



- 1 *Multicrystalline silicon block (85 kg) with a base area of 42 x 42 cm<sup>2</sup> (2 x 2 columns of 156 mm edge length each).*
- 2 *Blocks of multicrystalline silicon produced via the Vertical Gradient Freeze method at SIMTEC.*
- 3 *Multiwire saw for wafering blocks up to 156 x 156 mm<sup>2</sup>.*

## SIMTEC – SILICON MATERIALS TECHNOLOGY AND EVALUATION CENTER

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SIMTEC is our Silicon Material Technology research center at Fraunhofer ISE. It focuses on the front end processes of the solar value chain. Starting with various sources of silicon feedstock, it involves multicrystalline block crystallization, block shaping, wafering and – as a new technology in PV – silicon epitaxy for crystalline silicon thin-film wafer equivalents.

The need for cost reduction in silicon photovoltaics is also present at this early stage of the value chain. It has already brought new, varying qualities of silicon feedstock to the market, and it is calling for fast and inexpensive crystallization of high-quality crystals as well as lower cost, high-yield shaping and wafering processes. Supported by the German Ministry for the Environment, Nature Conservation and Nuclear Safety, we have set up SIMTEC as

a technology platform for research on all aspects of this part of the value chain. The laboratory also enables us to offer services related to existing technologies.

In addition to the standard technologies, we have established a "CVD Lab" at SIMTEC, dedicated to silicon epitaxy. With our two high-throughput silicon chemical vapor deposition reactors that were constructed in house, we can address the main issues of silicon deposition that are relevant to nearly all crystalline silicon thin-film solar cell approaches.

Using these reactors, process development can be done with a production-relevant throughput, especially for the epitaxial wafer equivalent. New concepts like emitter epitaxy for wafer solar cells will also be pursued.



The combination of wafer and wafer equivalent technologies at SIMTEC necessitates a very open philosophy concerning material purity. Therefore, the SIMTEC equipment offers great flexibility in the use of silicon material originating from either high-purity polycrystalline silicon or from upgraded metallurgical feedstock. Particularly for the latter, the co-operation within Fraunhofer ISE between SIMTEC and our PV-TEC and Module Lab facilities uniquely provides a continuous lab-line for material characterization from feedstock up to the cell and module level.

Fraunhofer ISE has a long tradition in processing, characterization and optimization of solar cell materials, solar cells, solar cell processes and manufacturing equipment. SIMTEC completes our research competence along the whole value chain. With more than 150 people in all kinds of laboratory environments, we can offer services across the entire range from single-sample to high-throughput processing, all under one roof.

**1** *Prototype in-line CVD reactor "ConCVD". The photo shows the loading and gas curtain zone in the foreground, as well as the furnace and unloading zone in the background.*

**2** *Two rows of substrate carriers loaded with 156 x 156 mm<sup>2</sup> large wafer equivalents, deposited in the ConCVD.*

### **Silicon Directional Solidification**

Our primary tool for directional solidification of silicon is a PVA Tepla Multi-crystallizer, implementing the so-called "Vertical Gradient Freeze" method. With this tool, we are able to crystallize ingots of various sizes equivalent to sixteen, four or one block of 156 x 156 mm<sup>2</sup>, corresponding to batch weights ranging from 20 to 250 kg.

For preparation of the crucibles before crystallization, an internally-developed coating unit and a sintering furnace complete the equipment. The research applying this coating facility focuses on optimizing crucible coatings with respect to purity and cost. With this approach, we aim for highest quality mc-Si ingots made from polycrystalline and UMG silicon.

### **Block Shaping and Wafering**

A band saw is used at SIMTEC for shaping the ingots. This saw provides a high level of flexibility due to the manual operation such that we are able to prepare almost any block shape and sample size needed for characterization. Shaped blocks can be surface finished using a grinding and chamfering tool, adapted to block size from 50 to 156 mm. We cut wafers of variable thickness from blocks of up to 250 mm height with our industrial multiwire saw DS265 from Meyer&Burger. Its flexible range of cutting parameters allows us to research and improve the cutting process. In recent projects, we were able to reproducibly cut wafers down to 70 µm thickness. A wet bench for cleaning the cut wafers completes the wafering section of SIMTEC.

### **High-Throughput Silicon Epitaxy**

Epitaxy of silicon has applications in photovoltaics both for conventional wafer technology and for crystalline silicon thin-film solar cells. At SIMTEC, we have set up two silicon epitaxy reactors that were designed and constructed in house specially for the requirements of photovoltaics, such as high throughput, high uptime and low processing cost. Our in-line test reactor, the ConCVD, features a throughput of approx. 0.5 m<sup>2</sup>/h at 20 µm layer thickness, and is used for feasibility tests and process development. The 156 x 156 mm<sup>2</sup> large substrates are transported continuously through the reactor in a "double-track" configuration of two long upright rows, mounted parallel to each other. Two consecutive deposition chambers inside the reactor allow for in-situ epitaxy of the base and emitter of a thin-film solar cell in a single pass.

The ProConCVD, the "big sister" of the ConCVD, is designed for a throughput of higher than 30 m<sup>2</sup>/h. It is therefore a unique tool for developing and testing new high-temperature thin-film solar cell concepts on a large scale, and a perfect prototype for an industrial epitaxy reactor for photovoltaics. The double-track principle of the ConCVD is mirrored in the ProConCVD, as well as the internal chamber configuration. The drastically increased throughput compared to the ConCVD is achieved by three independent double-track modules, with each substrate carrier scaled to approx. 500 mm (three standard wafers) useable height. Both reactors, together with supply infrastructure and a wet chemistry section, are located in the 600 m<sup>2</sup> large "CVD Lab" at SIMTEC.