Glass washing challenges in thin-film PV production

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ABSTRACT

Thin-film module production has proven itself as a forerunner in the race to drive down costs for photovoltaics. The type of semiconductor material used is the most differentiating factor for thin-film photovoltaics, playing the decisive role for determining which core processes are employed and what type of equipment is used. This explains why discussions related to thin-film costs and technologies usually focus on the semiconductor type. However, the effects of glass production, processing and handling are often underestimated: factors such as scaling, yield, unit cost and total cost of ownership of the equipment are defined by the glass-production side of the industry. This paper discusses the challenges faced in glass washing and handling in thin-film PV production.

Introduction: the role of glass in thin-film photovoltaics

While classic PV modules are produced in a production process of several steps by wiring crystalline silicon wafers, in thin-film module technology, the semiconductor layer is directly applied to the substrate in a thickness of a few micrometers. This saves material, process steps and energy. Several alternative semiconductor materials have been developed to substitute silicon for this technology. Moreover, thin-film technology's use of semi-transparent PV glasses opens up new markets such as window and automotive glass provision.

In commercially available thin-film photovoltaics, modules most commonly consist of a glass front and backplane with a foil layer in between (Fig. 1). This proven approach provides durable and secure encapsulation of the modules. The side of the module that faces the sun is usually an extra-clear float glass with low iron content to reduce absorption. Additionally, anti-reflection coatings or structured surfaces are applied to reduce reflections. The front side is 3-4mm thick and edge-seamed to ensure mechanical and thermal stability. Depending on the process depth of the manufacturer, the front glass is delivered with or without a transparent conducting oxide (TCO). The TCO can be coated directly after the glass melting furnace, which reduces cost.

Since glass adds significantly to the materials bill of a thin-film module, the solar industry needs high quality glass but at the same time considerably cheaper glass. Lately, concepts to use modified rolled glass were brought to the table, which can provide considerable cost savings. Textured rolled glass decreases reflectance, which allows for raw materials with a 30% higher iron content than for float glass [1] or results in a better overall module efficiency. Furthermore, the success of this format would render obsolete the extremely energy-intensive floating process.

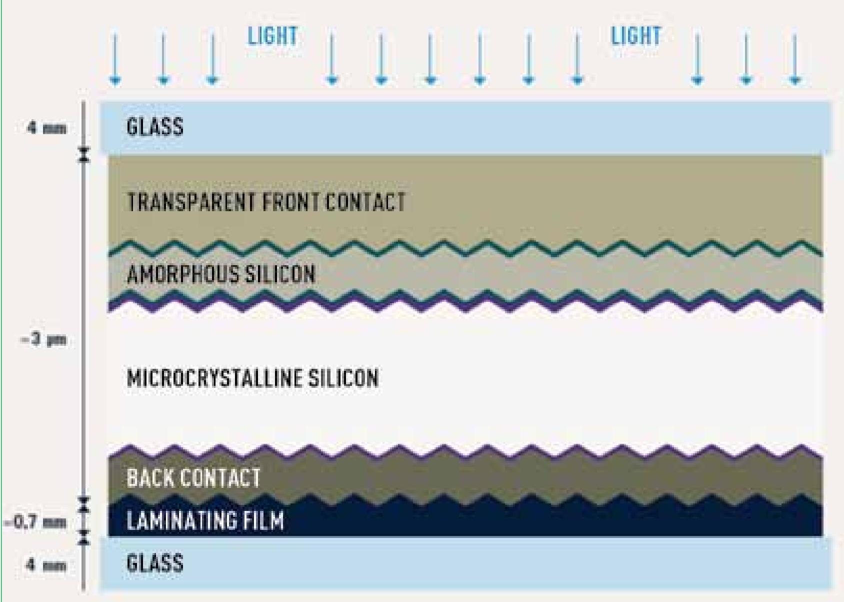
> "The solar industry needs high quality glass but at the same time considerably cheaper glass."

Benefits are possible in the texturing process itself. Instead of using a separate process, the texture can be applied to the surface of the glass during the rolling process. In addition, rolled glass factories can be built at a considerably lower cost than float glass facilities. These facilities can be built practically anywhere, in the immediate vicinity of solar energy factories, for example. Another great potential lies in weight reduction using the rolled glass procedure to produce 2mm-thick, surface finished, toughened safety glass as is also used by the solar energy sector [1].

The next technological revolution will be the mass production of plastic-based, printable organic semiconductors (organic PV) on flexible substrates, which will further reduce production prices and open new fields of applications. The share of costs for machines varies among the three technologies; for crystalline PV, the availability and the price of silicon is crucial. While capital expenditure for the production (with a large share for machines and equipment) for crystalline PV is not more than one sixth of total expenditure, it amounts to one third with thin-film technology and almost two thirds with new technologies such as organic PV.

Glass washing: a common but crucial step

Glass washing and handling are steps that are common to all thin-film PV technologies. Washing is carried out whenever the substrate is processed in any way: in the front end of line after loading and seaming, and after laser scribing of the TCO, the functional layers and edge deletion. The same applies for the cover glass. Photovoltaic glass cleaning is not just performed for aesthetic purposes, however. Although it seems trivial at first sight, glass washing is a critical step, especially in thin-film module production. The semiconductor layers need a clean and smooth surface – on the molecular level – to perform properly. Any trace of particles on the glass leads to poor adhesion or contamination of the photovoltaic layers and therefore reduces the performance of the product from the semiconductor side. Moreover, dirty substrates and covers can lead to a number of reliability problems, from incomplete scribing of the cells, decreased light transparency to delamination in some cases. The latter also applies in the case of crystalline modules where antireflective coatings for the cover glass can be affected.



Source: Sontor

Figure 1. Cross-section through a thin-film photovoltaic module.

Source: Bystronic glass

Figure 2. Vertical setup reduces footprint, avoids sag, and employs gravity for rinsing.

Different types of concepts and features

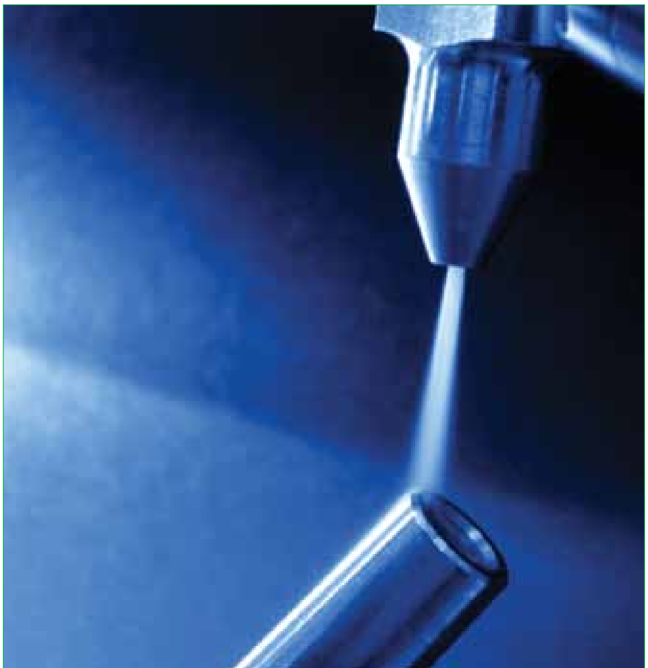
So where are the differentiating factors, the technological and cost challenges for glass washing? Most glass washers for the PV industry are derived from machines for architectural glass. But with the aforementioned boundary conditions, it is clear that solar-glass washing equipment has to be extremely accurate and efficient. On the other hand, solar glass has not reached architectural glass sizes (yet), although substrate scaling has been on the roadmaps of thin-film producers for quite a while. In the flat-panel display industry, this turned out to be the major cost saver. Substrate sizes in that industry have reached approx. 2.8 x 3m² (Generation 10), whereas the biggest panels used in the PV industry are 2.2 x 2.6m² (Generation 8.5).

Depending on the size of the glass, manufacturers offer horizontal or vertical stainless-steel systems from the traditional glass-equipment industry for use as both substrates and cover glass. The vertical concept has advantages over the horizontal due to glass sagging. Compared to a horizontal washing machine, the vertical version also has the advantage that the water runs off top-down, preventing water from aggregating as it does in a horizontal construction. Therefore, an associated formation of algae is avoided.

Flexible substrates like plastic or metal foils are playing an increasingly important role in thin-film photovoltaics. Roll-to-roll processing involves totally different setups for the washing machines. Sag does not play such an important role here. The supply industry offers horizontal washers with plastic casings for glass and foils, adapted from the semiconductor industry.

"Flexible substrates like plastic or metal foils are playing an increasingly important role in thin-film photovoltaics."

Various cleaning concepts are employed for the different applications. From the architectural glass side, mechanical brush cleaning is a common standard that is also applied to the PV industry. The machine shown in Fig. 2 has chainless brush and transport drives outside of the machine as well as variable brush rotation speed. The water-protected bearings of the brushes are maintenance-free.



Source: acp – advanced clean production GmbH

Figure 4. The CO_2 snow-jet does not use water and does not require manual handling.

Apart from the glass sizes, glass thicknesses vary in different types of machines from below 1mm up to 50mm; for flexible substrates the dimensions are down to 50µm.

Transport speed is also an important factor for in-line processing. Speeds range from below 1m/minute up to 25m/minute, while for some machines speed can be adjusted without steps. This latter factor is important as it allows for the adjustment to other in-line processes such as layer deposition.

Mechanical stress enhances breakage

Any mechanical stress on the substrate – be it the sag, handling between machines and in the machine, the brushing – increases the probability of breakage. Therefore, handling robots must be extra smooth, glass size and defect tolerances must be tight, the quality of edge treatment and holes are paramount, and brushes must be soft. The product shown in Fig. 3 is equipped with an automatic coating recognition and a frequency control of brush drives for especially sensitive coatings as well as a reversible transport drive for glass plates.

Source: Bystronic glass

Figure 3. Glass washing is a common production step for all thin-film technologies.

Some equipment makers have already introduced non-contact cleaning processes such as an ultrasonic cleaning technique. An innovative method introduced in PV glass washers is a carbon-dioxide (CO_2) snow-jet cleaning process (see Fig. 4). CO_2 snow-jet cleaning systems use solid CO_2 ice crystals as a jet medium. With its combination of mechanical, thermal and chemical properties, CO_2 snow is able to gently detach and remove a whole variety of surface contamination. Developed at the Fraunhofer IPA in Stuttgart, Germany, the sublimation-impulse technique is the most efficient process to date for cleaning with CO_2 snow worldwide. As the liquid CO_2 expands at the nozzle outlet, CO_2 snow is formed and accelerated to supersonic speed using a compressed-air jacketed jet and blasted onto the surface to be cleaned. The CO_2 snow cleans gently; it is dry, residue-free and suitable for use with a wide variety of materials and material combinations. CO_2 gas is non-flammable, non-corrosive, non-toxic and environmentally friendly. The method is suitable also for large surfaces and can help reduce breakage to a minimum.

Source: Grenzebach

Figure 5. TCO-coated glass needs extra careful handling from the back side.

Total cost of ownership and environmental issues

For an eco-energy like photovoltaics, production should be energy- and resource-efficient. This ensures a low total life-cycle cost of a machine. Another parameter adding to the cost of ownership is the machine's footprint, reducing cost for (clean) space. With this in mind, companies have been introducing technologies to save water and energy. Using DI water in extra cycles can save on detergents or chemicals, which not only improves on lowering the environmental impact but also saves money. Air knives also make the rinsing and drying process very effective. Washing machines from suppliers from Germany, Italy, the U.S. and China are currently on the market for between €14,000 and €600,000 [2].

"The sublimation-impulse technique is the most efficient process to date for cleaning with CO_2 snow worldwide."

Summary and conclusion

The machinery industry will continue to offer significant cost reductions for the PV sector in order to aid in making PV more competitive compared to conventional energy. In cooperation with the manufacturers, the equipment makers play an important role for the optimization of production technology while at the same time broadening production – charting their way along the learning curve. They have the ability to supply efficient, less expensive and long-lasting products to the market by ensuring the input of fewer materials and energy, higher effectiveness and optimized production methods. A higher degree of automation results in faster throughput and higher output, thereby leading to more efficiency and quality and reduced production costs.

Further development of machines for mass production as well as the standardization of interfaces again brings potential for lower investment in machinery. With increasing mass production, positive scaling effects in production will be used and lower costs per piece can be achieved. Glass production, processing and handling play a vital role in this endeavour.

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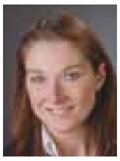
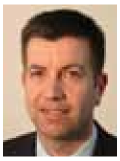
About the Authors

Eric Maiser has been Managing Director of the Photovoltaic Equipment Association within the German Engineering Federation (VDMA) since 2007. He also heads the VDMA Electronics Equipment association. From 2000 to 2007 he was responsible for Flat Panel Displays (DFF). He was appointed one of the Managing Directors of the German OLED Reference Line (DORAn) GmbH with coordination responsibility from 2002 to 2008. He earned a master's degree in physics in 1993 and a Ph.D. in solid-state physics in 1997, both from the University of Karlsruhe, Germany. He also worked as a researcher at the University of Maryland, College Park, USA.



Iris Minten has worked for Bystronic glass since June 2008, and has responsibility for Public Relations and Online Communication in all topics concerning the Bystronic glass group and its machinery. Prior to this role, she graduated from Gießen University, Germany in natural scientific studies, completed an extra-occupational study in public relations in Heidelberg, and also worked in various communications agencies until joining Bystronic glass.



Egbert Wenninger is on the Grenzebach Group Board of Management and is Head of the Grenzebach Group Glass Technology Sales Division accounting for worldwide sales activities. After graduating in engineering, he worked as a software developer with Pfister Systemtechnik in Augsburg and joined the Grenzebach Maschinenbau GmbH team as Sales Engineer in 1994. For the past eight years he has been responsible for the company's worldwide glass technology sales activities. A member of the glasstec advisory council for the Düsseldorf trade fair, member of the board of VDMA Photovoltaic Equipment as well as the VDMA Glass Technology Branch, Egbert has published articles in several specialist magazines.

After completing his degree in electrical engineering at the University of Stuttgart, Germany, **Karl-Heinz Menauer** worked at the Fraunhofer IPA in Stuttgart as a scientific employee. He then gained international marketing and management experience working for Alcatel SEL AG in Stuttgart and BOSCH Telecom GmbH in Munich. Since 2002, Mr. Menauer has been CEO of acp – advanced clean production GmbH, a spin-off of the Fraunhofer Gesellschaft. Since 2004, he has also held the role of managing director of ACI-ecotec GmbH & Co. KG. Mr. Menauer is also member of the board of VDMA Photovoltaic Equipment.

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