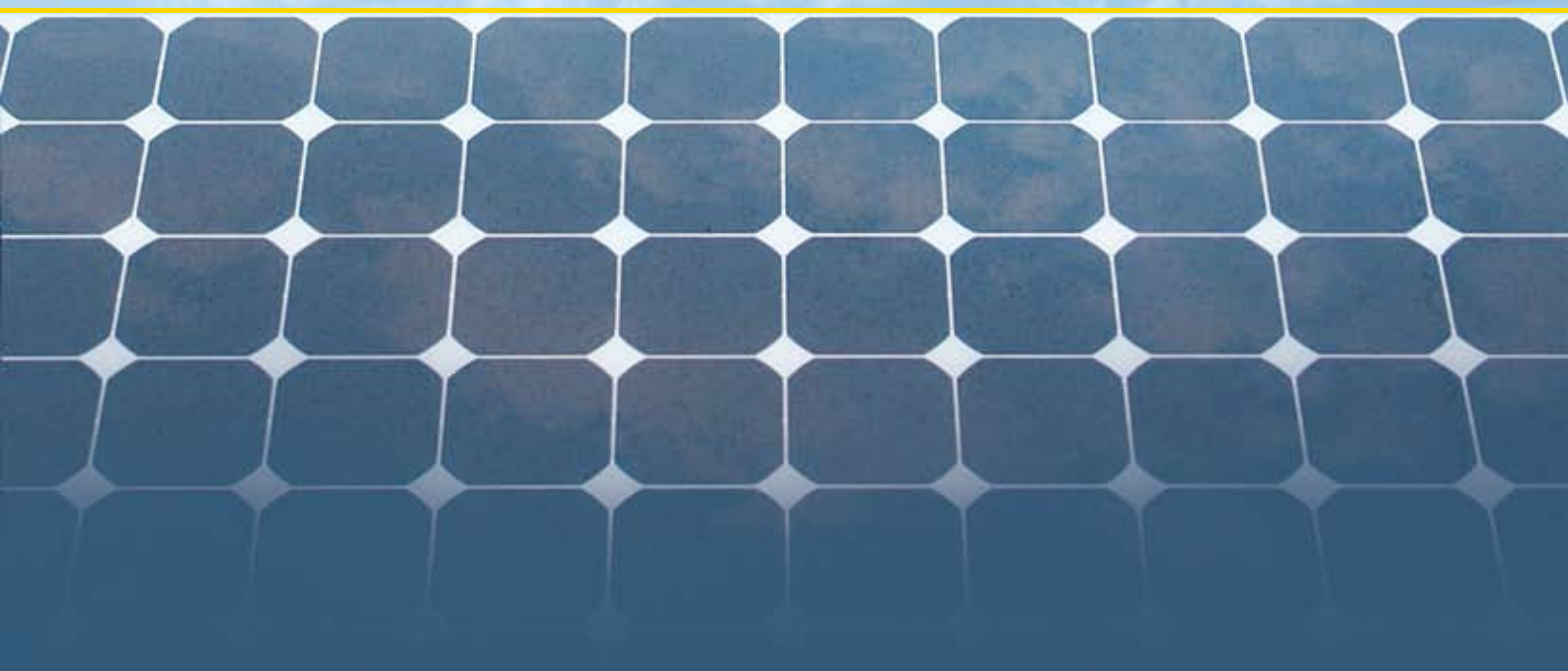
high ef

solar cell processing by diode lasers

- Large grained, low stress multi-crystalline silicon thin film solar cells on glass by a novel combined diode laser and solid phase epitaxy process.



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Project summary

HIGH-EF will provide the silicon thin film photovoltaic (PV) industry with a unique process allowing for high solar cell efficiencies (potential for >10%) by large, low defective grains and low stress levels in the material at competitive production costs.

This process is based on a combination of melt-mediated crystallization of an amorphous silicon (a-Si) seed layer (<500 nm thickness) and epitaxial thickening (to >2 µm) of the seed layer by a solid phase epitaxy (SPE) process. Melting the a-Si layer and solidifying large grains (about 100 µm) will be obtained by scanning a beam of a diode laser array. Epitaxial thickening of the large grained seed layer (including a pn-junction) is realized by deposition of doped a-Si atop the seed layer and a subsequent SPE process by way of a furnace anneal. Such a combined laser-SPE process represents a major break-through in silicon thin film photovoltaics on glass as it will substantially enhance the grain size and reduce the defect density and stress levels of multi-crystalline thin layers on glass compared e.g. to standard solid phase crystallization processes (SPC) on glass, which provide grains less than 10 µm in diameter with a high density of internal extended defects, which all hamper good solar cell efficiencies. It is, however, essential for the industrial laser-SPE implementation that such a process will not be more expensive than the established pure SPC process. A low cost laser processing will be developed in HIGH-EF using highly efficient laser diodes, combined to form a line focus that allows the crystallization of an entire module (e.g. 1.4 m x 1 m in the production line or 30 cm x 39 cm in the research line) within a single scan.

Specific attention has been given to identify each competence needed for the success of the project and to identify the relevant partners forming a balanced, multi-disciplinary consortium gathering 8 organizations from 4 different member states with 1 associated country.

Concept

The HIGH-EF project aims to advance the technology of multi-crystalline thin film silicon solar-cells by providing a completely new processing based on the laser-SPE process (cf. Fig. 1) to develop a high efficiency, low cost silicon solar cell on glass with low consumption of silicon.

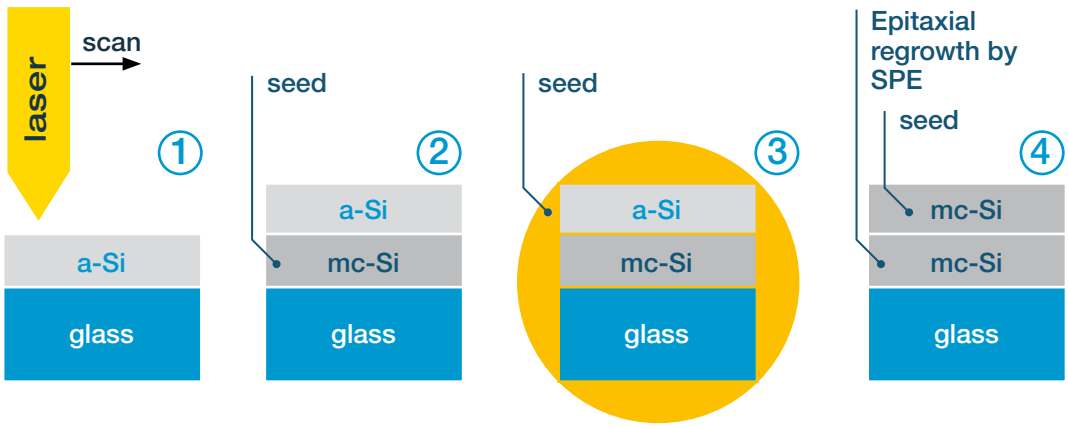


Figure 1:
Schematic of the laser-SPE process which will be established to realize large grained, low defective silicon layers on glass that have the potential for >10% efficiencies.

In PV industry, crystalline silicon (single- and multi-crystalline) bulk material dominates the market with over 90% market share. The difficulty in securing a feedstock supply to produce conventional wafer-based solar cells has encouraged a frenzy of industry projects related to thin-film solar cells. WTC, a technology consulting company based in Munich, Germany, has counted some 34 companies developing and in some cases building production lines for thin-film cells. Last year saw First Solar, Nanosolar, Schott Solar, and ERSOL announce investments in the range of $100 million each to build new thin-film plants. At this pace, thin-film cells could represent about 20% of the PV technology installed (on a year to year basis) worldwide in 2012. WTC estimates that the market for thin-film cells is set to explode in the next few years, reaching $1.5 billion in 2012. While the USA has been steadily loosing ground to Japan and Europe in wafer-based cells, about half of the thin-film cells are made by US companies and this share is expected to remain high (although the production may not be located in the US). A timely move is to join forces in Europe and provide one of the thin-film PV manufacturers, CSG Solar AG, with novel silicon thin film material that can be produced at competitive costs and efficiencies >10%.

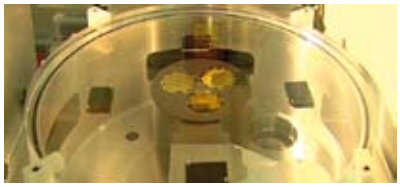
Innovations of HIGH-EF

Concerning the diode-laser crystallization process of a-Si layers on glass :

- Develop a custom made laser diode array (line focus of 30 cm and 7 kW/cm² power density) having a line focus to crystallize a-Si layers on glass of entire PV modules within a single scan.
- Establish the optimum parameter set based on experiments and numerical simulations to obtain large and low defective grains during the solidification process.
- Materials optimization with large grains, internally low defect density at low stress levels.

Concerning the development of a SPE process on multi-crystalline seed layer on glass :

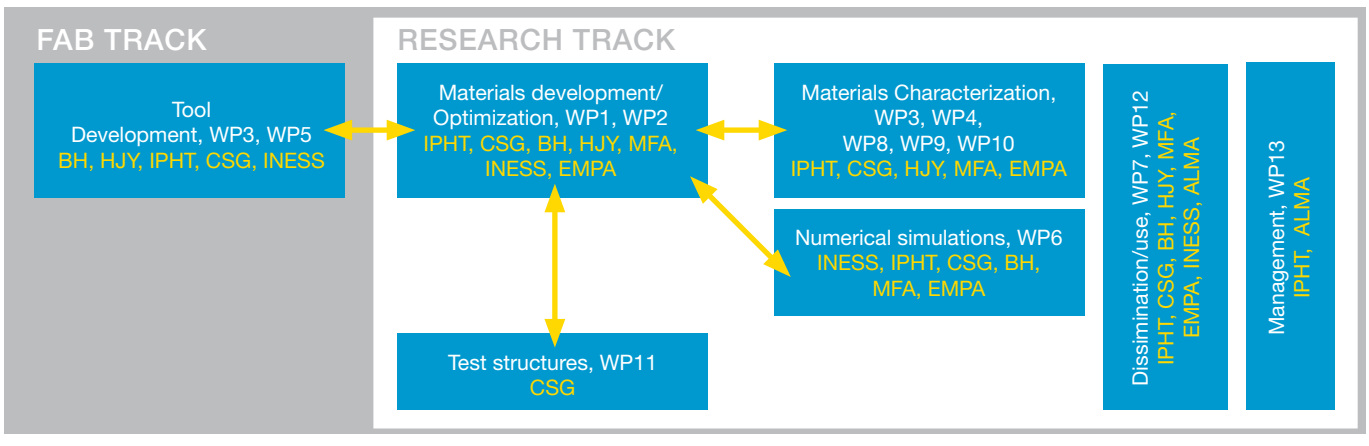
- Establish the thickening of a large grain seed layer by optimizing an SPE process of a-Si so that epitaxial re-growth on the seed is possible while low temperature processes are used to remain compatible with the glass softening temperature.
- Establish the suitable surface preparation of the seed layer silicon so that epitaxy in an SPE process is possible.



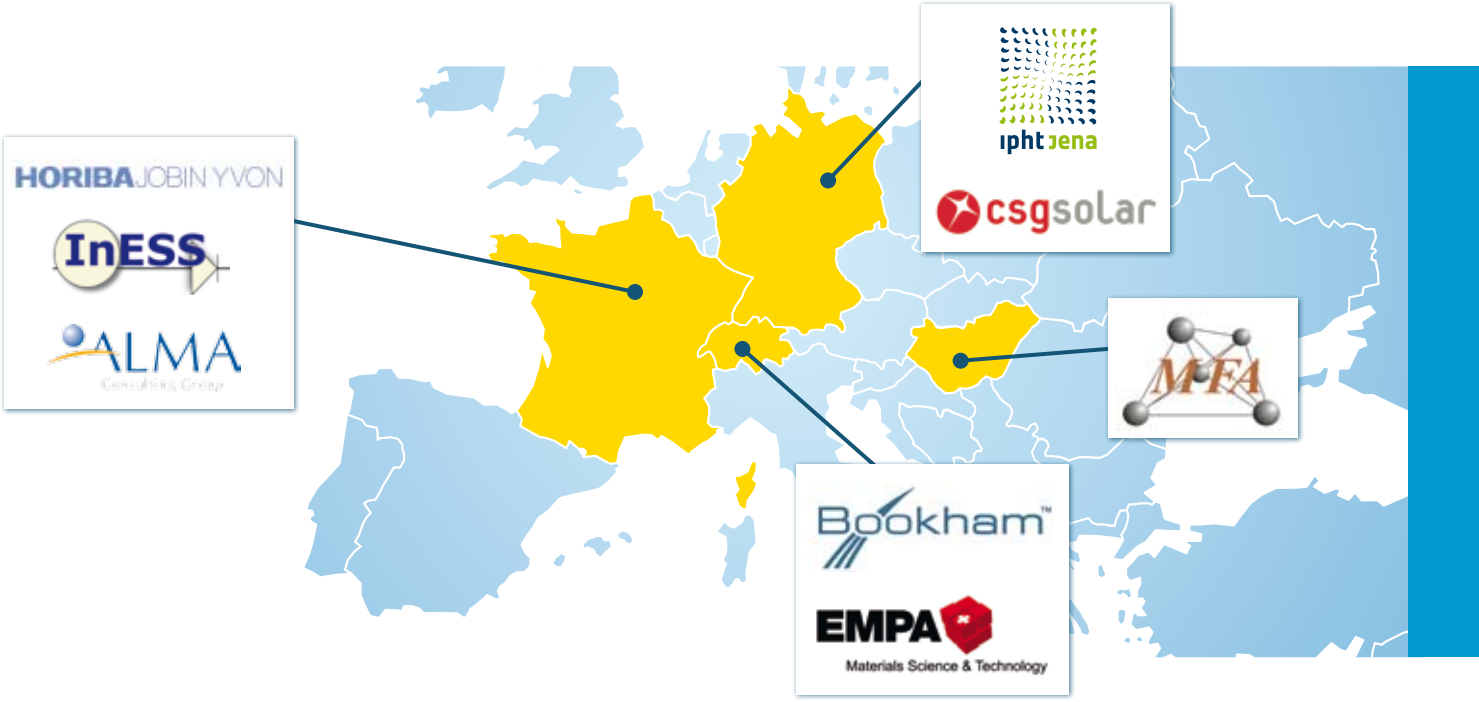
Concerning the relation between process parameters and material quality:

- Establish and use Electron Back Scatter Diffraction (EBSD) and Raman Spectroscopy to determine internal stress in the crystalline silicon film.
- Use the Transmission Electron Microscopy (TEM) to determine extended defects, to optimize process, and to explore interrelation to electronic quality.

Work plan



Consortium as a whole



Institute of Photonic Technology - **IPHT** - Germany

CSG Solar AG - **CSG** - Germany

Bookham Switzerland AG - **BH** - Switzerland

Horiba Jobin Yvon - **HJY** - France

InESS-CNRS/ULP Strasbourg - **InESS** - France

Swiss Federal Laboratories for Materials Testing and Research - **EMPA** - Switzerland

ALMA Consulting Group - **ALMA** - France

Research Institute for Technical Physics and Materials Science Hungarian Academy of Science **MFA** - Hungary

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The HIGH-EF project addresses the aera “Alternative approaches for crystalline silicon PV”.
It has been running since January 1st 2008.

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www.high-ef.eu

Coordinator: Institute of Photonic Technology
Fritz FALK - fritz.falk@ipht-jena.de

With the support of Alma CG: +33 (0)4 72 35 80 30
Anne-Sophie DEHLINGER - asdehlinger@almacg.com