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Quasi-mono Silicon: The best of both worlds

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There was a time when the crystalline silicon solar cell industry could be separated neatly into two camps –multi-crystalline and monocrystalline. But today a new technology blurs those boundaries, but no one is quite sure what to call it: quasi-monocrystalline, nearly-mono, castmono, monocast. The fact is that it lies somewhere in between multi-crystalline and monocrystalline.

The technology, which we'll call quasi-mono, seems almost too good to be true. It may allow multi-crystalline cell manufacturers to increase the efficiency of their cells for a small cost; and it offers mono-crystalline cell manufacturers the opportunity to manufacture their high-efficiency cells at considerably lower cost.

The basic idea behind quasi-mono is that a casting process is used instead of the slow and expensive Czochralski process (CZ) to manufacture monocrystalline ingots. The process is similar to that used for multi-crystalline wafers with two key differences: a monocrystalline wafer is used as a seed at the bottom of the crucible; and the temperature is carefully controlled.

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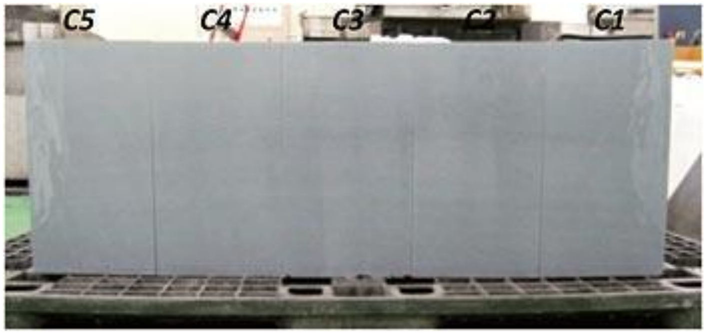
"With careful control of the vertical temperature gradient, the solidifying ingot will take up the crystal orientation of the seed wafer," explains says Nigel Mason, from UK-based PV Consulting. "This process not only gives an ingot that is largely monocrystalline, it also produces a square wafer, unlike the traditional mono process which typically gives a wafer with rounded corners resulting in reduced active area in the module."



Gen5 Mono² ingot cross section (bricks)

The idea for the quasi-mono technology is not new, but market conditions kept it in the lab for many years. But its advantages are just too good to resist for many solar cell manufacturers and the technology is coming quickly to market. The last twelve months has seen a plethora of announcements including Chinese companies ReneSola and JA Solar, German companies Q-Cells, Schmid and Schott, US company Tech Precision, US furnace manufacturer GT Solar and Dutch metals company AMG IdealCast.

Mono² ingot seed plate after it has been cut from the bottom of the ingot and etched---ready to use for next Mono² ingot

Many more companies, especially in China, have their own version of a quasi-mono process. With so many companies using similar ideas, it's surprising that no major patent disputes have ensued and the technology has been allowed to proliferate. AMG IdealCast was recently awarded a US patent, which the company claims covers the process for manufacturing the quasi-mono material process. The company bought the technology, called Mono^2, from BP Solar in 2010. "Over the last two years, we have optimized the Mono^2 technology utilizing our ALD SCU furnace," explains Roger Clark, Chief Operating Officer of AMG IdealCast. "We are continuing to monitor the marketplace to see if any company is infringing upon our patent. We also have four additional supporting patents pending in the US and other important solar jurisdictions."

Competitor GT Solar is confident that its technology does not infringe any patents.

Henry Chou, GT's product marketing manager for PV crystal growth systems, said that the company has been working on its Monocast for more than six years, and efforts intensified in 2010 when GT Solar bought Crystal System and brought its founder, Fred Schmid, on board. Chou noted that, “We have now scaled up to a level where production can happen in volume.”

Chinese company JA Solar is already producing its Maple quasi-mono solar cells in volume and has reached an average conversion efficiency of 18%, which the company claims is a new record for JA Solar, and they noted it that the industry standard average conversion efficiency for multi-crystalline solar cells is approximately 16.8%.

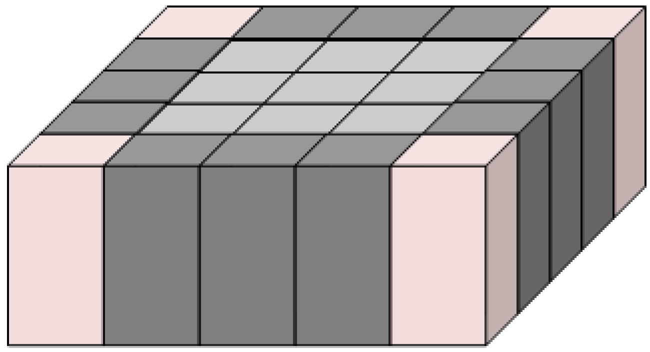
Panorama view of Frederick seed plate pilot line for customer demonstrations

With these increases in efficiencies, which are similar to those claimed by GT, AMG and other quasi-mono developers, the interest in the market is understandable. However, switching to quasi-mono is not without challenges, especially for the large integrated solar cell manufacturers. “When you grow a quasi-mono ingot, it will be monocrystalline at the base and in the centre, but at the sides it exhibits multi-crystalline properties,” explains PV Consulting’s Nigel Mason. “When the ingot is cut into bricks you can end up with two, or sometimes three, types of crystal structure; mono, multi and a mix of the two. Cell manufacturers then have to decide how best to process these wafers. If their production line is set up to etch multi-crystalline wafers, then it will not be the optimum for monocrystalline wafers and some of the cell efficiency gain from the casting process could be lost.”

But for companies that supply wafers to the solar industry, the figures speak for themselves. With a relatively small investment to retrofit their current furnaces they can manufacture wafers closer in performance to conventional CZ monocrystalline wafers at a cost close to multi-crystalline wafers. Roger Clark explains: “There are no industry-accepted standards, so cost comparison is difficult, but we estimate that, with a polysilicon feedstock price of $30/kg, our customers can achieve a savings of $0.45/wafer which equates to $0.11/W when compared with conventional mono wafers of a similar conversion efficiency.”

AMG IdealCast and GT Solar and several other companies are ready to take their technology to market. It remains to be seen if this traditionally cautious and cash-strapped market will have the resources to invest in this new technology.

Additional Quasi-Mono Technical Information



Quasi-mono Silicon: Processing wafers from ingots to cells

Each Mono^{2TM} ingot (representing the entire ingot produced by the ALD-SCU Gen 5 furnace) is cut into 25 bricks in a 5 x 5 array illustrated in the schematic shown here. All of the bricks are converted into wafers using a wire saw and all of the wafers are then used for solar cell production. Every Mono^2 ingot has four bricks at each corner that are called "corner bricks" and typically have both multi-crystalline and mono-crystalline areas. Mass ingot yields (brick mass/ingot mass) are at least as good as any casting method in today's market.

Corner brick cell process texture comparison

The image shown above is a composite photograph of four different solar cells, each made from wafers cut from a corner brick. The composite photograph illustrates the effectiveness of different texture etches that are industry standard production methods currently in use for mono-crystalline and multi-crystalline cell manufacturing.

NaOH: IPA --- solution of sodium hydroxide, isopropyl alcohol and water, commonly called “caustic”.
KOH: IPA--- solution of potassium hydroxide, isopropyl alcohol and water, also called “caustic”
ICT --- solution of acids such as: nitric acid, hydrofluoric acid and water, it is called ICT for the acronym Iso Chemical Texture§

The current industry standard for multi-crystalline wafers-to-cell processing use ICT methods and the standard monocrystalline cell processing production lines use KOH etching methods.

In summary: The entire Mono^2 yielded ingot mass is effective for cell production. Sorting is used to separate the mono wafers and multi wafers and different industry standard etching methods are used to achieve highest cell efficiencies and maximum economic benefit from Mono^2 ingots. No additional costs or technology modifications are required to process wafers from Mono^2 ingots into cells.

ICT is the best solution for wafers cut from corner bricks because from a module manufacturer’s point of view, a cell that does not have optical differences across the front surface of the cell or from cell to cell is best for its cosmetics.