Institut für Physikalische Elektronik

Institute of Physical Electronics

Universität Stuttgart

Jahresbericht

Annual Report 2007

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Annual Report 2007

Redaktion • edited by:

Christine v. Rekowski
Jürgen H. Werner

Vorwort

Liebe Freunde des *ipe*,

das Jahr 2007 war wieder gekennzeichnet durch den enormen Aufschwung, welchen die Photovoltaik-Industrie in Deutschland in den letzten Jahren durchlaufen hat: Jedes Jahr ein Umsatzwachstum von über 30 %. Die Universitäten können gar nicht mithalten, um genügend Personal auszubilden. Positiv an diesem Personalmangel ist nur, dass die Doktoranden und Diplomanden, welche das *ipe* verlassen, keinerlei Probleme haben, einen attraktiven Arbeitsplatz zu finden. Vorteilhaft ist auch zu vermerken, dass der Anteil der Industriemittel an den Drittmitteln des *ipe* gewachsen ist; dagegen gehen die öffentlichen Mittel zurück. Um uns den geänderten inneren und äußeren Rahmenbedingungen anzupassen, haben wir dieses Jahr drei neue Forschungsgruppen gebildet: Die Technologiegruppe, geleitet von Christiane Köhler, bildet das Rückgrat für unsere Laborarbeit. Michael Reuter hat die Leitung der Photovoltaikgruppe übernommen; Renate Zapf-Gottwick leitet die neu eingerichtete Siebdruckgruppe.

Jürgen H. Werner

Nicht nur positive Ereignisse und Sonnenschein zeichnen das Jahr 2007 aus; bei einigen unserer Mitarbeiter gab es persönliche Rückschläge, auch hat die eine oder andere Promotion länger gedauert als die vorgesehenen drei Jahre. Dennoch schauen wir mit Optimismus in die Zukunft. Ich danke allen, die uns ihr Vertrauen geschenkt haben, und setze weiterhin auf Ihre Unterstützung und die Kreativität und Leistungsbereitschaft der Mitarbeiterinnen und Mitarbeitern des *ipe*.

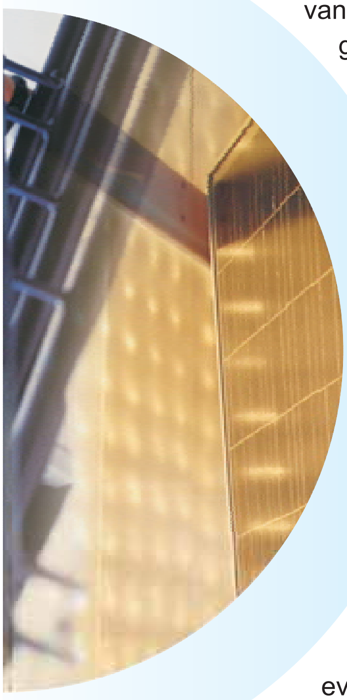
Stuttgart, Dezember 2007

J. Werner

Jürgen H. Werner

Preface

Dear friends of *ipe*,



The year 2007 was again characterized by the enormous upswing the German photovoltaics industry has taken during the last few years: every year an increase in turnover of more than 30 %. Universities cannot keep pace with educating enough people for the jobs. The advantage of this shortage of personnel is certainly that our graduate and PhD students have absolutely no problem in getting an attractive job after leaving *ipe*. Advantageous is also that the share of industry sources in the third-party funds of *ipe* continues to raise, whereas the public funds decrease. In order to adjust to the new internal and external boundary conditions, we established three new research groups. The Technology group led by Christiane Köhler, constitutes the backbone for our laboratory work; Michael Reuter assumed the leadership of the Photovoltaics group; Renate Zapf-Gottwick is heading the newly created Screen Printing group.

Not only positive events and pure sunshine characterized the year 2007. Some of our colleagues had to sustain personal set backs, and one or the other PhD thesis took longer than the scheduled three years. Nevertheless, we look into the future with optimism. I thank everybody for the trust put on us and I will continue to bet on the support of these people as well as on the creativity and commitment of our *ipe* staff.

Stuttgart, December 2007

J. Werner

Jürgen H. Werner


Institut für Physikalische Elektronik

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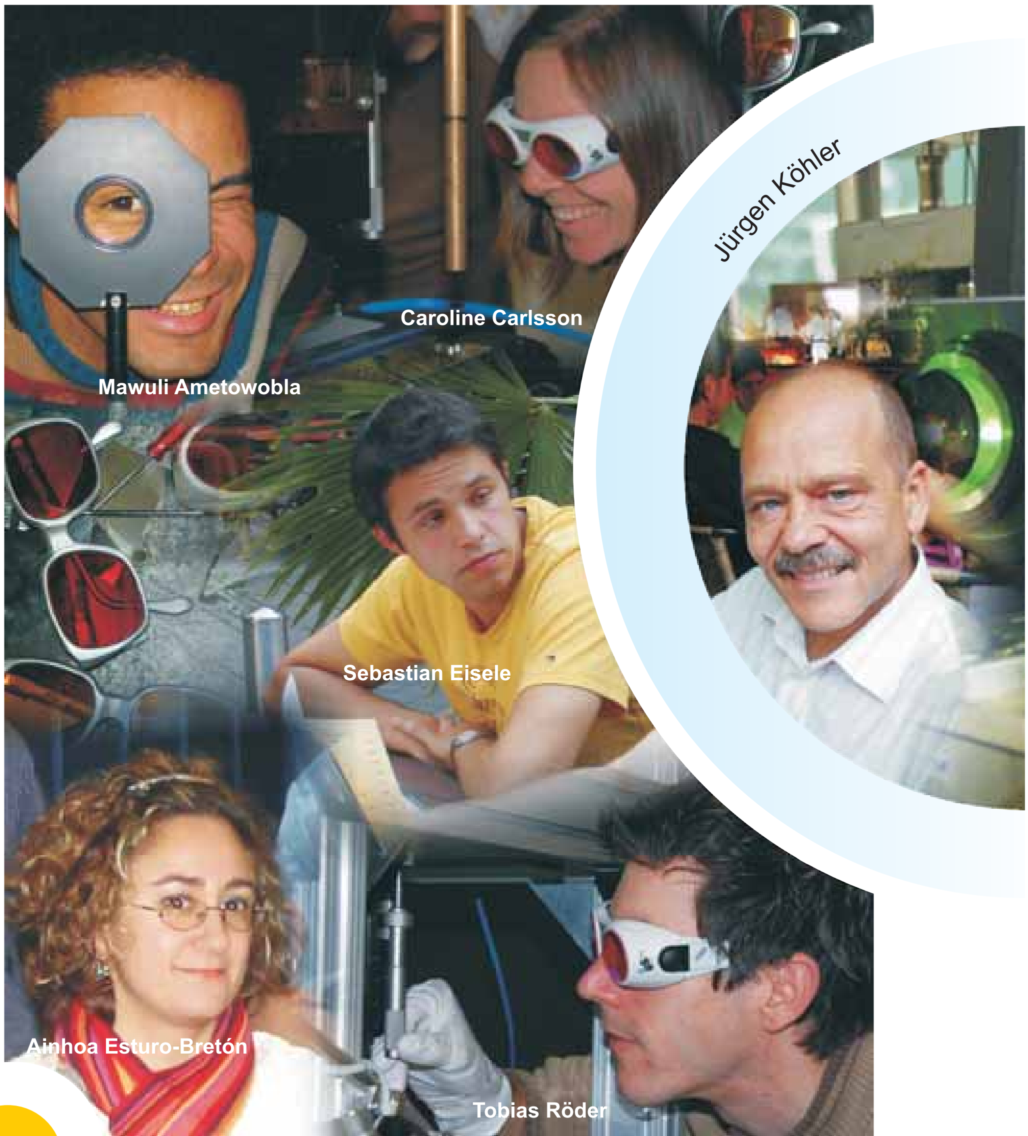
Gruppe Laserprozesse
Group Laser Processing

(Gruppenleiter / Group Leader: Jürgen Köhler)



Die Gruppe Laserprozesse entwickelt neue Technologien zur Laserprozessierung einkristalliner und multikristalliner Silizium-Scheiben. Hierzu zählen die Oberflächenstrukturierung, die Ablation dielektrischer Schichten, das Abscheiden von Kontakten sowie die Laser-Dotierung zur Herstellung von Emittern und die Passivierung von Rückseitenkontakten für Silizium-Solarzellen. Im Vordergrund unserer Arbeiten stehen Grundlagenuntersuchungen zur Laserdotierung kristallinem Siliziums. Entwicklungsziele sind die Erhöhung des Durchsatzes bei der laserunterstützten Emitterdotierung unter Verwendung neuartiger Festkörper-Laser mit über 1 kW Strahlleistung sowie die Steigerung der Wirkungsgrade von 125 mm x 125 mm großen Solarzellen auf über 17 %.

The laser processing group explores new technologies for laser processing of monocrystalline and multi-crystalline silicon wafers. Examples are laser structuring, laser ablation of dielectric coatings, laser assisted metallization and, large area as well as selective laser doping for solar cell emitters and the passivation of the back contact area of silicon solar cells. The main topic of our research work is the investigation of the fundamental processes involved in pulsed laser doping processes of crystalline silicon wafers. Development goals are the increase of the throughput rate of the laser doping process by using a new generation of high power solid state lasers with more than 1 kW output power, as well as the increase of the efficiency of 125 mm x 125 mm sized silicon solar cells to more than 17 %.

Gruppe Neue Materialien
Group New Materials

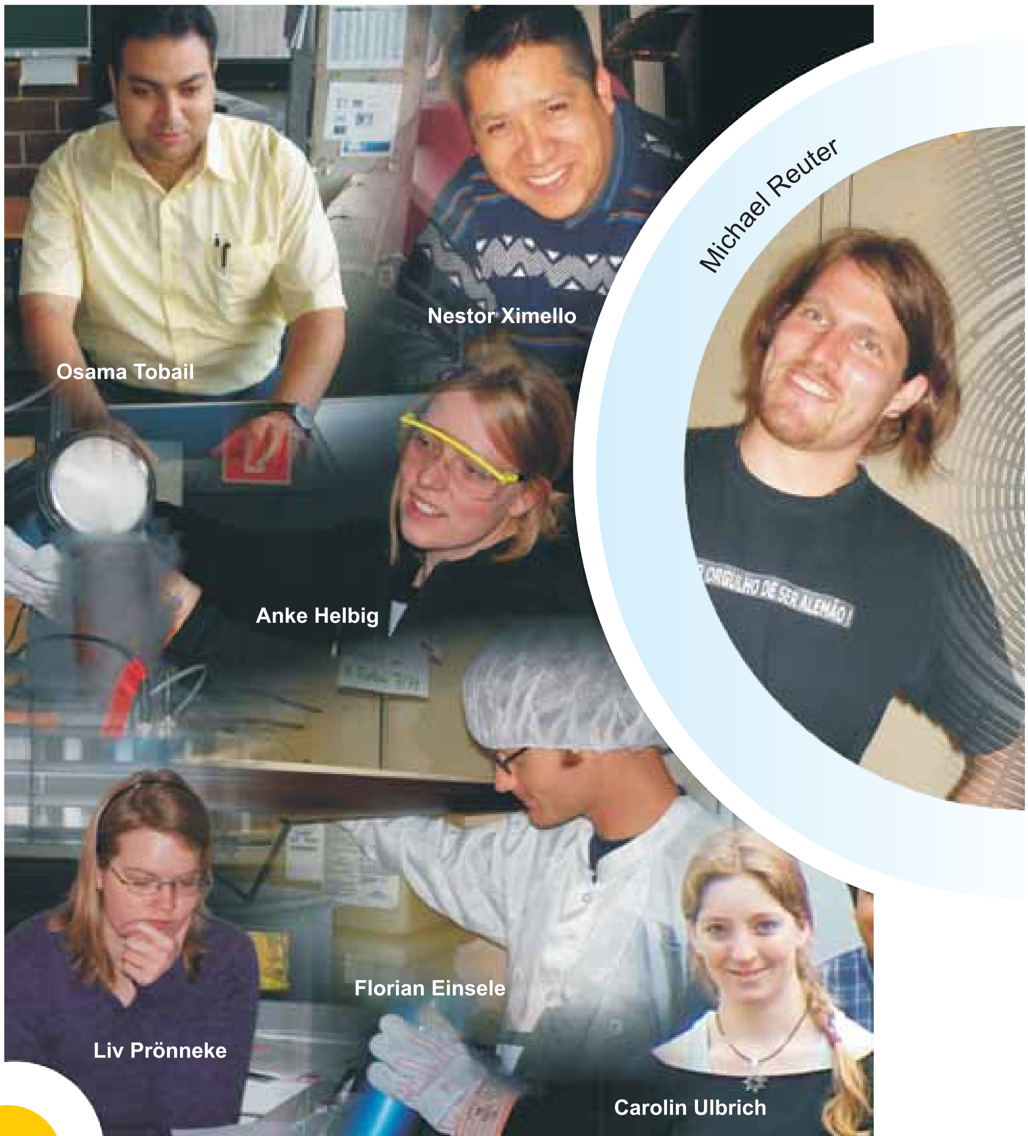
(Gruppenleiter / Group Leader: Gerhard Bilger)

Für die Entwicklung der Solarzellen der dritten Generation leisten neuartige Materialien als passive Beschichtung einen wichtigen Beitrag zur Erzielung gesteigerter Quantenausbeuten mit höchsten Wirkungsgraden. Zudem stellen sie bei der Optimierung von Dotierverfahren für Si-Solarzellen durch Niedertemperatur-Laserprozesse speziell angepasste Prekursoren zur Verfügung. Bei dem hier angewandten Verfahren der Hochfrequenz-Zerstäubung (HF-Sputtern) lassen sich praktisch alle Zusammensetzungen als dünne Schichten herstellen, wobei auch reaktive Gase in weiten Bereichen zugemischt werden können. Für die Charakterisierung dieser Schichten kommen Oberflächen- und Dünnschichtanalysemethoden wie die Sekundärionen-Massenspektrometrie (SIMS) sowie die Röntgen- und Ultraviolett-Photoelektronen-Spektrometrie (XPS, UPS) als unabdingbarer Bestandteil zum Einsatz. Die Oberflächenanalytik unterstützt auch wesentlich alle Forschungs- und Entwicklungsgruppen am *ipe* und wird als Dienstleistungen für andere Institute und die Industrie angeboten.

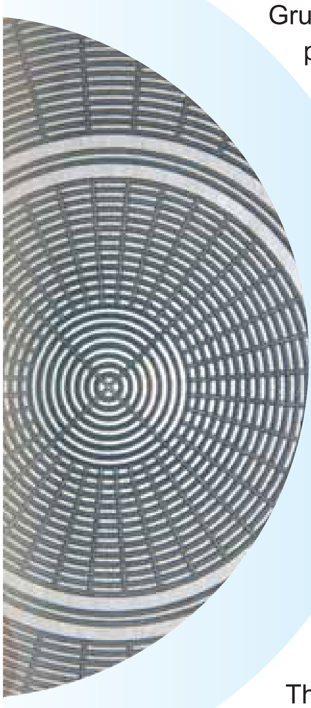
For the development of third generation solar cells novel materials used as passive coating will contribute significantly to an increased quantum efficiency. Furthermore, the optimization of doping procedures for Si solar cells with low-temperature laser processes requires specifically developed precursors. These materials are processed as thin films by means of high frequency sputtering techniques which admit the preparation of nearly all elemental compositions including reactive gases within wide ranges. For the characterization of these thin films, secondary ion mass spectrometry (SIMS) as well as X-ray and ultraviolet photoelectron spectrometry (XPS, UPS) are used as indispensable analysis methods. The analysis also substantially supports all research and development groups at the *ipe* and is offered to foreign institutes and the industry.

Gruppe Photovoltaik
Group Photovoltaiks

(Gruppenleiter / Group Leader: Michael Reuter)



Der Schwerpunkt der Arbeitsgruppe „Photovoltaik“ ist die Erforschung und Entwicklung neuer Konzepte und neuer, industrietauglicher Prozesse für kristalline Silizium-Solarzellen. Wir entwickeln flexible Solarzellen und –module auf der Basis von nur 20 bis 50 µm dicken einkristallinen Siliziumschichten. Diese Solarzellen erfordern qualitativ hochwertige Front- und Rückseitenkontakte, die unter anderem bei Temperaturen von weniger als 250 °C hergestellt werden können, wie z.B. Heterostrukturen aus amorphem und kristallinem Silizium. Darüber hinaus erforscht die Gruppe innovative Konzepte zur Wirkungsgradsteigerung von photovoltaischer Energiewandlung wie verbesserte Fluoreszenzkonverter oder optische Nanostrukturen für die Verbesserung der Lichtausbeute.

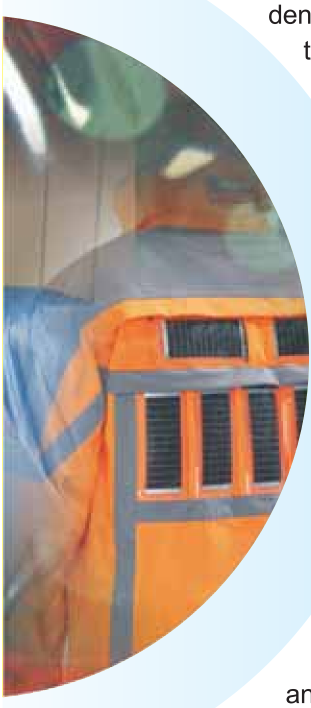


The focus of the "Photovoltaics" group is research and development of new concepts and industrial processes for monocrystalline silicon solar cells. We develop flexible solar cells based on only 20 to 50 µm thick monocrystalline Silicon layers. These solar cells require high-performance back and front contacts like our amorphous / crystalline hetero-contacts processed at temperatures below 250 °C. Further research is directed towards innovative concepts for the enhancement of photovoltaic power conversion efficiencies via the usage of fluorescent light conversion or optical nanostructures.

Gruppe Sensorik
Group Sensors

(Gruppenleiter / Group Leader: Markus Schubert)

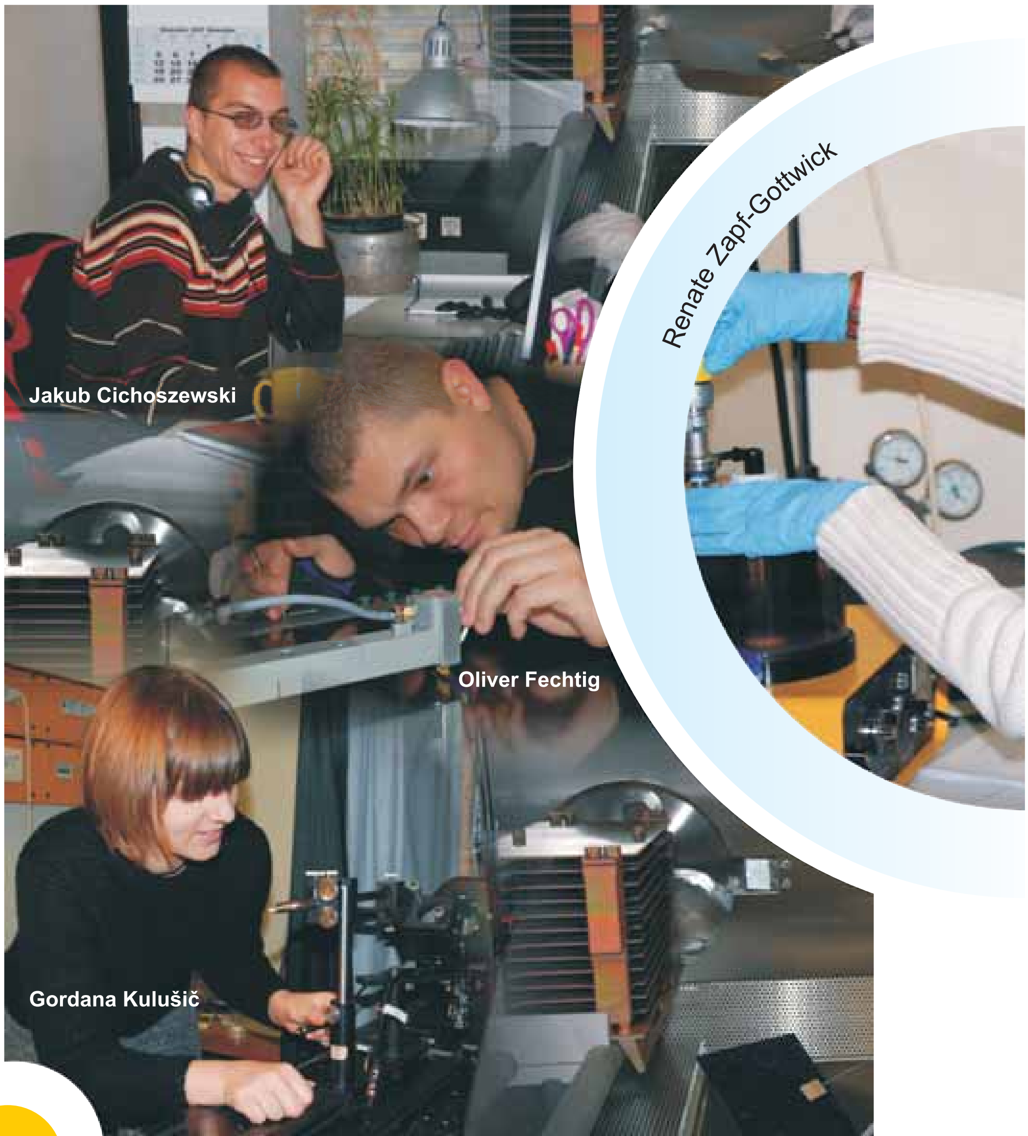
Die Arbeitsgruppe "Sensorik" des *ipe* entwickelt optische Detektoren und Solarzellen auf der Basis amorphen und nanokristallinen Siliziums. Ein weiterer Schwerpunkt ist die photovoltaische Systemtechnik. Neuartige Verfahren für die Herstellung von Solarzellen verwenden amorphes Silizium zur Niedertemperaturpassivierung kristalliner Siliziumsolarzellen und stellen Solarzellen und -module auf Plastikfolie her. In-situ Serienverschaltung, Erhöhung der Abscheiderate, Kleidungsintegration und neue Konzepte für Laderegelung und Energiemanagement sind die Themen der laufenden Forschungsarbeiten. Der Vergleich verschiedener Photovoltaiktechnologien an den Standorten Stuttgart, Nikosia und Kairo untersucht den Einfluss von Materialeigenschaften, Solarzellenstruktur und Klima auf den Jahresenergieertrag der netzgekoppelten Anlagen. In Zusammenarbeit mit der Universität Tübingen und mehreren Stuttgarter Instituten untersuchen wir die Integration neuartiger Dünnschicht-Photodetektoren in ein elektro-optisches Mikrosystem zur schnellen patientennahen Quantifizierung von Herzinfarkt-, Tumor- und Entzündungsmarkern.



The "Sensors" work group at *ipe* is developing photodetectors and solar cells based on amorphous and nanocrystalline silicon thin films. Another area of research addresses the optimization of photovoltaic systems. Novel technologies for manufacturing solar cells rely on amorphous silicon as a low-temperature passivation for crystalline silicon solar cells, and deposit flexible solar cells and modules on plastic foils. In-situ series connection, raising deposition rates, clothing integration and novel concepts for charge control as well as power management are the current research topics. The comparison of different photovoltaic technologies at the locations Stuttgart, Nicosia and Cairo evaluates the effect of materials properties, cell structure, and climate on the annual energy yield. In cooperation with the University of Tübingen and other Stuttgart based institutes, we investigate the integration of novel thin film photodetectors into a microsystem for so-called point-of-care diagnostics addressing heart attack, cancer, and inflammation markers.

Gruppe Siebdruck
Group Screen Printing

(Gruppenleiter / Group Leader: Renate Zapf-Gottwick)



In der industriellen Fertigung von kristallinen Silizium-Solarzellen ist der Siebdruck eine gebräuchliche Methode, um elektrische Kontakte aufzubringen. Im Rahmen einer Industriekooperation baut das *ipe* eine neue Siebdrucklinie auf. Neue Konzepte beim Siebdrucken, Trocknen und Einbrennen zielen auf eine Durchsatzverdopplung bei gleicher Anlagenlänge. Neben klassischen Untersuchungsmethoden wie der Rasterelektronenmikroskopie und der Messung der Strom/Spannungskennlinie entwickelt die Siebdruck-Gruppe neue Untersuchungsmethoden des *ipe*, um die entscheidenden Parameter der Solarzellen systematisch zu optimieren.

In the industrial production of crystalline silicon solar cells, screen printing is a common method to plate up the electrical contacts. The *ipe* builds up a new screen printing line in cooperation with an industrial company. New concepts in screen printing, drying and firing double the throughput while keeping the same length of equipment. Apart from classical examination methods such as scanning electron microscopy and current/voltage characteristics, our screen printing team also uses new methods developed by the *ipe* to systematically optimize the critical parameters of the solar cells.

Gruppe Technologie
Group Technology

(Gruppenleiter / Group Leader: Christiane Köhler)

Die Anfang 2007 neu gegründete Technologiegruppe setzt sich aus den technischen Mitarbeitern des gesamten Instituts zusammen. Damit sind verschiedene Aufgabenstellungen zur Absicherung der Institutsinfrastruktur, zu Prozessen und Prozessschritten sowie zu Routinemesstechniken zusammengefasst. Diese Vernetzung im technischen Bereich ermöglicht eine gute Koordinierung aller anfallenden Arbeiten, sei es bei Routineanalysen, Messplatzerweiterungen, Laborumbaumaßnahmen oder auch bei der Weiterentwicklung wichtiger Technologien, wie Nasschemie, Lithographie, Metallisierung, Diffusion, Oxidation sowie diversen Plasmadepositionsverfahren und vieles andere mehr. Die Techniken sind immer wieder weiterzuentwickeln, verursacht durch neue Anforderungen, die aus den laufenden Projekten erwachsen. Dabei ist die enge Zusammenarbeit bei Planung und Ergebnisdiskussion eine gute Grundlage mit dem Ziel, die Reproduzierbarkeit der Prozesse und Abläufe durch die Entwicklung von Qualitätskontrollstandards und standardisierten Prozessabläufen zu gewährleisten.

The group started its work at the beginning of 2007. This structure is teamwork-oriented to pool all technical assistants and engineers. We support the laboratory infrastructure, perform the different standard processes and do the routine measurements. The cross linking of technical experience allows an effective coordination of the requested demands. We make standard analyses, upgrade measurement setups, coordinate the reconstruction of the laboratory and enhance technological processes. We especially work on wet chemistry, metallization, lithography, diffusion and oxidation as well as on different plasma deposition methods etc. All techniques have to be adapted and developed in direction of the requirements of the current scientific projects at *ipe*. Our goal is a high reproducibility of all process steps as described above by developing quality control requirement and standard procedures. A close teamwork on planning and discussion of the results is seen as a proper base.

einkristallines

mikrokristallines

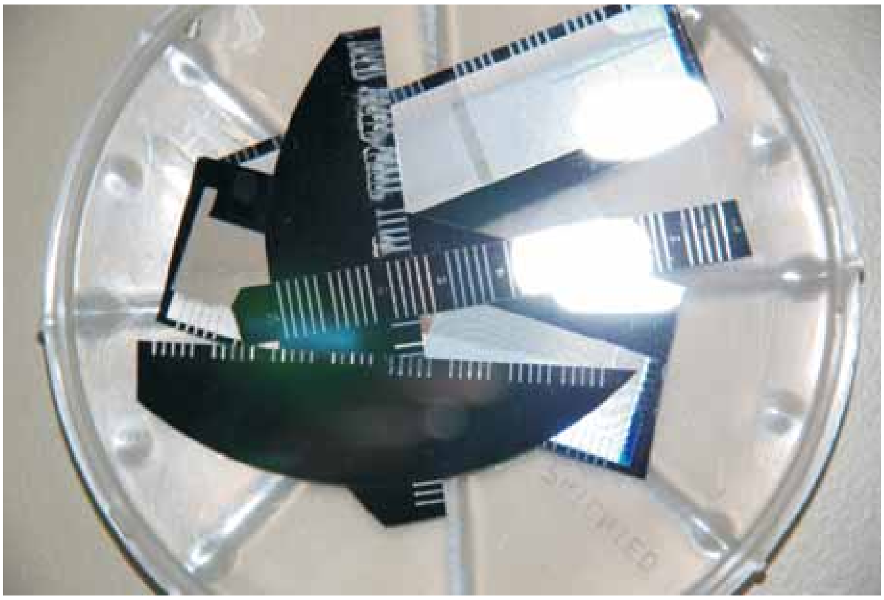
Silizium

nanokristallines

amorphes

Wissenschaftliche Beiträge
Scientific Contributions

Publikationen
Publications



Ultra Thin High Quality Amorphous Silicon

Author: C. Ehling
In collaboration with: M. B. Schubert, R. Merz

Rostan et al. [1] showed, that a thin passivation layer of amorphous Si (a-Si) on the back side of a crystalline Si solar cell leads to a high efficiency. On the one hand, high efficiencies require high quality surface passivation with effective minority carrier lifetimes τ_{eff} > 400 µs. On the other hand, current transport across the a-Si requires thicknesses d < 6 nm. A conventional PECVD system deposits such a layer within one min. Unfortunately, during this time the plasma is not stable and laterally homogeneous yet, therefore reproducible thickness control is difficult. Thus alternative deposition techniques are urgently required.

Here, we introduce triode deposition as a novel technique to meet all demands for the deposition of such thin, high quality a-Si layers for back side passivation. The method relies on slowing down the deposition process by introducing a mesh between the electrode and the substrate.

Figure 1 shows the principle triode deposition, which enables reproducible control of deposition rates as low as 0.5 nm/min. Therefore an (i) a-Si:H layer thickness of a few nm is accurately adjustable. The mesh is located at a well-defined distance between the substrate and the electrode. Consequently, the mesh separates the glow discharged from the substrate, protecting the growing layer from high energetic radicals. The smooth deposition leads to an excellent surface passivation, and thus to a high carrier lifetime τ_{eff}.

Figure 2 presents results from lifetime measurements. For an (i) a-Si:H layer thickness of $d \geq 6$ nm, an excellent effective carrier lifetime τ_{eff} = 800 µs is reached. Thus triode deposition opens a new avenue to the reproducible deposition of high quality ultra thin a-Si back side passivation layers for crystalline Si solar cells.

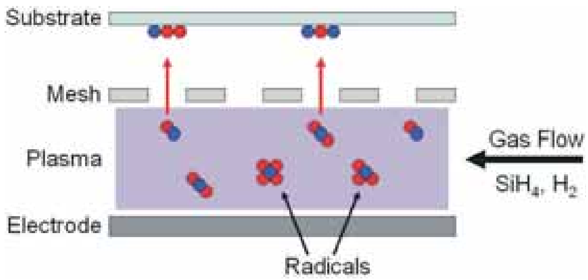


Figure 1:
Triode deposition. The plasma burns between mesh and electrode. Therefore, there is no direct contact between substrate and plasma. Radicals, generated in the plasma, diffuse through the mesh and deposit on the substrate.

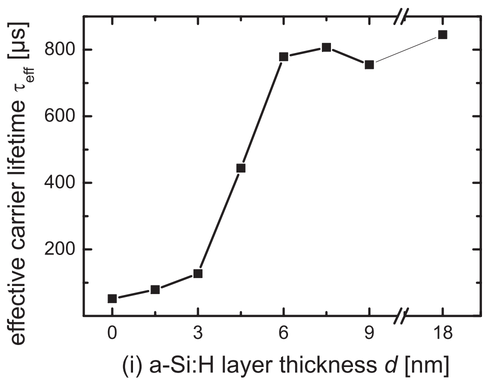


Figure 2:
For an (i) a-Si:H layer thickness $d \geq 6$ nm, an excellent effective carrier lifetime τ_{eff} = 800 µs is reached. Thus triode deposition affords a new possibility for ultra thin, high quality a-Si passivation.

References:

[1] P. J. Rostan, U. Rau, V. X. Nguyen, T. Kirchartz, M. B.Schubert, and J. H. Werner, Sol. Ener. Mat. Sol. Cells **90**, 1345 (2006).

Spatially Resolved Electroluminescence of Solar Cells and Modules

Author: A. Helbig
*In collaboration with: T. Kirchartz**

Recording the electroluminescence (EL) of a forward biased solar cell with a charge coupled device camera [1] is a fast and low-cost method to control cell quality. Recombination of the injected excess carriers results in the emission of infrared radiation close to the band gap energy. Monitoring the incident radiation with a camera generates a spatially resolved image of the solar cell's EL. The EL signal depends on the number of injected charge carriers, the ratio between radiative and non-radiative recombination rates and the optical properties of the device [2].

Figure 1a demonstrates a 125 x 125 mm^2 multicrystalline silicon solar cell featuring dislocations and a crack in the upper right hand side of the cell. Free charge carriers recombine non-radiatively at such defects. Since the gray-level intensity displays the EL intensity, these defects appear darker in the EL image. Detectable with EL are electrically active defects on surfaces and in the bulk as well as handling-induced defects or disconnected fingers. Besides surface and bulk defects, reflection properties of the surfaces define how much radiation is leaving the solar cell.

Setup properties like the number of pixels, the quantum efficiency and the optical system of the camera used determine the resolution of the EL image. A variable focal length of the object lens makes EL usable for focusing on interesting sections of a single solar cell but also for measuring whole modules. Figure 1b is an enlarged view of the middle of the solar cell in Fig. 1a with a more detailed run of the crack.

*Institute of Energy Research – Photovoltaics (IEF-5), Research Centre Jülich

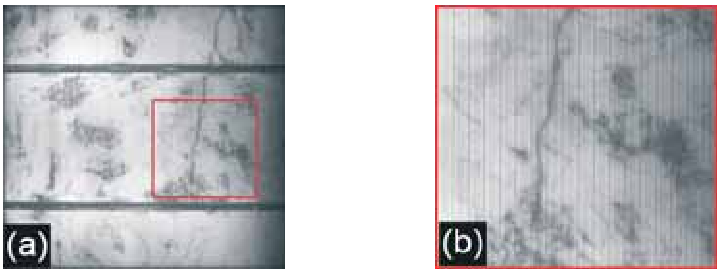


Figure 1:
EL images. a) A 125 x 125 mm^2 multicrystalline silicon solar cell featuring dislocations and a crack in the upper right hand side of the cell. Free charge carriers recombine non-radiatively at such defects and therefore appear darker. b) Enlarged view of the red square from (1a) showing a part of the crack.

Figure 2 shows an EL image of a multicrystalline silicon module. With such an image, efficiency-related properties like recombination and resistive effects of the individual cells are comparable and missing contacts or broken cells are located at a glance. This capability makes the EL a useful tool to check the performance of modules. Already before the assembly of the module, the EL allows to test strings for defects and reasons for a output deficiency.

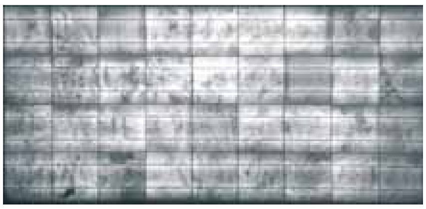


Figure 2:
EL image of a multicrystalline silicon photovoltaic module displaying the performance of every single solar cell, which makes efficiency-related properties comparable, like recombination and resistive effects of individual cells. Possible missing contacts or broken cells are located at a glance.

References:

[1] T. Fuyuki, H. Kondo, T. Yamazaki, Yu Takahashi, and Y. Uraoka, Appl. Phys. Lett. **86**, 262108 (2005).
[2] U. Rau, Phys. Rev. B **76**, 085303 (2007).

Precursor Layer Ablation Strongly Impacts Laser Doping of Silicon

Author: J. Köhler
In collaboration with: A. Esturo-Bretón, C. Carlsson, M. Ametowobla

Laser doping enables fast and cost effective solar cell processing and is therefore a competitive process to conventional furnace diffusion. The *ipe* laser doping process uses spin-on dopand precursors on silicon wafers. Pulsed laser beam scanning melts the silicon surface and enables dopand atom diffusion [1]. Process parameters are pulse energy density E_p and overlap of the laser pulses O_y. Secondary Ion Mass Spectroscopy (SIMS) proves that increasing O_y reduces the dopand atom concentration. A numerical simulation of the laser doping process identifies the ablation of the precursor layer and *not out-diffusion* of dopand atoms to be responsible for this decrease.

The SIMS measurements in Fig. 1 demonstrate that increasing E_p leads to a deeper phosphorus dopand diffusion depth z but not to a change in the dopand concentration on the wafer surface. However, the dopand concentration decreases with increasing O_y, while the diffusion depth virtually stays constant. Figure 2 illustrates the results of a numerical simulation of the laser doping process. In the case of *low* O_y each laser pulse ablates a wide area of the precursor layer. The center of the laser pulse leads to deep melting and, at the same time, phosphorus atoms from the ablated precursor layer are able to diffuse deeply into the molten silicon.

In the case of *high* O_y the low pulse to pulse advance leads to a very tiny area of the ablated precursor layer. Ablation occurs at low pulse energy densities and consequently, the melt depth is lower than in the center of the laser pulse, leading to a high dopand surface concentration but a small melt and diffusion depth. The center of the laser pulse again deeply melts the silicon. In contrast to low O_y, in-diffusion of dopand atoms cannot take place. The precursor layer has already been ablated by the previous laser pulses. Here deeper melting leads to an *increase of diffusion* depth, but not to a further in-diffusion of dopand atoms.

The consequence is a significant decrease of the maximum dopand concentration compared to laser doping with low overlap. The solid lines in Fig. 1b show simulation results using a threshold energy density E_{th} = 1 J/cm^2 for precursor layer ablation. Our simulations also indicate, that the out-diffusion coefficient for phosphorus in liquid silicon is between 0 cm/s and 6 cm/s and has only a minor effect on the doping profile if O_y < 95 %.

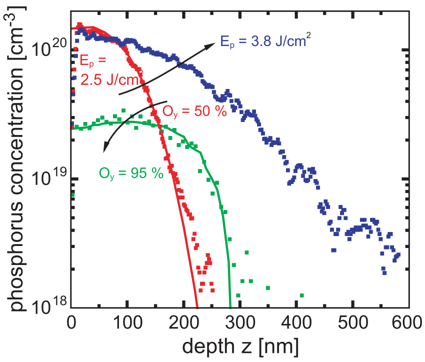


Figure 1:
Surface concentration of phosphorus does not depend on pulse energy density E_p, if the laser pulse overlap O_y is constant. Increasing O_y leads to a decrease of the dopand surface concentration even if E_p is constant.

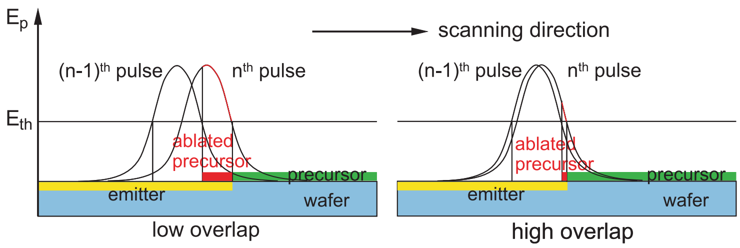


Figure 2:
A high laser pulse overlap leads to a decrease of the effective pulse energy density which is responsible for the reduction of dopand concentration.

References:

[1] A. Esturo-Bretón, M. Ametowobla, G. Bilger, U. Rau, J. R. Köhler, J. H. Werner, in *Proc. 20th Europ. Photovolt. Solar Energy Conf.,* edited by W. Palz, H. A. Ossenbrink, P. Helm (WIP-Renewable Energies, München,Germany, 2005), p. 85

Light Trapping Fluorescent Collectors for Photovoltaics

Author: L. Prönneke
*In collaboration with: U. Rau**

Fluorescent collectors (FCs) are plates of colored acrylic glass. The luminescent dye particles absorb incoming sunlight and emit it down-converted and spatially randomized. Total internal reflection keeps part of the emitted light in the FC. Monte-Carlo simulations investigated such a light trapping system on top of solar cells [1]. Surprisingly, a reduced solar cell area does not lead to a significant decrease in efficiency, if perfect reflectors cover the rest of the FC rear side.

Here, we present a model experiment to verify this interesting simulation result. Figure 1 shows the setup. One sun (100 mWcm^{-2}) impinges on an FC. Under the FC lies a white paperboard printed with black rectangles. The white surface simulates broad band reflector; black areas substitute solar cells. The red rectangle marks a cut-out of the paperboard. At this opening a thermopile measures the intensity of light leaving the FC. Thus, this method yields amount of absorbed light for different arrangements of solar cells and reflectors on the back side of an FC.

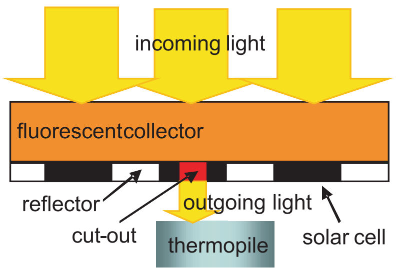


Figure 1:
Experimental setup. Printed paperboard lies under a fluorescent collector with black parts simulating absorption by solar cells, white parts representing back side reflectors. Thermopile detects amount of luminescent radiation, impinging on red marked cut-out.

*Research Centre Jülich, IEF-5, Photovoltaics, 52425 Jülich, Germany

Figure 2 depicts the proof of concept for this model experiment. The red marked openings are surrounded by different amounts of white and black areas. Most light (56 $mWcm^{-2}$) leaves the collector at the opening surrounded by white areas only. This gain is due to the reflecting behavior of the white paperboard: Reflected photons enter the FC again, where dye particles absorb and emit the light, which than is able to reach an opening. By contrast, openings bounded by black areas only collect fewest amount of light (49 $mWcm^{-2}$): Surrounding black areas absorb more of the incoming light, such that less photons reach the cut-out of the paperboard. Consistently, more white areas around a spot increase the amount of collected light (51 $mWcm^{-2} \rightarrow$ 55 $mWcm^{-2}$).

These results prove that this model experiment provides the amount of light a defined pattern of white and black areas absorbs. Further experiments will optimize the configuration in order to collect a maximum amount of sunlight. This takes place with respect to the dimension, distance and number of black areas on a white surface. Based on the best arrangement we will repeat this experiment with real solar cells under an FC.

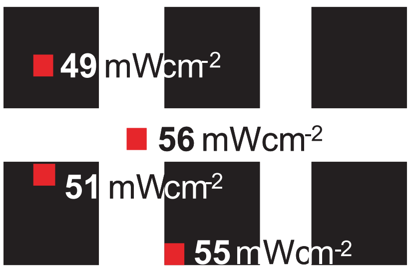


Figure 2:
Model for solar cell pattern, used for optimizing arrangement of solar cells under FC. Numbers give amount of outgoing light at red marked cut-outs. Spots adjacent to white, reflecting areas collect more radiation than spots surrounded by black, absorbing areas. Results show proof of concept for model experiment in Fig. 1.

References:

[1] G. C. Gläser, *Fluoreszenzkollektoren für die Photovoltaik*, (Shaker Verlag, Aachen, Germany, 2007).

50 µm Thin Solar Cells with 17 % Efficiency

Author: M. Reuter
In collaboration with: O. Tobail, R. Grimme, C. Zorn*, C. Wolz*, J. H. Werner*

The transfer layer process [1] produces thin silicon films in three steps. First, HF-acid etches pores into a silicon host wafer. Second, epitaxy deposits 20 to 50 µm thick monocrystalline silicon on the etched and restructured porous silicon. Third, the thin silicon layer is separated from the host wafer and serves as a wafer equivalent for solar cells.

The transfer layer process re-uses the host wafer for further transfer layer production. A high efficiency front side is manufactured while the thin film still is attached to the host wafer. Random pyramids structure the front side; the emitter is diffused in a furnace and has a sheet resistance of 100 Ω/□ . A silicon dioxide antireflection coating covers and passivates the front side. The front grid stems from photolithographic processes.

Figure 1 shows illuminated current/voltage characteristics of two record solar cells. Cell A has a high performance back contact as proposed by Brendle [2] and is produced by the conventional transfer layer process, where the solar cell is attached to a glass superstrate. Cell A has a record conversion efficiency η = 16.9 % (independently confirmed by ISE-CalLab) with an area A = 2 cm^2 and a thickness d = 41.6 µm [2]. Cell B is a free standing monocrystalline silicon solar cell: After front side formation, a pick and place tool designed and developed in cooperation with Fraunhofer IPA (Stuttgart) [3] detaches the thin films from the host wafer. Cell B with a high efficient photolithographic front side and a full side aluminium back contact yields an efficiency η = 17.0 % (in-house measurement) with an area A = 1.1 cm^2 and a thickness d = 47 µm.

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Absorption in the glass superstrate and epoxy resin, which attaches the solar cell to the glass, mainly limits the performance of cell A. The cell B has an increased short circuit current density J_{SC} compared to cell A, as there is no absorption in a glass superstrate. The not well passivated rear side structure of cell B reduces its open circuit voltage V_{OC}.

In conclusion, two different approaches of producing thin monocrystalline solar cells with thicknesses below 50 µm by the transfer layer process each result in 17 % conversion efficiency.

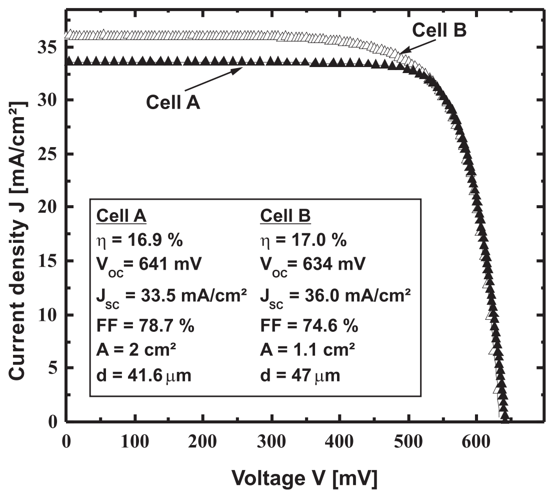

Figure 1: Cell A: High performance back contact 16.9 % efficient 41.6 µm thin crystalline silicon solar cell attached to a glass superstrate (independently confirmed by ISE-CalLab) [2].

Cell B: Free standing 17.0 % efficient 47 µm thin crystalline silicon solar cell (in-house measurement).

References:

[1] R. B. Bergmann, C. Berge, T. J. Rinke, J. Schmidt, and J. H. Werner, Sol. Energy Mater. Sol. Cells **74**, 213 (2002)

[2] W. Brendle, *Niedertemperaturrückseitenprozess für hocheffiziente Siliziumsolarzellen* (Shaker Verlag, Aachen, Germany, 2007)

[3] Final report project “HiFlex” FKZ 032 9818A (Universität Stuttgart, 2006)

Photodiodes as Biomedical Sensors

Author: M. Sämann
In collaboration with: M. B. Schubert, L. Steinle[1], G. Proll[1], F. Pröll[1], O. Zvyagolskaya[2]

Various applications of photodetectors in medicine and pharmaceutical research ask for low-cost, disposable sensor systems. Amorphous silicon (a-Si) based thin film photodetectors are ideal candidates to satisfy this demand, as they allow for a precise application-specific tailoring of the optical properties and their spectral sensitivity. Together with the *ITPC* we are developing a Point-of-Care testing system to examine for cardio-vascular diseases or tumor markers in the blood. The previous diagnosis system required a bulky, expensive spectrometer, which we replace by a small, inexpensive thin film photodetector.

This work presents the novel setup and demonstrates a first measurement. The system makes use of the Reflectometric Interference Spectroscopy (RIfS) [1] to detect antibodies label-free and directly optical. Figure 1a presents the novel setup. During a measurement, blood flows over the antigen containing biolayer surface. Antibodies in the blood that match the antigens bind to the biolayer and increase its thickness. A light source illuminates the biolayer from the back side of the glass. The a-Si based photodetector detects the reflected light. Detection of antibodies is based on the analysis of interference. Antibody induced growth of a biolayer results in a shift of the interference spectrum and directly gives evidence of the specific antibodies in the blood. Detection of the shift requires a spectrally selective photodetector. Photodetectors with a *piin* layer sequence allow for adjusting the spectral selectivity by varying the read-out voltage. Figure 1b demonstrates a simplified RIfS measurement with light emitting diode illumination at a wavelength λ = 660 nm and a constant read-out voltage of V = -5 V. The *piin* photodetector measures the reflected light from the biolayer. Measurements start with a calibration, which records a base current I_1, while a liquid flows over the biolayer.

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[2]Institut für Technische Optik (ITO), Universität Stuttgart

At t = 180 s antibodies are mixed into this liquid. The signal change during the association phase indicates a growing antibody layer on the biolayer surface. At t = 680 s an acid initiates the dissociation phase, where the bindings of the antibodies to the biolayer dissolve. Subsequently, the liquid solution washes the dissociated antibodies away and the biolayer regenerates, identifiable at the signal decrease. The current ratio I_1 / I_2 provides information about the thickness d of the growing biolayer. The *ITO* modeled d-dependence of the reflected light for our measurement setup. This simulation yields the thickness increase Δd = 12 nm, which corresponds to a mono-layer of antibodies.

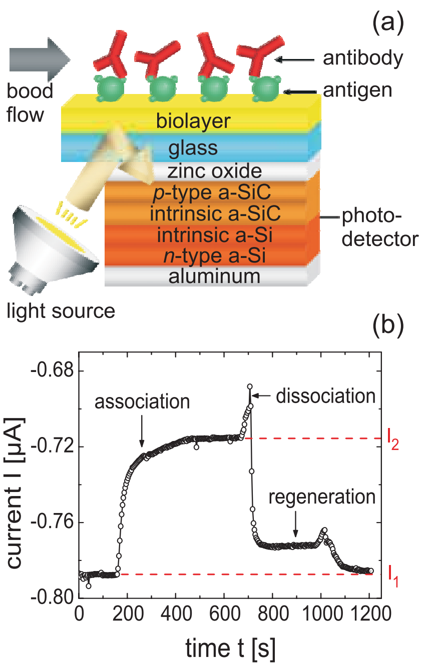

Figure 1:
a) Novel diagnosis setup: Antibodies in the blood flow bind to fixed antigens on the glass. A light source illuminates the biolayer from the back side. Antibody induced growth of this biolayer affects the reflected light into the *piin* photodetector.

b) RIfS measurements start by recording a base current I_1. During the association phase antibodies bind to antigens, the current signal changes to I_2. In the dissociation phase an acid dissolves the bindings. During the regeneration phase a liquid washes the antibodies away, the biolayer regenerates; the photocurrent equals the base current I_1 again. The current ratio I_1 / I_2 reveals a thickness change of Δd = 12 nm.

References:

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Novel Separation Process for Free-Standing Thin-Film Silicon

Author: O. Tobail
In collaboration with: S. Eisele, M. Reuter, and J. H. Werner

The transfer process enables the formation of thin monocrystalline Si films and solar cells on foreign substrates [1]. The transfer process is based on Si epitaxy on a porous Si double layer after a high temperature treatment. Porous Si forms by electrochemically etching a Si wafer in hydrofluoric acid. After the heat treatment, the upper porous Si layer recrystallizes and forms the Quasi-Monocrystalline Si (QMS) layer which is suitable for high quality epitaxial growth [1]. The buried porous layer forms the separation layer, which contains cavities and Si-columns. The structure of the separation layer has to be well adjusted to fulfill two conditions: 1) mechanical stability during the device fabrication which depends on the Si-columns density, and 2) the capability to separate the fabricated device from the wafer which depends on the volume of the cavities. The two conditions are so correlated that a complicated experimental optimization procedure is required. For example, the structure of the separation layer changes during the device fabrication due to the high temperature steps. Therefore, it is difficult to predict the separation capability of the fabricated device, because the process windows are extremely narrow.

The present contribution introduces a novel method to produce stand-alone Si epitaxy layers and solar cells, which separates the upper two conditions of the transfer layer from each other and hence simplifies the transfer process optimization. The method is based on the fact that p-type Si has a higher electrochemical etching selectivity in dark than n-type Si. A laser doped n-type patterned layer masks the wafer partially during porous Si formation.

Figure 1a shows cross-sectional scanning electron micrographs (SEM) of the wafer after the epitaxial growth. The buried continuous cavity, which does not contain Si-columns, simplifies the transfer after the device fabrication.

The Si layer has to be stable during device fabrication steps. Figure 1b shows a SEM photo at the edge of the n-type laser doped region. The n-type laser doped region is the only position which fixes the device layer. The device layer is transferred from the host wafer just be separating the fixed edge by laser ablation and removed by a vacuum die. This method enables the fabrication of free standing thin film solar cells and devices without the need of a foreign substrate.

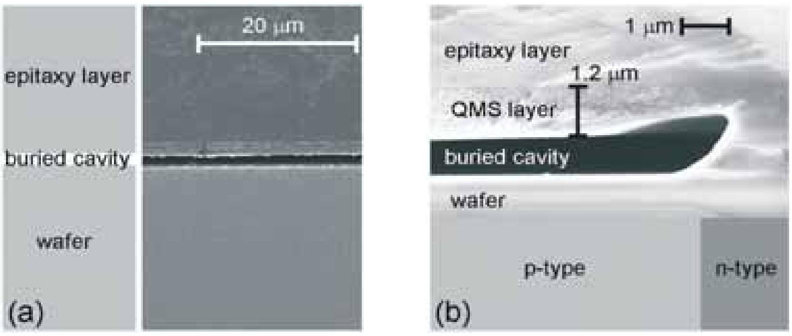

Figure 1:
Cross-sectional SEM photos after the epitaxial growth: a) Epitaxial Si and wafer separated by a 1.6 µm thick buried cavity. No connecting Si colums left due to novel selective etching process of porous Si. Cavity allows separating the epitaxy layer from the wafer. b) Buried cavity stops at the edge of the n-type laser doped region, because the laser doped n-type region acts as a masking layer during electrochemical etching. The 1.2 µm thick QMS-layer (originating from a recrystallization of porous Si) serves as a seed for the epitaxy layer.

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[1] R. B. Bergmann, C. Berge, T. J. Rinke, J. Schmidt, J. H. Werner, "Monocrystalline Si Films from Transfer Processes for Thin Film Devices", Sol. Energy Mater. Sol. Cells **74**, 213 (2002).

Low Temperature Porous Silicon Passivation

Author: J. N. Ximello
In collaboration with: L. Martin, O. Tobail, C. Ehling, J. H. Werner

Since the first Photo-Luminescence (PL) signal of Porous Silicon (PS) at a wavelength of around 800 nm was observed [1], PS has attracted the attention of researchers as a material for light emitting diodes [2] and photodetectors [3]. In order to produce efficient devices, the PL signal of PS has to be high and stable.

To form PS, electrochemical etching is used, which leads to a PS surface with unstable Si-H bonds. When the as-formed PS is exposed to air, hydrogen is desorbed from the PS surface, leaving dangling bonds on the surface. Dangling bonds act as non-radiative recombination centers and inhibit the PL signal considerably. Therefore, finding a way to avoid dangling bonds by passivation is of great interest. For example, the deposition of silicon thin films [4] or hydrogenated amorphous silicon (a-Si:H) [5] increases PL signal up to seven times. Unfortunately, a previous thermal annealing at 800 °C and a post treatment annealing at 900 °C are necessary for these passivation techniques. High temperature processes restructure the PS and hence change ist properties.

The present work introduces a *low* temperature passivation technique, which increases the PL signal up to ten times. Our method passivates PS with a hydrogenated intrinsic amorphous silicon (i-aSi:H) thin film layer deposited at low temperature.

Electrochemical etching forms porous Si on single-crystal Si (100) wafers of p-type with resistivity $\rho = 0.2 - 0.5\ \Omega$cm by using in a 41 % HF solution and a current density $J = 100$ mA/cm^2 for 60 s. Immediately, after PS formation, plasma enhanced chemical vapor deposition applies a 7 nm (i) a-Si:H thin film layer at $T = 210\ ^\circ$C. Afterwards, room temperature PL measurements using an argon laser ($\lambda = 488$ nm) investigate the quality of the passivation.

Figure 1 shows the PL intensity of PS to increase due to the passivation with an intrinsic a-Si:H layer. Compared to the as-formed PS sample, the PL intensity signal increases by a factor of ten. We ascribe the increment of PL to the substitution of unstable Si-H bonds by stable Si-Si bonds during deposition of intrinsic a-Si:H thin film layer on PS surface.

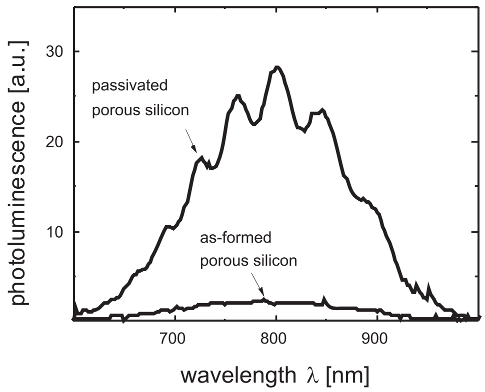

Figure 1:
Compared to an untreated sample, a 7 nm thin intrinsic a-Si:H passivation on porous Si increases photoluminescence by a factor of ten.

References:

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[4] G. G. Siu, X. L. Wu, Y. Gu, and X. M. Bao, J. Appl. Phys. **88**, 3781 (2000).
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Energy Yield of Photovoltaic Systems in Nicosia and Stuttgart

Author: B. Zinßer
In collaboration with: G. Makrides, G. E. Georghiou*. M. B. Schubert, J. H. Werner*

For several reasons, the real energy yield of different photovoltaic (PV) technologies is of great interest: Researchers seek for the difference between different PV technologies, manufacturers need arguments to sell their products, and investors want to predict their profit. Therefore, the *ipe* investigates 14 different PV technologies in Nicosia (Cyprus), and Stuttgart (Germany).

Figures 1a and 1b show the systems, each with a power of 1 kW_p. The equal inverter type ensures that all systems operate at the same conditions. The monitoring system with high time resolution and precision collects AC/DC-power, temperatures, and the solar irradiation.

Figure 1:
a) PV systems in Nicosia (Cyprus), b) PV systems in Stuttgart (Germany)

In addition, a two axis tracked system is installed to investigate the energy gain by following the sun. In Nicosia a concentrating PV system is installed, too. Figure 2 shows the energy yield of the PV systems for the time June 2006 to May 2007. The average of all fix mounted systems in

*University of Cyprus

Nicosia (1580 kWh/kW$_p$) is 32 % higher than in Stuttgart (1194 kWh/kW$_p$). During the observed time period, however, the solar radiation in Cyprus was 4 % lower and in Germany 19 % higher than on the long term average. Considering these deviations, the corrected long term average annual energy yield is 1646 kWh/kW$_p$ in Nicosia and 1003 kWh/kW$_p$ in Stuttgart. The gain of the tracked system in Cyprus is 28 % compared to the fixed system with the same type of solar modules. The difference between the best and the worst PV-system is 15 % at both locations [1]. The web page of the *ipe* [2] shows live data. Therefore, everybody has access to power and energy values of the different PV technologies.

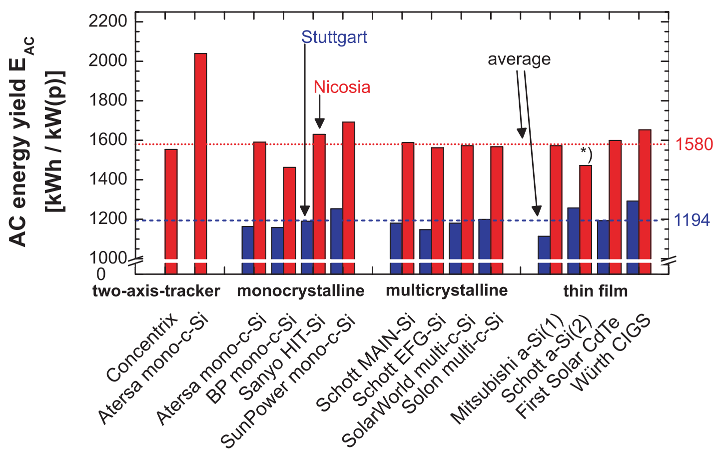

Figure 2:
Energy yield (1.06.2006 to 1.06.2007) of 14 photovoltaic technologies in Nicosia (Cyprus) and Stuttgart (Germany). Solar radiation in the observed time period in Cyprus was 4 % lower and in Germany 19 % higher than the long time average value. At the system marked with *) one module was broken. Lines show the average energy yield of non tracked PV systems: 1194 kWh/kW$_p$ in Stuttgart and 1580 kWh/kW$_p$ in Nicosia.

References:

[1] B. Zinßer, G. Makrides, W. Schmitt, G. E. Georghiou and J. H. Werner, in *Proc. 22nd Europ. Photovolt. Sol. En. Conf.* (WIP-Renewable Energies, München, Germany, 2007) in print

[2] Live data web page → www.ipe.uni-stuttgart.de → Research → PV Systems Test

Publikationen
Publications

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Annual Energy Yield of 13 Photovoltaic Technologies in Germany and in Cyprus
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C. Carlsson, A. Esturo-Bretón, M. Ametowobla, J. R. Köhler, J. H. Werner
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High Quality Baseline for High Efficiency $Cu(In_{1-x},Ga_x)Se_2$ Solar Cells
P. Jackson, R. Würz, U. Rau, J. Mattheis, M. Kurth, T. Schlötzer, G. Bilger, and J. H. Werner
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G. C. Glaeser, and U. Rau
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T. Kirchartz, U. Rau, M. Kurth, J. Mattheis, and J. H. Werner
Thin Solid Films **515**, 6238 (2007)

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B. Zinßer, W. Schmitt, and J. H. Werner
in *Proc. 22. Symp. Photovolt. Solarenergie* (OTTI, Regensburg, 2007) 61/A13

17 % Efficient 50 µm Thick Solar Cells
M. Reuter, W. Brendle, O. Tobail, and J. H. Werner
in *Techn. Digest 17th Photovolt. Sci. Eng. Conf.* (Fukuoka, Japan, 2007), p. xxx

Temperature Behaviour of Different Photovoltaic Systems Installed in Cyprus and Germany
G. Markides, B. Zinßer, G. E. Georghiou, M. Schubert and J. H. Werner
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0.4 % Absolute Efficiency Gain by Novel Back Contact
C. Ehling, M. B. Schubert, R. Merz, J. Müller, M. Hlusiak, P. J. Rostan, and J. H. Werner
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In-Situ Series Connection of Solar Cells
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a-Si:H/c-Si Heterojunction Solar Cells with p-type Base Doping
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in *Techn. Digest 17th Photovolt. Sci. Eng. Conf.* (Fukuoka, Japan, 2007), p. xxx

Pulsed Laser-Doped Selective Emitter for Silicon Solar Cells
C. Carlsson, J. R. Köhler, and J. H. Werner
in *Techn. Digest 17th Photovolt. Sci. Eng. Conf.* (Fukuoka, Japan, 2007), p. xxx

Improved Transfer Process Using Selective Electrochemical Etching
O. Tobail, M. Reuter, S. Eisele, and J. H. Werner
in *Techn. Digest 17th Photovolt. Sci. Eng. Conf.* (Fukuoka, Japan, 2007), p. xxx

Sputtered Phosphorous Precursors for Laser Doping
S. Eisele, G. Bilger, M. Ametowobla, J. R. Köhler, and J. H. Werner
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Performance Assessment of Different Photovoltaic Systems under Indentical Field Conditions of High Irradiation
G. Makrides, B. Zinßer, G. Georghiou, J. H. Werner
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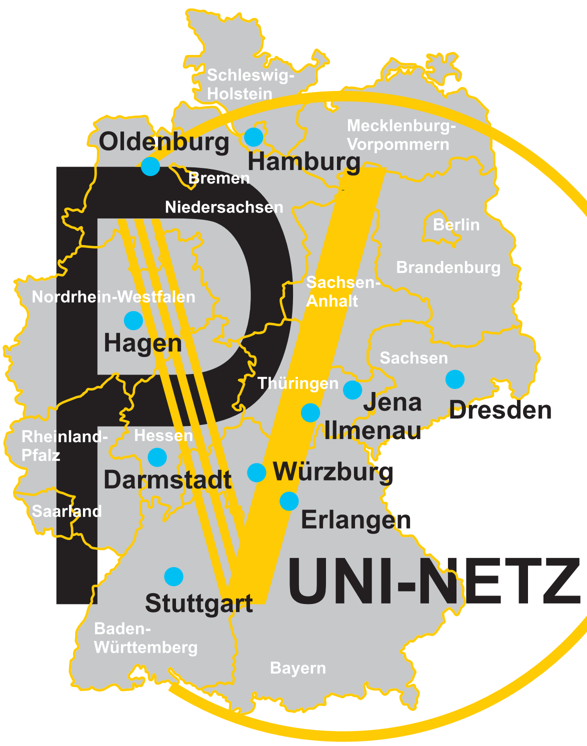

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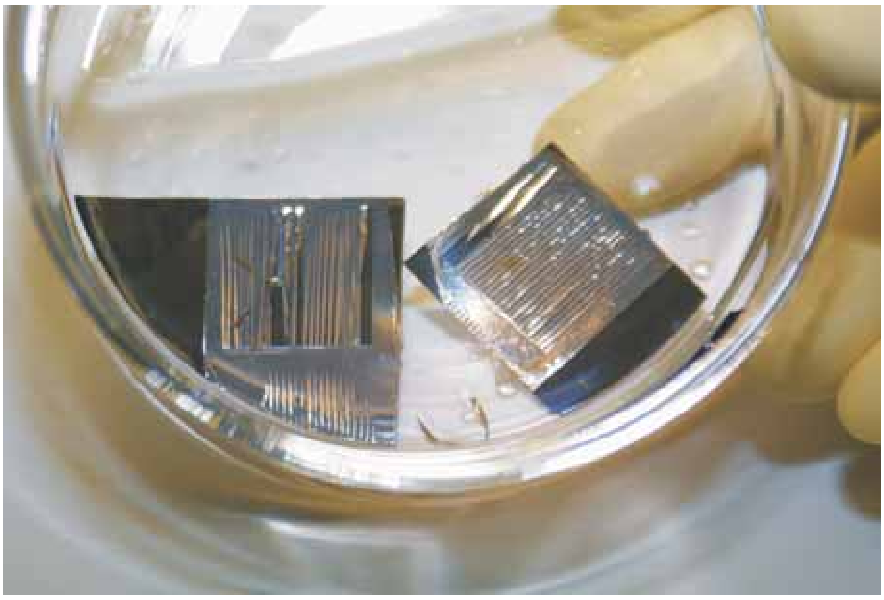
Studienarbeiten
Major Term Projects

Gäste & ausländische Stipendiaten
Guests



Bauelemente der Mikroelektronik (1. Semester)

Energiebänder und Leitfähigkeit

Silicium - der Werkstoff der Mikroelektronik

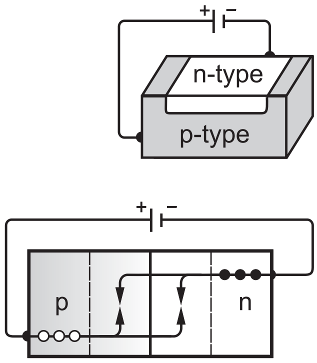
Elektronen und Löcher in Halbleitern

Ströme in Halbleitern

Nichtgleichgewicht und Injektion

Elektrostatik des pn-Übergangs

Ströme im pn-Übergang



Energiewandlung (6. / 8. Semester)

Grundlagen der Kernenergie

Thermodynamik

Direkte Nutzung der Sonnenenergie (Solarthermie, Photovoltaik)

Indirekte Nutzung der Sonnenenergie (Wasserkraft, Windenergie)

Chemische Wandlung und Speicherung elektrischer Energie

Laser and Light Sources (5. / 7. Semester)

The Human Eye

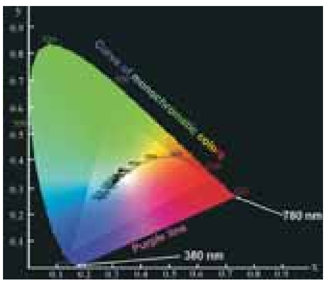
Light and Color

Photometry

Incoherent Light Sources

Light Emitting Diodes

Lasers



Optoelectronic Devices and Circuits I (6. / 8. Semester)

Basic physics

Thermal radiation

Coherence

Semiconductor basics

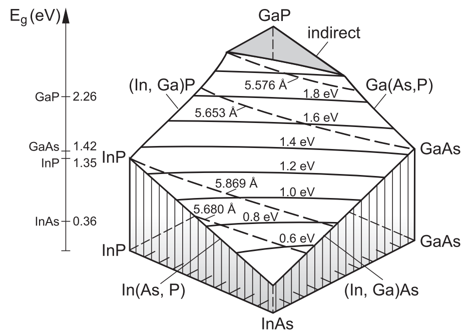
Excitation and recombination processes in semiconductors

Light emitting diodes

Semiconductor lasers

Glass fibers

Photodetectors



Photovoltaics (6. / 8. Semester)

Energy data

The solar spectrum

Potential of solar radiation

The principal function of photovoltaic systems

Generation and recombination in semiconductors

Basic semiconductor equations

pn-Junctions

Current/voltage-curve of solar cells

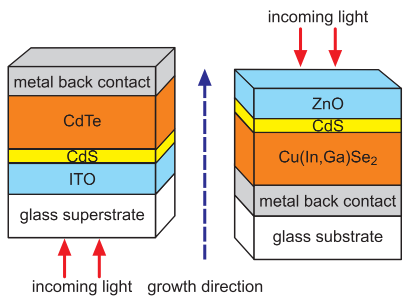
Maximum efficiency of solar cells

Preparation of crystalline silicon

Amorphous silicon solar cells

$Cu(In,Ga)Se_2$ solar cells

Technology of crystalline silicon solar cells

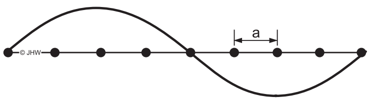


Solid State Electronics (5. / 7. Semester)

Free electrons as particles and waves

Electronic bands in solids

Band diagrams of semiconductors



Currents in semiconductors

Emission of electrons from metals and semiconductors

The Schottky-contact

Photoeffects in semiconductors

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Ph. D. Theses

Anas Al Tarabsheh
Amorphous silicon based solar cells

Willi Brendle
Niedertemperaturrückseitenprozess für hocheffiziente Siliziumsolarzellen

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Jakub Cichoszewski
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Michael Gratzke
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Herstellung und Charakterisierung von einseitig kontaktierten Solarzellen

Diego Plaza González
Mikroprozessorgesteuerter Maximum Power Point Tracker in Form eines Spannungswandlers

Marc Sämann
Dünnschichtphotodioden für reflektometrische Interferenzspektroskopie

Javier Stillig
Leistungsentwicklung von Solarmodulen im ersten Betriebsjahr

Na Wei
High Temperature Stable Silicon Carbide

Studienarbeiten
Major Term Projects

Fabian Fertig

Titanium Dioxide as Anti-reflective Coating for Crystalline Silicon Solar Cells

Max Siegloch

Aufbau und Erweiterung einer Dish-Stirling-Anlage zur solaren Stromerzeugung

Zhao Yan

Charakterisierung von Schichten und Schichtsystemen aus porösem Silizium

Gäste & ausländische Stipendiaten
Guests

Anas Al Tarabsheh
Jordan University of Science and Technology, Jordanien,
01.03.03 - 31.01.2007

Jakub Cichoszewski
Gdansk University of Technology, Polen, seit 01.10.2007

Ainhoa Esturo Bretón
UPV-Universidad del País Vasco, Spanien, 01.12.2001 - 30.09.2007

Yasser Tamer Karawia
Universität Cairo, Ägypten, 01.07.2007 - 30.09.2007

Caroline Karlsson
Göteborgs Universitat, Schweden, seit 01.03.2003

Gordana Kulušič
St. Cyril and Methodius University, Skopje, Mazedonien, seit 01.10.2007

Osama Tobail
Arab Academy for Science and Technology & Maritime Transport,
Alexandria, Ägypten, seit 01.07.2003

José Nestor Quiebras Ximello
Instituto Politécnico Nacional, México D.F., Mexiko, seit 01.04.2006

Was sonst noch war ...
More than Science ...

Mitarbeiterliste
Staff Members

Lageplan
Location Map

Was sonst noch war ...
More than Science ...

(Christine v. Rekowski)

ipe in Stuttgart präsent

Ein bisschen Werbung darf schon sein. Im Oktober nahm das *ipe* am Aktionstag des KUS (Klima- und Umweltbündnis Stuttgart) mit einem eigenen Stand auf dem Stuttgarter Schlossplatz teil, wo *ipe*-Studenten unter der Leitung von Bastian Zinßer fünf Solarmodule aufstellten und demonstrierten. Die Resonanz in der Presse war durchaus beachtlich, das Interesse der Passanten auch. Danke an Bastian und seine Mannschaft!

Improvisierte Energiewandlung

Alle Jahre wieder dürfen auch Studenten ihre Kreativität bei eigenständigen Energiewandlungsprojekten unter Beweis stellen: Werden sie es erneut schaffen, aus Resten, Abfällen und mit Plündern der Institutswerkstatt ein funktionierendes Energiemodell zu bauen? Ja, dies konnten sie wahrhaftig, und zwar mit großem Erfolg. Danke auch an Anton für tatkräftige Unterstützung in der Werkstatt!

ipe's presence in Stuttgart

During an "Action Day" organized by KUS (Climate and Environment Association Stuttgart), downtown in Stuttgart on the Schlossplatz, *ipe* was represented by Bastian Zinßer and some of the *ipe* students, explaining and demonstrating five different solar modules. The press, as well as the pedestrians, showed great interest. Thanks to Bastian's team!

Improvised Energy Conversion

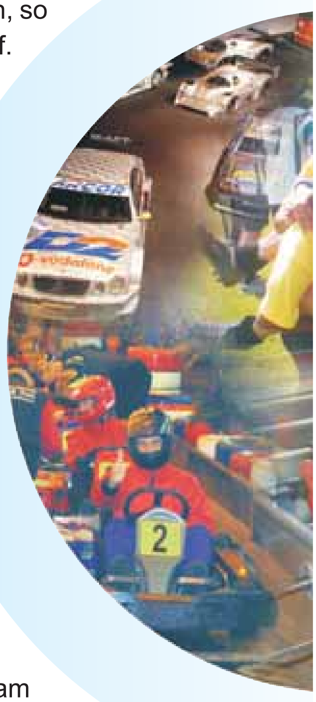
Every year, students may also prove their creativity during the lecture "Energy Conversion": will they be able to make up some functional model out of nothing, meaning out of remains and waste, and plundering the institute's workshop? Yes indeed, they proved they could. Thanks to Anton for his active support in the workshop!

ipe-Ausflug

Eine alte Tradition ist in Eigeninitiative der Doktoranden zum Leben erweckt worden: der Jahresausflug für alle Mitarbeiter, der dieses Jahr zum klassischen Wandertag wurde. Nach der Besichtigung des neuen Daimler-Museums ging's durch Weinberge in Richtung Esslingen. Danke an Christian für die Oberorganisation!

Kartrennen

„No risk no fun" scheint gelegentlich das Motto am *ipe* zu sein, so dass sich eine wagemutige *ipe*-Auswahl zum Kartrennen traf. Auf der Rennbahn und in entsprechendem professionellen Outfit wurden die Rennfahrer-Seiten der Teilnehmer herausgefordert. Neben großem Spaß zählten aber auch ein paar blaue Flecken zu den Errungenschaften.



***ipe* Getaway**

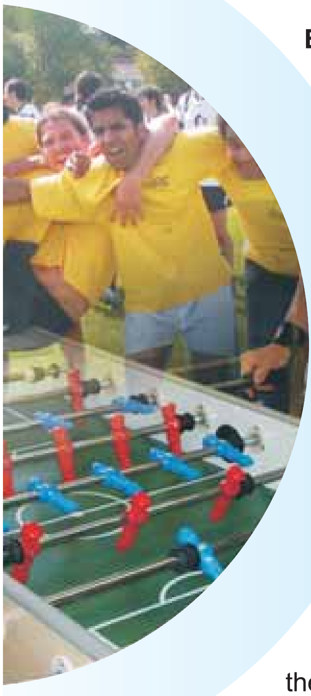
An old tradition has been revived by our scientific staff: the yearly getaway for the institute staff. After visiting the new Daimler Museum in Stuttgart-Bad Cannstatt, everybody went for a long hike along the vineyards and the Neckar until the final destination Esslingen, where the exhausted team was rewarded with an opulent dinner and drinks. Thank you Christian for all the preparation!

Kart Race

Not only does the *ipe* staff get together to discuss *ipe* matters: an institute „selection" met for a kart race, quite a risky undertaking for newcomers. On a special race track and in professional dressings all the participants had a lot of fun finding out who was the fastest, meaning that some of them brought back haematomas. No risk no fun!

Girls' Day

Die Universität bietet inzwischen vermehrt an, dass Schüler und Schülerinnen sich frühzeitig mit dem Hochschulambiente vertraut machen. Insbesondere sollen Mädchen dazu animiert werden, die Scheu vor naturwissenschaftlich-orientierten Studienfächern zu verlieren. So freute sich das *ipe* über regen Besuch einer „Girls' Group“, die unter der fachkundigen Anleitung von Jakub und Anke erste Löterfahrungen machten und Fragen zu allem „Photovoltaischen“ stellen konnten.



ETI-Cup

Wer hätte das geglaubt: Kaum ein Jahr nach der Fußball-Weltmeisterschaft konnte das *ipe* mit seinem eigenen, gut vorbereiteten und internationalen Fußballteam den Pokal der Fakultät „nach Hause“ führen, und das, obwohl manche Mitarbeiter(innen) unter fremder Flagge segelten… Das gesamte Institut hat sich mitgefreut und wird die Trophäe nächstes Jahr mit doppelter Motivation verteidigen.

Girls' Day

The University of Stuttgart offers new possibilities for high school students to discover the university surroundings in order to motivate young people to choose a scientific-technical career. Especially girls are invited to think about options within sciences. *ipe* was happy to welcome a highly motivated group of high school girls during the University's "Girl's Day". The girls were shown facilities of the institute and introduced to everything concerning solar cells. Thank you Jakub and Anke for your commitment!

ETI Cup

Can you believe it? One year after the soccer world championship, the motivated, well trained and international *ipe* soccer team was able to win the faculty soccer cup, even though some staff member had decided to play within another team. The whole institute was very proud! Next year, the trophy will be vindicated with double motivation.

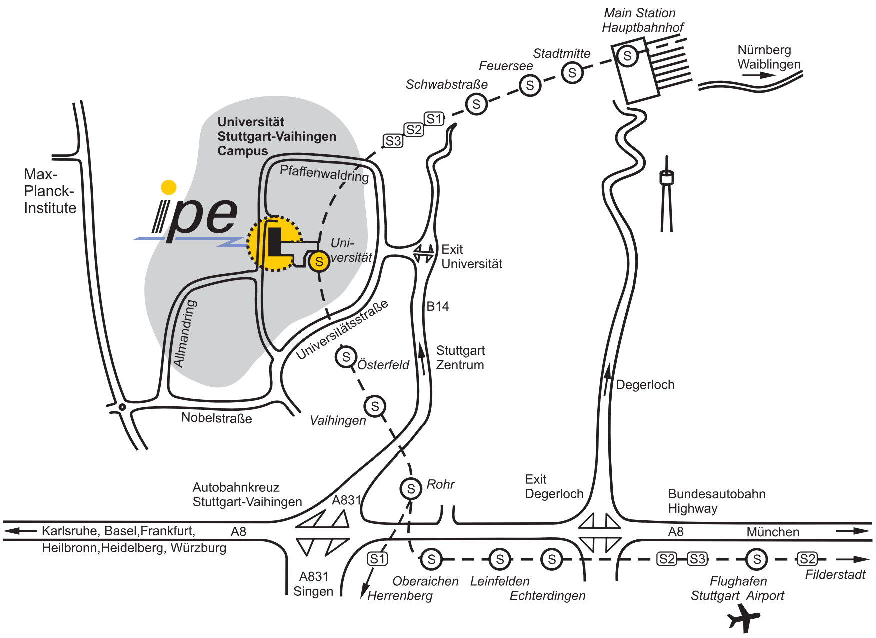
Mitarbeiterliste
Staff Members

Name	Titel	Telefon 0711 - 685 - ...	E-Mail (vorname.name) @ipe.uni-suttgart.de	Arbeitsgebiet
Ametowobla, Mawuli	Dipl.-Ing.	67160	mawuli.ametowobla	Laserprozessierung von Silizium-Solarzellen
Bauer, Leo		60105	leo.bauer	Metallisierung, Photoarbeiten, Maskentechnik
Bilger, Gerhard	Dr.-Ing.	67176	gerhard.bilger	Oberflächenanalytik; Technologie Support
Brenner, Klaus	Dipl.-Ing. (FH)	67201	klaus.brenner	Technologische Infrastruktur
Carlsson, Caroline	M. Sc.	69223	caroline.carlsson	Laserprozessierung von Solarzellen
Cichoszewski, Jakub	Dipl.-Ing.	69219	jakub.cichoszewski	Passivierprozesse für Solarzellen
Ehling, Christian	Dipl.-Ing.	67161	christian.ehling	Passivierprozesse für Solarzellen
Eisele, Sebastian	Dipl.-Ing.	67198	sebastian.eisele	Passivierprozesse für Solarzellen
Fechtig, Oliver	Dipl.-Phys.	69214	oliver.fechtig	Dünnschichttechnik
Helbig, Anke	Dipl.-Nat.	67169	anke.helbig	Lumineszenz
Kessler, Isabel	M. A.	67141	isabel.kessler	Sekretariat, Verwaltung

Köhler, Christiane	Dipl.-Phys.	67182	christiane.koehler	Leitung Technologiesupport, Niedertemperaturtechnologie
Köhler, Jürgen	Dr.-Ing.	67159	juergen.koehler	Laser Annealing, Verwaltung
Kulušič, Gordana	M. Sc.	69218	gordana.kulusic	Siebdruckprozesse
Laptev, Viktor	Dr. rer. nat.	67197	viktor.laptev	Chemische Schichtabscheidung
Lutz, Brigitte		67200	brigitte.lutz	Analytik, Elektrochemie
Merz, Rainer	Dipl.-Ing.	67184	rainer.merz	Integrierte Photovoltaik
Moutchnik, Galina	Dipl.-Ing.	67163	galina.moutchnik	Laserprozesse
Prönneke, Liv	Dipl.-Phys.	67180	liv.proenneke	Optik von Solarzellen
Reim, Annette		67158	annette.reim	Verwaltung
Rekowski, Christine v.	Dr. phil.	67141	christine.rekowski	Sekretariat, Verwaltung
Reuter, Michael	Dipl.-Ing.	67168	michael.reuter	Dünnes Silizium
Riß, Anton		67214	anton.riss	Werkstatt
Röder, Tobias	Dipl.-Phys.	69213	tobias.roeder	Laserprozessierung von Solarzellen

Sämann, Marc	Dipl.-Ing.	67142	marc.saemann	Amorphes Silizium, Biosensoren, Administrator
Schlegel, Peter	Dipl.-Ing. (FH)	60106	peter.schlegel	Laserprozesse
Schubert, Markus	Dr.-Ing.	67145	markus.schubert	Stellvertr. Institutsleiter, amorphes und nanokristallines Si
Tobail, Osama	M. Sc.	69216	osama.tobail	Poröses Silizium
Ulbrich, Carolin	Dipl.-Phys.	69217	carolin.ulbrich	Optik von Solarzellen
Werner, Jürgen	Prof. Dr. rer. nat. habil.	67140	juergen.werner	Institutsleiter, Leiter der Forschung, Lehre, Verwaltung
Wille, Werner		67158	werner.wille	Buchhaltung, Verwaltung, Administrator
Winter, Birgitt	Dipl.-Ing. (FH)	67162	birgitt.winter	Technologie kristalliner Si-Solarzellen
Ximello Quiebras, José Nestor	M. Sc.	69224	nestor.ximello	Amorphes Silizium
Zapf-Gottwick, Renate	Dr. rer. nat.	69225	renate.zapf-gottwick	Siebdruck
Zinßer, Bastian	Dipl.-Ing.	67170	bastian.zinsser	Jahresenergieerträge verschiedener Photovoltaik-Technologien

Lageplan
Location Plan



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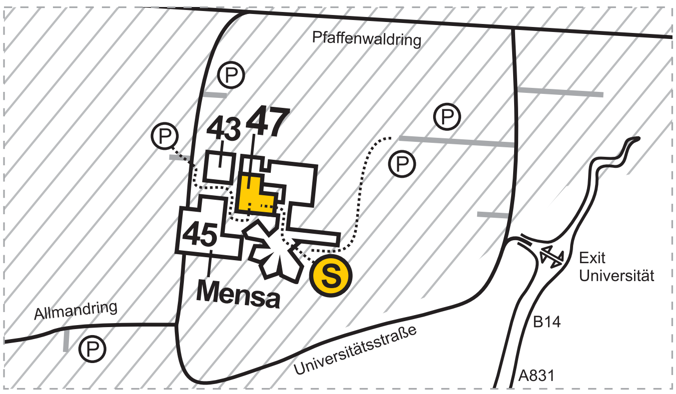

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