



1 Quantitative photoluminescence imaging of solar cells: dark saturation current image (left) and series resistance image (right).  
2 Automated IV-curve measurement at PV-TEC.

### 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, processes and cell concepts to be systematically improved.

Using a large variety of inline metrology systems we are able to measure all relevant quality parameters on starting wafers, solar cell precursors and finished solar cells on statistically relevant basis. Metrology systems with high spatial resolution allow loss mechanisms of cells to be analyzed in-depth. A well equipped wet chemistry analysis laboratory allows inline-monitoring of chemical baths.

#### 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 reproducibility may be tested by temporarily incorporating inline measuring systems into automatic measuring stations.

#### Metrology Development

We are developing metrology in various areas, both independently and with partners. A major focal point lies in electro- and photoluminescence imaging where we develop hardware setups, inline-capable image recording methods for contrast differentiation and quantitative determination of physical parameters and image processing algorithms for automated identification of process and material defects. Another example are measurement blocks for back-contact solar cells which can be adapted to individual customer requirements. Finally, we are also developing simulation tools for loss mechanism analysis.

#### Characterization of New Silicon Materials

We are analyzing all wafer-based silicon materials from alternative feedstock such as UMG (Upgraded Metallurgical Grade) and compensated 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 efficiency potential on adequate statistical basis.

#### Wet Chemistry Analysis

We are developing volumetric, chromatographic and spectroscopic methods for an automated determination of concentrations in chemical baths to enable insitu observation of etching systems and systematic development of etching, texturization and cleaning processes.

#### Characterization of Pastes and Inks

With our partners we evaluate metallization pastes for the use in screen-printing, inkjet-printing and novel metallization processes. In addition we evaluate various types of functional inks e.g. diffusion barriers or local etchants.

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## PV-TEC: PHOTOVOLTAIC TECHNOLOGY EVALUATION CENTER



COVER PHOTO  
Furnace automation with inline characterization instruments.

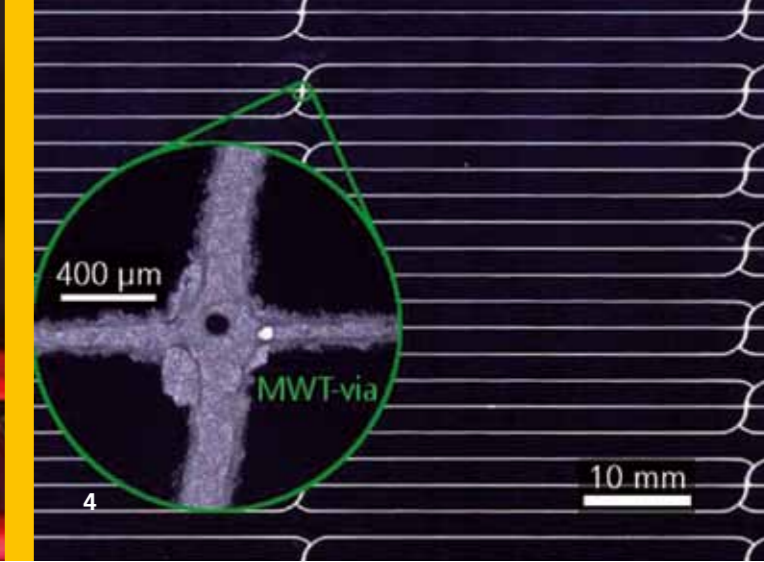
#### PV-TRAINING

- In cooperation with the PSE AG we are offering training courses covering topics throughout the entire PV value chain on engineering and decision maker level.
- Already more than 600 persons have been trained at PV-TEC.
- More information are available on our website: [www.pv-training.org](http://www.pv-training.org)

[WWW.PVTEC.DE](http://WWW.PVTEC.DE)

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# PV-TEC: PHOTOVOLTAIC TECHNOLOGY EVALUATION CENTER



## Production Technology Research at Fraunhofer ISE

Since more than 15 years Fraunhofer ISE conducts intense R&D in the field of PV production technology. The main objectives are an increase of efficiency and a reduction of process cost based on advanced cell concepts, highly productive processes and a more efficient use of resources.

In 2005 the Photovoltaic Technology Evaluation Center (PV-TEC) was set up with a basic investment of 12 million Euro mainly covered by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) to support the German/European PV industry, enabling solar cell processing and characterization on a level of several 100 wafers/hour.

Since its inauguration in early 2006 PV-TEC has been the largest non-profit R&D laboratory in the field of crystalline silicon solar cells and has been continuously extended. More than 2000 large scale experiments have been conducted so far. In 2010 a staff of more than 140 researchers, engineers, technicians and students enthusiastically works for further progress in PV.

»AT PV-TEC YOU GET PROFOUND EXPERTISE IN SOLAR CELL PRODUCTION TECHNOLOGY.«

- 1 Industrial inline processing tool for acidic texturing and single side etching applications (PV-TEC).
- 2 Automated tube furnace in PV-TEC with inline characterization instruments.
- 3 High speed laser drilling process for EWT solar cell fabrication.
- 4 In the rear contacted MWT solar cell metallized vias conduct the electrical current to the rear surface.

### AREAS OF SERVICE

#### We offer customized services to

- solar cell and module manufacturers
- equipment vendors
- silicon and other material suppliers

#### Our services

- development and evaluation of processes as well as process and characterization equipment
- design and realization of advanced solar cell structures
- characterization and evaluation of materials and cells
- evaluation and improvement of production lines
- training for PV-companies
- process transfer/in-house support
- economical cost evaluation

## Development and Evaluation of Processes and Equipment

### Laboratories

To conduct our research we are operating various laboratories with state of the art equipment and metrology instruments. The PV-TEC industrial R&D platform features automated equipment ready for large scale and at the same time complex experiments. In total, with associated laboratories, 2000 m<sup>2</sup> of high quality lab space are operated.

### Technology

Our labs feature industrially relevant technology elements needed for advanced solar cell processing:

- wet chemical etching and cleaning (texturing, single side etching, industrial cleaning sequences): inline and batch systems on industrial scale but also smaller wet benches available
- diffusion/oxidation inline and batch (dry and wet oxidation processes are implemented)
- PECVD (Plasma Enhanced Chemical Vapor Deposition) of AR and passivation layers (silicon nitride, aluminum oxide, stack systems, a-Si layers) – various systems available
- plasma conditioning and etching (completely dry cell processes are possible)
- screen printing of metal-, polymer-, dielectric- and etchant pastes, high precision automated and semiautomated printing tools, various fast firing options
- LIP – Light Induced Plating inline system for silver plating
- inkjet printing and structuring: polymers but also dielectric and other materials can be printed on various inkjet platforms.
- laser processing: ablation, doping and alloying (selective emitter formation, Laser Fired Contacts LFC) – various high quality laser workstations can be used.
- sputtering of dielectric layers (silicon nitride, aluminum oxide)
- inline sputtering and evaporation of metals (metals and metal stacks both for front and rear contacts of solar cells)

### 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 accomplished by detailed process descriptions and customer site support during process start-up.

»DEVELOP YOUR TECHNOLOGY AND CELL STRUCTURES WITH US.«

### CONFIDENTIALITY: A BASIS FOR IP DEVELOPMENT

Within the department currently 30 patents are filed. This way we protect the generated intellectual property (IP) together with our patent experts. Licenses can be granted for various patents to allow a safe market entry.

### PATENTS AND LICENCES: PROFIT FROM OUR IDEAS

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

## Design and Evaluation of Advanced Solar Cell Structures

### PERC Solar Cells

For the development of solar cells with passivated rear surfaces we develop both individual technological components and complete process sequences. Main technological fields for this structure are:

- single side treatment processes for cleaning and passivation
- Laser Fired Contact (LFC) for locally contacted rear surface
- selective emitter formation
- process developments suitable for thin wafers
- passivation based on vacuum deposition (aluminum oxide, silicon nitride and customized stacks)
- passivation based on thermal oxidation (wet and dry processes)
- metallization for advanced front and rear contacts

### Back Contact Solar Cells

We develop Metal-Wrap-Through (MWT) cells which are very close to the standard fabrication sequences lowering market entry barriers. Compared to the H-patterned cells ~0.4 % efficiency gain is achieved. A further gain on module level adds up to a significant advantage.

Further benefit is achieved by combining PERC and MWT concepts to MWT-PERC solar cells with superior efficiencies. For avoiding bus bars in concentrator applications MWT concentrator cells have been developed exceeding 19 % efficiency at 10x concentration.

Emitter-Wrap-Through (EWT) cells are developed both on mc and mono substrates. Highly efficient EWT cells with screen printed rear metallization have been achieved on small area.

Further rear contact cell structures are under development.

Contact us for more information.

»WE IMPROVE YOUR CELLS AND TECHNOLOGIES.«

### RANGE OF CELL STRUCTURES DEVELOPED AT PV-TEC

- standard H-patterned cells
- industrial PERC solar cells
- MWT and MWT-PERC solar cells
- EWT and EWT-PERC solar cells
- back junction solar cells
- thin and ultrathin cells