

# Slurry still in use

Current trends in wafer manufacturing: science and industry are investigating the diamond wire saw. Silicon consumption is no longer the focus of grinding and cutting processes.



Slurry reprocessing, especially when it involves silicon wafer slicing, is a precise business. CRS Reprocessing Services from Kentucky, USA, is one of a few suppliers worldwide.

Photo: CRS

The wafer production's core process has remained virtually unchanged since the beginning of industrial PV production. Wire saws turn silicon bricks into single wafers. They use a metal wire of up to 400 km in length which eats through the brittle silicon. To be more precise: the real cutting work is carried out by what is known as slurry – a mixture of oil and silicon carbide grains. The process is not popular, but has no real alternative in industrial manufacturing. Possibly sawing using diamond wire could make slurry superfluous in wafer production.

But the discussion is still going on. William Lawrence, president of CRS Reprocessing Services – a slurry-recycling company located in Kentucky – is absolutely sure about what his company is doing. “As manufacturers continue to look for ways to reduce costs, our best assessment at this point is that slurry remains the optimal way to produce an ideal wafer surface at the lowest cost. Diamond wire sawing still suffers from technical and cost issues for wafering – particularly for multicrystalline.”

## 100 percent yield?

Viable efforts to get rid of slurry sawing have been few and far between. Schott has given up the EFG pulling process. SiGen, the American Silicon Genesis enterprise, caused quite a stir two years ago when it presented “PolyMax-Wafering”. PolyMax-Wafering involves an ion accelerator firing shots of hydrogen protons at a silicon plate in a vacuum chamber. Depending on the energy, the protons penetrate the silicon between 50 and 150 micrometers deep. These protons enrich themselves to form a layer at this depth – to make a pre-determined breaking point. Then a wafer can be detached in the desired thickness. The advantage of the process is the virtually 100 % yield of the silicon material. There is no waste. However, transforming this process into large-scale industrial lines is the weak point. “I don't believe this is a viable alternative”, concludes Hans-Joachim Möller, professor at the German Technical University Bergakademie Freiberg. “To date, it's still three times as expensive as conventional sawing. The question is also how stable the process is”.

## Diamond wire raises questions

The wafer industry is pinning new hopes on the diamond wire saw that Swiss manufacturer Meyer Burger is launching. With the acquisition of American

Diamond Wire Materials Technology in Colorado in 2009, the Swiss have laid the foundations for expanding their strong position in the wafer production equipment market. The process does not use slurry. The diamond splinters responsible for the cutting are firmly attached to the sawing wire. Sawing requires water and, likely, specialized coolants for cooling.

In fact, Meyer Burger has already achieved initial successes with this technology. "Some major wafer manufacturers in Japan apply this method", confirms Martin Kölbl, head of engineering at PV Silicon, a PV Crystalox Group's subsidiary. According to Kölbl, the issue of security of energy supply played a role because slurry was sourced almost to 100 % from China. This fact is obviously a matter of concern to Japanese enterprises.

Production experts are also not sure about the wafer's surface properties after cutting with a diamond wire. Möller cannot confirm insider reports that say a wafer's surface is generally rougher than discs which were sawed using conventional slurry technology. However, he does point out that information is contradictory. The spectrum ranges from "strong damage" to "reduced roughness" as Kölbl from PV Crystalox claims to have noticed.

### Impact unsure

This is possibly due to different source materials. Reports from industry give some indications: monocrystalline materials, sawed using diamond wire, show

nearly the same surface quality as those which were slurry sawed, but multicrystalline materials, sawed using diamond wire, display more surface damage. Evidence shows that surfaces which were sawed using a diamond wire have a different structure. Grooves can be clearly discerned. Möller's experiments at Technologiezentrum Halbleitermaterialien in Freiberg were unable to prove that their roughness is generally greater. A link to crystal orientation is quite probable. Möller points to the fact that the meshing mechanism during diamond cutting differs from the conventional process. Möller says that the action of the diamond wire leads to a further phenomenon as latest experiments showed. He adds that the diamond wire saw causes a phase change in the areas immediately concerned. Under the high pressure that the wire triggers, silicon transforms into an amorphous state. This phase change and its consequences still have to be clarified because as Möller remarks: "They have never been studied in this context".

Both Kölbl, who knows about real-world conditions, and Möller as a scientist say that diamond wire saws are not yet performing at their best by any means. They comment that the sawing wire's thickness, costs and service life do not respond to industry's requirements. Perhaps the most important objection is that both criticize that the diamond wire saw's sawing gap would be larger than that associated with the slurry process and its silicon loss would also be higher. Higher silicon losses mean higher costs.

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CRS President Lawrence stressed that the slurry process would continue to improve while also reducing the costs. "There is substantial room to lower the cost of slurry over the next several years, perhaps as much as 33 percent from today", he adds. Where diamond wire has made initial inroads, its application may make more economic sense. Namely, cutting very hard materials like SiC or sapphire, and the ingot shaping process. Otherwise, the implementation costs are too high and the benefits, as yet, are not definite.

Since 2002 CRS has improved SiC recovery by 10 % and carrier recovery by 15 %, while at the same time reducing Fe, SiC and Si fine content by 75 % in the recycled ready-to-use slurry. Stressing the advantages is one story – a look at the crystal ball another one. CRS is prepared for the day after the slurry-use. „Our ongoing research and development efforts will continue to focus on slurry recycling process improvements and also diamond wire coolant recycling“, he says.

### Kerf loss loses its significance

With silicon shortage coming to an end, a paradigm shift is taking place in wafer processing. "Not just silicon consumption during processing – known as kerf loss – lies at the heart of investment decisions, but investment costs in conjunction with the running production costs as well", says Wolfgang Schürgers when asked about his customers' standpoint. As Managing Director, he is head of distribution for the

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German Arnold Group which is concerned with grinding and cutting machines in the photovoltaics industry. Schürgers adds: "Production must function at high levels of availability. This does not only mean stable process technology but also reducing maintenance requirements significantly."

Saw use for what is called "cropping" shows just how strongly operation costs determine the technology employed. Cropping is the specialist term for removing a silicon crystal's upper and lower sections, because these zones are contaminated with residues from the melting process. Until a few years ago, the cutting was done by an outside diameter saw (OD) which looks like one of the ordinary disc saws and is also equipped with a saw blade. Blade thickness at that time was more than 3.5 mm. "Then the silicon price went up", recalls Schürgers, "and customers only wanted to use kerf loss optimised processes, or in other words have an extra-thin saw gap. Finally this resulted in a replacement of the outside diameter saw by other cutting technologies such as the ID (inner diameter) saw." This saw differs from conventional saws because it has an inside lying cutting face. It consists of a thin metal disc which is clamped over a ring similarly to a drumskin. This disc has a circular hole in the middle, the inside edge is the cutting face covered with diamond splinters. The rotating saw blade moves slowly through the centred workpiece which is then cut. The saw gap is just a few micrometers – so all in all complex and costly technology. "When silicon prices were high, this saw was superior to ordinary OD saws thanks to its minimal saw gap and therefore small silicon losses", explains Schürgers. But the ID process wasn't stable enough.

### Maintenance costs before silicon consumption

Following the end of silicon shortage, the industry is returning to tried and tested and more process-stable solutions. "We have seen a come-back of the OD saw", says Arnold's head of sales. But in a greatly improved shape, because the sawing gap was more than halved to 1.5 mm. "We apply a special alloy for the extra-thin saw blade which was not available a couple of years ago", he explains. Much lower operation costs were crucial for this saw's return. "The op-

erator still has to replace the ID saw's cutting blade after about 1,000 cuts. He has to loosen 50 to 60 screws and subsequently ensure controlled tightening which takes about five hours. An OD saw's cutting blade can sustain up to 15,000 cuts until it is replaced. An exchange takes just half an hour".

Maintenance costs and capacity clearly take priority over silicon consumption. Arnold development engineers are focusing on improving machine performance. Performance must keep up with cell manufacturing which is still setting the pace in PV fabrication. Capacity of 3,000 to 3,600 wafers per hour has now become standard. Investment is not the only issue in focus with the high capacity required, but also the tools' and machines' service lives. "Long machine running times with highly accurate results are challenging", comments Schürgers. The 156 mm outer dimension of the wafers, pre-determined by grinding the bricks, has to be kept to allowing for a tolerance of  $\pm 0.05$  mm.

Jörn Iken

## Balance achieved between supply and demand

According to Swiss Bank Sarasin & Cie, a wafer shortage is not on the horizon. Worldwide capacities are expected to amount to 15 GW by the end of 2011. Patrick Markschläger, Managing Director Schott Solar Wafer GmbH, confirmed that the relatively calm development of prices indicates a good balance between supply and demand. "For 2011, I estimate the wafer market volume to be between 16 and 18 GW. The end market could be slightly bigger." Markschläger believes that prices for wafers and polysilicon will both remain relatively stable. He uses the qualifier "relatively", because even short-term market fluctuations have an effect on prices. That is why according to Markschläger, in January 2010 spot market prices for a 200 micrometer thick six inch wafer amounted to US\$ 3.20. Yet in the fourth quarter 2010 it had again gone up to US\$ 4.00, indicating supply was getting shorter. Markschläger explains that this is supported by the fact that what is called prepayment (an advance payment for delivery of goods) has again become an integral part of delivery contracts – as in 2008 and in the years before. In the crisis year 2009, only short-term delivery contracts were concluded without prepayment.

Markschläger explicitly states that competitive wafer production is possible in Germany. "Disadvantages in terms of location are outweighed by a higher degree of automation", he underlines. He went on to say that while annual wafer manufacturing productivity amounts to 1 MW per employee, the same productivity in China requires four workers. He also said that another reason for this productivity difference was that east Asian manufacturers went back to turnkey lines without optimizing them with their own expertise. Markschläger stressed that in sawing alone, Schott surpassed the standard process by 50 %.

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