High-efficiency solar cells on n-type silicon

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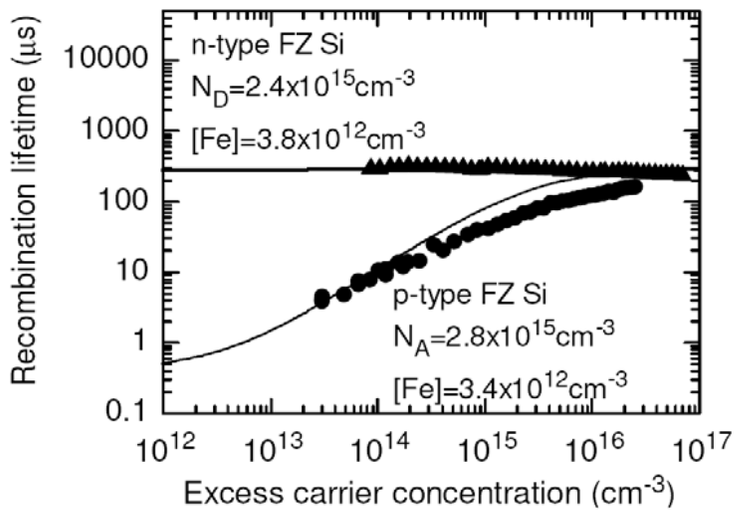
Initial Position

- Most impurities have larger cross sections for electron capture than for hole capture
- n-type silicon shows a relative tolerance to common impurities (e.g. Fe)
- n-type silicon shows higher minority carrier lifetimes and no light-induced degradation
- Goal of this work:
  Development and optimization of cell structures for n-type silicon



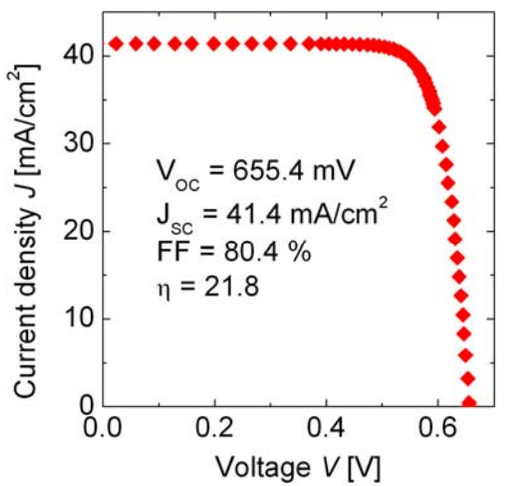
Lifetimes on n-type and p-type silicon with similar Fe concentration (by Macdonald and Geerligs, 19th EUPVSEC, Paris, 2004

„Buried-Emitter“ solar cell on n-type silicon

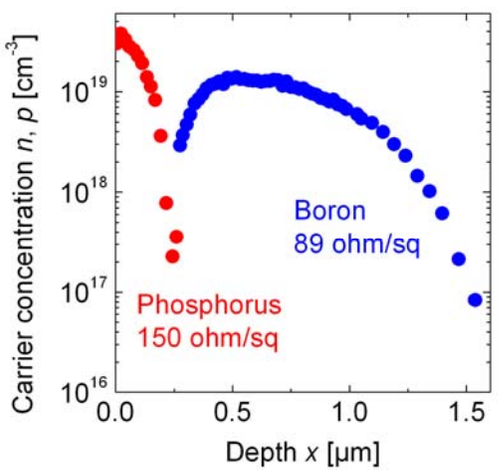
Results I

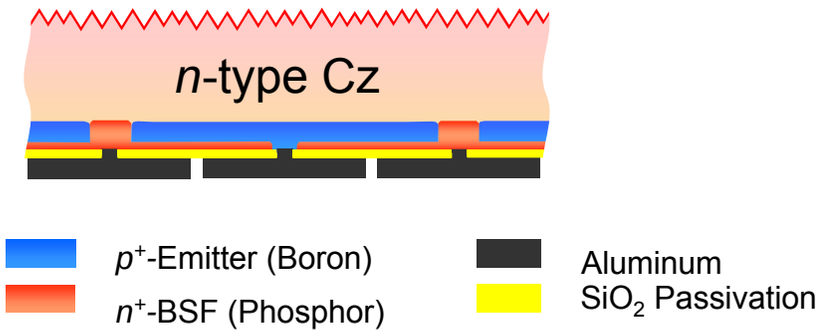
- 80% coverage of rear boron emitter for effective collection of minority carriers
- Passivation of the emitter by oxidized n^+ surface diffusion

- Cell result:



Diffusion profile:





Structure of a buried emitter solar cell.

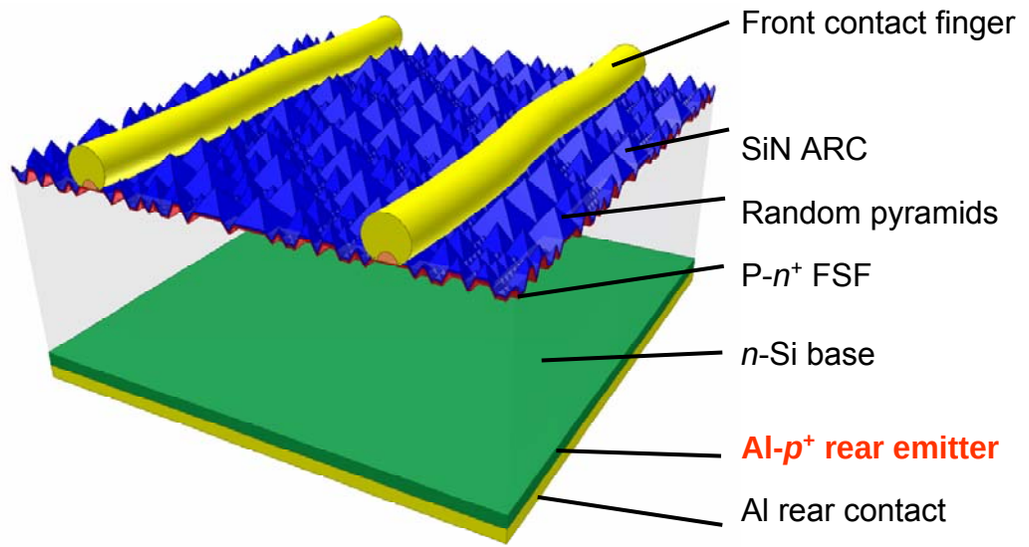
Aluminum back junction solar cells

Fraunhofer ISE

Results II

- Standard industrial process of solar cells on p-type silicon can be used
- Process very close to industry
- Junction is formed at the rear side by aluminum alloying
- Excellent result on large areas with industrial process

Area [cm²]	V_{oc} [mV]	J_{sc} [mA/cm²]	FF [%]	η [%]
148.5	**632**	**36.0**	**80.0**	**18.2**



Structure of an aluminium back junction cell.

On laminate laser-soldering of rear-contact solar cells

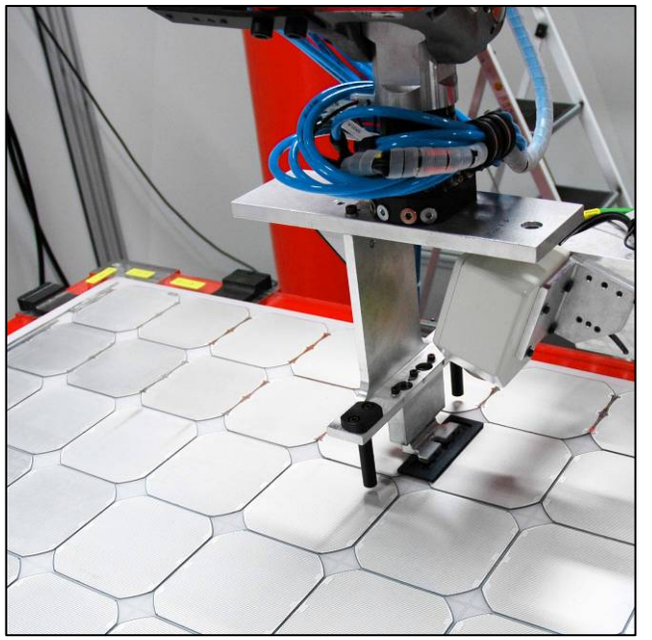
ISFH

Initial Position

Worldwide rear-contact solar cells are being developed or are already on the market. Rear-contact solar cells are characterized by a special design.

The positive and negative contact electrodes are placed on the rear side, i.e. they are not illuminated. The reflection losses from the front metal grid experienced with conventional solar cell design are avoided.

Furthermore the rear-contact solar cell enables a simple PV-module production process compared with conventional solar cells due to an in-plane rear-to-rear connection over the solar cell edges.



A robot positions and solders solar cells and interconnectors

On laminate laser-soldering of rear-contact solar cells

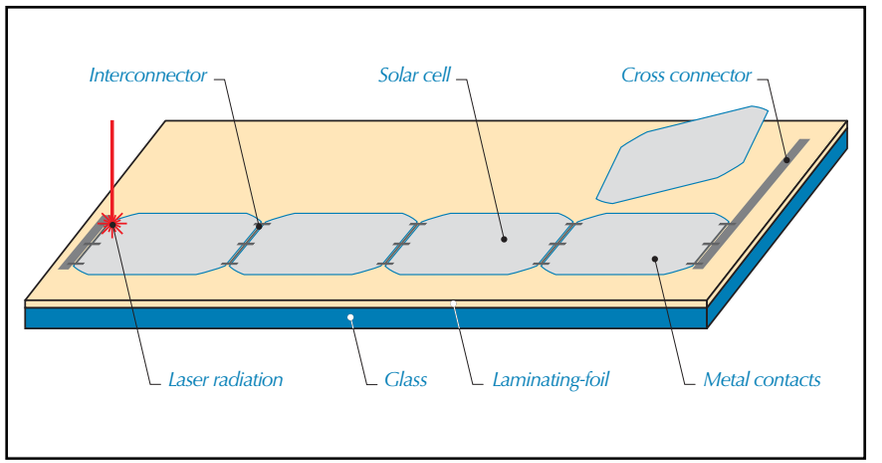
Research

At ISFH a high speed process to connect rear-contact solar cells for module fabrication is developed.

Instead of connecting the cells one by one in a stringer, they are interconnected on the glass pane and the laminating foil, which is used for subsequent encapsulation of the cells.

The cells are placed matrix-like on the laminating foil, interconnectors are placed between every two cells and a diode laser solders the interconnector to the cells.

Finally, standard lamination on top of the solar cells seals and completes the PV-module manufacturing process.



Scheme of the ATLAS process.

On laminate laser-soldering of rear-contact solar cells

Results

An ATLAS module has the same efficiency as a module produced with the same cells using a non-laser soldering process. The processing time cycle for a production machine is calculated to be two seconds per solar cell. Soldering on the heat-sensitive laminating foil slightly melts the foil, but does not damage it. High quality joints are produced by laser-soldering.

Unlike with conventional interconnection machines, the fragile solar cells are handled only once, no more. This reduces the incidence of solar cell breakage.The ATLAS production concept is twice as fast as standard interconnection machines. The high production speed reduces the equipment costs for PV-module manufacture.

Modul of rear contact solar cells made by the ATLAS process

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Module Technology for Back-contact Solar Cells

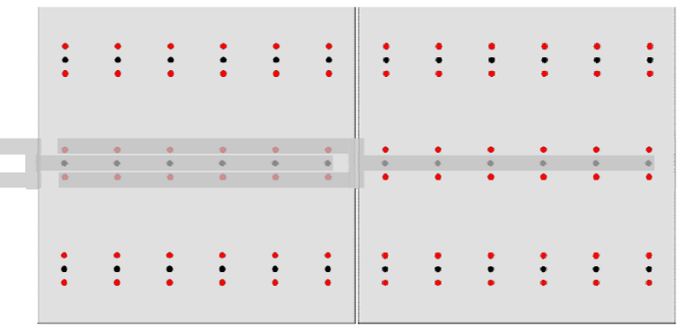
Fraunhofer ISE

Initial Position

Back-contact solar cells promise efficiency gains on the cell and module level as well as cost reduction in an efficient module production.

The contact design of these cells requires new interconnection technologies to provide reduced thermo-mechanical stress and lower series resistance losses.

While conventional cell strings lose 3% fill factor compared to the single cell level, the losses in back-contact cell strings can be reduced to 1% or less, if the interconnection challenge can be met.



Sketch of MWT cell contact and interconnector design

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Module Technology for Back-contact Solar Cells

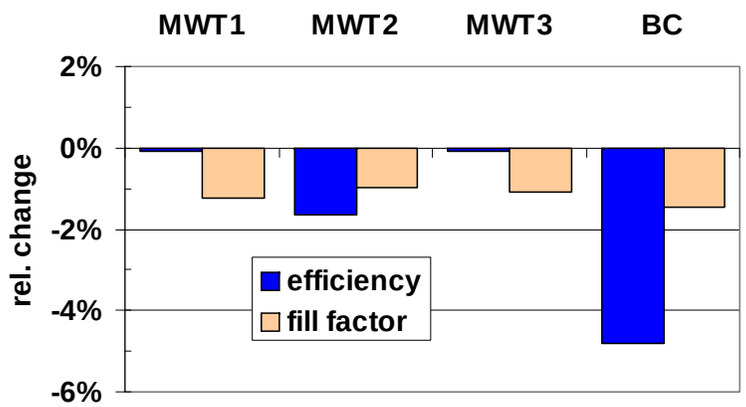
Research

Using Finite Element Modelling, we investigated interconnector designs that reduce the thermo-mechanical stress due to cooling after soldering.

By means of electric network analysis we looked at optimal interconnector cross-sections in the cell string.

Soldering technologies were investigated by a variety of methods including X-ray, pull test and metallografy.

Interconnector prototypes have been tested with regard to their mechanical and electrical properties. Module samples have been subjected to accelerated aging and monitored in terms of performance.



Performance change of 4 module samples after accelerated aging procedure

Module Technology for Back-contact Solar Cells

Results

A interconnection technology based on a flexible sheet has been developed.

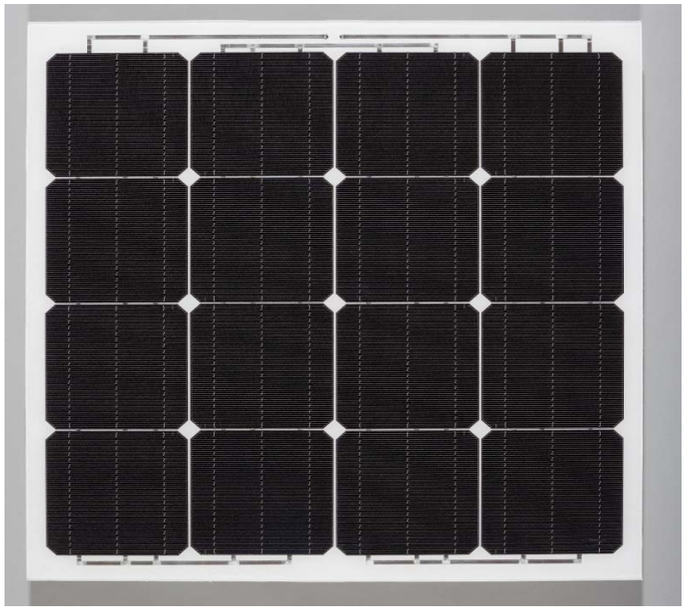
Mechanical stress on cells has been reduced by 90%, compared to conventional approaches.

The interconnection is carried out with lead-free solder and may be applied to thin cells.

Electric efficiency can be improved by 2% on MWT (Metal wrap through) cells.

Module samples of up to 24 cells have been built and tested.

In this project, Fraunhofer ISE cooperated with Schmid Technology Systems, Aleo Solar, Somont and Swiss Solar Systems.
This work was supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under contract no. 0327611.



Module sample with MWT-cells from Bosch Solar

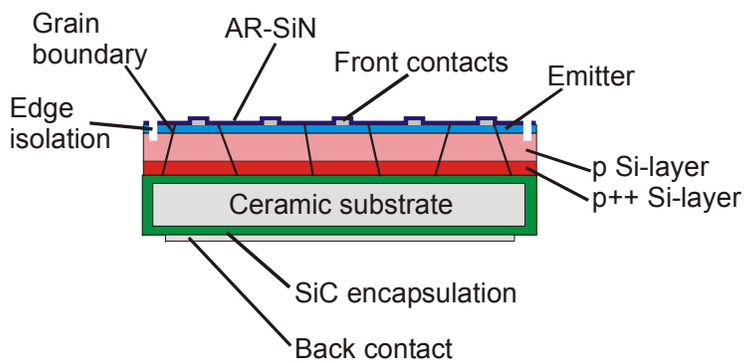
Crystalline silicon thin-film solar cells on foreign substrates

ZAE BAYERN

Initial Position

Most of today's photovoltaics is based on silicon wafers. However, the high quality wafers contribute significantly to the overall costs of PV solar cells and modules.

These costs could be significantly reduced if silicon containing gases (preproducts of the silicon production process) are used for the deposition of silicon layers on a carrier substrate.
(i) A thin p++-type silicon layer as seeding layer
(ii) A 15 µm-thick silicon layer as absorber layer



Concept of a crystalline silicon thin-film solar cell on low-cost ceramic substrate. The total thickness of Si-layers is only 30 µm or less.

Crystalline silicon thin-film solar cells on foreign substrates

ZAE BAYERN

Research

An approach is to deposit thin silicon layers on low-cost foreign substrate. The difficulty of this approach is that recombination of minority charge carriers within the silicon layer at crystal defects has to be avoided.
In order to minimize the influence of grain boundaries, the first silicon seeding layer is recrystallized.

For the deposition of the Si layers an epitaxial reactor was developed for substrates up to 40 cm 40 cm.

Crystalline silicon thin-film on low-cost ceramic substrate.

Crystalline silicon thin-film solar cells on foreign substrates

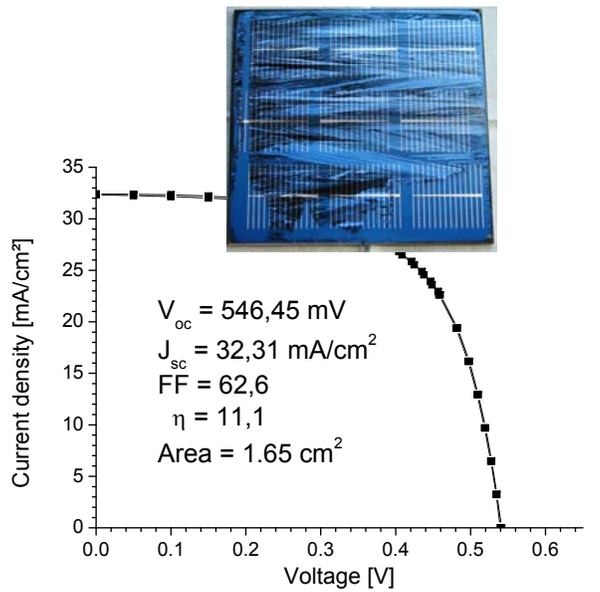
ZAE BAYERN

Results

In our cell concept, the porous substrate was sealed by an SiC barrier layer.
The recrystallization process of the first Si layer results in a grain size of the seeding layers in the mm range.

High qualtity epitaxial absorber layers were grown on the seeding layers by vapor phase epitaxy. Passivation in hydrogen plasma is effective for further neutralization of the remaining crystal defects.

First cells with a conversion efficiency of up to 11.1% have been obtained so far.



Crystalline thin-fim Si colar cell:

Illumination current voltage curve at AM1.5 spectrum. Cell conversion efficiencies of up to 11.1% have been obtained.

Copper Indium Selenide/Sulfide – A Suc**CIS**s Story

ZSW

HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

ZSW

ZSW has been developing materials and processes for the fabrication of Copper Indium Gallium Diselenide (CIGS) thin-film solar cells since 1993:

- 1997: Integrated 30 x 30 cm² solar module with efficiency of > 12 %
- 1999: Founding of solar manufacturer Würth Solar
- 2000: Technology transfer from ZSW to Würth Solar pilot plant in Marbach near Stuttgart:
  - → capacity: 1 MW_p/a of 60 x 120 cm^2 modules
  - → average module efficiency: 10-12 %.

HZB

Development of thin-film solar cells based on the CIS technology (Copper Indium Sulfide) has been in progress since 1990:

- 1991: Evolvement of the CIS-technology at the then HMI (Hahn-Meitner-Institut)
- 2001: Foundation of the spin-off company Sulfurcell
- 2005: Upscaling from 5 x 5 cm^2 to 65 x 125 cm^2, prototype introduced Commencement of pilot production with 1 MW_p/a
- 2008: Continuous improvement of production up to now 2.5 MW_p/a with 80 % yield

Top: CIGS production line in pilot production of Würth Solar at Marbach near Stuttgart (2001)

Bottom: New headquarter and production hall of Sulfurcell in Berlin-Adlershof

Technology Transfer and Special Analytics

ZSW

ZSW continues its research on the thin-film semiconductor materials and production technology. The aims:

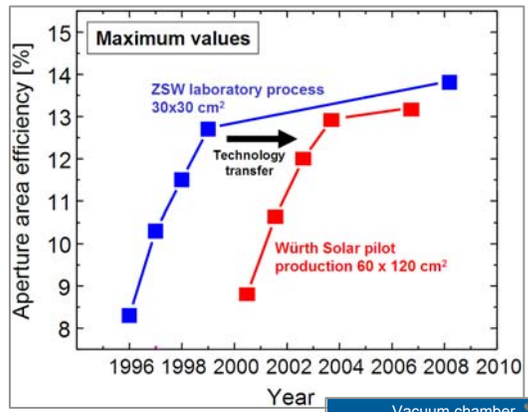
- improved productivity due to
- higher ‚industrial' efficiencies
- reduction of materials costs
- improvement of throughput and yield
- new products for different applications including BIPV with high long-term stability

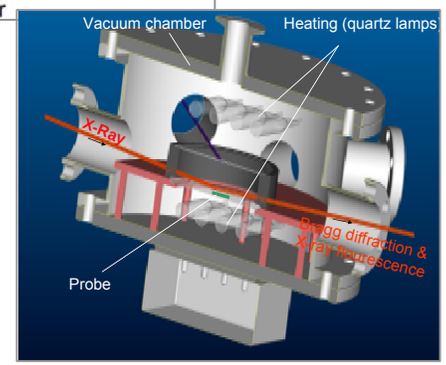
for continuous transfer from lab to production

HZB

In a continuous base-line process, the HZB-experts are improving yield, efficiency and stability of the $CuInS_2$ modules with a sample size of up to 10 x 10 cm^2.

- Implementation of results from base-line into Sulfurcell production line.
- Research on practical process issues
- Strong emphasis on in-situ methods applicable in industrial processes
- Sophisticated analytical tools such as the synchrotron radiation source BESSY II allow in-situ process analysis and optimisation





Top: Transfer of efficiency gains at ZSW to Würth Solar production line

Bottom: Energy dispersive x-ray diffraction (EDXRD): In-situ analytics at BESSY II

Applications and Records

ZSW

HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

ZSW

- 2006: successful transfer of CIGS technology to mass production
- 2007: CISfab in Schwäbisch Hall reaches capacity of 15 MW_p/a.
- 2008: further increase in production capacity → 30 MW_p/a.
- ZSW accompanies production and continues its research on ever more efficient and more stable solar cells.
- 2009: ZSW achieves European cell efficiency record of 19.6 %:
  → with own CIGS deposition system for all process steps over the area of 30 x 30 cm^2
  → plant represents pre-industrial scale
  → prerequisites for cutting costs and increasing efficiency further

HZB

- 2006: The Sulfurcell modules have been installed in several projects already, eg. in the aesthetically pleasing facade of the Ferdinand-Braun-Institut in Berlin-Adlershof (picture right bottom).
- July 2008: Sulfurcell starts its expansion of production up to 75 MWp/a with equity funding of EUR 85 million. The new HQ building receives about one third of its energy consumption via building integrated PV-Modules (slide 1).
- 2009: The HZB sets a record by adding Ga to the CIS to improve the efficiency of sulfur based cells to 13 %.

Top: Test strip with CIGS solar cell with record efficiency achieved at ZSW

Bottom: Facade of the Ferdinand-Braun-Institute in Berlin-Adlershof

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Flexible CIGS Thin-Film Solar Cells

Dr. Roland Würz (ZSW) • Dr. Christian A. Kaufmann (HZB)

ZSW

HELMHOLTZ ZENTRUM BERLIN
für Materialien und Energie

Initial Position

Advantages of Flexible Solar Cells

- product integration (thin and light weight modules)
- mobile modules for Consumer Electronics
- new applications in architecture
- high productivity with Roll to Roll deposition
- less material and energy consumption

Low cost flexible substrates

Material	☺ advantage	☹ disadvantage
stainless steel (Cr steel)	high thermal stability low thermal expansion	diffusion of iron (Fe) into CIGS
mild steel	high thermal stability low cost	high diffusion of iron into CIGS high thermal expansion corrosion
polyimide	insulating → monolithic series connection	very high thermal expansion low thermal stability

Mobile modules for consumer electronics
CIGS on stainless steel (Cr steel)
(www.global-solar.com)

Detrimental diffusion of iron into CIGS layers

CIGS solar cells on polyimide

Dr. Roland Würz (ZSW) • Dr. Christian A. Kaufmann (HZB)

Research

Detrimental diffusion of iron from steel subtrates into CIGS layers

- Reduced efficiency on steel substrates compared to glass substrate
- Enhanced iron concentration in CIGS on steel substrates

→ Iron reduces solar cell efficiency

- Diffusion is higher for mild steel compared to Cr steel
- Iron diffusion from steel substrate into CIGS layer at high substrate temperatures (T ~ 600°C)

→ Development of diffusion barrier layers to prevent diffusion

CIGS solar cells on Polyimide (low temperature CIGS process)

- Polyimide is only stable up to substrate temperatures of 450°C
- Problem: Efficiency is lower at lower substrate temperatures

→ Development of high efficiency CIGS process at low substrate temperatures

substrate	efficiency η_{max} / %	iron conc. / ppm
mild steel	6.0	314
stainless steel	8.9	48
glass reference	10.9	3

Influence of iron concentration in CIGS layer on solar cell efficiency η

(R. Würz, Thin Solid Films 517 (2009) 2415)

Flexible CIGS Thin-Film Solar Cells and modules

Dr. Roland Würz (ZSW) • Dr. Christian A. Kaufmann (HZB)

ZSW

HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

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Results

CIGS solar cells and modules on steel substrates (ZSW)

Efficiency of CIGS solar cells on steel substrates with(out) diffusion barrier:

substrate	with barrier	without barrier	glass reference
mild steel	11.0 %	5.8 %	12.1%
stainless steel	15.2 %	7.3 %	14.6 %

- Diffusion barrier (here: silicon oxide) is inevitable to reduce iron diffusion and to achieve high efficiency CIGS solar cells on steel substrates
- 8.6 % module efficiency on mild steel with insulating barrier layer (module area ~ 47cm²)

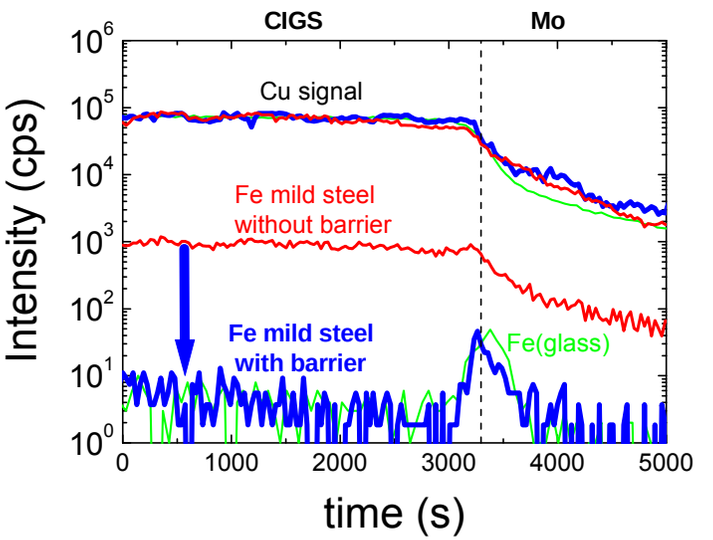
High efficiency CIGS solar cells on Polyimide

- 15.1 %[1)] Helmholtz Zentrum Berlin (lab, batch process, with ARC*, aa*)
- 13.4 % Solarion, Leipzig (pilot production, Roll to Roll process, ta*)

→ high efficiency is also achievable with low temperature CIGS-process

*ARC = with anti reflective coating, ta = total area, aa = active area

[1)] R. Caballero, Mater. Res. Soc. Symp. Proc. 1165 (2009) 1165-M02-10



SIMS depth profile of copper (Cu) and iron (Fe) in CIGS layer on mild steel with(out) diffusion barrier layer

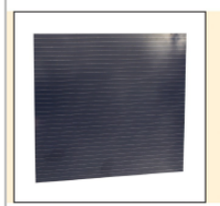
→ iron diffusion is suppressed by diffusion barrier layer (here: silicon oxide layer)

Science Meets Industry – Technology Transfer at PVcomB

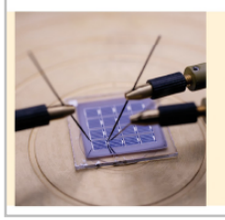
Excellent research needed in industry

- The Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (HZB) is one of the leading research institutions worldwide for thin-film solar cells.
- Due to the steady rise in activities in the thin film photovoltaics (PV) market, an increasing number of companies are asking HZB for support.
- To meet this demand, in 2007 HZB and the Technische Universität Berlin (TUB) have initiated PVcomB – Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin
- PVcomB's main goal is to support world wide growth of thin-film photovoltaic technologies by providing top-level technology transfer.

Typical module on the market - 60 x 125 cm² (Sulfurcell)



Intermediate-Size Modul, 30 x 30 cm² (PVcomB)



Laboratory cell, typical size 0,5 x 0,5 cm² (HZB)

From laboratory to market modules – Technology transfer at PVcomB

Research-Lines for Baseline-Production

pvcomB

Finding Synergies in Different Technologies

- In a baseline process, two dedicated research-lines will produce thin-film PV modules with an area of 30 x 30 cm^2. This intermediate size is well suited to address questions arising in industrial production.
- The fact that thin-film silicon (a-Si/µc-Si) and CIS/CIGSe will be studied within one research centre offers the unique opportunity to unlock synergies in many topics common to all thin-film based technologies.
- PVcomB´s activities are planned and carried out in close co-operation with the research activities at the HZB. All research is embedded in activities with regional, national and international universities and educational institutions.
- Together with the solar energy research of the HZB and other stakeholders in the PV-sector, PVcomB creates a leading international PV-cluster in Berlin-Adlershof.

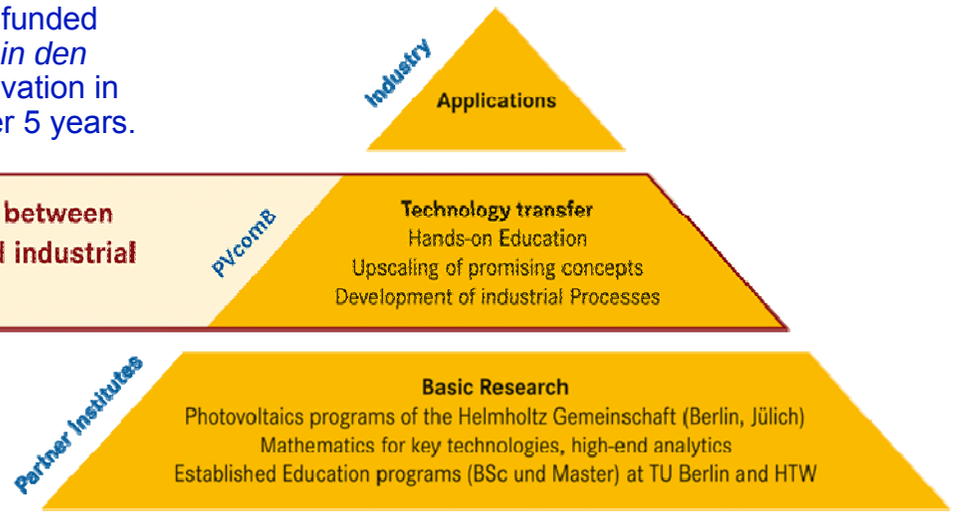
Cluster tool for thin-film solar cells (Institute for Technology, HZB)

Bridging the Gap

pvcomB

Technology Transfer in Berlin-Adlershof

- The unique approach of PVcomB has been recognised by the BMBF (Federal Ministry of Education and Research):
  In May 2009, PVcomB has been appointed as one of the funded projects in the program *Spitzenforschung und Innovation in den Neuen Bundesländern* (Leading-edge Research and Innovation in the new German Länder) and will receive 15 million € over 5 years.



- Additionally, the PVcomB is already working on R&D contracts with major PV-companies worth well over 5 million €.
- PVcomB has moved into its new location in September 2009.
- The laboratories are under construction, first module-production is expected to commence late summer 2010.

PVcomB bridges the gap between fundamental science and industrial application

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Development of III-V-based Concentrator Solar Cells with Efficiencies beyond 40 %

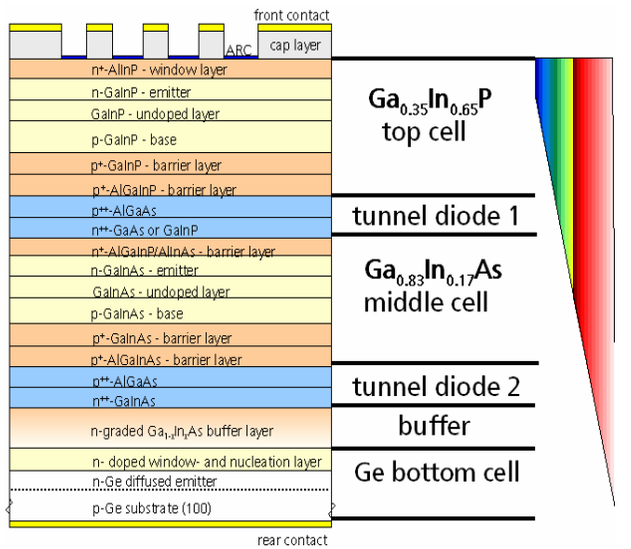
Fraunhofer ISE

Initial Position

- High-concentration photovoltaic (CPV) systems can produce electricity at low cost level. A CPV systems uses comparatively cheap optics which reduces the demand on more expensive semiconductor materials. Specifically at higher concentration levels (> 0.3 MW/m²) triple-junction solar cells made of III-V materials are attractive. They can achieve efficiencies beyond 40 %.

- By theoretical calculation it was found that a metamorphic structure, i.e. a structure where the lattice constants of the semiconductors are different, will provide higher efficiency.

- The challenge is to grow metamorphic materials with sufficiently high electrical quality. A special issue is the development of a suitable buffer structure.



The internal structure of a monolithic triple-junction solar cell is shown.

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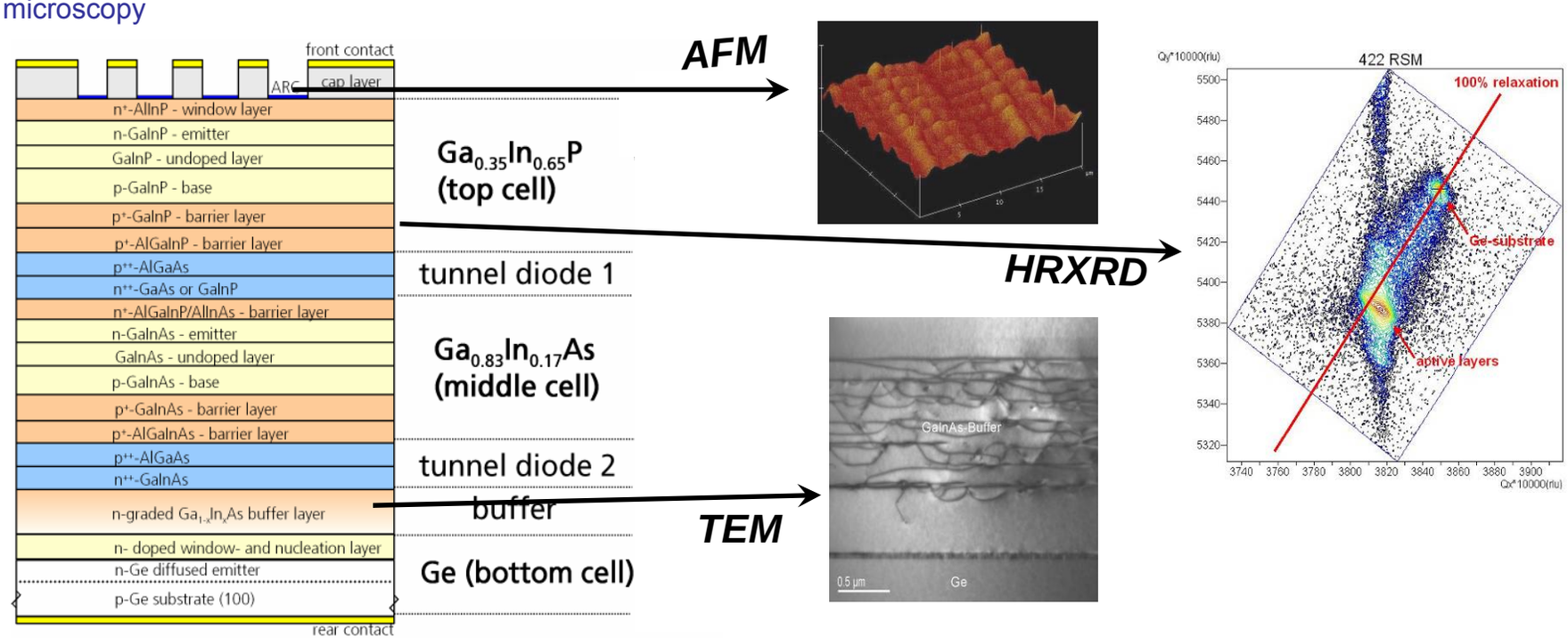
Development of III-V-based Concentrator Solar Cells with Efficiencies beyond 40 %

Fraunhofer ISE

Research

Intensive material research has been conducted in order to improve the material quality. Different material characterization has been used: AFM: atomic force microscopy: HRXRD: high resolution X-ray diffraction; TEM: transmission electron microscopy



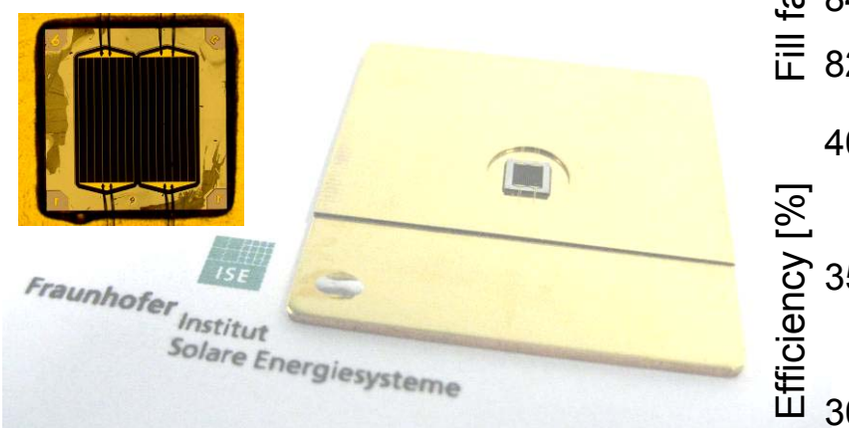
Development of III-V-based Concentrator Solar Cells with Efficiencies of 41.1 %

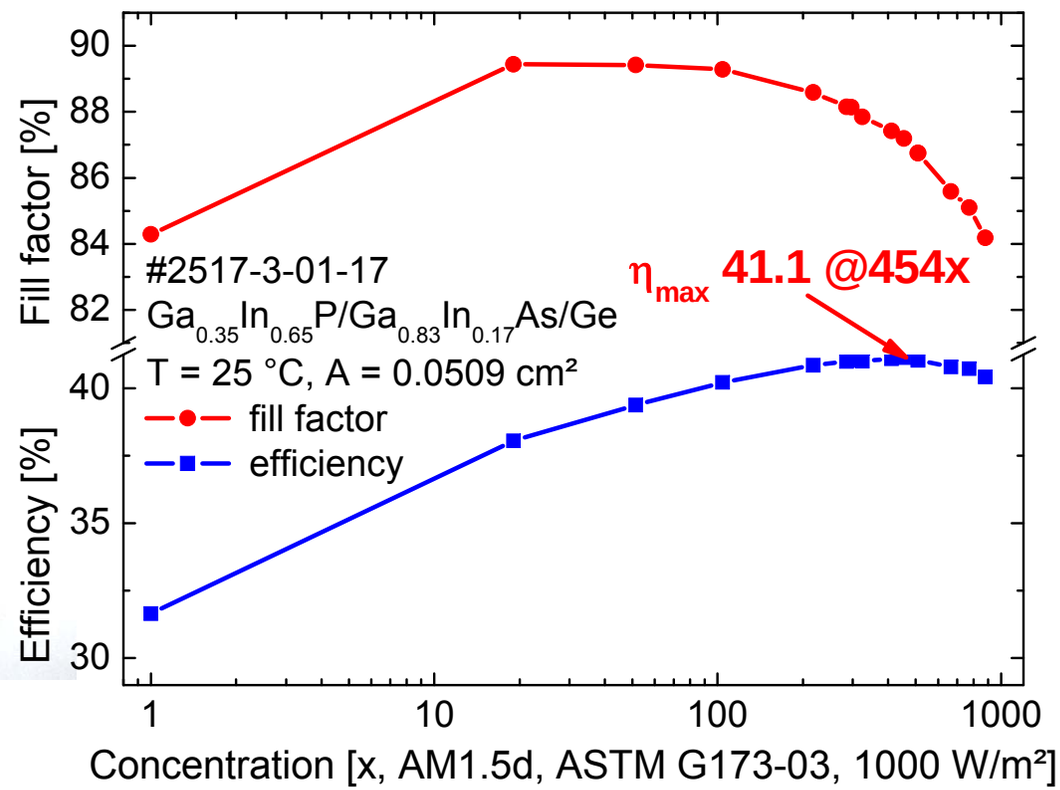
Fraunhofer ISE

Results

η= 41.1 % @ C = 454

η = 40.4 % @ C = 880





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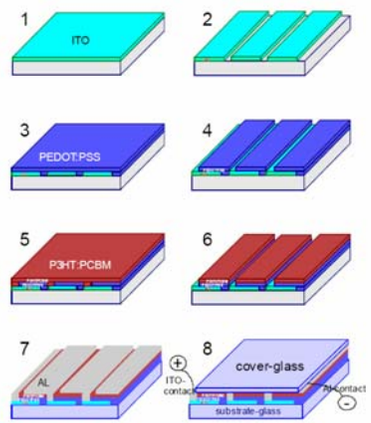
Organic photovoltaics:
IR-thermography of polymer solar cells

ZAE BAYERN

Initial Position

Organic photovltaic modules have a high efficiency potentia
results are still after.
Infrared thermography is used to investigate failure mechan
defects in polymer photovoltaic modules and cells.



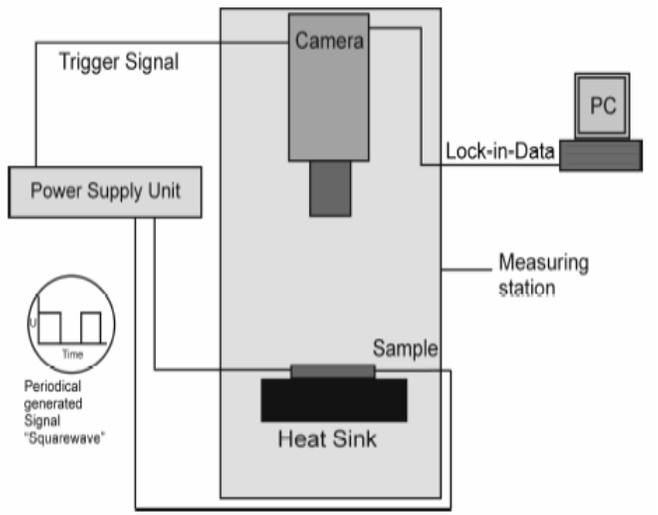
Production scheme of photovoltaic modules bassed on P3HT:PCBM-blends. Module with 3 cells.

Organic photovoltaics:
IR-thermography of polymer solar cells

ZAE BAYERN

Research

Lock-In thermography is applied to the forward or reverse biased polymer modules. The camera system used has a HgCdTe detector working in the range of 2 µm to 5 µm and triggerd with a voltage source.



Thermography setup used for DLIT measurement. The camera is triggered by the voltage supply.

Organic photovoltaics:
IR-thermography of polymer solar cells

ZAE BAYERN

Results

DLIT image of a polymer solar cell module operated in forward volatge bias (Figure, left) and reverse bias (Figure, right).

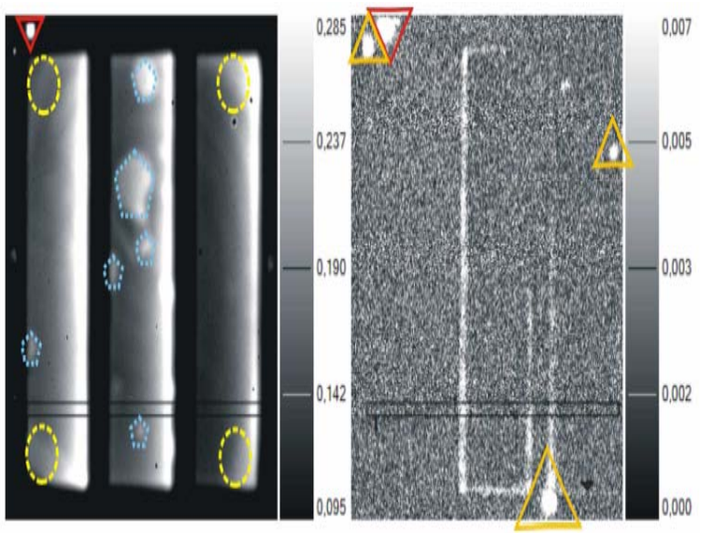
Observed efects in forward dirction (marked in the figure):

Hexagons: spots indicate air inclusions within the encapsulant

Circles: thickness variation of the photoactive layer

Triangle: Active shunts (forwar and reverse bias)

DLIT is a useful tool to optimize production related parameters of polymer solar cells.



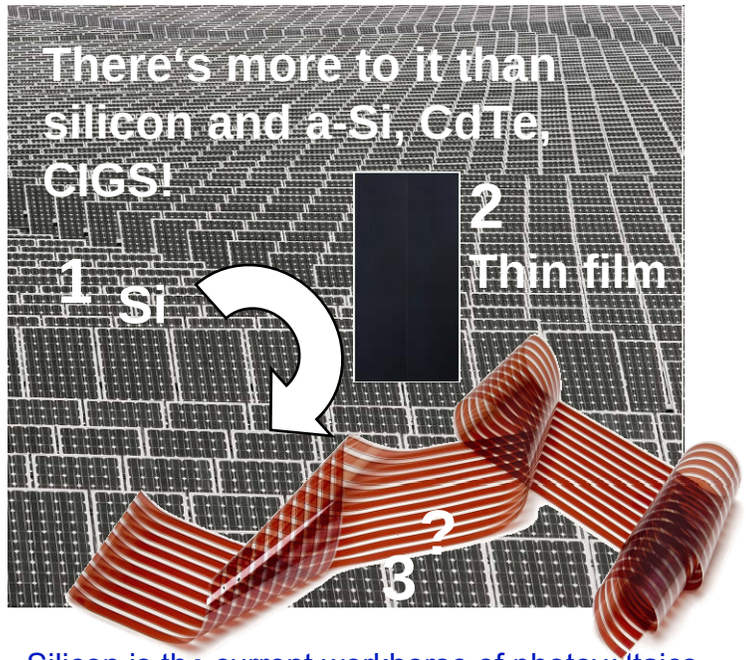
DLIT image of a polymer solar module

Organic Photovoltaics: Tandem Solar Cells • Dr. E. Ahlswede

Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg
(Centre for Solar Energy and Hydrogen Research, Stuttgart)

Initial Position

- Photovoltaics is a highly complex technology involving largely vacuum-based production processes and in part expensive materials.
- For organic photovoltaics, custom-tailored molecules and polymers can be used. These carbon-based materials promise low costs for the fabrication of large quantities.
- Organic layers are deposited from solutions in a vacuum-free process.
- Printing processes enable a very fast deposition. Flexible cells and modules can be produced from role-to-role.



Silicon is the current workhorse of photovoltaics, thin-film technologies are on the rise. Will organic photovoltaics be the next, most cost-effective technology?
(Montage: ZSW. Includes Konarka's Power Plastic®)

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Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg
(Centre for Solar Energy and Hydrogen Research, Stuttgart)

Research

- Current standard polymer single cells are limited to efficiencies around 5–6 %.
- New polymers with higher absorption (smaller band gap) are needed!
- Tandem concepts comprising two stacked sub-cells for a better exploitation of the sun spectrum are being developed, using two polymers with complementary absorption spectra.
- Efficiencies are expected to go beyond 10 % for such systems.
- Such tandem cells need optimized absorber materials, but also suitable interface engineering with respect to the back, front and intermediate contacts.

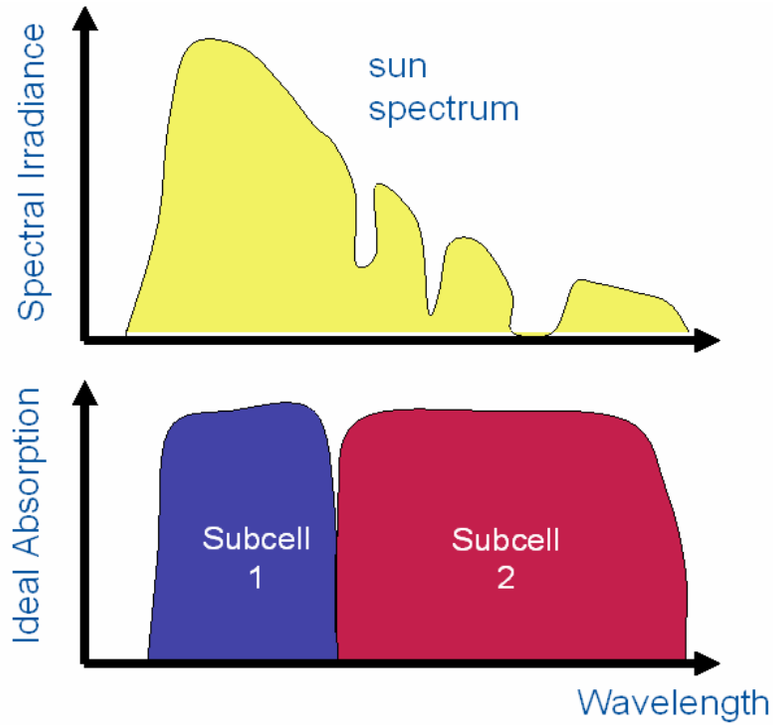

Chart of the spectral irradiance across the sun spectrum (top) and the ideal absorption of the sunlight by the two sub-cells of organic tandem cells

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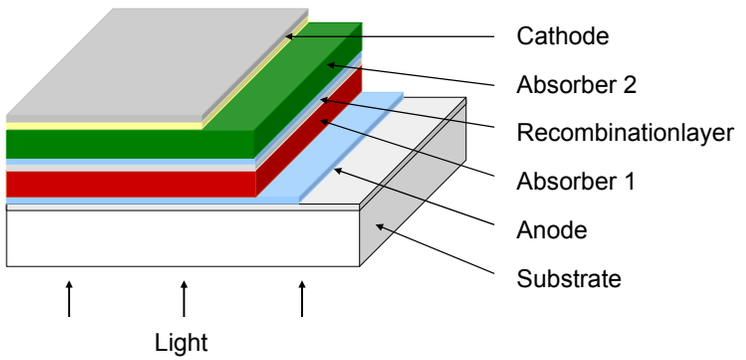
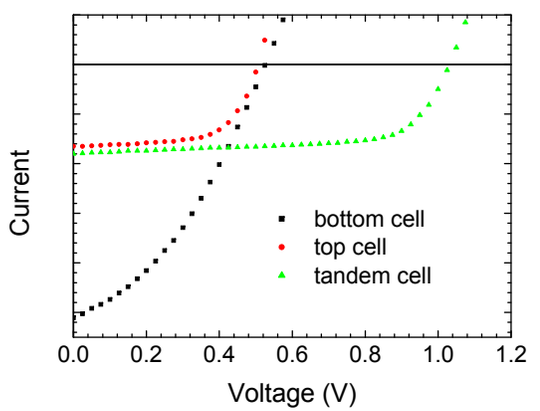
Results

- Currently, organic tandem solar cells are investigated and developed in close cooperation with various partners within the BMBF project EOS including university partners and industrial companies, like Konarka.
- Promising results can be obtained with sub-cells connected in series. As can be seen, the open circuit voltages of the subcells add up. The individual short-circuit currents have to be adjusted properly for optimized performance.
- Different organic absorbers are under investigation and combined in such tandem structures.





Device structure and I-V-characteristics of a tandem device connected in series

Contact:
Claudia Brusdeylins (ZSW)
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Organic photovoltaics:

Elucidation of important recombination loss mechanisms

ZAE BAYERN

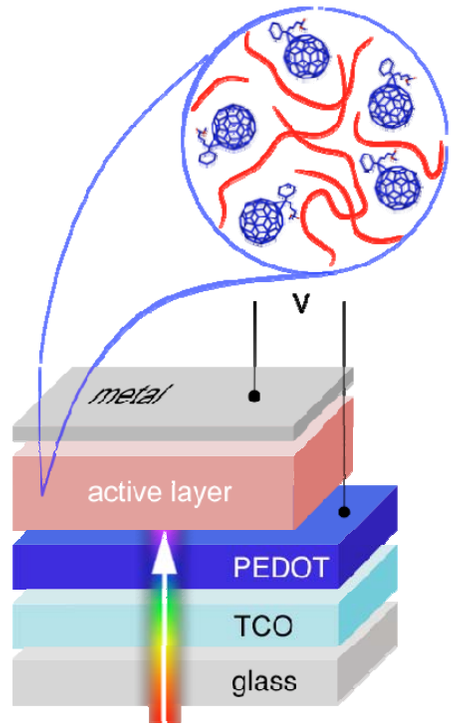
Initial Position

Improvements in the performance of organic solar cells based on polymer:fullerene blends (to date 5-6%) are strongly dependent on understanding the dominant loss mechanisms in these devices.

The relevant processes during which the losses can occur are
- geminate recombination during e-h pair dissociation
- non-geminate recombination during transport of the already separated e-h pairs
- charge extraction from the device.

Complex morphology of the device absorber may strongly influence the performance of this type of solar cells and should be taken into account, too.

A combined experimental and theoretical analysis considering the interplay of these mechanisms has still to be done.



Scheme of a polymer-fullerene bulk-heterojunction solar cell.

Organic photovoltaics:

Elucidation of important recombination loss mechanisms

ZAE BAYERN

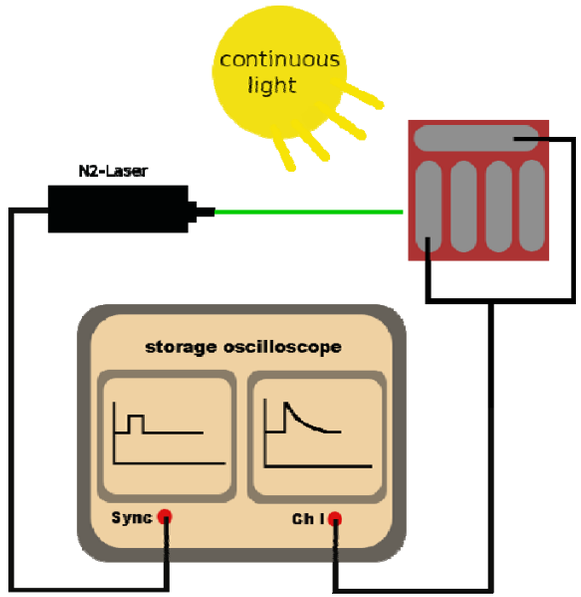
Research

We used transient photovoltage (TPV) and transient photocurrent (TPC) techniques in order to determine the charge carrier lifetime and charge carrier density in polymer-fullerene solar cells under solar cell working conditions.

TPV:
- Illumination with bias light by LED → V_{OC}
- Small optical perturbation by pulsed N_2-Laser → ΔV_{OC}
- Exponential TPV decay monitors loss kinetics
- Charge carrier lifetime can be calculated:

$$\frac{d(\Delta V)}{dt} \propto \frac{d(\Delta n)}{dt} = -k_{eff}\Delta n = \frac{\Delta n}{\tau_{\Delta n}}$$

TPC:
- Illumination with bias light by LED → I_{SC}
- Small optical perturbation by N_2-Laser → ΔI_{SC}
- Integration of I_{SC} over time → ΔQ (charge added to device)
- Differential charging: $C=\Delta Q/\Delta V_{OC}$
- Extrapolation of C, integration over V_{OC} → charge carrier density n



Setup for transient photovoltage (TPV) and photocurrent (TPC)

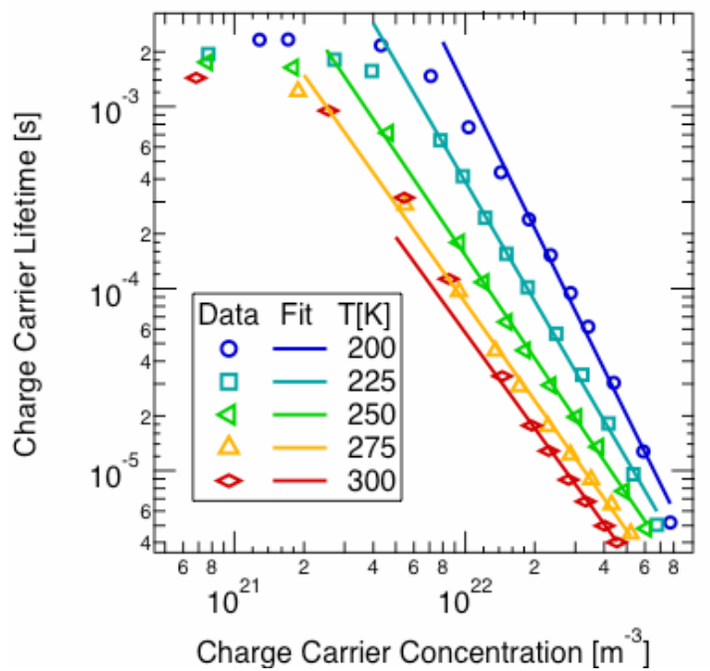
Organic photovoltaics:

Elucidation of important recombination loss mechanisms

ZAE BAYERN

Results

- Monomolecular (MR) and bimolecular (BR) recombination mechanisms for photo-generated electrons and holes in the device absorber were identified.
- BR becomes dominant at carrier concentrations $n > 3x10^{21}$ m^{-3} (see Fig.) and shows a decay of an order exceeding the expected bimolecular case (n^3 instead of n^2).
- We explain the higher order recombination by the carrier concentration dependence of the bimolecular recombination Langevin prefactor.
- The charge carrier concentration dependence is strongly temperature dependent. At higher temperatures the effect of trapping and release due to disorder was found to be negligible.
- These observations may have important implications on the understanding and modelling of organic solar cells.



Concentration dependence of the charge carrier lifetime in a P3HT:PCBM solar cell at various temperatures.

The solar greenhouse

izes gGmbH
Institut für ZukunftsEnergieSysteme

Initial Position

Together with partners IZES is testing a new concept for power and heat supply for a greenhouse. For this purpose actually a solar hybrid system developed by the company Sunvention is tested. At the final stage it should be able to cover a big part of the power and heat demand of the newly constructed greenhouse.

Targets:

- Further modifications of the concept to series maturity
- Integration in an overall concept with seasonal heat storage
- Investigation of possibilities to use the system also in existing greenhouses
- Suitability tests for producing plants with good quality standards

The solar greenhouse from the outside

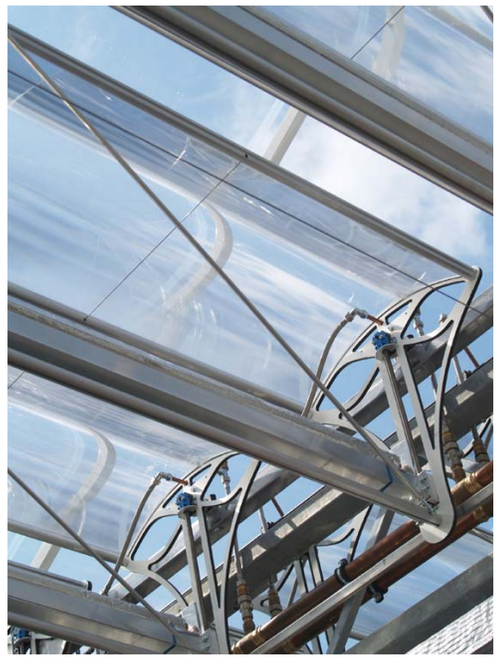
The solar greenhouse

Research

In one part of the greenhouse the solar hybrid system will be installed, in the other part plants are grown with „normal“ technical equipment and under „normal“ conditions.

The newly developed system is tracked to the sun. It consists in Fresnel lenses which are integrated in the roof of the greenhouse. The lenses focus the sunrays on a receiver equiped with PV cells. While the PV cells transform the sunlight into electrical power, they are cooled with a liquid conducting the heat in a 100 m^3 hot water storage.

The measuring program:
- Metrological capture of the most important climatic growth conditions
- Measuring of the energy balance
- Monitoring of the operational behaviour of the PV plant
- Investigations on physiological and cultivation conditions of the plants
- Permanent mobile differential spectrometric capture

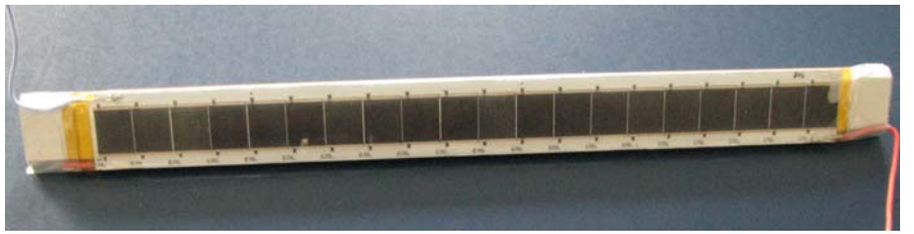


The Fresnel lense system integrated in the roof of the greenhouse

The solar greenhouse

Results

As neither the combined PV-lense-system nor its use under real operation conditions had been tested before, the project course, the system itself and the test design had been modified and adapted several times. So the receiver for the PV plant was improved to better fit to the lense system and the installation in the roof of the greenhouse. Actually a part of the new receivers are already installed. The rest will be mounted by the end of the year.



receiver with PV cells

First test results are exspected by the beginning of next year.

Contact person: Ulrich Bruch, bruch@izes.de

Das Projekt wird durch das Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz gefördert.

Qualification of Technical Components for Different Climates – Challenge for PV-Module Design and Testing

Initial Position

PV-module manufacturers usually give a warranty for at least 20 years although there is still only little knowledge about the lifetime of newly developed modules. How do they cope with snow, salty ambience, desert-climate or tropical humidity?

Modules degraded by delamination and browning

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Qualification of technical components for different climates – challenge for PV-module design and testing

Fraunhofer ISE

Research

The Fraunhofer-Institute for Solar Energy Systems and TÜV Rheinland have installed different outdoor exposure sites where modules have to stand extreme climates: high temperatures with high differences between day and night in the Negev desert in Israel, snow, wind and extreme UV-irradiation and frost in the German Alps, high humidity at warm temperatures in Indonesia.
UV-irradiation, solar-irradiation, ambient- and module-temperature, ambient humidity and wind speed is measured and collected at a central server in Germany.

Especially directed towards long term stability aspects of the emerging thin film technologies, ZSW is developing methods to identify degradation indicators which are correlated with exposure to various operation conditions (outdoor operation in different climates, artificially accelerated outdoor ageing, combination of different laboratory stress tests, e.g. damp heat corrosion under high voltage). The intention is to give an early feedback to manufacturers for optimisation of production processes.

Extreme outdoor exposure sites:
Zugspitze, Sede Boqer (Israel), Serpong (Indonesien), Pozo Izquierdo (Gran Canaria)

Qualification of technical components for different climates – challenge for PV-module design and testing

Fraunhofer ISE

Results

The different test sites with a comprehensive climate and load monitoring provide a good basis for the evaluation of the stress levels for accelerated service life tests of PV-modules. First results show that the UV-load is much higher than anticipated by the type approval testing according to IEC 61215 ed.2 and IEC 61646 ed.2 and the damp-heat testing might underestimate the real loads even at moderate climates and under tropical conditions, especially. The effect of the temperature load is most probably tested simultaneously in the standard damp-heat test (85%RH @ 85°C for 1000h), since temperature induced degradation processes usually have a higher activation energy than diffusion processes.

Better UV-sources are needed for accelerated testing, providing a higher intensity and being operated at higher temperature levels and in combination with other important stress factors: the humidity and the DC-system voltage.

Solar tracker for accelerated outdoor tests under concentrated sunlight at ZSW test site Widderstall