Characterization and Material Evaluation

The technological work is accompanied by comprehensive analysis and qualification of silicon materials and solar cells which enable efficiency-limiting mechanisms to be identified and material, process, and cell concepts to be systematically improved. Using a large variety of state-of-the-art off-line and inline metrology systems, we are able to measure all relevant quality parameters on starting wafers, solar cell precursors and finished solar cells on a statistically relevant basis. Metrology systems with high spatial resolution allow loss mechanisms of cells to be analysed in depth. A well-equipped wet-chemistry analysis laboratory allows inline-monitoring of chemical baths.

Metrology Development, Data Analysis and Simulation

We develop metrology, data analysis and simulation tools in various areas, both independently and with partners. A major focal point lies in electro- and photoluminescence imaging where we develop inline-capable image recording methods for constant differentiation and quantitative determination of physical parameters, image processing algorithms for automated identification of process and material defects and complete wafer rating models for a performance prediction based on raw-wafer data, which can be adapted to customer processes. Finally, we also develop simulation tools to analyze efficiency potential and loss mechanisms of the developed-cell concepts as well as their sensitivity towards process variations.

Characterization of New Silicon Materials

We analyze all wafer-based silicon materials from standard and alternative feedstock such as upgraded metallurgical grade and compensated silicon, standard and high-performance multi- and monocrystalline silicon, with respect to the efficiency-limiting electrical characteristics such as recombination lifetime, impurity content and crystallographic structure taking into account block position. We develop adapted processes for material improvement and determine the efficiency potential on an adequate statistical basis.

Metrology Evaluation

PV-TEC provides excellent conditions for qualifying new measuring instruments from manufacturers for use in PV industry. Measurement suitability testing can be performed on any form of test samples, measurement accuracy can be determined by numerous reference methods and reliability and repeatability may be tested by temporarily incorporating inline-measuring systems into automatic measuring stations.

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Production Technology Research

Since its foundation in 1981, Fraunhofer ISE conducts R&D in the field of photovoltaics (PV) and since 1996 in the field of production technology. The main objectives are an increase of efficiency and a reduction of process cost based on advances in cell concepts, highly productive processes and materials and a more efficient use of resources.

In 2005 PV-TEC – Photovoltaic Technology Evaluation Center was set up with a basic investment of 12 Mio. Euro. Since its foundation, the German Ministry of the Environment supported the institute. Due to the increasing importance of photovoltaic technology, since the beginning of 2018, lab restructuring resulted in the opening of two separated large area laboratories, the PV-TEC Technology Evaluation Center was the first non-profit R&D laboratory in the field of crystalline silicon solar cells based on large-scale and mostly automated equipment. Since then more than 6000 extensive experiments have been conducted and the infrastructure has been continuously improved to match the demand on cutting-edge pilot technology.

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Development and Evaluation of Processes and Equipment

We offer customized services to:
- enable large-scale research and development targeting highest cell performance
- offer technology evaluation and improvement of production lines
- training for PV companies
- process transfer / in-house support

We hold and file patents on our research, thus protecting the generated intellectual property (IP) together with our partners and customers. Licenses can be granted for various patents to allow a safe market entry.

In all areas of technology, we offer computer-aided modelling for fast and efficient development and optimization of processes and equipment components.

We develop and offer technology to process a wide range of advanced cell structures. Additionally we use and offer support for the modelling of such cell structures and structural elements based on single and multi-dimensional fluid-kinematic simulation and analytic calculation tools.

Design and Evaluation of Advanced Solar Cell Structures

Back-Contact Solar Cells

Back-contact solar cell structures enable increased efficiency and modular design. We develop and transfer technology for:
- standard Si metal through (MTW) structures which can be combined with passivated surfaces
- modular MTW cell design (all-purpose MTW) for low concentration application (around 1X) but also for low light applications (indoor etc.)
- back-contact junction IBC-SC without any front contacts which allow very high efficiencies

Carrier Selective Solar Cell Structures

We conduct process and equipment research as well as material characterization to optimize solar cells with carrier selective surfaces (i.e. heterojunction (HJ), poly-Si based structures) in order to reduce the production cost of these high-efficiency cell structures. We feature very low contamination conditions for front-end processes in PV-TEC’s clean room class 1000.

- simplified cleaning and surface conditioning prior to intrinsic amorphous silicon deposition
- intrinsic deposition of intrinsic and doped a-Si layers on various technology platforms
- tunnel oxide formation
- LPCVD (low pressure chemical vapor deposition) of intrinsic and doped a-Si layers
- alternative TCVD deposition techniques and materials
- line-to-line deposition of low light a-Si layers on screen printing, dispensing and inkjet techniques
- inline PO deactivation of metal contacts for rear side metallization

Further cell structures are under development.

1. PV-TEC back-endo cell cleaning bench for coating; 2. PV-TEC back-endo cell cleaning furnace; 3. High-speed laser drilling system; 4. PV-TEC back-endo wafer cleaning furnace.

Areas of Service
- development and evaluation of processes and characterization as well as equipment itself, including technical and economical parameters
- design and realization of advanced solar cell structures
- characterization and evaluation of materials and cells
- technology assessment
- evaluation and improvement of production lines
- training for PV companies
- process transfer / in-house support

Patents and Licences
We hold and file patents on our research, thus protecting the generated intellectual property (IP) together with our patent experts. Licenses can be granted for various patents to allow a safe market entry.

Confidentiality
A very high degree of confidentiality is of paramount importance. On request, all correspondence and cooperation results can be covered by NDAs to protect customer interests.

Process Transfer
Beside the in-house development, we also offer to transfer individual PV-TEC processes or complete process sequences into the industrial process lines of our customers. The transfers are accompanied by detailed process descriptions and customer site support during process start-up.

Development and Evaluation of Processes and Equipment

PV-TEC features industrially relevant production technology, needed for advanced solar cell processing of silicon wafers of standard and specific size (can request): including - wet-chemical etching, cleaning, and etching processes
- inline PVD deposition of metal stacks for rear side contacting
- LPCVD (low pressure chemical vapor deposition) furnace
- screen printing after PO deactivation of metal contacts
- LPCVD furnace for the manufacture of metal layers
- NILPO (intrinsic a-Si) layers in automated and direct and remote plasma systems
- laser processing: ablation (local contact opening), laser-assisted transfer of contacts
- high-speed laser drilling through a full wafer
- sinter and curing technology: in-line furnace for contact opening and curing (temperature range up to 900°C), photonic sintering, thermal annealing processes
- R&D of (Plasma Enhanced) Chemical Vapor Deposition coating with various Rb (anti-reflection) and passivation layers in automated and direct and remote plasma systems
- laser passivation: ablation (local contact opening), laser-assisted transfer of contacts; full metallization laser-assisted transfer of metal and dopants, scribing and regenerators, various high-quality automated and manual laser workstations, optical bench for laser testing
- in-line and off-line passivation (etching, wet-chemical etching, cleaning and conditioning technology and equipment components)
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