Jahresbericht *Annual Report* 2004

Redaktion • edited by:

Lydia Diegel
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Vorwort

Liebe Freunde des *ipe*,

der Jahresbericht 2004 ist gegenüber seinen Vorgängern nochmals gestrafft und in seiner Form modernisiert, um noch besser über Menschen, Forschung und Lehre am *ipe* zu berichten.

Das Jahr 2004 war spannend, und es brachte Veränderungen. Ich erhielt einen Ruf an die Universität Hannover, der mit der Leitung des Instituts für Solarenergieforschung in Hameln verbunden war. Es wäre äußerst attraktiv gewesen, die erstklassige Arbeit von Professor Hezel weiter zu führen. Dennoch habe ich nach reichlicher Überlegung das Angebot abgelehnt und beschlossen, meine Arbeit mit jungen Studenten und Doktoranden am *ipe* in einer internationalen Umgebung fortzusetzen.

Nach 36 Jahren am *ipe* ging Dr.-Ing. Fritz Pfisterer diesen Sommer in den wohlverdienten Unruhestand. Er hat nicht nur die Verwaltung des *ipe* über viele Jahre geleitet, sondern vor allem in der Lehre und bei der Unterstützung der jungen Forscher unschätzbare Dienste geleistet, die weit über seine Verpflichtungen hinaus gingen.

Unser Dr.-Ing. Hans-Werner Schock hat nach 30 Jahren Arbeit am *ipe* eine neue Herausforderung als Abteilungsleiter am Hahn-Meitner-Institut in Berlin angenommen, um dort an Solarzellen aus $CuInS_2$ zu forschen. Viel Glück dabei!

Ich danke ganz herzlich allen Mitarbeitern des *ipe*, insbesondere jedoch Hans-Werner Schock und Fritz Pfisterer für die loyale und erfolgreiche Zusammenarbeit.

Stuttgart, Dezember 2004

Prof. Dr. Dr. habil. Jürgen H. Werner

Preface

Dear friends of *ipe*,

compared to the past years, this annual report 2004 has been shortened and modernized to give you a better overview over the people, the research and the teaching at *ipe*.

The year 2004 was full of suspense, and it brought changes. I received the offer to lead the Institute for Solar Energy Research (ISFH) in Hameln, combined with teaching at the University of Hannover. It would have been very attractive for me to carry on with the excellent work of Professor Hezel, but upon mature consideration I decided to stay in Stuttgart, and to continue working with young students and Ph. D. candidates at *ipe* within an international environment.

Last summer, after 36 years at *ipe*, Fritz Pfisterer finally retired. He was not only responsible for all administration matters related to *ipe* for many years, but also contributed in an inestimable way to teaching and supporting young scientists, going far beyond his obligations.

After 30 years at *ipe*, Hans-Werner Schock decided to accept a new challenge as head of a department at the Hahn-Meitner-Institute in Berlin, doing research on improving $CuInS_2$ solar cells. We wish him all the best for the future!

I would like to thank the whole *ipe* staff, specially, however, Hans-Werner Schock and Fritz Pfisterer, for their loyal and successful cooperation and teamwork.

Stuttgart, December 2004

J. Werner

Prof. Dr. Dr. habil. Jürgen H. Werner


Institut für Physikalische Elektronik

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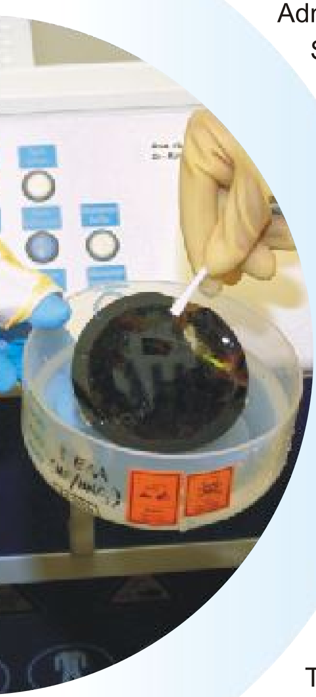
Gruppe Bauelementanalyse
Group Device Analysis

(Gruppenleiter / Group Leader: Uwe Rau)

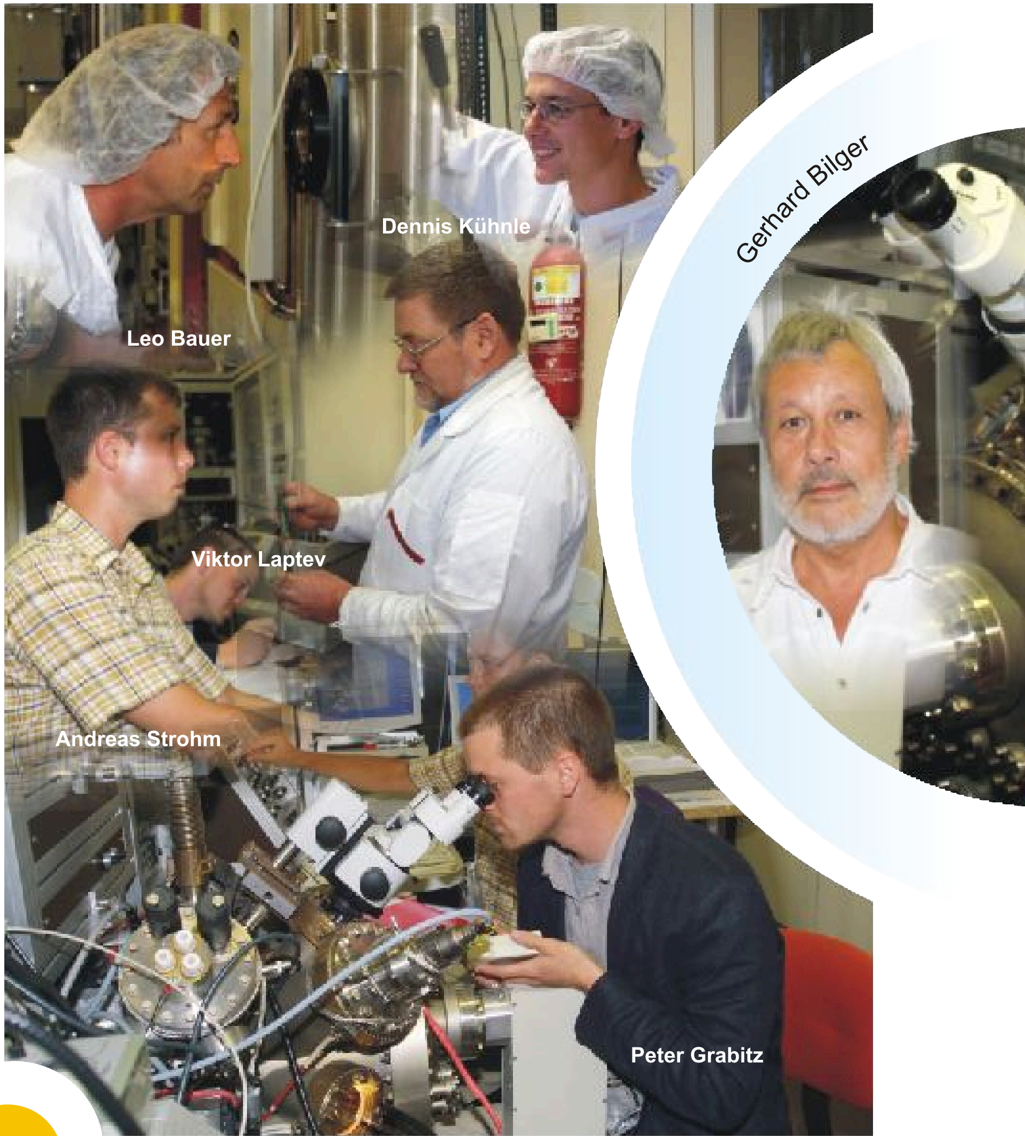
Die Gruppe „Bauelementanalyse" befasst sich mit der elektrischen und optischen Charakterisierung sowie der numerischen Simulation von Solarzellen basierend auf $CdS/Cu(In,Ga)Se_2$ und a-Si:H/c-Si Heterostrukturen, sowie mit Farbstoff-Solarzellen auf der Basis von nano-porösem TiO_2. Ziel unserer Aktivitäten ist ein grundlegendes Verständnis der Funktionsweise dieser Bauelemente, des Einflusses der Präparationsbedingungen und des Designs des Baulements auf seine Leistungsfähigkeit. Wir benutzen elektrische Analysemethoden wie Strom/Spannungs-Messungen, Admittanzspektroskopie und Transienten-Spektroskopie tiefer Störstellen (DLTS). Messungen der internen Quantenausbeute und Photolumineszenz dienen zur Untersuchung der elektro-optischen Eigenschaften der Materialien. Die experimentellen Resultate werden mit quantitativen, numerischen wie analytischen, Modellen verglichen, um ein kohärentes Verständnis der Bauelemente zu erhalten.



The "device analysis" group investigates the electrical and optical properties of solar cells based on $CdS/Cu(In,Ga)Se_2$ and a-Si:H/c-Si heterojunctions as well as dye-sensitized solar cells based on nano-porous TiO_2. We focus on a fundamental understanding of the working principle of these devices, the influence of preparation conditions and device design on the performance and, finally, on the improvement and optimization. Electrical analysis is performed with the help of current/voltage measurements, admittance spectroscopy, deep level transient spectroscopy (DLTS), and similar methods. Electro-optical analysis comprises measurements of internal quantum efficiency, optical transmittance and reflectance, photoluminescence, etc. The quantitative and coherent interpretation of these experimental results requires detailed modeling and simulation.

Gruppe CIS-Technologie
Group CIS-Technology

(Gruppenleiter / Group Leader: Gerhard Bilger)



Die Methoden der Oberflächenanalyse sind die Sekundärionen-Massenspektrometrie (SIMS) sowie die Röntgen- und Ultraviolett-Photoelektronen-Spektrometrie (XPS, UPS). Die Analytik unterstützt die Gruppen, die Forschung und Entwicklung am *ipe* betreiben. Nach außen wird die Analytik als Dienstleistungen für die Industrie und andere Institute angeboten. Als sehr empfindliche Methode weist SIMS alle Elemente und deren Verbindungen bis in den ppb-Bereich nach. XPS-Analysen, empfindlich bis in den 0,1 Atom%-Bereich, sind quantitativ und geben Auskunft über Bindungszustände der Elemente. Die extrem oberflächensensitive Methode weist noch Oberflächenbedeckungen von 1/10 einer Monolage nach. Mit UPS wird die Valenzbandstruktur von Festkörpern untersucht. Die Gruppe „CIS-Technologie" erbringt auch die routinemäßige Präparation von CIS-Solarzellen.

The methods of surface analysis are the Secondary Ion Mass Spectrometry (SIMS), X-ray- and Ultraviolet-Photoelectron Spectrometry (XPS, UPS). These methods support the work of the groups at the *ipe* involved in research and development. Analyses are also offered as a service to other institutes and to industry as well. The method SIMS is very sensitive to the detection of all elements and their compositions with concentrations down to the ppb region. The analysis technique XPS is quantitative down to a concentration of 0.1 atomic% and gives information about the chemical binding state. XPS detects surface coverages down to 1/10th of a monolayer. The method UPS is applied to study the structure of the valence band in solids. The "CIS technology" is responsible for routine preparations of thin films and the maintenance of the infrastructure necessary for it.

Gruppe Laserprozesse
Group Laser Processing

(Gruppenleiter / Group Leader: Jürgen Köhler)

Die Gruppe „Laserprozesse" entwickelt neue Verfahren zur Laserprozessierung für kristalline Silizium-Solarzellen. Hierzu zählen sowohl die Strukturierung, als auch die laserunterstützte Dotierung von Silizium-Scheiben. Die kostengünstige Herstellung von Solarzellen erfordert einfache und schnelle Einzel-Prozessschritte, die sich in einen kontinuierliche Fertigungsprozeß integrieren lassen. Bei der klassischen Herstellung von Solarzellen erzeugt ein Hochtemperaturschritt den Solarzellenemitter, welcher beide Anforderungen nicht erfüllt. Der am *ipe* entwickelte Laser-Dotierprozess erfolgt bei Zimmertemperatur unter Umgebungsbedingungen. Mit dieser Technologie hergestellte Solarzellen zeigen einen Wirkungsgrad von 15,6 %. Ziel ist, sowohl den Wirkungsgrad der hergestellten Solarzellen auf über 17 % zu steigern, als auch den Durchsatz, der sich mit kommerziell verfügbaren Lasern erzielen lässt, auf über 10 cm^2/s zu steigern.

The "laser processing" group explores new technologies for laser processing of crystalline silicon wafers for solar cell applications. Examples are laser structuring and laser assisted doping, which is our most important application. Low cost solar cell processing requires simple and fast processing steps suitable for in-line process integration. The classical emitter formation step requires high temperature processing of silicon wafers for typically 30 minutes. In most cases batch processing is utilized, which requires expensive wafer handling systems and increases risk of wafer damage. Our laser assisted doping process takes place at room temperature and does not require expensive clean room technology. First solar cells show efficiencies of 15.6 %. Our goal is to improve efficiencies to more than 17 % and to verify a throughput of more than 10 cm^2/s using commercially available laser systems.

Gruppe Silicium
Group Silicon

(Gruppenleiter / Group Leader: Markus Schubert)

Die Arbeitsgruppe „Silicium" des *ipe* entwickelt elektronische Bauelemente auf der Basis von Silicium. Dabei arbeiten wir mit allen Modifikationen des Siliciums vom einkristallinen Wafer bis zum nanokristallinen oder amorphen Film. Der Transfer einkristalliner Dünnschichten oder die direkte Abscheidung von amorphem Silicium auf Plastikfolie dienen der Herstellung flexibler Solarzellen, welche als „integrierte Photovoltaik" (*ipv*) in Kleidung integriert werden können und damit mobile elektrische Energie zum Betrieb elektronischer Kleingeräte bereit stellen. Wafertechnologie und Dünnschichttechnik unterstützen und befruchten sich gegenseitig, zum Beispiel bei der Entwicklung von „Thin-Film-on-CMOS"-Kameras für Sternsensoren und Endoskope, die in Kooperation mit dem Institut für Mikroelektronik Stuttgart (ims-chips) erfolgt.

The "silicon" group at *ipe* develops electronic devices based on silicon. We employ all modifications of silicon, from single-crystalline wafers to nanocrystalline as well as amorphous films. The transfer of single-crystalline thin films to plastic substrates, or the direct deposition of amorphous silicon onto polymer foils enable the manufacturing of mechanically flexible solar cells. Integrating such cells with clothing constitutes "Integrated Photovoltaics" (*ipv*) which provides mobile electric power for communication and entertainment devices. Wafer-based technology and thin film processing mutually enhance each other, e.g. in developing "Thin-Film-on-CMOS" cameras for star sensors and endoscopes, in close cooperation with the Institute of Microelectronics Stuttgart (ims-chips).

Gruppe Verbindungshalbleiterschichten (CIS)
Group Compound Film Semiconductors (CIS)

(Gruppenleiter / Group Leader: Hans-Werner Schock)

Die Gruppe „Verbindungshalbleiterschichten" entwickelt Dünnschichtsolarzellen mit Heterostrukturen aus ternären Halbleiterverbindungen wie $CuInSe_2$ (CIS) und verwandten Materialien. Herstellungsverfahren für die Dünnschichten sind eigens hierfür entwickelte Aufdampf- und Sputterprozesse. Hilfsmittel zur Analyse der Schichten und der Heterostrukturen sind Photoelektronenspektroskopie, Rasterelektronenmikroskopie sowie Röntgenspektroskopie und Röntgenbeugung. Entwicklungsziele sind die Steigerung der Effizienz der Solarzellen auf 20 %, die Weiterentwicklung von Solarzellen aus Verbindungen mit Bandabständen größer als 1,3 eV und entsprechend hoher Leerlaufspannung, die Optimierung von Cd-freien Frontelektroden. Forschungsthemen sind die generellen Eigenschaften von komplexen Verbindungshalbleitern, insbesondere die Zusammenhänge zwischen Eigendefekten, Verunreinigungen und elektrischen und optischen Eigenschaften.

The "Compound Semiconductor" Films group investigates thin film solar cells based on ternary compound semiconductors such as $CuInSe_2$ and related compounds. For the deposition of thin films, special co-evaporation and sputtering processes are designed. Main tools for the optimization of heterostructures are photoelectron spectroscopy, scanning electron microscopy, as well as X-ray spectroscopy and X-ray diffraction. Goals of the developments are solar cells with an efficiency of about 20 %, the improvement of solar cells with band gaps in excess of 1.3 eV for high-voltage cells and the optimization of Cd-free front electrodes. Topics for research are the general properties of complex compound semiconductors, in particular the relations between native defects, impurities, and the electrical and optical properties.

Kristallines Silicium

Farbstoffzellen

Verbindungshalbleiter

amorphes Silicium

Wissenschaftliche Beiträge
Scientific Contributions

2

Publikationen
Publications

Laser Doped Monocrystalline Solar Cell Emitters

Author: A. Esturo-Breton
In collaboration with: J. R. Köhler, J. H. Werner

Low temperature processing of monocrystalline or polycrystalline silicon solar cells has the potential to lower the production costs of state of the art high temperature solar cell processing. Laser processing does not require expensive equipment and may be competitive, if the throughput can be scaled to a range high enough for in-line processing.

We investigate a pulsed-laser based doping technique for monocrystalline silicon wafers. Spin-coating of a phosphor containing doping liquid results in a thin doping layer at the surface of silicon wafers. The focus of a 25 ns pulsed 532 nm frequency doubled Nd:YVO_4-laser melts a thin layer of silicon. Phosphor atoms from the doping layer diffuse into the liquid silicon. Rapid cooling of the melt after the laser pulse induces epitaxial growth of the phosphorous doped silicon on the surface of the p-type crystalline silicon wafer.

By this method we produce pn-junctions cells up to 16 % efficiency with highly P-doped emitters. The doping process takes place if the laser pulse density E_p exceeds the threshold value E_{th} = 1.2 J/cm^2 needed to melt the silicon. The sheet resistance ρ_s is inversely proportional to the laser pulse density E_p according to ρ_s [$\Omega/\square$] = C (E_p [J/cm^2] – 1.2)$^{-1}$ as shown in Fig.1. The thickness d_e of the phosphorous doped layer increases linearly with laser pulse energy density E_p as shown by SIMS measurements, whereas the measured doping concentration is nearly independent of E_p. These findings allow us to easily control the sheet resistance ρ_s and thickness de of the emitter with the laser pulse energy density E_p.

This laser-doping process is useful for the production of 4 cm^2 sized solar cells on a 350 µm thick boron doped FZ-wafer with a resistivity ρ = 0.35 Ωcm. The characterization of the solar cells shows, that an increase in the emitter thickness d_e reduces the internal quantum efficiency *IQE* of the solar cells in the short wavelength regime. We control the *IQE* of the solar cells with the pulse energy density E_p, which directly determines the emitter thickness d_e. Figure 2 shows the reduction of the *IQE* in the short wavelength regime if the pulse energy density E_p is increased.

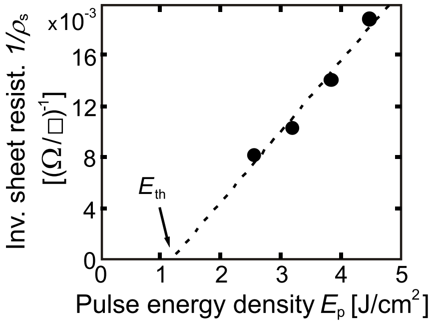


Figure 1:
The sheet resistance ρ_s of laser doped emitters decrease inversely proportional with the laser pulse energy density E_p. A threshold energy of E_{th} = 12 J/cm^2 is necessary to melt the silicon.

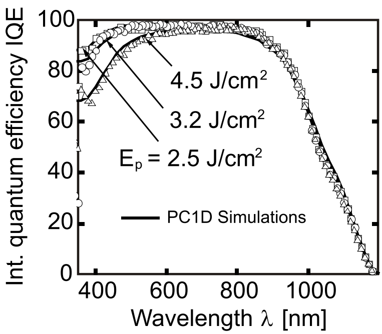


Figure 2:
Internal quantum efficiency *IQE* of 2×2 cm^2 solar cells with laser doped n-emitter. An increase in the pulse energy density E_p reduces the *IQE* in the short wavelength regime. Best cells of monocrystalline Si have efficiencies up to 16 %.

Grain Boundary Effects in $Cu(In,Ga)Se_2$ Solar Cells

Author: K. Taretto
In collaboration with: U. Rau, J. H. Werner

The grain size *g* of polycrystalline absorber $Cu(In,Ga)Se_2$ (CIGS) films for solar cells hardly exceeds the film thickness *d* of typically *d* = 1.5 - 2 µm. It is intuitively clear that the electronic activity of the grain boundaries (GBs) in such a situation is a much more critical parameter than it is, e.g., in multi-crystalline Si solar cells with *g* being of the order of *g* = 5 - 10 mm and an absorber thickness *d* = 300 - 500 µm. Despite of the importance of GB effects on polycrystalline CIGS, all numerical simulations up to now were based on one-dimensional model assumptions and, therefore, disregard the two- or three-dimensional effect of GBs in this material.

Our recent work [1] presents first results from two-dimensional simulations of polycrystalline CIGS using a numerical approach that was applied earlier for the simulation of microcrystalline Si [2] and is now adapted to the situation of CIGS. In the following, we restrict ourselves to columnar grains with a width *g* = 2 µm and a CIGS film thickness *d* = 2 µm.

Figure 1 shows the dependence of the efficiency on the concentration N_{it} of the interface defect at 270 meV (full symbols) or 550 meV (open symbols). The assumption of a defect concentration $N_{bt} = 1\times10^{14}$ cm^{-3} in the grain interior yields $\eta = 21.7$ % for $N_{it} = 0$, i.e., a value well above the current record efficiency $\eta = 19.2$ % [3]. However, increasing the defect concentration N_{it} at the GBs to a maximum value of $N_{it} = 4\times10^{11}$ cm^{-2} decreases the efficiency by 5 - 11 % absolute, depending on the defect energy and capture cross section, the lowest calculated efficiency being $\eta = 10.7$ %.

Thus, we have demonstrated that the electronic activity of GBs is able to determine the photovoltaic output power within a wide range of relevant efficiencies, i.e., a range that covers the best laboratory results as well as cell efficiencies that stem from less sophisticated absorber growth processes.

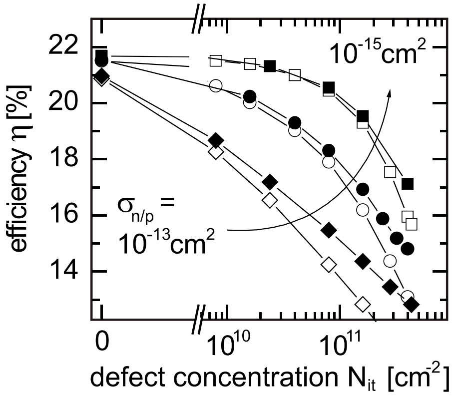


Figure 1:
Simulated dependence of the efficiency η on the defect concentration N_{it} at the grain boundaries (GB) of a polycrystalline CIGS film with grain size g = 2 µm and thickness d = 2 µm. The defects have an energy E_t = 270 meV (full symbols) or 550 meV (open symbols) above the valence band. Capture cross sections $\sigma_{n/p}$ for electrons and holes are σ_n = σ_p = $10^{-13}/10^{-14}/10^{-15}$ cm^2 (diamonds, circles, squares).

References:

[1] K. Taretto, U. Rau, and J. H. Werner, Thin Solid Films (in print)

[2] K. Taretto, U. Rau, J. H. Werner, Solid State Phenomena **80**, 311 (2001)

[3] K. Ramanathan, M. A. Contreras, C. L. Perkins, S. Asher, F. S. Hasoon, J. Keane, D. Young, M. Romero, W. Metzger, R. Noufi, J. Ward, A. Duda, Progr. Photovolt.: Res. Appl. **11**, 225 (2003)

Thin Film Monocrystalline Silicon for CMOS Devices

Author: C. Berge
In collaboration with: M. Zhu, M. B. Schubert, W. Appel (ims-chips Stuttgart)

The fabrication of thin monocrystalline silicon films of high electronic quality by transfer of epitaxial layers from a host wafer to arbitrary substrates has been investigated in detail at the *ipe* during the last years. The suitability of the transfer approach for fabricating silicon thin film solar cells has been convincingly demonstrated by record cell efficiencies of more than 16 % on glass and close to 15 % on flexible plastic foils [1].

Recently, the suitability of transfer layers for the fabrication of CMOS devices was investigated in close collaboration with the Institut für Mikroelektronik Stuttgart (ims-chips) in the frame of the TransSi project. The use of transfer layers for CMOS fabrication would enable the only known way of fabricating thin CMOS devices without mechanical wafer thinning, thus avoiding a strongly yield-reducing process in chip fabrication.

In first experiments, the CMOS process established at ims-chips proved much more demanding than the solar cell processing sequence with respect to the mechanical stability of the transfer layers. Main reason for the need of higher stability is mechanical stress introduced by the masking layers used in microelectronics. The bending of the layers caused by the mechanical stress is responsible for breaking the layer due to inhomogeneous mechanical characteristics of the separation layer. These first experiments clearly indicated that ways for increasing the layer stability have to be found as well as means for increasing the etching homogeneity.

Necessary modifications of the etching cell geometry used for separaton layer formation to obtain more homogeneous mechanical layer characteristics were derived by finite element numerical modeling. To further increase the stability of the transfer layers, on some wafers the etched region was limited to 3 cm in diameter by use of a plastic mask during separation layer formation. Wafers prepared in this way displayed no breakage after the first masking step and therefore underwent a complete 0.8 µm CMOS process.

At the moment of the printing of this report, the CMOS process is finished, and functionality checks on wafer level show a functionality yield of slightly above 50 %, which for a first run is more than could be expected. Figure 1 shows a yield measurement with black squares corresponding to checked working devices. Further work currently concentrates on developing and optimizing the process of decollating the single chips and package mounting.

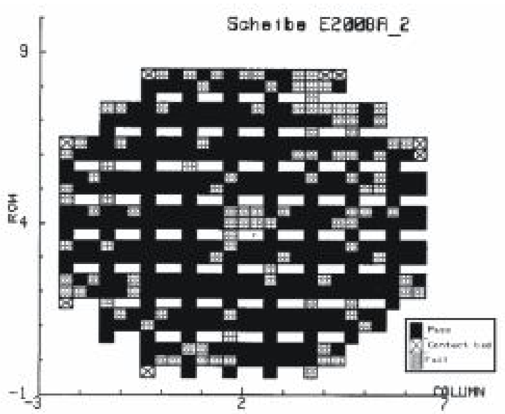


Figure 1:
Yield image (screen shot) of the functionality check on wafer level before decollation and transfer. The overall yield is slightly above 50 %. Black squares indicate checked working devices, whereas patterned squares indicate checked devices that failed the functionality test.

References:

[1] C. Berge, T. A. Wagner, W. Brendle, C. Craff-Castillo, M. B. Schubert, J. H. Werner, Mat. Res. Soc. Symp. Proc. **769**, H2.7.1-6 (2003)

Non-Stoichiometric Silicon-Nitride as a Diffusion Barrier

Author: G. Bilger
In collaboration with: A. Strohm

Nitrogen as a reactant in the preparation process of amorphous silicon thin film layers by sputtering not only dopes the silicon if added in low doses to the sputtering gas [1] but also gradually widens the band gap up to an insulator. It is well known that Si_3N_4 is transparent with a band gap of 4.5 eV and acts traditionally as a diffusion barrier in various thin film layer systems. Here we report on Si-rich non-stoichiometric $Si_{3+x}N_{4-x}$ layers with extremely low diffusion coefficients. Thin films $Si_{3+x}N_{4-x}$ pre-annealed at 1050°C block the diffusion of Au and Ge up to 869°C and 936°C, respectively [2].

In 2004, at the cyclotron in Jyväskylä (Finland) we could prove that the blocking behavior of these films holds also for Si up to a temperature of 1050°C (Fig. 1). At higher temperatures, the diffusivities increase to 10^{-17} m^2/s for Au, 10^{-19} m^2/s for Ge, and $2x10^{-18}$ m^2/s for Si. Figure 2 shows that thin, however not pre-annealed $Si_{3+x}N_{4-x}$ layers, act as diffusion barriers and avoid the incorporation of substrate elements like Fe in $Cu(In,Ga)Se_2$-layers prepared as absorber for solar cells on steel foils. Secondary ion mass spectrometry (SIMS) depth profiles across the absorber layer and the Mo back contact into the substrate reveal that without a $Si_{3+x}N_{4-x}$ barrier the Fe concentration exceeds 5 at.-%, which is lethal to the semiconductor (Fig. 2a), whereas a $Si_{3+x}N_{4-x}$ barrier layer in between the substrate and the Mo back contact reduces the Fe concentration by three orders of magnitude (Fig. 2b). Pre-annealed $Si_{3+x}N_{4-x}$ barrier layers presumably show concentration levels which are well beyond the detection limit of the SIMS system and not further harmful to the semiconductor. Due to the extremely good blocking characteristics of the nonstoichiometric silicon-nitride layers they may surely receive acceptance as diffusion barriers in a variety of applications.

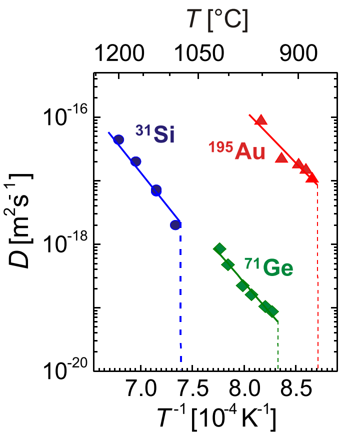


Figure 1:
Arrhenius diagrams of the diffusion coefficients D for Au, Ge, and Si in Si_4N_3. The dashed lines indicate the onset where the diffusion drops to immeasurably small values. The diffusion coefficients are determined with radiotracers implanted into the sample. After annealing, the sample is sputter-sectioned. The sputtered-off material of each section is collected on a foil. The diffusion curve is then put together by the radioactive tracer count rate of each foil.

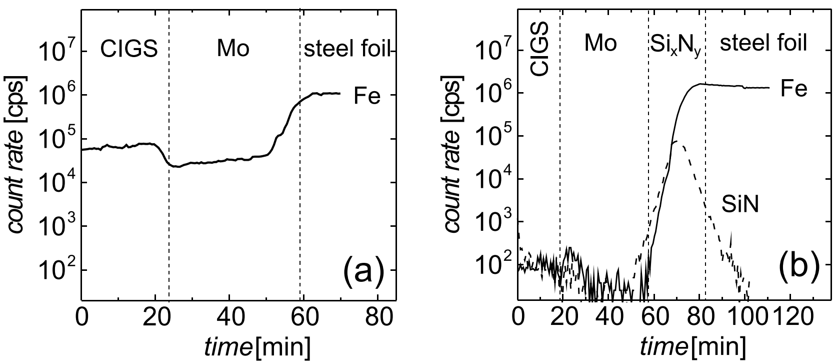


Figure 2:
SIMS depth profiles of Fe in the CIGS absorber and the Mo back contact a) without and b) with a Si_4N_3 barrier layer on the steel substrate.

References:

[1] G. Bilger, Präparation und Dotierung von amorphem Silizium durch die Kathodenzerstäubung, Dissertation (Universität Stuttgart, 1992)

[2] T. Voss, S. Matic, A. Strohm, W. Frank, G. Bilger, Physica B **308-310**, 431 (2001)

Implementation of a Stable High Efficiency Reference Process for Silicon Solar Cells

Authors: K. Brenner, C. Berge
In collaboration with: B. Lutz, M. Zhu, M. B. Schubert, J. H. Werner

The development, evaluation and optimization of cell processing schemes and cell designs especially suited for thin films (transfer silicon) and new silicon materials is the main research objective of the "silicon" and the "laser processing" group. Such investigations are possible only if reference processing steps are stable on a high efficiency level. This requirement demands a highly reliable yet simple high efficiency pn-junction reference process to distinguish between process technology restrictions and material limits.

One working package of the Si group during the last year consisted in establishing such a stable high efficiency process using the new 150 mm processing equipment acquired during the last one and a half years. The present reference cell design for this purpose is a compromise between desired high efficiency and simple processing sequences. The design incorporates an alkaline random pyramid surface texture with a pyramid base length of 2 to 5 µm, an oxide-passivated single-stage emitter, evaporated Ti/Pd/Ag contacts formed by lift-off on the front side, and an oxide-passivated back side with aluminum point contacts. The process requires three lithography steps, two oxidations, one diffusion, and two metal evaporation steps.

During the last four solar cell batches, the achieved efficiency on 0.8 Ωcm FZ silicon with polished front- and backside was stable well above 18 % (measured at *ipe* under AM1.5G illumination with mask, 4 cm^2 aperture area) with open circuit voltages V_{OC} > 660 mV. Figure 1 shows the efficiencies of 28 cells with 4 cm^2 on seven wafers from a series of four batches in a row: Figure 2 shows an exemplary current/voltage curve (cell number 25 from Fig. 1).

The low deviations from cell to cell within one wafer as well as from wafer to wafer within one batch and the high batch-to-batch reproducibility make the process suitable as a reference process. Such a reference process is needed for evaluation of new front- and backside processing schemes as well as investigations of innovative processes developed specifically for new silicon materials, and enables processing of thin film transfer silicon solar cells with good front side characteristics.

As a next step, the introduction of a double-diffused emitter process for even higher efficiencies is currently in progress. This design requires additional processing steps - at least one lithography and one diffusion step - as well as a complete re-optimization of the diffusion parameters.

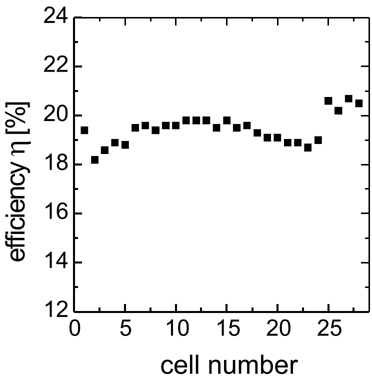


Figure 1:
Solar cell efficiencies on 0.8 Ωcm FZ Si obtained from seven 6"-wafers (4 cells per wafer) from the last four solar cell batches, measured at *ipe* under AM1.5G illumination with shading mask. Cell area is 4 cm^2.

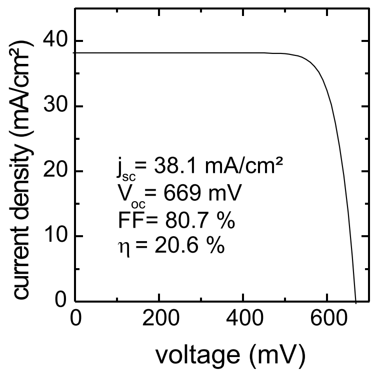


Figure 2:
Current voltage/curve of cell number 25 from Fig 1 measured at *ipe*. The cell's photovoltaic parameters short circuit current density j_{SC}, open circuit voltage V_{OC}, fill factor *FF*, and efficiency η are given in the figure.

Flexible Si Solar Cells on Plastics for Clothing Integration

Author: Y. Ishikawa
In collaboration with: M. Schubert, J. H. Werner

Solar cells on plastics such as PET(Polyethylene-terephthalate) must be fabricated at temperatures T < 110 °C due to the low melting point of this plastic material. Unfortunately, conventional amorphous Si (*a*-Si:H) contains too many defects after such a low temperature deposition and thus has poor electronic properties. In order to fulfill the requirements of low temperature deposition and high material quality, we use a protocrystalline Si (*pc*-Si:H) phase which exists at the transition edge between *a*-Si:H and microcrystalline Si (*μc*-Si:H). Compared to *a*-Si:H, such protocrystalline films should not only have higher electronic quality but also less degradation during light soaking.

The conductivity data of Fig. 1 show the transition behavior of intrinsic amorphous Si layers; the deposition temperature is 110 °C. The photoconductivity σ_{Ph} varies only slightly with the hydrogen dilution R. However, the dark conductivity σ_d increases significantly at $R > 17$, since the deposited material changed to *μc*-Si:H. Therefore, the photosensitivity σ_{Ph}/σ_d takes a maximum at $R = 17$. At this same point of R, the absorption coefficient α (for radiation of 1.2 eV derived from constant photocurrent measurements) takes a minimum of $\alpha \approx 5$ cm^{-1} (data not shown). These values indicate a high material quality for $R = 17$.

Pin-type solar cells on ZnO:Al coated glass substrates are fabricated using the same materials as those in Fig. 1. The efficiency η of the pin a-Si:H based solar cell at $R = 17$ shows a maximum value η = 5.2 % (J_{sc} = 8.9 mA/cm^2, V_{oc} = 916 mV, FF = 63.9 %). Earlier we reported already a 6 % cell with a *pin-pin* double junction deposited at 100 °C cell on Asahi U substrate [1]. By optimization of the intrinsic layer, we now obtain a similar efficiency even with a single pin junction.

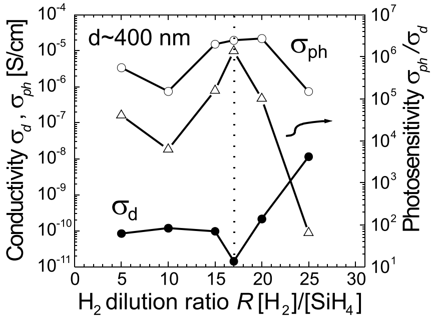


Figure 1:
Conductivity under dark (σ_d) and illuminated (σ_{Ph}) conditions for different function of hydrogen dilution ratios *R*. The photosensitivity is show on the right side. At *R* = 17, maximum photosensitivity is obtained. This value indicates the protocrystalline Si phase. At higher *R*, the deposited Si phase is microcrystalline, at lower *R* the Si is amorphous.

Under the same conditions as for glass, we also fabricate protocrystalline cells on PET using the optimized condition mentioned above. Figure 2 shows an image of flexible solar cells deposited on PET. The deposition temperature is 110 °C. The cell performances were as follows: J_{sc} = 8.8 mA/cm^2, V_{oc} = 908 mV, *FF* = 61.1 %, η = 4.9 %. Due to the differences of the thermal expansion coefficient between the plastic substrate and the semiconductor, the cells are warped. For the fabrication of modules which will be integrated into clothing, the warping problem has to be overcome.

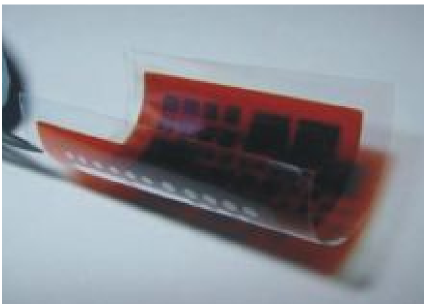


Figure 2:
PIN type solar cell on flexible PET substrate. The deposition temperature was 110°C. As a transparence electrode, ZnO:Al was used. The best cell has an efficiency η = 4.9 %.

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Static Concentrating Photovoltaic Systems

Author: C. Karlsson
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Concentrators have the potential to lower the cost of a photovoltaic system. In contrast to tracking systems, static concentrators do not track the sun's position on the sky and therefore have to collect rays within a range of incoming angles. As the concentration of a collector varies with the angle of the incident rays, the annual collection efficiencies of the concentrators are found by investigation of the concentration for the different incidence angles of the light.

This study focuses on the annual irradiance gain for V-trough type static concentrator systems, using the ray-tracing program C-Calc developed for this purpose. The simulation investigates the V-trough for both the two- and three-dimensional (2D, 3D) case with a collector tilt of 48° towards South. The ray-tracing program uses rays with a range of incoming angles representing the sun's changing position in the sky. With irradiation data representative for Stuttgart, C-Calc simulates the annual concentration gain for the two V-trough systems.

The manufacturing of concentrator modules with the 2D and 3D V-trough layout enables a comparison between measured irradiance gain and simulated values from C-Calc. Figure 1 shows a photograph of the 3D V-trough system.

The comparison of the irradiance gain between C-Calc and the real concentrators is carried out for normal incident light. The theoretical irradiance gain for the 2D trough is 2.0 from the ray-tracing program, whereas the real measured irradiance gain is 1.6. For the 3D trough, the ray-tracing program shows an ideal irradiance gain of 3.3 while the measured value is 2.5. The difference is due to assumed ideal reflections wheras the manufactured modules are optically not perfect.

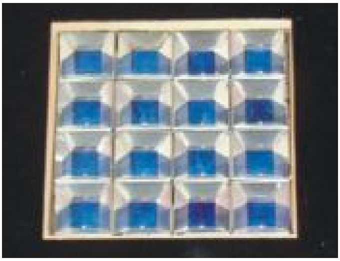

Figure 1:
Top-view of one of the concentrator module built for this study. The module consists of 16 monocrystalline silicon solar cells, each one with an adherent 3D concentrator. The output from the module is measured via the two cables. A metallic block mechanically supports the solar cells and a transparent plastic plate serves as protection.

The ray-tracing program derives an annual optical acceptance of 66 % for the 2D trough and 23 % for the 3D trough. Figures 2a, b show the variation of the optical acceptance for different months (and hence elevation of the sun), where an elevation of 0° represents normal incident light.

The simulations with C-Calc also reveal that the 3D collector has an annual irradiance gain of 1.4 and the 2D collector has an annual irradiance gain of 1.5.

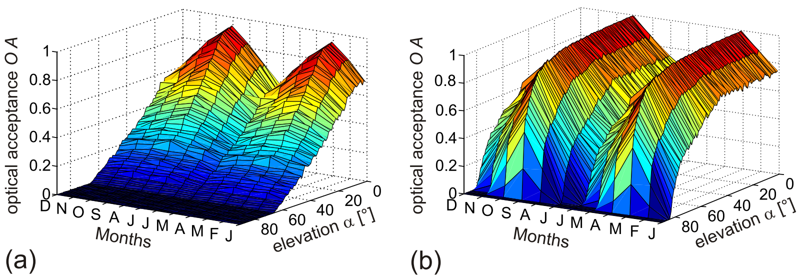

Figure 2:
Simulated annual optical acceptance for a) the 3D trough and b) the 2D trough. For both troughs, the maximum of the optical acceptance occurs during March and September for an elevation of 0° which represents normal incident light on the cell since the troughs have an inclination of 48° towards South.

Radiative Efficiency Limits of Solar Cells with Lateral Bandgap Fluctuations

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

The maximum power conversion efficiency of a solar cell as given by the Shockley-Queisser (SQ) radiative recombination limit [1] relies on the assumption of a solar cell made from a semiconductor with a single, spatially uniform band gap energy E_g. However, this ideal situation is not warranted by most semiconductor materials [2]. Band gap non-uniformities arise, e.g., in compound semiconductors, because of changes of the material stochiometry across the cell or module area, likewise in semiconductors alloys because of composition variations. Moreover, in polycrystalline semiconductors, local disorder at grain boundaries causes a significant density of electronic states within the forbidden energy region of the bulk semiconductor as well as band tail states.

In general, the effects of band gap non-uniformities on electronic transport and recombination are quite intricate. However, there is one consequence of band gap fluctuations on the photovoltaic performance of solar cells that is rather straightforward: band gap fluctuations do not only modify light absorption (leading, e.g., to band tails) but they also modify light *emission* in these materials. In consequence, already the *radiative* limit for photovoltaic power conversion in non-homogeneous materials will be deteriorated [3].

We model semiconductors with band gap fluctuations by assuming a Gaussian distribution $P_G(E_g)$ of band gap energies [3] distributed with a standard deviation σ_{Eg} around a mean band gap $\bar{E}_g$. Figure 1 shows the dependence of the radiative AM 1.5 efficiency on $\bar{E}_g$ and on σ_{Eg}. We recognize the efficiency curve for $\sigma_{Eg} = 0$ as the radiative limit for single band gap solar cells under AM1.5 spectral irradiation featuring the familiar two maxima at $\bar{E}_g \approx 1.15$ eV and 1.35 eV due to the spectral features of the AM 1.5 spectrum.

These features increasingly average out when band gap inhomogeneities increase. More importantly, the overall efficiencies drastically decrease as soon as these inhomogeneities exceed the thermal energy kT. For instance, we find instead of a maximum efficiency of η = 33.2 % at a homogenous E_g = 1.34 eV, values of η = 31.5, 29.6, 27.1 % at $\bar{E}_g$ = 1.34 eV for σ_{Eg} = 50, 75, 100 meV, respectively. The maxima of the efficiencies curves decrease by about 1.7 % (σ_{Eg} = 50 meV), 3.6 % (σ_{Eg} = 75 meV), and 6.1 % (σ_{Eg} = 100 meV) together with a slight shift of the optimum band gap towards higher energies [3].

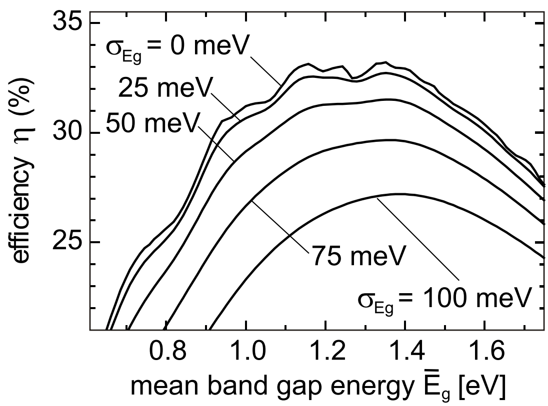

Figure 1:
Theoretical radiative efficiency limits for solar cells under illumination of an AM 1.5G solar spectrum. Band gap fluctuations deteriorate the limiting efficiency by about 1.7 % and 6.1 % (absolute) for standard deviations σ_{Eg} = 50 meV and σ_{Eg} = 100 meV, respectively. The optimum (mean) bandgap energy $\bar{E}_g$ shifts slightly towards higher energies with increasing σ_{Eg}.

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Transparent and Ohmic ZnO:Al/$MoSe_2$ Back Contacts for Bifacial Cu(In,Ga)Se_2 Solar Cells

Author: P. J. Rostan
In collaboration with: J. Mattheis, G. Bilger, U. Rau, J. H. Werner

Transparent, Ohmic back contacts to Cu(In,Ga)Se_2 (CIGS) absorber layers are a prerequisite for producing bifacial solar cells that are illuminated from front and back side. Moreover, this type of contact allows the enhancement of light trapping by a highly reflective back side mirror which can be deposited behind the glass substrate and therefore has no degrading influence on the electronic properties of the CIGS solar cell. The Transparent Conductive Oxide (TCO) ZnO:Al has not yet been considered as a potential back contact although it is advantageous as a highly conductive, cheap material that already makes up the front contact in CIGS solar cells. Probably, it has never been used as a back contact because, usually, *n*-type ZnO:Al and *p*-type CIGS interfaces form a rectifying rather than an Ohmic junction.

We showed [1] that Ohmic and transparent ZnO:Al back contacts for CIGS-solar cells are achieved by using a thin Mo interlayer on the ZnO:Al together with an additional NaF-precursor. The Mo forms $MoSe_2$ during growth of the absorber and the optical and electric properties of the opaque Mo change to the characteristics of a $MoSe_2$ semiconductor which is semitransparent. Figure 1 shows that the formation of such a transparent $MoSe_2$ interlayer is only possible in the presence of Na during growth of the CIGS absorber. CIGS solar cells with efficiencies up to 13.4 % were fabricated on transparent ZnO:Al/$MoSe_2$ back contacts.

We measure the internal quantum efficiency (IQE) of CIGS solar cells with graded band gaps on ZnO:Al/$MoSe_2$ contacts with lock-in amplification [2]. Figure 2 shows the IQE measured from the front and from the back. To analyze the spectral IQE curves we solve the continuity equation in the quasi-neutral base of the absorber. We assume a Lambert-Beer generation profile with a spatially independent absorption coefficient α without considering multiple reflections. In addition, we include the current generated in a region of enhanced carrier collection probability $f_C = 1$ adjacent to the pn-junction. The straight lines in Fig. 2 depict the results of our simulations.

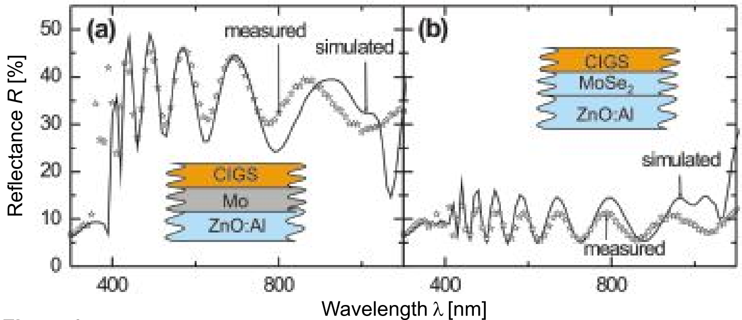

Figure 1:
Reflectance measurements under back side illumination (inset). a) Sample without NaF precursor. Measurement and simulation unveils that the Mo interlayer remains metallic. b) Sample with NaF precursor. The Na leads to selenisation of the Mo interlayer with the consequence of a drastically reduced reflection.

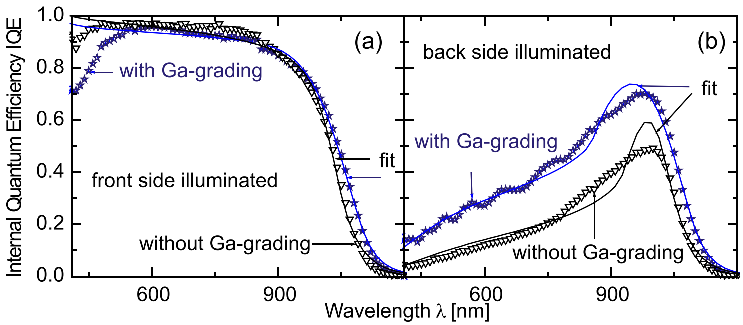

Figure 2:
IQE measurements and simulations from a) front and b) back side. The figure depicts a graded and a non-graded CIGS absorber.

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Texture Evolution in $Cu(In,Ga)Se_2$ Thin Films

Author: T. Schlenker
In collaboration with: H. W. Schock, J. H. Werner

$Cu(In,Ga)Se_2$ (CIGS) absorber films with a preferred (220/204) surface orientation lead to solar cells with higher efficiencies [1,2]. Thus it is of particular interest to understand the texture evolution in polycrystalline CIGS films in order to finally control it. This contribution presents a model that explains the CIGS texture evolution on polycrystalline Mo.

An ultrahigh vacuum chamber serves to deposit $Cu(In,Ga)Se_2$ by a single layer process with a deposition rate R = 0.55 nm/s and a substrate temperature T = 550 °C. Polycrystalline Mo layers on soda-lime glass, Mo (100), (110) and (111) oriented polished single crystals, and freshly cleaved highly oriented pyrolytic graphite (HOPG) serve as substrates. Highly oriented pyrolytic graphite is characterized by weak van-der-Waals interaction with thereon adsorbed material. X-ray diffraction (XRD) measurements allow the determination of the CIGS film texture.

The Lotgering factors $L(hkl)$ obtained from XRD measurements at a 0.5 µm thick CIGS film deposited on HOPG, Mo (100), and Mo (111), reveal a complete (112) surface orientation, whereas CIGS grown on Mo (110) features a pronounced (220/204) surface orientation. On polycrystalline Mo, the Lotgering factor is almost zero for all possible orientations, i. e. the film has no preferred film orientation. The diagram in Fig. 1 visualizes our model for the texture evolution in CIGS films. Earlier investigations showed that (112) surface oriented grains are energetically preferred and consume grains with a different surface orientation during grain growth [3]. The Lotgering factor of $L(112) = 1$ for CIGS grown on HOPG, i. e. on a substrate with no impact on the adsorbate, underlines the finding, that (112) oriented grains are energetically preferred. Consequently, Mo (100), and Mo (111) do not have a significant impact on the CIGS film texture either and we expect a pure (112) orientation throughout the film growth.

Mo (110) forces CIGS to grow with a pronounced (220/204) surface orientation, i. e., a supressed (112) orientation and only for a sufficiently large film thickness, grain growth will enable a preferred (112) film texture. Polycrystalline Mo has a columnar grain structure and shows a (110) preferred surface orientation. During the initial growth phase, isolated islands (see Ref. [4]) growing on (110) oriented Mo grains are forced in a (220/204) texture. After the coalescence phase, the remaining (112) oriented CIGS islands consume the grains oriented in other directions and, finally, the (112) texture prevails with increasing film thicknesses.

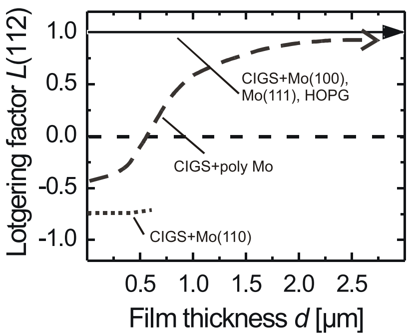

Figure 1:
Model for the texture evolution in CIGS films. The dashed line at L = 0 corresponds to the Lotgering factor of a powder sample. The weak impact on the CIGS film texture of Mo (100), Mo (111) and HOPG leads to at (112) texture for all stages of growth. A pronounced (110) oriented polycrystalline Mo substrate initially forces the CIGS film to grow with a slightly preferred (220/204) film texture until the (112) oriented grains prevail. On Mo (110), CIGS initially grows with a heavily understated (112) film texture.

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Laser Processed Sprayed Emitters on Crystalline Si Solar Cells

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

Laser processing of emitters bears the potential to lower processing cost of crystalline silicon solar cells. First experiments (see report of A. Esturo-Breton) yielded single crystalline cells with efficiencies up to about 16 %. These cells have been fabricated by spin-on doping sources which contain phosphorus. Alternatively, we use also processes such as spraying-on or printing the phosphorus containing paste before laser heating. In addition, we also compare spraying and printing of boron containing pastes on n-type and p-type polycrystalline silicon wafers.

The spray coating process utilizes an electrically actuated airbrush. Alternatively, a simple inking roller deposits the rolled-on doping sources films. The resulting films have average thicknesses between 80 nm < t_S < 670 nm, depending on spraying and rolling parameters. A pulsed Nd:YVO_4-laser carries out the subsequent laser processing. The laser beam melts the silicon up to a certain depth, enabling liquid-phase diffusion of atoms from the doping films into the silicon. For the fabrication of solar cells on n-type wafers, a similar doping step with P containing doping solution is applied to the back side in order to form an Ohmic contacts.

We characterize the pn-junction solar cells with four-point probe and SIMS measurements, as well as by current/voltage curves and internal quantum efficiency measurements. Analysis of emitter sheet resistances shows that the dopant deposition process does not significantly affect the efficiency of the laser doping. SIMS analysis reveals maximum dopant concentrations above 10^{19} cm^{-3} within the emitter, with a depth d_E in the range 200 nm < d_E < 800 nm for both P- and B- doped emitters. Thus sheet resistances range down to 30 Ω/□ . This value is sufficiently low to apply screen printing metallizations.

The solar cells have open-circuit voltages 450 mV < V_{OC} < 539 mV for the solar cells on n-type wafers and short-circuit current densities J_{SC} in the range 25 mA/cm^2 < J_{SC} < 32.2 mA/cm^2. The internal quantum efficiency (IQE) in Fig. 1 shows that the boron doped emitter on the n-type wafer solar cells limits the open circuit voltage. In contrast, the best cell with a phosphorus doped emitter on a p-type wafer shows a higher V_{OC} = 596 mV, J_{SC} = 29.9 mA/cm^2, and an efficiency η = 12.2 %, indicating a more progressed optimization of laser processing parameters. At present we are investigating the reason for the lower quantum efficiency in the boron doped emitters. In recent experiments we achieved efficiencies up to 13 % even on polycrystalline silicon wafers, whereas the experiments on single crystals (see report of A. Esturo-Breton) yield up to 16 %.

Our results reveal that laser-assisted doping in combination with simple and cheap deposition methods (spraying, printing) for the dopant precursors is appropriate for fast and reliable solar cell processing.

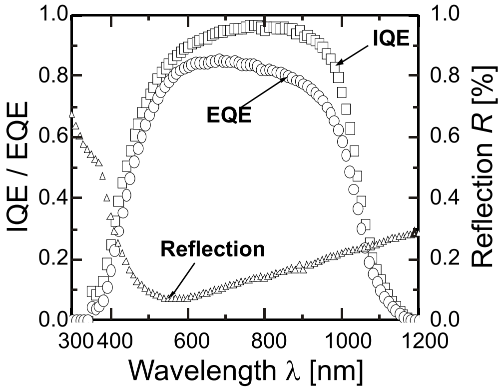

Figure 1:
External (*EQE*) and internal (*IQE*) quantum efficiency of a laser processed, boron-containing spray-on emitter precursor on an n-type Cz-wafer. In the short wavelength regime up to 500 nm the *IQE* is poor, indicating low carrier collection from the boron doped emitter.

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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.

PV-UNI-NETZ ist Forum für die Diskussion und Koordination neuer Ideen und zukunftsweisender Photovoltaikforschung an deutschen Universitäten und universitätsnahen Instituten.

PV-UNI-NETZ vertritt die Interessen und das Wissen der deutschen Universitäten im Bereich der Photovoltaik.

www.pv-uni-netz.de

Lehrveranstaltungen
Lectures

3

Bauelemente der Mikroelektronik (1. Semester)

Energiebänder und Leitfähigkeit

Silicium - der Werkstoff der Mikroelektronik

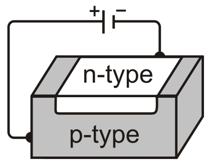
Elektronen und Löcher in Halbleitern

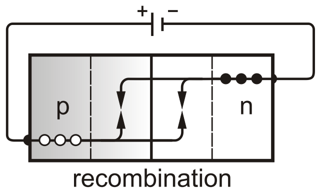
Ströme in Halbleitern

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

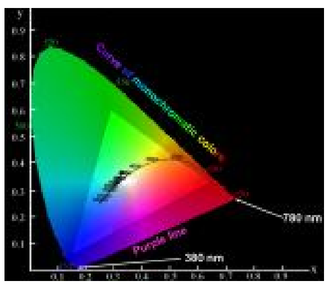
Light and Color

Photometry

Incoherent Light Sources

Light Emitting Diodes

Lasers



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

Basic physics

Thermal radiation

Coherence

Semiconductor basics

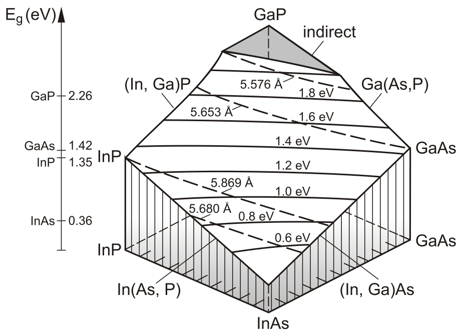
Excitation and recombination processes in semiconductors

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

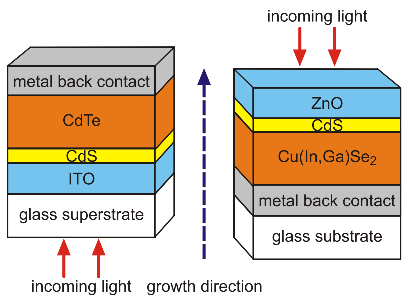
Maximum efficiency of solar cells

Preparation of crystalline silicon

Amorphous silicon solar cells

$Cu(In,Ga)Se_2$ solar cells

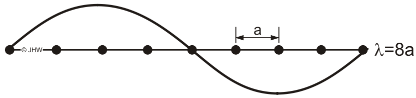
Technology of crystalline silicon solar cells



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

Halbleiterschichten für elektronische Bauelemente
- Herstellung und Charakterisierung (Dr. habil. Ralf B. Bergmann)

Wachstum dünner Halbleiterschichten

Epitaxieverfahren

Elemente der Kristallographie

Strukturelle Charakterisierung des Halbleitervolumens

Strukturelle Charakterisierung von Halbleiteroberflächen

Elektrische Charakterisierung - Majoritätsladungsträgereigenschaften

Elektrische Charakterisierung - Minoritätsträgereigenschaften

Sensoren für die Kfz-Elektronik (Dr. habil. Ralf B. Bergmann)

3S-Programm: Sauber, Sicher Sparsam - nicht ohne Sensoren

Sensorprinzipien; Drehzahl- und Geschwindigkeitssensoren,
Beschleunigungs- und Vibrationssensoren

Drucksensoren; Kraft- und Drehmomentsensoren

Durchflussmesser; Gassensoren, Konzentrationssensoren,
Temperatursensoren

Mikromechanische Sensoren;
Mikromechanik Technologie, Mikrosystemtechnik

Promotionen
Ph. D. Theses

Diplomarbeiten
Diploma Theses

Studienarbeiten
Major Term Projects

Gäste & ausländische Stipendiaten
Guests

Promotionen
Ph. D. Theses

Christopher Berge
Separation Layers from Sintering of Porous Silicon

George Hanna
Determination and Influence of Na supply and Se flux during Growth of $Cu(In,Ga)Se_2$ Thin Films

Hong Quang Nguyen
The Role of the Heterointerfaces in the $Cu(In,Ga)Se_2$ Thin Film Solar Cell with Chemical Bath Deposited Buffer Layers

Kay Orgassa
Coherent Optical Analysis of the $ZnO/CdS/Cu(In,Ga)Se_2$ Thin Film Solar Cell

Mircea Turcu
Defect Energies, Band Alignments, and Charge Carrier Recombination in Polycrystalline $Cu(In,Ga)(Se,S)_2$ Alloys

Kristin Weinert
Einfluss von Protonen- und Elektronenbestrahlungen auf die photovoltaischen Parameter von $Cu(In,Ga)Se_2$-Solarzellen

Diplomarbeiten

Diploma Theses / Master Theses

Mawuli Ametowobla
Kontaktierung und Dotierung von Silizium mit Hilfe von Sprühprozessen

Mikel Azpeitia Urquia
Entwicklung eines Polysilizium-Gate-Prozesses für eine 0,5 µm CMOS Technologie

Albrecht Kern
Optimierung der Passiviereigenschaften dielektrischer Schichten auf Silicium

Jochen Staack
Einfluss der Eindiffusion von Substratelementen auf flexible $Cu(In,Ga)Se_2$-Solarzellen

Verena Schneider
Data Acquisition with LabView-Quality Assurance by Standardization

Studienarbeiten

Major Term Projects

Jens Krämer
Autonome Solarstrom-Versorgung elektronischer Kleingeräte in Ski-Bekleidung

Matthias Kraus
Photovoltaik-Versorgung für Kühlsysteme in Kraftfahrzeugen

Rainer Merz
Aufbau eines Versuchs "Dünnschichttechnologie" für das Grundlagenpraktikum

Guangyong Sun
Interaction of Laser Radiation with Molybdenum and Molybdenum-CIGS-Layers on Glass Substrates

Bernhard Wille
Photovoltaikversorgung von Bluetooth-Geräten

Gäste & ausländische Stipendiaten
Guests

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

Bayhan, Murat
Mugla University, Türkei (19.04.04–10.07.04)

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

Ferreira de Carvalho, Marco
Universidade do Minho, Braga, Portugal (08.03.04–29.07.04)

Ishikawa, Yasuaki
Nara Institute of Science and Technology, Japan (seit 1.04.03)

Karlsson, Caroline
Göteborgs Universitat, Schweden (seit 1.03.03)

Nguyen Van, Cuong
Da Nang University, Vietnam (15.07.04–20.07.04)

Nguyen, Hong Quang
National Center for Natural Science and Technology, Hanoi, Vietnam (seit 1.10.1999)

Nguyen, Xuan Viet
National Center for Natural Science and Technology, Hanoi, Vietnam (seit 1.11.2001)

Sun, Yongming
Tsinghua University, Beijing, China (seit 1.10.2004)

Turcu, Mircea
National Institute for Research and Development, Timisoara, Rumänien (1.04.1999–30.06.04)

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

Zhu, Minji
Shanghai TEMIC Microsystems Co., China (seit 15.04.03)

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

Mitarbeiterliste
Staff Members

Lageplan
Location Map

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

(Christine v. Rekowski)

Natürlich spielt die Wissenschaft am *ipe* eine absolut zentrale Rolle. Daneben gibt es aber immer wieder Gelegenheiten, bei denen sich *ipe*-Mitarbeiter informell zusammensetzen, sich unterhalten oder feiern.

Das Jahr endet am *ipe* mit einer traditionellen Weihnachtsfeier, zu der alle Mitarbeiter samt ihren Familien eingeladen sind, um in gemütlicher Stimmung ein üppiges Büffet, einen humoristischen Bilder-Jahresrückblick und weitere kreative Einlagen zu genießen.

Eine der wichtigsten Feiern ist natürlich nach der Promotion. Dieses Jahr konnte das *ipe* zum ersten Mal einen „Dreierpack“ vorweisen, da drei Doktoranden am gleichen Tag geprüft wurden.

Familienangehörige und Freunde sind willkommene Gäste und oft gleichzeitig Gastgeber der Promotionsfeiern.

Even though the focus of *ipe* is research, there are always opportunities for informal gatherings, exchanges or parties.

The year always ends with the traditional Christmas Party, to which the whole staff and their families are invited to enjoy an opulent buffet, an amusing yearly report and other creative contributions.

One of the most important events is the “doctoral party”, after the Ph.D. candidates passed their oral exams. This year, for the first time, the *ipe* celebrated a triple graduation, three staff members having passed their exam on the same day.

Family members and friends are cordially invited to the graduation parties, they are often even the hosts.

Manche Institutsfeiern bedeuten einen endgültigen Abschied. So wurde dieses Jahr Dr. Fritz Pfisterer in den Ruhestand verabschiedet, nachdem er das *ipe* jahrzehntelang begleitet und durch seine Persönlichkeit geprägt hat.

Eines der jährlich wiederkehrenden Events heißt „ETI-Cup“, ein fakultätsinternes Fußballturnier, an dem Institutsmannschaften gegeneinander antreten. Das *ipe* konnte dieses Jahr den ehrenwerten 3. Platz gewinnen.

Kontakte zwischen Studenten und dem *ipe*-Team werden auch während der jährlich stattfindenden mehrtägigen Exkursionen geknüpft. Hier besteht die Möglichkeit, einen Einblick in Industriebetriebe zu bekommen, die mit der Forschung des *ipe* in Verbindung stehen.

Kein Wunder, dass sich die Institutsverbundenheit nicht übersehen lässt!

Some parties mean a farewell. This year, Dr. Fritz Pfisterer retired after having accompanied and formed the *ipe* for the last decades.

One of the yearly returning events is the soccer tournament within the faculty, to which every institute may participate with an own team. The *ipe* won the 3rd position with its international team, representing 6 countries!

A possibility for students to get to know some of the *ipe*-team is given during the study trip lasting several days, when there is the opportunity to visit partners of the industry.

No wonder that the *ipe* community spirit can be seen!

Mitarbeiterliste
Staff Members

Name	Titel	Telefon 0711 - 685 - ...	E-Mail ...@ipe.uni-suttgart.de	Arbeitsgebiet
Al Tarabsheh, Anas Ibrahim	MSc	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
Berge, Christopher	Dipl.-Phys.	7162	christopher.berge	Dünnschicht-Solarzellen aus kristallinem Silicium
Bilger, Gerhard	Dr.-Ing.	7176, 7154	gerhard.bilger	Oberflächenanalytik mit SIMS und XPS; Technologie Support
Brendle, Willi	Dipl.-Ing.	7178	willi.brendle	Niedertemperatur-passivierung für Transfer-Solarzellen
Brenner, Klaus	Dipl.-Ing. (FH)	7201	klaus.brenner	Technologische Infrastruktur und Prozesse der Si-Technologie
Diegel, Lydia		7163	lydia.diegel	Sekretariat, Verwaltung, www
Eisenmann, Lorenz		7182	lorenz.eisenmann	Aufdampfen von Halbleiterschichten in-situ
Esturo-Breton, Ainhoa		7169	ainhoa.esturo-breton	Laserprozessierung von Si-Solarzellen
Gläser, Gerda	Dipl.-Ing.	7168	gerda.glaeser	Charakterisierung von Monograin-Solarzellen

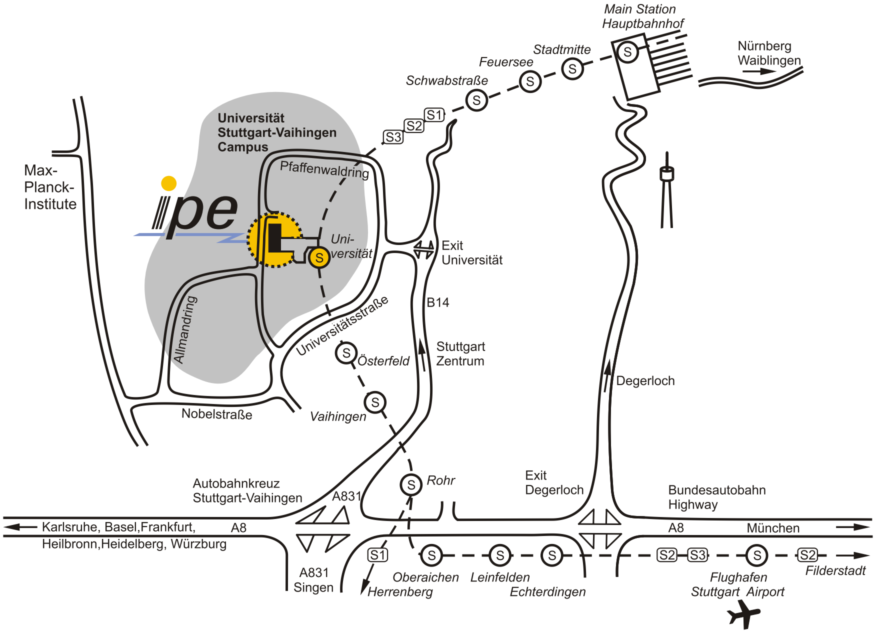
Grabitz, Peter	Dipl.-Phys.	7197	peter.grabitz	Flexible Verbindungshalbleiter-Solarzellen
Ishikawa, Yasuaki	Dipl.-Ing.	7167	yasuaki.ishikawa	Serienschaltung von flexiblen a-Si Solarzellen
Jackson, Philip	Dipl.-Phys.	7198	philip.jackson	flexible Substrate
Karlsson, Caroline	MSc	7160	caroline.karlsson	Hocheffiziente Solarzellen für Konzentratoren
Kessler, Isabel	M.A.	7141	isabel.kessler	Sekretariat, Verwaltung
Khanna, Pramod	Dr.	7178	pramod-kumar.khanna	Modulentwicklung,mono-kristalline Dünnschicht solarzellen
Köhler, Christiane	Dipl.-Phys.	7182	christiane.koehler	Si-Niedertemperaturtechno-logie, XRD, transparente Kontakte, Ramanstreuung
Köhler, Jürgen	Dr.-Ing.	7159	juergen.koehler	Laser Annealing, Verwaltung
Kühnle, Dennis		7200	dennis.kuehnle	Aufdampfen von Halbleiterschichten
Laptev, Viktor	Dr. rer. nat.	7197	viktor.laptev	Chemische Schichtab-scheidung,Röntgenbeu-gungsmessungen
Lutz, Brigitte		7200	brigitte.lutz	Analytik, Elektrochemie, GCMS
Mattheis, Julian	Dipl.-Ing.	7161	julian.mattheis	Optische Eigenschaften von Solarzellen
Nguyen Xuan Viet	MSc	7179	viet.nguyen	a-Si:H/c-Si Heterostrukturen
Rakhlin, Michail	Dipl.-Phys.	7183	michail.rakhlin	Thermoelektrik, Silizium-Germanium-Dünnschichten

Rau, Uwe	Dr. rer. nat.	7199	uwe.rau	Elektr. Charakterisierung, Modellierung von Dünnschichtsolarzellen (CIGS, Si, org.)
Riß, Anton		7214	anton.riss	Werkstatt
Schlenker, Thomas	Dipl.-Phys.	7178	thomas.schlenker	Wachstum dünner CIGS Absorberschichten
Schleußner, Sebastian	Dipl.-Ing.	7142	sebastian.schleussner	Hocheffizienz-Dünn-schichtsolarzellen (CIGS)
Schlötzer, Thomas	Dipl.-Phys.	7181	thomas.schloetzer	In-situ Prozessierung von Dünnschicht-solarzellen
Schubert, Markus	Dr.-Ing.	7145	markus.schubert	Projektleitung amorphes und nanokristallines Si, Solarzellen 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
Wagner, Martin	Dipl.-Phys.	7184	martin.wagner	Dünnschichtprozesse
Werner, Jürgen	Prof. Dr. rer. nat. habil.	7140	juergen.werner	Institutsleiter, Leitung der Forschung, Lehre, Verwaltung
Wiesner, Holm	Dipl.-Ing.	7197	holm.wiesner	CIS-Technologie
Wille, Werner		7158	werner.wille	Buchhaltung, Verwaltung
Zhu, Minji	MSc	7163	minji.zhu	Optimierung von kristalli-nen Silicium-Solarzellen, QMS Transferschichten

Stand 12/04

Lageplan

Location Plan



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