Novel industrial approaches in solar-cell production

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Laser technology applications are indispensable in the photovoltaic industry, allowing both enhanced energy-generating efficiency and reduced costs.

The photovoltaic industry has experienced enormous growth in recent years. However, for solar-cell technology to become competitive in the long term, both an increase in energy-generating efficiency and a reduction in production costs is required. Several laser applications for solar-cell production are shown in Figure 1, of which three—hole drilling for back-contacted solar cells, silicon dioxide (SiO\(_2\)) removal for making grooves, and scribing of thin-film cells—are described here in more detail.

Hole drilling for back-contacted cells
Laser drilling is a key technology used in many new back-contact solar-cell production concepts because alternative economically feasible drilling processes are not yet available.\(^1\)\(^-\)\(^4\) Square 6in-wide (156×156mm\(^2\)) and 250µm-thin wafers are standard in industry. Common industrial photovoltaic cells have a screen-printed contact layer on the front, which blocks 5–7% of the incoming light by shadowing. To overcome this performance degradation, many new cell concepts are being developed, usually with the emitter contact either completely or partially on the rear. This results in higher cell efficiencies for energy generation. For these emitter wrap-through (EWT) cells, laser drilling is the only suitable method to create the necessary holes from the front to the back. Typically, a drilling efficacy of 15,000 80µm-diameter holes is required.\(^1\) Figure 2 shows a typical hole. Up to several thousand holes can be drilled per second.

SiO\(_2\) removal for grooves
For wafer-based solar cells, grooves are used in several novel designs.\(^1\)\(^,\)\(^5\) Grooves typically have a depth of up to several tens of microns. The groove is obtained in two steps. First, a barrier layer, such as SiO\(_2\) or silicon nitride (SiN\(_x\)), is removed using a laser beam. Subsequently, a chemical etching process is applied to remove the laser-damaged silicon and to obtain the desired

Figure 1. Laser applications for solar-cell production: hole drilling of back-contact solar cells, SiO\(_2\) removal for groove production, laser welding/soldering of contacts, edge isolation, wafer cutting, removal of dielectric layers for improved contact performance, texturing to increase the absorption of sunlight and therefore to enhance the efficiency of the cell, scribing of thin-film cells, and edge deletion.

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Figure 2. A typical hole drilled with a pulsed-fiber laser, characterized by a burst of 20 pulses and a pulse energy of 1 mJ (after etching). A human hair illustrates the small diameter of the holes.

Figure 3. Groove processed with an excimer laser at a wavelength of 248 nm. The rectangular laser spot is shown in the processed area. The groove depth is about 20 µm. The laser-processed surface is smooth after chemical etching, and does not contain any debris.

depth. The residual SiO₂ or SiNₓ layer functions as a barrier during the etching process. Figure 3 shows a typical groove result.

Scribing of thin-film cells
Scribing is required to obtain a monolithic series connection of modules. This essential technology has both allowed economica-
foil. Generally, the cell itself consists of a back contact, a frontcontact layer, and an absorber material in between. For the contacts, transparent conductive oxides (TCOs) or metals are used. Commonly used absorber materials include silicon, cadmium telluride, copper-indium di-selenide (CIS), and other combinations with copper indium, such as CIGS or CIGSSe. The layers are typically up to several microns thick. In Figure 4, a thin-film solar-cell cross-section is shown. Common referencing to the laser processes includes ‘patterning 1’ or P1 for the first contact, P2 for the absorber, and P3 for the second contact.

Thin-film solar-cell scribing is, in essence, based on the different transmissivities of the film materials at the laser wavelengths used. The deposition and scribing processes are shown schematically in Figure 5. The first TCO layer deposited can be zinc oxide, tin dioxide, or indium-tin oxide. Usually, when glass is used as the substrate, scribing is done from the glass side. An example is shown in Figure 6. Silicon as the absorber material is usually scribed with a laser wavelength of 532 nm. For this setup, TCO is transparent, and silicon absorbs radiation in a thin layer. Scribing of the third layer can be done using the same laser wavelength as for the absorber. In this case, the second absorption layer is also removed. This is not necessary, but it does not affect the solar-cell function either.

In summary, the role of laser technology in the solar photovoltaic industry is gaining importance. Laser applications enable economic and technical feasibility of new design concepts. To achieve the required performance quality in acceptably short processing times, further technological system development is necessary. Both system and process development of newly emerging laser sources and their applications are the subject of future research at our institute.

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Aart Schoonderbeek obtained his PhD at the Netherlands Center for Laser Research in 2005, supported by the chairs of Applied Laser Technology and of Laser Physics and Nonlinear Optics, both at the University of Twente (Netherlands). He was subsequently employed as a research scientist at the Laser Zentrum Hannover. He works on process technologies for nonmetals, concentrating on laser processing of glass and silicon.

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