cast method that utilizes directional solidification system (DSS) furnaces to cast monocrystalline ingots by using a monocrystalline seed layer, a proprietary growth nucleation (crystal forming) method, and the casting (shaping) of bricks of silicon.

The process is similar to how multicrystalline is made, but a key difference is that Mono 2 uses a monocrystalline silicon substrate to grow polysilicon material with monocrystalline-like structures. According to BP Solar, Mono 2 cells have fewer defects than multicrystalline cells, which can develop defects due to grain boundaries and different crystal orientations. The company also claims the Mono 2 process is faster and less expensive than the CZ process.

In 2009, BP Solar announced new Mono 2-produced 156 mm square wafers that were 130 µm thick and featured a conversion efficiency of 18%. Then, in 2010, BP Solar sold the technology to Advanced Metallurgical Group N.V. , an Amsterdam, Netherlands-based company with U.S. operations in Wayne, Pa.

The story of Mono 2 technology, however, does not end here; other manufacturers are now developing or are interested in similar technologies, often called cast-mono or mono-like cells.

"Most of the big companies are working on this," says Wayne McMillan, vice president of sales and marketing for BT Imaging, based in Australia. "The advantage is that the wafer is square, and has lower oxygen content." For solar cells, oxygen content can contribute to light-induced degradation.


Wayne McMillan

In June, China-based solar wafer manufacturer ReneSola announced it had begun shipping its new Virtus wafers and Virtus modules made with Virtus wafers. The company says the mono-like wafers are 1% more efficient than multicrystalline wafers.

"Virtus wafers have a single-crystal orientation, in which more than 75 percent is single crystal grain," says Zhidong Zheng, vice president of wafer technology for ReneSola. "It has a good cell performance, with a high average efficiency of more than 17.5 percent in the industrial line, close to the efficiency of


Zhidong Zheng

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a monocrystalline silicon wafer, but at a relatively low cost."

Cost is, of course, very important with any new solar technology seeking to gain entry into the market. "In today's development of crystalline silicon solar cells, only technologies that have low processing cost or are capable of achieving high cell efficiency will be accepted," Zheng says.

Slicing the new ingots

Romain Beau de Lomenie, global product management director for Applied Materials' Precision Wafering Systems division, says new cast mono might have an effect on the ongoing diamond-wire-versus-slurry debate in the wafering industry.

A few years ago, some manufacturers began to switch from slurry, which uses fluids to aid the wafer-slicing process, to a diamond-coated, high-tension wire for slicing ingots into wafers. Diamond wire is expensive, Beau de Lomenie says, and it is used more often for squaring the ingots before slicing wafers.

"The issue with diamond wire squaring is [cost], because the price of the thick diamond wire used for squaring is very high," he says. "Manufacturers are either continuing to use slurry and structured wire - the standard in squaring - or even switching back from diamond wire to slurry."

In wafering, diamond wire is most often used for processing monocrystalline silicon wafers. "The limited use of diamond wire for multicrystalline silicon applications underscores how challenging using diamond-wire technology for this material type is," Beau de Lomenie says. "It is not yet clear if and when these multicrystalline challenges can be overcome or if new cast-mono furnaces will make the issue irrelevant by replacing multi with cast mono."

Currently, Applied Materials is developing both structured-wire and diamond-wire technologies. For squaring, the company says it is developing high-tension technology and processes that it hopes will increase slurry processing's productivity to match that of diamond wire - but at a lower cost. The technology also has potential for diamond wire, increasing its productivity.

Imaging enables manufacturers to sort wafers by electricity potential, as well as by thickness and roughness.

For wafering, the company plans to unveil structured-wire wafering technology, targeted to wafer manufacturers that see diamond wire as too high-risk and too expensive in a challenging market.

Lowering costs

Cast mono is still a relatively new technology, so until it becomes more widely used, wafering companies are concentrating on the usual factors - keeping costs low, reducing waste and speeding up the inspection process to keep up with production.

Wolfgang Schmutz, managing director of Germany-based Day4 Systems, says the company is currently investigating new basic materials that might enable cheaper and better cells, improvements in process steps to reduce breakage, and processes that could improve cell efficiency and reduce production costs.

In the meantime, wafer slicing is becoming more efficient and is thus helping to lower PV costs. "Actual cost issues are the biggest driving factors," Schmutz says. "Process-quality issues are following in second place, with similar importance."

According to Schmutz, approximately two years ago, only about 1% of wafering processes used diamond wire, and today, about 20% of production does. This switch has contributed to higher outputs, he says.

"The technology change from slurry to diamond wire doubles the production capacity," Schmutz notes. "Sawing was - up to now - the bottleneck."

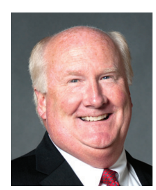
Beau de Lomenie says that polysilicon costs are still low, and that trend continues to affect the choice of wire size that wafer makers use. "Cheaper polysilicon makes the move to thinner wire less compelling, as decreasing productivity associated with thinner wires no longer makes economic sense," he says. "Wafer makers are going back to thicker and higher-productivity wire sizes.

"Medium to long term, kerf loss will be minimized by the use of filtration technologies to recover silicon kerf in water-based coolants used with diamond-wire technology," he adds.

Beau de Lomenie points out that silicon kerf can be recycled, which offers both cost advantages and environmental benefits. Applied Materials is working with filtration companies to develop better fab-level filtration systems for this process.

The use of water-based coolants makes diamond wire generally more environmentally friendly than slurry, but slurry recycling companies say they are working to manage the carbon footprint of disposal and recycling of slurry.

William Lawrence, president of CRS Reprocessing Services in Louisville, Ky., calls slurry "the lifeblood of wafering," but notes that any new technologies for crystalline silicon wafering - including diamond-wire cutting, improvements to wire saws, different sizes and sources of silicon carbide - all impact the slurry reprocessing industry.



William Lawrence

"We manage the footprint by reducing the volume of waste in comparison to not recycling or using do-it-yourself methods," he says, adding that the CRS process uses no chemicals for reprocessing slurry, in order to reduce the environmental footprint of the process.

The impact of slurry reprocessing can also be minimized by performing the recycling at the customer's wafering facility, which reduces the transportation of materials and minimizes the risk of spills.

Lawrence notes that the recycling process for wafering is now highly automated. "Human labor is being used more and more in an analytical and troubleshooting role to ensure consistency of slurry," he says.

Wafer inspections are also becoming more automated, says Jeff Donnelly, group vice president of growth and emerging markets at KLA-Tencor in Milpitas, Calif. "We are hearing from a lot of Chinese manufacturers that as total yields of production lines go up, by having automated systems that can process wafers at production-line speeds, it gives them the tools for analyzing their [defects] so they can improve the process," he says.

The reduction in labor has an important economic benefit in China, which has become the biggest global market for many wafering companies and others in the industry. "The wage rates in China, although still low by international standards, are going up 20 percent or 30 percent a year," Donnelly says. "As we hear from our customers, the cost of labor is certainly an issue."

In June, KLA-Tencor introduced FabVision Solar, software that helps manufacturers identify the cause of defects that may have developed during wafering and react quickly to resolve these issues. "Micro-cracks have been a big issue in the industry for a long time, but the feedback we get from manufacturers is they are still not satisfied with existing techniques for identifying these defects," Donnelly says.

Speed is also important, as inspections must keep up with increased production demands. McMillan says BT Imaging's inline photoluminescence-based tools can inspect as-cut wafers as soon as they come off the wafering line.

Images produced allow users to see any structural defects in the wafer that might reduce the efficiency of the cell, McMillan says. "We use image processing algorithms to quantify the defects so that the wafer performance can be graded and sorted," he adds.

The imaging enables manufacturers to sort wafers by electricity potential, as well as by thickness and roughness. Manufacturers can bin the best-quality wafers into the higher-cost, high-efficiency cell lines, and the lower-performing wafers can be placed into lower-cost cell lines. The poorest-quality wafers can be recycled.

"Most of the defects that matter for cell performance get locked into the crystal during the ingot manufacturing," McMillan adds.

The photoluminescence imaging can help manufacturers optimize the process and reduce structural defects. In fact, this imaging is one factor that could cause cast mono to be more popular, McMillan says. With photoluminescence, manufacturers can see more clearly the physical characteristics of the new cells. "Photoluminescence imaging is really enabling [cast-mono wafers' development]," he says.

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