Institut für Physikalische Elektronik

Institute of Physical Electronics

Universität Stuttgart

Jahresbericht

Annual Report 2006

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Annual Report

2006

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Uwe Rau
Jürgen H. Werner

Vorwort

Liebe Freunde des *ipe*,

dieses Jahr des *ipe* war stark beeinflusst von verschiedensten Aktivitäten im Rahmen der Exzellenzinitiativen der Universität Stuttgart. Leider hat keine dieser Initiativen durchschlagenden Erfolg gehabt, was mit Sicherheit nicht am hohen Engagement der Mitarbeiter/innen des *ipe* lag. Die Zukunft wird zeigen, ob sich die Universität Stuttgart, die bei allen Beurteilungen des Fachbereichs Elektrotechnik und Informationstechnik regelmäßig sehr gut abschneidet, auch als Ganzes besser positionieren kann; die Chancen dafür sind gut.

Das *ipe* steht nach wie vor gut da. Seit knapp einem Jahr konzentrieren wir uns im Wesentlichen auf den Werkstoff Silizium, arbeiten mit anderen Partnern zusammen als früher. Wir haben vor allem unsere Kooperationen mit Firmen weiter ausgebaut. Auch diese Neuorientierung hat dazu geführt, dass Studenten, Doktoranden und andere Mitarbeiter aus dem *ipe* keinerlei Probleme haben, einen Arbeitsplatz zu finden, egal ob in der Photovoltaik-Industrie oder in Firmen der Mikro- und Optoelektronik. Auch im Jahr 2007 werden wir unseren eingeschlagenen Weg fortsetzen. Wenn nicht an einem Universitätsinstitut, wo eigentlich sonst sollten neue Dinge ausprobiert werden?

Den Mitarbeiterinnen und Mitarbeitern des *ipe*, danke ich für das kreative und von Vertrauen geprägtes Arbeitsklima. Es macht Spaß, an einem solchen Institut zu arbeiten!

Stuttgart, Dezember 2006

J. Werner

Jürgen H. Werner

Preface

Dear friends of *ipe*,

this year at *ipe* has strongly been influenced by various activities within the excellence initiatives of the University of Stuttgart. Unfortunately, none of these initiatives had been successful, a fact that certainly has nothing to do with the high commitment of our people at *ipe*. The future will show whether the University of Stuttgart, which always comes off very well in all the ratings concerning the field of Electrical Engineering and Information Technology, will be able to get a better position in its entirety; the chances are good.

Now as before, *ipe* is developing very well. Since approximately one year, we are essentially concentrating on the material properties of silicon as well as cooperating with different partners than before. Above all, we have extended our cooperations with companies. This reorientation has also led to the fact that alumni of *ipe* have no problems to find a job in the photovoltaics industry or in companies for microelectronics and optoelectronics. We will follow up this adopted course also in 2007. Where should new things be tried out unless at an institute of a university?

I would like to thank the whole *ipe* staff for their creative and trustful atmosphere at work. It is a pleasure to work at an institute like this!

Stuttgart, December 2006

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 multicrystalline 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.

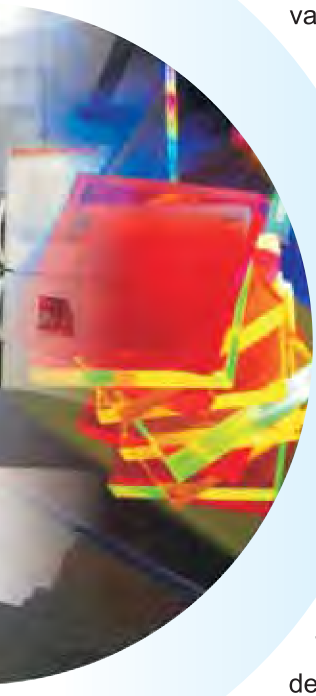
Gerhard Bilger

For the development of third generation solar cells novell 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 characterisation 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 Photovoltaics

(Gruppenleiter / Group Leader: Uwe Rau)

Der Schwerpunkt der Arbeitsgruppe „Photovoltaik" ist die Erforschung und Entwicklung neuer Konzepte und neuer, industrietauglicher Prozesse für kristalline Silizium-Solarzellen. Wir entwickeln u.a. flexible Solarzellen und –module auf der Basis von nur 20 bis 50 µm dicken einkristallinen Silizium-schichten. Diese Solarzellen erfordern qualitativ hochwertige Front- und Rückseitenkontakte, die 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 SiO_2/Si-Quantenstrukturen, 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 mono-crystalline silicon solar cells. We develop flexible solar cells based on only 20 to 50 µm thick mono-crystalline Silicon layers. These solar cells require high-performance back and front contacts processed at temperatures below 250°C like our amorphous/crystalline heterocontacts. Further research is directed towards innovative concepts for the enhancement of photovoltaic power conversion efficiencies via the usage of SiO_2/Si quantum structures, fluorescent light conversion, or optical nanostructures.

Gruppe Sensorik
Group Sensors

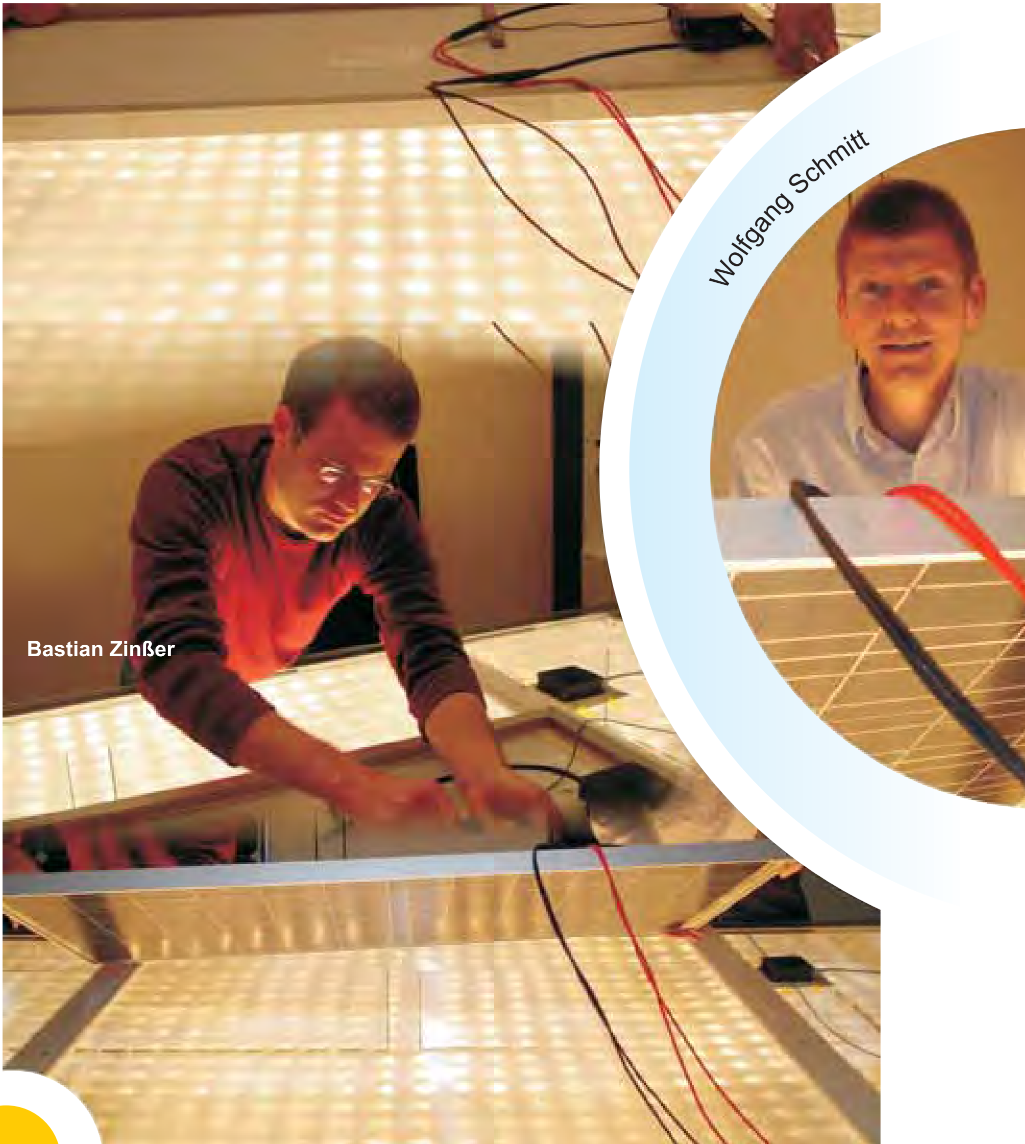
(Gruppenleiter / Group Leader: Markus Schubert)

Die Arbeitsgruppe „Sensorik" des *ipe* entwickelt optische Detektoren und Dünnschichtsolarzellen auf der Basis amorphen und nanokristallinen Siliziums. In enger Kooperation mit dem Institut für Mikroelektronik Stuttgart (IMS-CHIPS) optimieren wir Fotodioden für Sternsensoren und Endoskope in „Thin-Film-on-CMOS"-Technologie. Eine Zusammenarbeit mit der Universität Tübingen erprobt neuartige Dünnschichtdetektoren in der Bioanalytik, und speziell optimierte Schichtsysteme dienen der Herstellung von Positionssensoren zur Justage von Experimenten am CERN in Genf. In der Photovoltaik verwenden wir amorphes Silizium zur Niedertemperaturpassivierung kristalliner Siliziumsolarzellen und stellen Solarzellen und -module auf Plastikfolie her. Flexible amorphe Solarzellen lassen sich in Kleidung oder Kleingeräte integrieren und liefern mit einer eigens entwickelten, verlustarmen Ladeelektronik auch bei geringer Beleuchtung Energie zum mobilen Betrieb von Handys und MP3-Spielern, für netzferne Bauwerksüberwachung oder drahtlose medizinische Sensorik.

The "Sensors" work group at *ipe* is developing photodetectors and solar cells based upon amorphous and nanocrystalline silicon thin films. A close cooperation with the Institute of Microelectronics Stuttgart (IMS-CHIPS) optimizes photodiodes for star sensors and endoscopes in "Thin-Film-on-CMOS" technology. In cooperation with the University of Tübingen, we evaluate novel thin film photodetectors for bioanalytics. Specially designed layer stacks enable high-performance position sensing for the adjustment of characterization equipment at CERN in Geneva. In photovoltaics, we use amorphous silicon as a low-temperature passivation for crystalline silicon solar cells, and we deposit flexible solar cells and modules on plastic foils. Flexible cells integrate well with clothing or small electronic devices. An optimized low loss, high efficiency charge controller enables energy harvesting even at low ambient light levels, and thereby fosters the operation of mobile phones or MP3 players, remote sensing, or wireless medical surveillance.

Gruppe Systeme
Group Systems

(Gruppenleiter / Group Leader: Wolfgang Schmitt)



Die Gruppe „Systeme“ befasst sich mit der Systemtechnik elektrischer und elektronischer Geräte und Anlagen. Im Vordergrund stehen dabei sowohl netzgekoppelte als auch netzautarke Photovoltaik(PV)-Anlagen. Ein Schwerpunkt liegt auf der Vermessung, Charakterisierung, Modellierung und Dimensionierung von PV-Systemen und deren Komponenten wie PV-Module, Leistungselektronik sowie der Komponenten zur Energiespeicherung. Außerdem arbeiten wir an der Entwicklung von spezifischen leistungselektronischen Schaltungen (Strom-, Spannungs-, Laderegler) in den Bereichen der kleidungsintegrierten Photovoltaik (*ipv*) und der Energieversorgung von Kleinverbrauchern. Ein aktuelles Forschungsprojekt konzentriert sich auf den Vergleich der Jahresenergieerträge von netzgekoppelten PV-Anlagen unterschiedlicher moderner PV–Technologien (monokristallines, multikristallines und amorphes Silizium, EFG, CdTe, $CuInSe_2$, HIT-Zelle, Rückseitenkontaktzelle) an drei klimatisch relevanten Standorten (Stuttgart, Kairo, Nicosia).

The ”Systems” group is concerned with the system technology of electrical and electronic devices. The main interest is laid on grid-connected as well as on grid-independent Photovoltaic(PV)-systems. An emphasis is laid on measuring, characterization, modelling and dimensioning of PV-systems and their components as PV-modules, power electronic circuits and systems and electric storage systems. Furthermore, we develop specific power electronic circuits (current, voltage and charge controllers) for clothing integrated photovoltaics (*ipv*) and for the energy supply of small consumers. A recent research project is concentrated on the comparison of the yearly energy yield of different grid-connected PV-systems at three different sites (Stuttgart, Cairo, Nicosia). A number of modern PV-technologies (single crystalline, poly crystalline and amorphous silicon, EFG, CdTe, $CuInSe_2$, HIT-cell, all-back-contact solar cells) is analyzed.

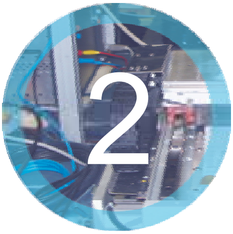
einkristallines

mikrokristallines

Silizium

nanokristallines

amorphes



Wissenschaftliche Beiträge
Scientific Contributions

Publikationen
Publications

Analytical model for the current/voltage characteristics of a-Si:H (pin) solar cells

Author: A. Al-Tarabsheh
In collaboration with: U. Rau, M. B. Schubert

The following briefly describes a new analytical model [1] for calculating the current/voltage (*J/V*) characteristics of a-Si:H *pin* solar cells. The *pin*-structure consists of an intrinsic absorber layer sandwiched between two photovoltaically inactive p-type and n-type doped layer. Our model is a generalization of earlier models presented in [2-4] and takes into account different mobilities μ_n, μ_p and different lifetimes τ_n, τ_p for electrons and holes. Note that in a-Si:H we typically have $\mu_n\tau_n > 50\mu_p\tau_p$.

The basic idea of this model is the solution of the transport equations for electrons and holes in two different regions of the absorber layer where the role of both types of carriers as minorities or majorities are interchanged. In both regions, we independently solve the continuity equations for the minority carriers, and then enter this solution into the equations for majority carriers, which are solved subsequently. The solution of the two second order differential equations in the two different regions together with the boundary conditions at the *p*/*i*- and *n*/*i*-interfaces as well as between the two different regions of the *i*-layer yields a set of eight algebraic equations. These equations are finally solved with a matrix inversion [1].

Our model is especially suitable to describe the current density *J* of bifacial a-Si:H solar cells where the light alternatively enters through the *p*-layer, or through the *n*-layer. Figure 1 demonstrates that significantly more charge carriers reach the contacts if the light enters through the *p*-layer as compared to the opposite situation. Since $\mu_p\tau_p << \mu_n\tau_n$ holds for a-Si:H, many holes recombine on their long way across the whole thickness of the cell if the generation rate peaks close to the *n/i*-interface upon illumination through the *n*-layer.

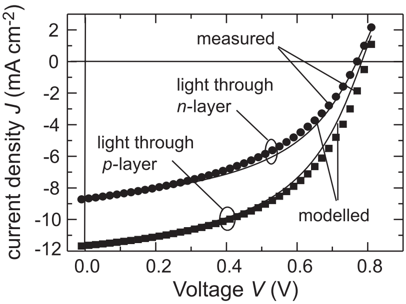


Figure 1:
Current density *J* of a bifacial a-Si:H solar cell where the light alternatively enters through the p- or n-layer. Our model (solid lines) matches the measured data (circles and squares) for both directions of illumination. The modeling parameters are $\mu_n\tau_n$=7.5×10^{-6} cm^{2}V^{-1} and $\mu_p\tau_p$=6.57×10^{-10}cm^{2}V^{-1}.

References:

[1] A. Al-Tarabsheh, U. Rau, M. B. Schubert, in *Proc. 21st Europ. Photov. Solar Energy Conf.,* edited by J. Poortmanns, H. Ossenbrink, E. Dunlop, and P. Helm (WIP, Munich, 2006) p. 1677.

[2] R. Crandall, J. Appl. Phys. **53**, 3350 (1982).

[3] H. Okamoto, H. Kida, S. Nomomura, K. Fukumoto, Y. Hamakawa, J. Appl. Phys. **54**, 3236 (1983).

[4] K. Taretto, U. Rau, J. H. Werner, Appl. Phys. A **77**, 865 (2003).

Characterization of a laser doping process for crystalline silicon solar cells

Author: M. Ametowobla
*In collaboration with: A. Esturo-Bretón, J. R. Köhler, J. H. Werner, R. Köhler**

The *ipe* laser doping process allows for the fabrication of crystalline silicon solar cells with open-circuit voltages V_{oc} up to V_{oc} = 645 mV. Transmission electron microscopy (TEM) reveals that no extended crystal defects exist inside the irradiated silicon [1]. However, the efficiency of laser doped solar cells still lacks behind the one of conventional cells with a furnace diffused emitter. This work characterizes the impact of the laser irradiation on the silicon material by measuring the effective minority carrier lifetime of irradiated and non-irradiated samples by means of Quasi-Steady-State-Photoconductive Decay (QSSPC). Additionally, we use X-Ray Topography [2] and defect etching to gain insight into possible changes in crystal structure.

The results show a reduction of the effective minority carrier lifetime τ_{eff} by the laser irradiation, for both mounting pulse energy density E_p as well as number of melting cycles N_{melt}. The magnitude and nature of the decrease additionally seem to be dependent on the resistivity of the substrate material. By removal of a few µm of the silicon surface in a concentrated KOH solution we confirm, that the lifetime deterioration is confined within this surface layer, as this etching process completely restores minority carrier lifetime of irradiated samples to reference values. Figure 1 shows the effective lifetime of samples irradiated at E_p = 3.8 J/cm^2 and $0 < N_{melt} < 20$. The lifetime degradation is monotonic, from τ_{eff} = 560 µs for the reference to τ_{eff} = 2 µs for 20 fold melting. After the etching, the lifetime of the irradiated samples is completely restored to or even above reference values, as shown in Fig. 2. The lifetimes for all samples ranges between 350 µs and 640 µs. Thus, we prove that the irradiation does not cause defects inside the silicon bulk.

*Humboldt University, Berlin

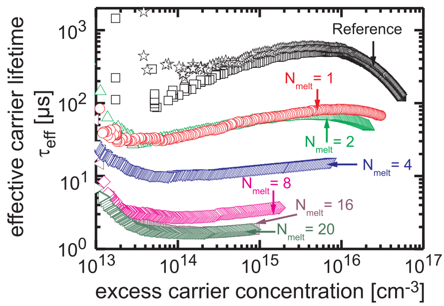


Figure 1:
The effective lifetime of 1 Ωcm samples irradiated with E_p = 3.8 J/cm^2 degrades strongly with repeated melting from values of τ_{eff} = 560 µs for the not irradiated reference samples to $\tau_{eff} \approx$ 2 µs for the sample with 20 melting cycles.

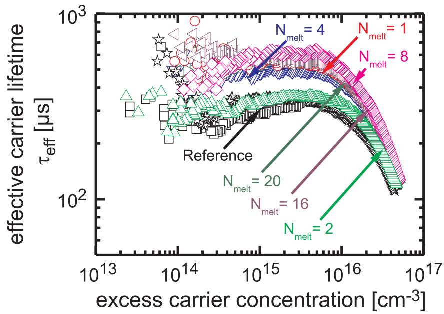


Figure 2:
After removal of a surface layer of about 3 µm thickness, the laser induced lifetime degradation vanishes as well as any reference to the number of melting cycles.

Neither chemical defect etching with a modified Schimmel solution, nor X-Ray topography characterization reveal any observable crystal defects inside the irradiated areas. Thus, we attribute the significant lifetime reduction, observed in spite of no visible crystal defects, to the formation of point defects or the introduction of impurity atoms from the ambience during the melting period. Further experiments are under way to clarify the reasons for the lifetime degradation.

References:

[1] J. R. Köhler, M. Ametowobla, A. Esturo-Bretón in *Proc. 20th European Photovolt. Sol. Energy Conf.*, edited by W. Palz, H. Ossenbrink, P. Helm (WIP-Renewable Energies, München, Germany, 2005), p. 1162

[2] R. Köhler, Appl. Phys. A **58**, 149 (1994)

Laser doping for selective solar cell emitters

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

The emitter strongly influences the performance of crystalline silicon solar cells. Solar cells with high efficiencies often use selective emitters. A selective emitter has different doping under and between the metallic finger contacts. The result is a better fill factor *FF*, higher open circuit voltage V_{oc} and, consequently higher efficiency η [1-3]. The selective emitter should have low sheet resistance ρ and a deep doping profile under the metallic finger contacts, between the finger contacts the sheet resistance ρ should be higher and the doping profile thinner [1]

We present a simple method to form a selective emitter by using a laser doping process suitable for local dopant diffusion. Common furnace diffusion results in a homogenously but lowly doped emitter. After furnace diffusion, laser scribing with a Nd:YVO_4 laser (λ = 532 nm) on the metallic contact areas takes place. Pulsed laser irradiation on furnace diffused emitters, results in a second local "diffusion" and changes the sheet resistance ρ and doping profile [4]. The most important parameters during laser irradiation are pulse energy density E_p, and the number of irradiation cycles N_{irr}, of the selectively doped emitter areas. Figure 1 shows the sheet resistance ρ for furnace diffused and laser treated samples. The sheet resistance ρ reduces

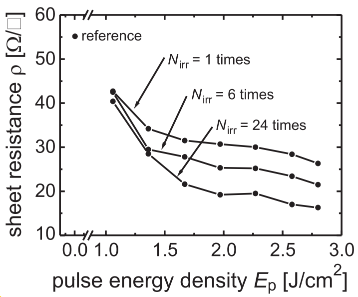


Figure 1:
Samples with a furnace diffusion show a sheet resistance ρ = 57 Ω/□. After laser irradiation, the sheet resistance ρ reduces with increasing pulse energy density E_p and number of irradiation cycles N_{irr}. The sheet resistance reduces down to ρ = 16 Ω/□ for a pulse energy density E_p = 2.7 J/cm^2 and N_{irr} = 24 times.

for increased pulse energy density E_p of the laser and number of irradiation cycles N_{irr}. For the highest pulse energy density E_p = 2.7 J/cm^2 and N_{irr} = 24 the sheet resistance reduces from ρ = 57 Ω/□ (for not laser treated samples) down to ρ = 16 Ω/□.

Figure 2 shows the doping profile from a secondary ion mass spectroscopy (SIMS) measurement. The SIMS measurements show that increased repeated cycles N_{irr} makes the doping profile deeper and reduces the surface concentration. Our results show that it is possible to create a second and local “diffusion” on furnace diffused emitters by using a pulsed laser doping process. Furnace diffusion creates a homogenous emitter with low doping concentration. Laser scribing on the areas under the metallic contact fingers results in the selective emitter formation. Laser irradiation on furnace diffused areas results in both reduced sheet resistance ρ and a deeper doping profile in one single step.

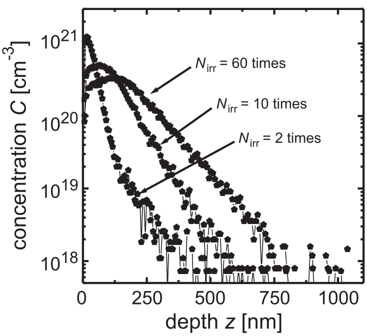


Figure 2:
Doping profile from secondary ion mass spectroscopy measurements on samples after furnace diffusion and laser irradiation. For increased number of irradiation cycles N_{irr}, the doping profile becomes deeper and the surface concentration reduces.

References:

[1] A. Aberle, W. Warta, J. Knobloch, B. Voss in *Proc. 21st Photovolt. Spec. Conf.* (IEEE, New York, 1990), p. 233.

[2] S. Sterk, S. W. Glunz, J. Knobloch, W. Wettling, in *Proc. 24th Photovolt. Spec. Conf.* (IEEE, New York, 1994), p. 1303.

[3] N. Stem, M. Cid, Mat. Res. **4**, 143 (2001).

[4] E. Fogarassy, R. Stuck, J. C. Muller, A. Grob, J. J Grob, P. Siffert, J. Electr. Mat. **9**, 197 (1980).

Diffusion of tri-iodide in ionic liquids for dye-sensitized solar cells

Author: F. Einsele
*In collaboration with: U. Rau, R. Sastrawan, A. Hinsch**

Dye-sensitized solar cells (DSCs) use an electrolyte that carries iodide (I^-) and tri-iodide (I_3^-) ions for charge transportiation. These ions act as a redox couple to regenerate the dye after excitation and electron transfer. Standard DSCs use highly volatile acetonitrile as a solvent and reach efficiencies up to $\eta \approx 10$ % [1]. A major research aim is to replace this electrolyte by novel ionic liquids that are less volatile [2]. Unfortunately, DSCs with ionic liquids exhibit lower efficiencies η, mainly due to low short circuit current densities J_{sc}. Here, we study the role of ion diffusion with respect to its limitations on the cell currents.

Figure 1 sketches the devices used for the diffusion studies. The cells, filled with the electrolyte, feature two platinized catalytic electrodes where redox reactions between I^- and I_3^- take place. This generation and annihilation of ions leads to concentration gradients and ion diffusion. The Butler-Volmer (BV) equation gives an expression for the current voltage dependence $J(V1/2)$ at an electrode-electrolyte interface under steady-state conditions. Two BV characteristics in series yield the current voltage characteristic $J(V)$ of the cell, as shown in Fig. 2a. Mainly because of its lower concentration, the diffusion of I_3^- accounts for the limiting current denisity J_{lim}. We identify the diffusion coefficient of I_3^- as $D \approx 10^{-5}$ cm^2/s in acetonitrile and around $D \approx 10^{-7}$ cm^2/s for different ionic liquids [3].

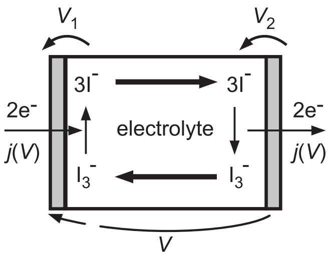


Figure 1:
Experimental cell with two platinized electrodes (grey). Generation and annihilation of ions (vertical arrows) leads to concentration gradients and diffusion (horizontal arrows).

*Fraunhofer Institute for Solar Energy Systems (Freiburg)

The diffusion processes contribute to the complex AC impedance of the cell. This is known as the Warburg impedance $Z_W(\omega)$. We deduce this impedance directly from the BV equation and the diffusion equation. In principle, the diffusion of both ions, I^- and I_3^-, contribute to $Z_W(\omega)$. However, detailed considerations unveil that for typical DSC electrolytes, the contribution of I^- can be neglected when compared to that of I_3^- [3].

Figure 2b shows the cell impedance $Z(\omega)$ of an experimental cell. For low frequencies, the curve represents the Warburg impedance $Z_W(\omega)$, whereas for higher frequencies we observe the characteristics of an RC element formed by the double-layer capacitance C_{DL} at the electrodes and a series resistance R_S. Curve fitting shows good agreement between measured (open symbols) and calculated values. The fitting of the impedance data in Fig. 2b yields the same diffusion constant as the evaluation of the $J(V)$ characteristics in Fig. 2a.

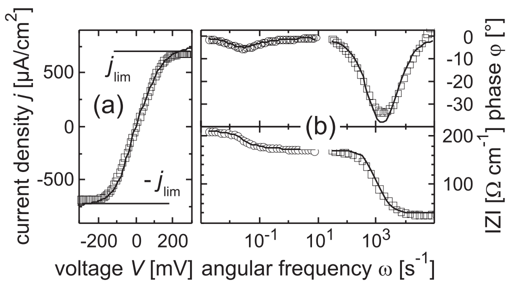


Figure 2:
a) The current voltage curve $j(V)$ of an experimental cell shows the limiting current density j_{lim}. b) The cell impedance $Z(\omega)$ exhibits two characteristic phase shifts: a low-frequency shift attributed to diffusion and a high-frequency shift that is characteristic for the RC element. Good accordance between measured and calculated values.

References:

[1] M. K. Nazeeruddin, A. K. Kay, I. Rodicio, R. Humphry-Baker, E. Müller, P. Liska, N. Vlachopoulos, M. Grätzel, J. Am. Chem. Soc. **115**, 6382 (1993).

[2] P. Wang, S. Zakeeruddin, J. Moser, M. Grätzel, J. Phys. Chem. B **107**, 13280 (2003).

[3] F. Einsele, Diploma Thesis, University of Stuttgart, 2006.

Improved laser doping process for silicon solar cells

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

Laser doping permits an alternative method [1] to create the emitter of crystalline silicon solar cells instead of conventional [2] emitter diffusion in a furnace. Pulsed laser doping has the advantage of melting only the wafer surface without heating the rest. This local melting also allows selective doping of well defined areas. Our laser doping process uses a line beam shaped laser focus. The intensity distribution in both directions is Gaussian. Solar cell emitters processed with such a line-beam shaped laser focus suffer from lateral inhomogeneities of the emitter doping concentration. They show also high ideality factors n [1]. The non-uniformity of the contact resistance caused by inhomogeneous emitter doping is one possible reason for the high ideality factors [3].

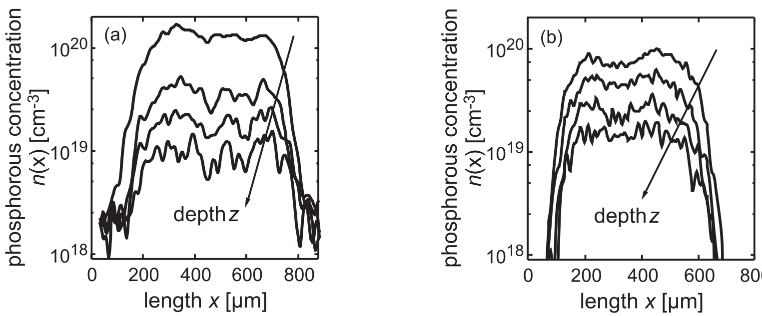


Figure 1:
Lateral Secondary Ion Mass Spectroscopy of two silicon wafers, both selectively laser doped with three laser scans separated by 200 µm in x-direction. a) Cell 1, irradiated with conventional optics, and b) cell 2, irradiated with modified optics. The use of modified optics results in a more homogenously doped emitter.

In order to proof if lateral inhomogeneities of the emitter dopant concentration are the reason for increased ideality factors *n* found in our solar cells, we irradiate a sample using a modified focussing optics, which reduces lateral inhomogeneities of the doping concentration (cell 2). We compare it with a sample irradiated with our old focussing optics (cell 1). The results in Fig. 1 and Table 1 confirm our predictions. A more homogeneous dopant distribution in the emitter improves the ideality factor n of solar cells from $n = 2.07$ to $n = 1.28$. The consequence is a notable increase of fill factor $FF = 78.4$ % and efficiency $\eta = 15.4$ % of the solar cell with laser doped emitter.

Table 1:
Solar cell parameters under illumination with a 100 mW/cm^2 AM1.5G spectrum. Both solar cells (area A = 4 cm^2) are laser doped using comparable processing parameters but different focusing optics. The homogenization of the lateral dopant distribution in the emitter of cell 2 results in an improvement of the ideality factor n. Therefore, the cell reaches a higher fill factor *FF* and an increased efficiency η.

sample	J_{sc} [$mAcm^{-2}$]	V_{oc} [mV]	FF [%]	η [%]	n
cell 1 (1)	32.8	615	63.4	12.8	2.07
cell 2 (2), (*)	31.6	623	78.4	15.4	1.28

(1) with conventional optics, (2) with modified optics, (*) independently confirmed by ISE (Freiburg)

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Improved photon collection in fluorescent collectors by photonic band stop filters

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In collaboration with: U. Rau

Fluorescent collectors (FCs) use organic dyes or inorganic fluorescent molecules embedded in a dielectric material to collect and concentrate solar light [1]. The dyes absorb incoming light and emit it at a lower photon energy *E*. Thereby the direction of the emitted light is randomized and a portion of the light is trapped in the FC via total internal reflection. Finally, a solar cell placed at the edge of the collector absorbs these photons and converts them into electrical energy.

Recently, we proposed that a combination of classical FCs with a photonic band stop (PBS) filter should improve the photon collection in such a system [2]. This is because photon re-emission within the critical angle of total reflection leads to considerable losses in classical collectors whereas in systems with a properly designed PBS all photons are kept in the system. The following demonstrates that the use of a Bragg filter enhances the photon collection of a FC system using the dye LUMOGEN® F red in combination with a GaAs solar cell by a bout 30 %.

Figure 1a shows the arrangement of the FC system where we have covered the bottom and all sides (except for the 20 mm wide cell area) by a 100 nm thick Ag layer. A 20×3 mm^2 wide GaAs solar cell is glued to the cell area at one side of the collector. The FC is analyzed by quantum efficiency (QE) measurements as shown in shown in Fig. 1b. We find that the QE data strongly depend on the location where the analysis is performed. The difference amounts nearly to a factor of 2 when comparing the data taken at position 1 close to the GaAs cell (cf. Fig. 1a) to those taken at a distance of 25 mm (position 2). This finding shows that considerable losses by parasitic absorption (e.g., at the Ag/FC interface and/or due to non-radiative recombination in the dye) are present in the system. However, we also observe an enhancement of photon collection by approximately 30 % in both positions by the Bragg filter. Thus, the experiments demonstrate a substantial enhancement of photon collection in FCs by photonic filters. Therefore, seen as a model experiment, the present results clearly underline the usefulness of a relatively simple photonic structure, the Bragg filter, for enhancing photon collection in FC systems.

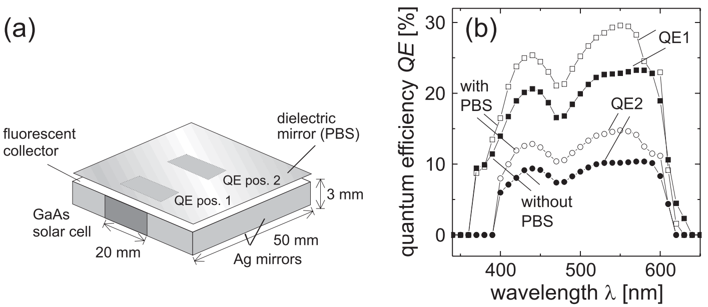

Figure 1:
a) Sketch of the experimental system containing a 3×20 mm² GaAs solar cell and a fluorescent collector of size 50×50×3 mm³. All surfaces except for the cross section of the solar cell and the top surface are covered by a 100 nm Ag layer acting as a mirror. The photonic band stop filter (PBS) consists of a commercially available Bragg filter tuned to reflect the light emitted by the dye in the collector. b) Quantum efficiency curves taken at the QE positions 1 and 2 of the FC system shown in a). The QE in the presence of the Bragg filter is larger than that without the filter in the entire spectral range. The spectral features of the QE result from the absorptance of the dye LUMOGEN® F red.

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Electroluminescence from highly efficient $Cu(In,Ga)Se_2$-solar cells

Author: T. Kirchartz
In collaboration with: U. Rau. J. Mattheis, J. H. Werner

Solar cells based on polycrystalline $Cu(In,Ga)Se_2$ absorber material achieve efficiencies $\eta > 19$ % on an area $A = 0.5$ cm^2. A large series of such highly efficient cells area was prepared at *ipe* by a three-stage co-evaporation process on a Mo-coated glass substrate [1]. Here, we present electroluminescence (EL) analysis of these highly efficient thin film solar cells performed in a temperature range 90 K $\leq T \leq$ 300 K [2].

Figure 1a shows the EL spectra of a $Cu(In_{1-x},Ga_x)Se_2$-solar cell (η = 18 %, open circuit voltage V_{oc} = 739 mV) with a Ga-content x = 40 %. The spectra correspond to measurements performed at three different temperatures, T = 120 K, 180 K, 300 K. The peak energy of the electroluminescence spectra shows a clear transition from lower to higher energies with increasing temperature. At T = 180 K, both peaks coexist. We identify the origin of the peaks as donor-acceptor-pair (DAP) recombination dominating at lower temperatures and as band-to-band (BB) transition dominating at higher temperatures. Evidence for this interpretation stems from excitation current dependent EL-measurements at temperatures above and below the transition temperature [2]. The current-dependence of the DAP-peak shows a strong blue-shift of 40 meV/decade, being characteristic for DAP-transitions [3], whereas at room temperature the peak energy remains independent of excitation current. We attribute the broadening of the peaks to potential fluctuations in the case of the DAP transitions and to band-gap-fluctuations in the case of BB-recombination [4].

Figure 1b displays the development of the peak energy as a function of sample temperature. For temperatures T = 160 K and 180 K, the maxima are found by deconvolution of the EL-spectra. Additional electroluminescence measurements on $Cu(In,Ga)Se_2$-solar cells with a similar Ga-content but a lower open circuit voltage V_{oc} = 700 mV showed a clear difference to the spectra in Fig. 1a.

The distinct transition from DAP to BB-recombination in a small temperature range does only occur for the cells with the higher V_{oc}. Cells with a lower V_{oc} have a much larger transition range and exhibit the coexistence of DAP, BB and a third radiative recombination path (probably free-to-bound) up to room temperature.

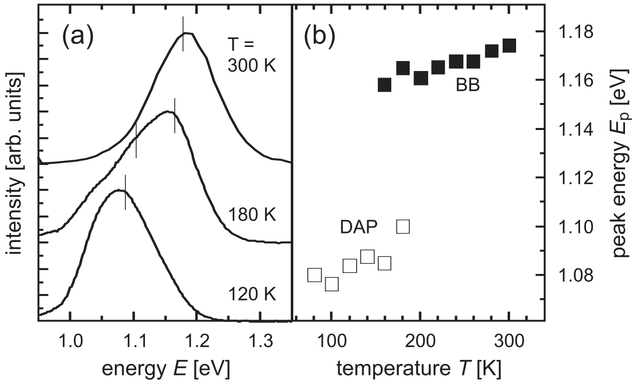

Figure 1:
a) Electroluminescence spectra of an η = 18 % $Cu(In_{1-x},Ga_x)Se_2$-solar cell at three different temperatures and b) the evolution of the peak energy vs. temperature. The spectra show a transition from donor-acceptor-pair (DAP) recombination to band-to-band (BB) recombination between 160 K < *T* < 180 K.

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Finite mobility effects on the radiative efficiency limit of pn-junction solar cells

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In collaboration with: U. Rau, J. H. Werner

The maximum power conversion efficiency of a solar cell as defined by the Shockley-Queisser (SQ) radiative recombination limit relies on the assumption that the collection probability for all photogenerated electron/hole-pairs is unity [1]. This assumption implies a virtually infinite mobility μ of the photogenerated charge carriers. In order to compute the radiative efficiency limit with finite mobility, we solve the continuity equation for minority carriers including an additional integral term that accounts for emission of photons by radiative recombination and their subsequent reabsorption. This reabsorption process is called 'photon recycling' [2]. Even when assuming radiative recombination as the only recombination mechanism, the achievable efficiency is reduced drastically when μ drops below a critical value that depends on the absorption coefficient and the doping density of the semiconductor. Thus, we give a criterion that has to be fulfilled by any photovoltaic material in order to guarantee charge separation even in an otherwise most ideal case [3].

Figure 1 shows the computed radiative efficiency limit vs. the band gap energy E_g. For high mobility, the efficiency approaches the SQ limit (stars). For low mobilities, however, the efficiency is reduced drastically. Losses in the radiative power conversion efficiency are caused by incomplete carrier collection and the resulting lower short circuit current.

Figure 2 displays the efficiency η / η_{SQ} normalized to the maximum value in the SQ-limit versus the ratio of radiative and non-radiative lifetime for different mobilities. For low mobilities, the efficiency is limited by the short circuit current. For sufficiently high mobilities, however, virtually complete carrier collection guarantees a high short circuit current and the efficiency is dominated by the open circuit voltage.

Involving non-radiative recombination into our model bridges the gap between the SQ-theory and the classical diode theory ([4], dashed lines in Fig. 2) of *pn*-junction solar cells. The latter one is sufficiently accurate only if the non-radiative lifetime is at least ten times smaller than the radiative lifetime.

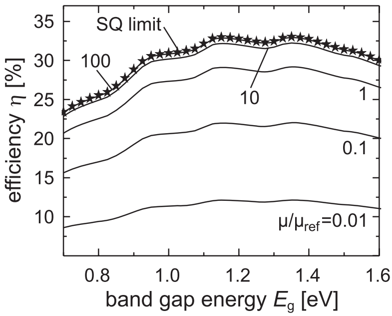

Figure 1:
Radiative efficiency limit vs. band gap energy E_g. For increasing normalized mobility the efficiency approaches the SQ limit.

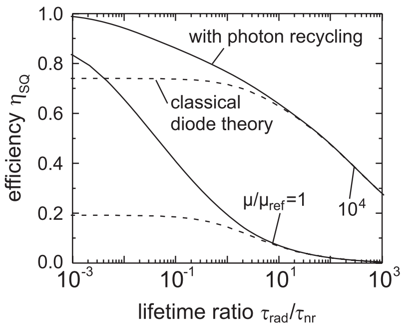

Figure 2:
Efficiency η / η_{SQ} normalized to the maximum value in the SQ-limit versus the ratio of radiative and non-radiative lifetime. For dominating non-radiative recombination, the results from the computation with photon recycling (solid lines) turn into the classical diode theory (dashed lines).

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Low-loss charge controllers for integrated photovoltaics

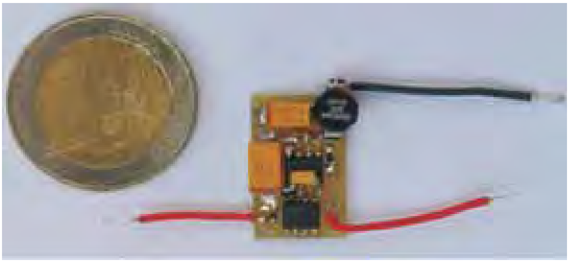
Author: R. Merz
In collaboration with: G. Fritsch, M. B. Schubert

Clothing integration of solar cells [1] enables the independent wireless operation and an extended stand-by time of portable electronic devices, like mobile phones, MP3 players, or personal digital assistants. Integrated photovoltaics (*ipv*) harvests electric power from the ambient light, indoor or outdoor, and thereby greatly enhances the mobility of wireless communication and entertainment devices. The most universal interface for supplying power to the portable devices employs a standard USB plug. For continuous availability of *ipv*-generated power, independent of the actual illumination conditions, built-in accumulators of the devices are charged, or additional accumulators integrate with the garments for providing even longer periods of operation and stand-by.

This contribution presents a low loss, high efficiency charge controller developed within the SOLARTEX project [2,3]. Real life operation implies greatly varying illumination spectra and intensities, which the charging circuitry should convert into accumulator charge with ultimate efficiency, and over a wide range of intensities. Moreover, the start-up current of the charge controller ought to be as low as possible in order to make best use of low light levels.

Figure 1a presents a circuit based on a buck boost converter which converts a maximum input power of 2.5 W at efficiencies up to η_{max} = 75 % over a wide range of input voltages V_{IN} = 3 V to 16.5 V. The improved circuit depicted in Fig. 1b controls both, the output and the input voltages. The lower limit of its input voltage is set to the output voltage of given *ipv* modules at their low intensity limit. The efficiency of the charge controller according to Fig. 1b reaches η = 50 % for input currents I_{in} > 5 mA, corresponding to an output power P_{el} > 35 mW. The start-up current of this circuit is lower than 1 mA.

The key feature which reduces electrical losses of the circuit according to Fig. 1b, comprises a Schmitt trigger for monitoring the input voltage V_{IN}. The Schmitt trigger output controls the buck boost converter in order to inhibit an input voltage drop below some adjustable level.



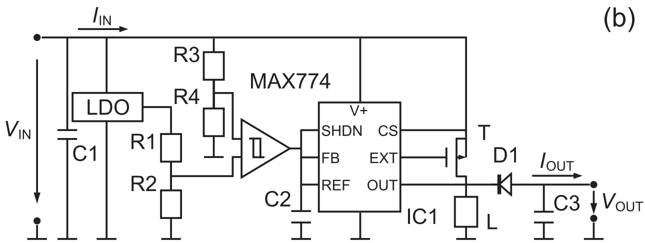


Figure 1:
Low loss, high efficiency charge controllers optimize the performance of integrated photovoltaics (*ipv*). The solar modules of a clothing integrated ipv systems deliver their energy harvest to the accumulator via one of these controllers. Their efficiency exceeds 75 % for high illumination intensity. a) Board photograph of a simple buck boost converter circuit. b) Layout of an improved circuit with additional Schmitt trigger for reducing power losses at low illumination levels.

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Automated handling of thin mono-crystalline silicon layers

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

Today, 95 % of the photovoltaic market is made up by crystalline silicon wafers. These wafers have a thickness around 300 µm and the consumption of silicon ranges around 12 g/W. Due to the 30 % annual growth rate of the photovoltaic market, there is, at present, a lack of sufficient silicon to satisfy the demand. At present, more than 40 % of the silicon consumption of 30.000 t is going into the photovoltaic industry while the rest is used for microelectronics.

In order to overcome the lack of sufficient silicon for photovoltaics, there is a world wide trend toward thin crystalline silicon cells. While the traditional wafer-based silicon photovoltaics aims a thicknesses around 150 µm and a silicon consumption of about 7 g/W, the TRANSFER process at *ipe* aims at a silicon consumption < 1 g/W with wafer thicknesses around 25 µm.

The thin silicon layers are manufactured in the TRANSFER process by etching pores into a silicon host wafer, on which a 20 to 50 µm thick mono-crystalline silicon layer is epitaxially deposited. The thin silicon layer is then separated from the host wafer and used as a wafer equivalent for either solar cells or for integrated circuits. When reusing the host wafer for the next TRANSFER process, only a few µm of the host wafer is actually used up. At present, the *ipe* holds the world record for such technologies with a mark of 16.9 % efficiency for a 4 cm^2 cell. Cells of sizes up to 150 cm^2 are under investigation.

With cell thicknesses below 100 µm mechanical handling of silicon during cell processing and module manufacturing becomes a serious challenge. For this reason, in cooperation with the Fraunhofer Institute IPA we have developed a handling system.

*Fraunhofer Institute for Manufacturing Engineering and Automation IPA, Stuttgart

Figures 1a, b show the experimental assembly. Figure 1a presents the vacuum picker which is used for separation of the thin silicon layer from the host wafer. Figure 1b shows a magazine which is capable of holding up to 13 silicon layers. The layers are further processed while stored in the magazine. In order to be able to use high temperature, chemical etching and cleaning processes, it is important to be able to switch magazines and to turn layers upside down. Pick-and-place operations from one magazine into a second one are possible. Thus, it is possible to perform all solar cell processing steps with thin mono-crystalline silicon layers stored in magazines.

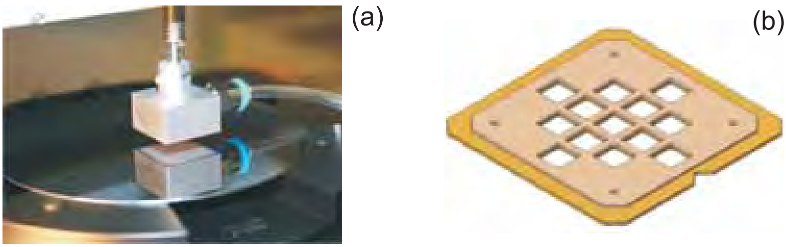

Figure 1:
a) Experimental vacuum picker of size 2×2 cm^2, which is used to transfer thin mono-crystalline layers from the substrate wafer to a magazine. The shape of the layer is defined by a laser cutting process. b) CAD picture of a magazine, in which thin mono-crystalline layers are stored for further processing. This magazine is either made out of steel, for high temperature processes, or made out of plastics in order to withstand chemical processes.

A further step of research at *ipe* will be to show the industrial feasibility of automated handling of thin silicon layers. Further on, the knowledge of automated handling and processing of thin silicon films has to be transferred into an industrial feasible production.

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TCO/(n-type)a-Si:H/(p-type)c-Si heterojunction solar cells with high open circuit voltages

Author: P. J. Rostan
In collaboration with: U. Rau, M. B. Schubert, J. H. Werner

Today's high efficiency crystalline silicon solar cells based on p-type substrates are usually equipped with diffused homojunction emitters. In contrast to the high temperature phosphorous diffusion process, the plasma enhanced chemical vapour deposition (PECVD) of amorphous silicon as a heterojunction emitter offers fast and energy-saving low temperature manufacturing. Experimental open circuit voltages of such n-a-Si:H/p-c-Si heterostructure solar cells fabricated by PECVD are in the range of 635 to 655 mV [1].

Here we report on a-Si:H emitters for p-type solar cell applications fabricated by low temperature PECVD with open circuit voltages V_{OC} in excess of 660 mV. Figure 1 shows a sketch of our flat (a) and textured (b) solar cells together with the external quantum efficiency of a non-textured device (c). The emitter consists of an intrinsic a-Si:H layer for surface passivation and an n-type doped a-Si:H layer that forms the emitter. The intrinsic passivation layer can lead to significant losses in the fill factor due to its high resistance that hampers the current transport. Therefore, we fabricate in a first step samples that are symmetrically equipped with double layers of i-a-Si:H and n-a-Si:H. We then measure the effective lifetime of these samples and subsequently decrease the i-layer thickness step by step. With an i-layer thickness d_i = 2.5 nm we still find an effective carrier life-time τ_{ff} = 1 ms. Further decreasing the i-layer causes significantly decreased lifetimes [2].

Applying this i-a-Si:H/n-a-Si:H emitter to non-textured wafers equipped with a local metal back contact that uses a thermal oxide passivation yields open circuit voltages V_{OC} > 680 mV and efficiencies up to η = 17.4 %.

So far, the efficiency of these cells is only limited by the short circuit current. Using textured surfaces, we reach open circuit voltages V_{OC} = 660 mV and efficiencies up to η = 18.5 %, up to now limited by a relatively low fill factor due to a high series resistance [2].

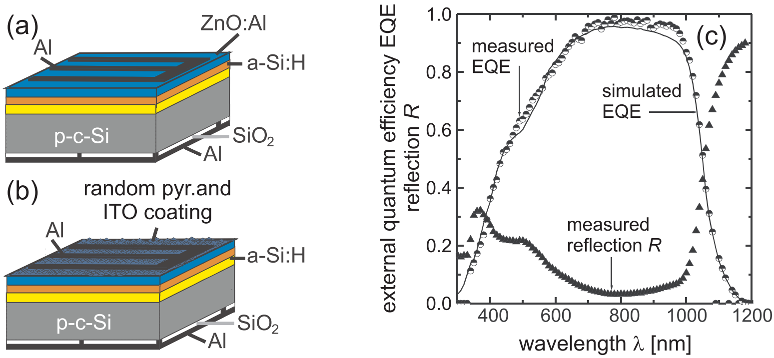

Figure 1:
Sketch of our a) flat and b) textured solar cell devices together with c) a measured and simulated external quantum efficiency of a flat device. We use p-type ρ = 1 Ωcm wafers equipped with a high efficiency PERC-type back contact. The emitter consists of intrinsic and phosphorous doped a-Si:H together with an n-type ZnO:Al (non-textured samples a) or ITO (textured samples b) window layer. The Al contact grid is subsequently evaporated through a shadow mask. c) The simulated EQE (chart (c)) is mainly given by the c-Si absorption and fits well the measured data. This result shows the excellent front and back side passivation of our devices.

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Infrared luminescence from porous silicon

Authors: J. N. Ximello, A. Kiss
In collaboration with: O. Tobail, M. Kurth, J. Mattheis, J. H. Werner

There is an increasing demand for light-emitting devices for displays and communication. Although there are well established technologies for light emitting diodes and semiconductor lasers, none of them can be easily integrates on silicon based CMOS chips. Hence, research is ongoing to establish silicon optoelectronic devices that overcome the drawback of silicon's indirect bandgap. The present approach uses electrochemically etched porous silicon (PS).

Porous silicon has several advantages when compared to other materials. One is that PS-Light emitting diodes could be integrated with electronics on one chip, which can perform logic operations and transmit the results directly by light. The other is that the emitting wavelength in PS can be tuned by adjusting the erosion process (electrochemical etching).

Here, we report on PS with infrared PS-photoluminescence (PL) (wavelength of around 800 nm) at room temperature. Single-crystalline p-type doped Si (100) wafers of 0.2-0.5 Ωcm resistivity are electrochemically etched in a HF solution of HF (50%) and ethanol in the ratio 3:1 by applying a current density of 10 mA/cm^2 for 5 s and then 140 mA/cm^2 for 20 s. Figure 1 shows a PL spectrum which features both, the peak from crystalline silicon at a wavelength of 1120 nm (E_g=1.12 eV) and the luminescence peak (around 800 nm) produced by the erosion process.

For surface passivation, the samples are annealed in oxygen or nitrogen atmosphere for 30 s at 850 °C. Figure 2 displays the PL spectra for a sample without annealing (solid circles) and the spectra of samples annealed in oxygen (solid squares) or nitrogen (solid triangles).

The PS annealed in nitrogen ambient shows a much more enhanced peak intensity than that of the sample annealed in oxygen ambient. The intensity of luminescence of the fresh sample was 10 to 20 times smaller. The post-annealing of PS in O_2 gas passivates the surface, but also increases the amount of silicon oxide (SiO_2) and results in a decrease of the active porous silicon. Annealing in nitrogen ambient obviously passivates the defect centers in porous silicon, hence leading to the highest PL yield.

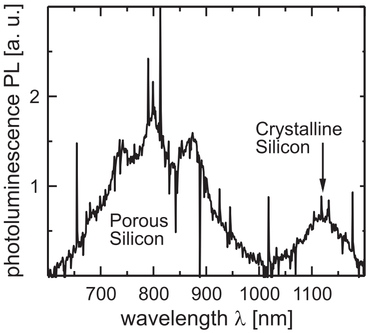

Figure 1:
Photoluminescence (PL) spectrum of porous silicon. The signal includes the peak of crystalline silicon and the peak of porous silicon.

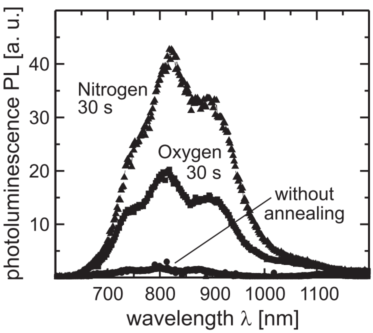

Figure 2:
Photoluminescence (PL) spectra of porous silicon annealed in O_2 ambient gas, N_2 ambient gas and not annealed. Annealing enhances the PL yield by a factor of 10 to 20.

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Das *ipe* ist Mitglied im PV-UNI-NETZ

PV-UNI-NETZ ist ein Verbund unabhängiger Hochschulprofessoren, die Photovoltaik in Forschung, Entwicklung und Lehre betreiben.

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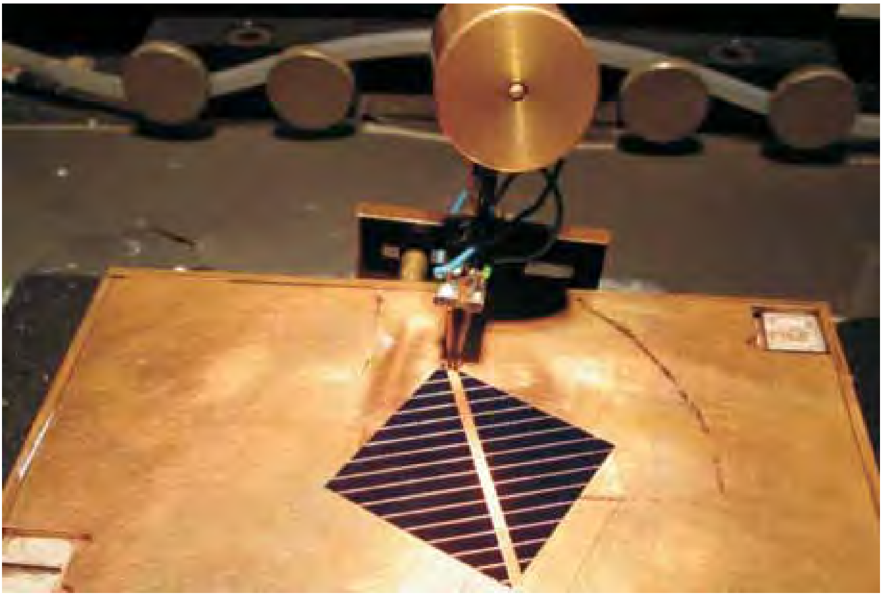
Lehrveranstaltungen
Lectures

Diplomarbeiten
Diploma Theses

Studienarbeiten
Major Term Projects

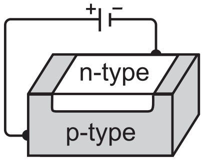
Gäste & ausländische Stipendiaten
Guests

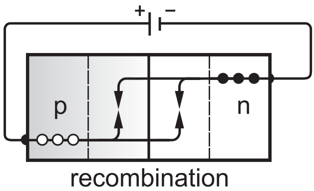


Lehrveranstaltungen
Lectures

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



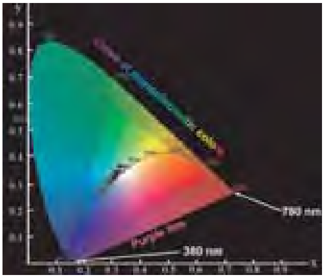


Energiewandlung (6. / 8. Semester)

Grundlagen der Kernenergie
Thermodynamik
Direkte Nutzung der Sonnenenergie (Solarthermie, Photovoltaik)
Indirekte Nutzung der Sonnenenergie (Wasserkraft, Windenergie)
Chemische Wandlung und Speicherung elektrischer Energie

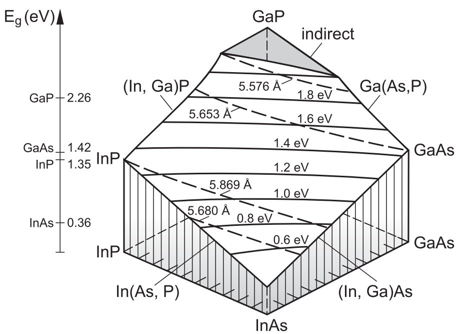
Laser and Light Sources (5. / 7. Semester)

The Human Eye
Light and Color
Photometry
Incoherent Light Sources
Light Emitting Diodes
Lasers



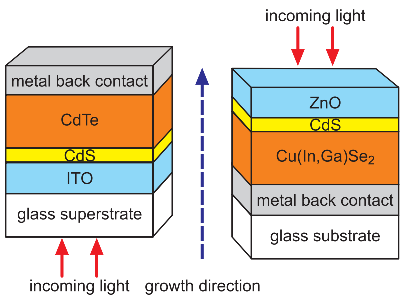
Optoelectronic Devices and Circuits I (6. / 8. Semester)

Basic physics
Thermal radiation
Coherence
Semiconductor basics
Excitation and recombination processes in semiconductors
Light emitting diodes
Semiconductor lasers
Glass fibers
Photodetectors



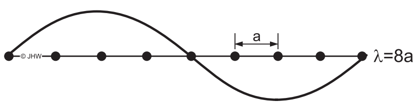
Photovoltaics (6. / 8. Semester)

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



Diplomarbeiten
Diploma Theses / Master Theses

Jens Armbruster
Verschaltungselektronik für integrierte Photovoltaik

Christian Ehling
Charakterisierung von laserinduzierten Defekten

Florian Einsele
Triiodid-Diffusion in ionischen Flüssigkeiten für Farbstoffsolarzellen

Sebastian Eisele
Interdigitated Back Contact-Solarzelle

Victor Garcia Garcia
Textured Laser Processed Solar Cells

Claudia Gatzert
Laser Applications for the Processing of Back Contact Solar Cells

Matthias Geiger
Highly Phosphorous Doped Emitter for Crystalline Silicon Solar Cells

Thomas Kirchartz
Reciprocity between Electroluminescent and Photovoltaic Action of Solar Cells - Theory and Experiments

Johannes Maier
Gesputterte und aus der Gasphase abgeschiedene a-Si:H-Schichten für a-Sie:H/c-Si-Heterosolarzellen

Thomas Rabe
Photovoltaische Spannungsversorgung von Ultraschallsendern und Fernsteuerungen

Jesús Rebollar
Preparation and Characterization of Photonic Layers based on Silicon-Oxynitrides

Osama Tobail
Analyse der Verluste in Cu(In,Ga)Se_2-Solarzellen

Armin Werneth
Photodioden mit hoher spektraler Selektivität für die Bioanalystik

Studienarbeiten
Major Term Projects

Michael Benzinger
Weiterentwicklung eines mobilen Messgeräts für Strom-/Spannungs-kennlinien von Solarzellen (iu-mobil)

Günter Fritsch
Aufbau und Charakterisierung von Ladeelektroniken für integrierte Photovoltaik

Marion Hanstein
Niedertemperaturkontaktierung von Silizium

Astrid Kiss
Leuchtendes Silizium - Herstellung und Vermessung

Stafan Klingbeil
Charakterisierung von laserbestrahltem Phosphorglas für Solarzellen

Gisbert Krauter
Entwurf, Simulation und Aufbau eines Tiefsetzstellers mit Pulsweitenmodulation

Gäste & ausländische Stipendiaten
Guests

Anas Al Tarabsheh
Jordan University of Science and Technology, Jordanien, seit 1.03.03

Adnan Al Shariah
Dept. of Applied Physics, Jordan University of Science and Technology (JUST), Jordanien, vom 17.06. - 6.09.06

Ainhoa Esturo-Bretón
UPV-Universidad del Pais Vasco, Spanien, seit 01.12.2001

Ahmed Samir Garamoun
Universität Cairo, Ägypten, vom 01.07. - 30.09.06

Caroline Karlsson
Göteborgs Universitat, Schweden, seit 1.03.03

Daria Panchuk
Lomonosov Moscow State University, Russland, vom 01.06. - 31.08.06

Osama Tobail
Arab Academy for Science and Technology & Maritime Transport, Alexandria, Ägypten, seit 01.07.03

Zhengjue Wu
Zhejiang University, Hangzhou, China, vom 01.10. - 31.12.06

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

Mitarbeiterliste
Staff Members

Lageplan
Location Map

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

Sommerhitze - ideal für Wandlung von Energie (und Kalorie)

Die diesjährigen Ergebnisse der Vorlesung „Energiewandlung" konnten im Rahmen des *ipe*-Sommerfestes bewundert werden. Außerordentlich kreative Ideen, in Verbindung mit neu erworbenen Grundlagen aus der Vorlesung, ergaben ungewöhnliche Geräte wie eine Essigbatterie, neben der klassischen Parabolschüssel zur Bündelung von Sonnenenergie zu kulinarischen Zwecken. So versammelten sich die *ipe*-Studenten und Mitarbeiter mit Familienangehörigen zum informellen Sommergrillfest, das nur von einem Wolkenbruch gestört wurde.

Zypern - Ganz weit weg und doch so projektnah

Schon lange existieren Kontakte zwischen dem *ipe* und Zypern, wo vor einiger Zeit ein Kooperationsprojekt mit der dortigen Universität ins Leben gerufen wurde. Im Frühjahr reiste eine mehrköpfige Stuttgarter Delegation nach Nicosia, wo sie hochrangige Wirtschafts- und Regierungsvertreter zu Gesprächen traf.

Like Ice in the Sunshine

This year, the results of the lecture ”Energy Conversion” could be admired during the *ipe*-Summer Barbecue Party. Combined with freshly applied knowledge from the lecture, exceptional creative ideas resulted in very orginial devices and appliances. The *ipe*-staff and family members were then invited to share a nice afternoon, the only disturbance being a thunderstorm bringing some refreshment.

Cyprus - Far Away and Close Anyway

For some time now, *ipe* has maintained good contacts with the Cyprus University and official authorities, initiating a cooperation project between Cyprus, Egypt and Germany (University of Stuttgart). A prominent Stuttgart delegation travelled to Nicosia in the spring in order to meet high-ranking local authorities.

Konferenz unter eigener Führung - Polyse 2006

Zum neunten und letzten Mal wurde die Konferenz „Polyse" von Jürgen Werner und Horst Strunk veranstaltet, die im zahlenmäßig idealen wissenschaftlichen Kreis und umgeben vom herrlichen Schwarzwald-Panorama in Freudenstadt-Lauterbad stattfand. Das außerordentliche Engagement des *ipe*-Teams trug großen Anteil an der Zufriedenheit und dem Erfolg der Veranstaltung bei. Danke an alle Helfer!

Silicon Forest - in Deutschland?

Schon mal was von Silicon Forest im Schwarzwald gehört? Jährlich treffen sich bundesweit Doktoranden, die auf dem Gebiet der Silizium-Forschung tätig sind, um sich wissenschaftlich und informell auszutauschen. Zahlreiche *ipe*-Doktoranden nutzen die Gelegenheit, um Kontakte zu knüpfen, Anregungen mit nach Hause zu nehmen, aber auch, um die Wintersportverhältnisse auszunutzen.

Polyse 2006 - For the Last Time

The final conference "Polyse" took place in Freudenstadt-Lauterbad, Black Forest, within beautiful surroundings, and under the guidance of Jürgen Werner and Horst Strunk. With an ideal number of participants, scientific exchange took place on a very high level. The outstanding dedication of the *ipe*-staff members very much contributed to the success of the conference and to the complete satisfaction of the participants.

Silicon Forest in Germany?

Once a year, German PhD-students working in the area of silicon research meet in order to exchange ideas and expert knowledge, but also to build up a network between each other. This time, the meeting took place in the Black Forest, with the advantage that the surroundings offered some winter sports facilities as a balance to mental work.

Tor!

Was wäre 2006 ohne die Fußball-Weltmeisterschaft? Da am Institut zahlreiche Nationen vertreten sind, wurde nach Feierabend gemeinsam gejubelt, angefeuert oder über Enttäuschungen hinweggetröstet. Den ganzen Monat hindurch konnten eifrig interne *ipe*-Wetten abgeschlossen werden und - es gab durchaus optimistisch-realistische Gewinner.

Das Wandern ist des *ipe*'lers Lust

Lange ist's her, dass das *ipe*-Team zum Wandertag geladen wurde. Unter der fachkundigen Führung von Julian und Hintergrundscoaching von Brigitte ging's nach einer informativen Institutsversammlung in Richtung Remstal, wo die Strapazen der ungewöhnlichen körperlichen Anstrengung (im Vergleich zur üblichen Kopfarbeit) während einer Weinprobe gestillt werden konnte.

Goal!

The German year 2006 is unthinkable without the Soccer World Championship. Being an institute with international staff members, soccer fans met after work to watch the games together, everyone cheering, trembling or exulting with their favourite team.

***ipe*-Staff on Hiking Tour**

It has been a while that the institute had organized a hiking tour in the nearby surroundings. Under the guidance of Julian, the *ipe*-team went off after an institute talk to discover the Remstal north of Stuttgart, where the efforts were rewarded with a wine-tasting in between vineyards.

Herzlichen Glückwunsch!
Jürgen Köhler kann stolz auf 25 Jahre Universitätsdienst zurückschauen, wozu ihm das Institut recht herzlich gratuliert und wünscht, dass er mindestens nochmal so lange sein Wissen hier einbringen wird.

Gerhard Bilger lud zum großen Fest ein, an dem die begeisterten *ipe*'ler Original-Schweizerkäse zusammen mit einem edlen Tropfen „degustieren" konnten. Die gemütliche Dekoration kann als bisher ungeschlagen betrachtet werden!

Congratulations!
For Jürgen Köhler's 25th anniversary, the *ipe*-staff raised a glass (of champagne), congratulating and wishing him to stay at least as long in the future, in order to keep things going.

Gerhard Bilger invited the thrilled *ipe*-staff to taste excellent and original Swiss cheese together with a glass of good wine. Thank you Gerhard and our best wishes for the next years.

Mitarbeiterliste
Staff Members

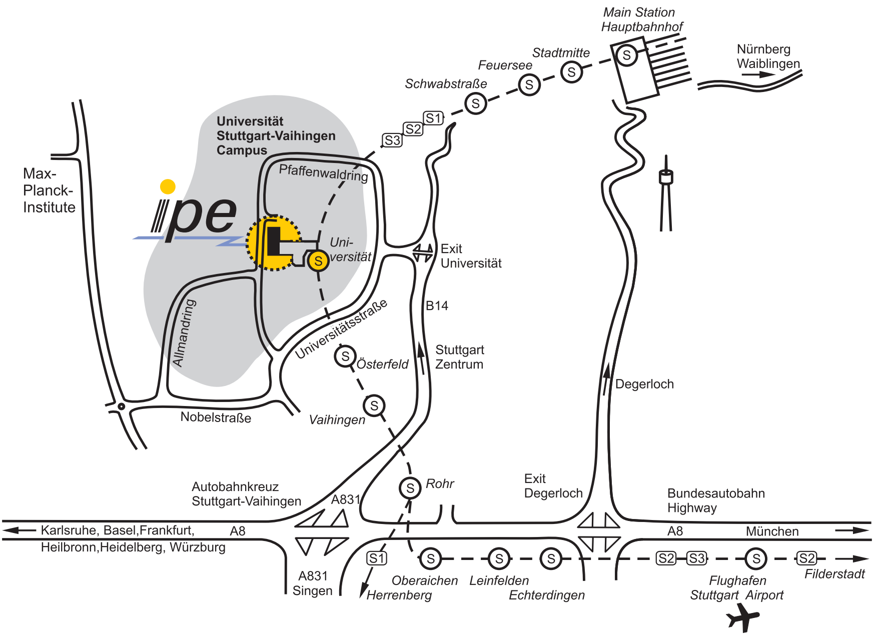
Name	Titel	Telefon 0711 - 6856 - ...	E-Mail ... @ipe.uni-suttgart.de	Arbeitsgebiet
Al Tarabsheh, Anas Ibrahim	M. Sc.	7179	anas.al-tarabsheh	Optimierung und Charakterisierung von amorphen Silicium-Solarzellen
Ametowobla, Mawuli	Dipl.-Ing.	7160	mawuli.ametowobla	Laserprozessierung von Silicium-Solarzellen
Bauer, Leo		7182	leo.bauer	Metallisierung, Photoarbeiten, Maskentechnik
Bilger, Gerhard	Dr.-Ing.	7176, 7154	gerhard.bilger	Oberflächenanalytik mit SIMS und XPS; Technologie Support
Brenner, Klaus	Dipl.-Ing. (FH)	7201	klaus.brenner	Technologische Infrastruktur und Prozesse der Si-Technologie
Carlsson, Caroline	M. Sc.	7160	caroline.carlsson	Laserprozessierung von Silicium-Solarzellen
Einsele, Florian	Dipl.-Ing.	9219	florian.einsele	Bauelemente
Esturo-Bretón, Ainhoa	M. Sc.	7169	ainhoa.esturo-breton	Laserprozessierung von Silicium-Solarzellen
Hansel, Rusudan	M. Sc.	9213	rusudan.hansel	Bauelemente
Kessler, Isabel	M. A.	7141	isabel.kessler	Sekretariat, Verwaltung
Khlyap, Halyna	PhD	9225	halyna.khlyap	Laserprozesse

Kirchhartz, Thomas	Dipl.-Ing.	9218	thomas.kirchhartz	Bauelemente
Köhler, Christiane	Dipl.-Phys.	7182	christiane.koehler	Si-Niedertemperaturtechnologie, XRD, transparente Kontakte, Ramanstreuung
Köhler, Jürgen	Dr.-Ing.	7159	juergen.koehler	Laser Annealing,Verwaltung
Kurth, Matthias	Dr. rer. nat.	7142	matthias.kurth	Temperatur- und leistungsabhängige Photolumineszenz-Messungen an Halbleitern
Laptev, Viktor	Dr. rer. nat.	7197	viktor.laptev	Chemische Schichtabscheidung, Röntgenbeugungsmessungen
Lutz, Brigitte		7200	brigitte.lutz	Analytik, Elektrochemie, GCMS
Merz, Rainer	Dipl.-Ing.	7184	rainer.merz	Solalrzellen und Module für integrierte Photovoltaik
Moutchnik, Galina	Dipl.-Ing.	7163	galina.moutchnik	Laserprozesse
Prönneke, Liv	Dipl.-Phys.	7180	liv.proenneke	Bauelemente
Rau, Uwe	Dr. rer. nat. habil.	7199	uwe.rau	Elektr. Charakterisierung und Modellierung von Dünnschichtsolarzellen (CIGS, Si, org.)
Reuter, Michael	Dipl.-Ing.	7168	michael.reuter	Einseitig kontaktierte Solarzellen
Riß, Anton		7214	anton.riss	Werkstatt
Rostan, Johannes	Dipl.-Ing.	7179	hannes.rostan	Amorphe/kristalline Si-Heterostrukturen

Schlegel, Peter	Dipl.-Ing. (FH)	70106	peter.schlegel	Laserprozesse
Schmitt, Wolfgang	Dr.-Ing.	7171	wolfgang.schmitt	Photovoltaische System-technik, Leistungselektronik
Schubert, Markus	Dr.-Ing.	7145	markus.schubert	Projektleiter amorphes und nanokristallines Si, Solar-zellen mit Sensoren,Studien- und Diplomarbeiten, www
Tobail, Osama	Dipl.-Phys.	7183	osama.tobail	Verlustanalyse von CIGS-Solarzellen
v. Rekowski, Christine	Dr. phil.	7141	christine.rekowski	Sekretariat, Verwaltung
Werner, Jürgen	Prof. Dr. rer. nat. habil.	7140	juergen.werner	Institutsleiter, Leitung der Forschung, Lehre, Verwaltung
Wille, Werner		7158	werner.wille	Buchhaltung, Verwaltung
Winter, Birgitt	Dipl.-Ing.	7162	birgitt.winter	Technologie kristalliner Si-Solarzellen
Ximello, Nestor	M. Sc.	9224	nestor.ximello	Photovoltaik
Zinßer, Bastian	Dipl.-Ing.	7170	bastian.zinsser	Jahresenergieerträge verschiedener Photovoltaik-Technologien

Stand 12/06

Lageplan
Location Plan



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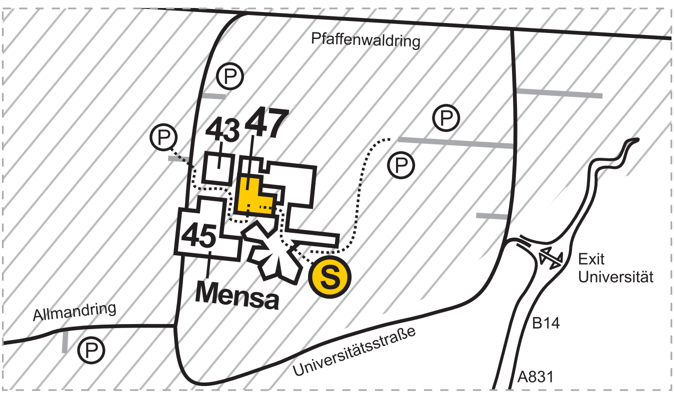

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