Fraunhofer

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FRAUNHOFER-INSTITUT FÜR ELEKTRONENSTRAHL- UND PLASMATECHNIK FEP

ANNUAL REPORT 2013/14

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2013/14








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1 *Acting Director Prof. Dr. Volker Kirchhoff and Deputy Director Dr. Nicolas Schiller*

FOREWORD

Dear Readers,

First of all we would like to thank all our partners for the successful 2013. This year we have grown again and have achieved good returns. Over the past years, we have succeeded to implement sustainable projects with several companies in the region. Therefore, we would like to kindly thank our staff for their customer-oriented work.

We would like especially to highlight the good performance in the department of „Medical Applications“. The department is able to stand on its own economically since 2013 and provides R&D services to customers in the field of sterilization and bio-functionality.

Due to a major contract in the field of high-rate evaporation, the business unit „Electron Beam Applications“ can look back on a successful year.

Seed treatment with electrons gained momentum through the internal PROFIL project and the funding through the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). These projects refer to the resource-saving seed treatment with new, low-cost electron beam guns that can be used in small laboratories and industrial plants. Technical work and a brief overview of the symposium „15 years ELBE-seed – a Saxon invention on its way to success“ are presented in this report.

The „PreSensLine“ for large-area deposition of precision coatings was put into operation in 2013. It offers many possibilities for production of precise multilayer systems for applications in laser optics, spectroscopy and display manufacturing among others.

The conference pro flex, attended by speakers and visitors from many international organizations and companies, gained significance last year.
The interest in the roll-to-roll vacuum technology is growing steadily. This means new and exciting projects in our department „Flexible Products“. This department examines currently rapid thermal annealing of coated polymer substrates with the electron beam and is looking for industrial partners for the optimization of this technology.

Through the investment at the Fraunhofer FEP there is a possibility to analyze optical layer systems, coatings for photovoltaics and bearing layers with a new RF glow discharge spectrometer. With these analyses, the understanding of the influence of process parameters on the structure and electrical properties of the CdTe thin film solar cells can be improved.

The department „Coating of Components“ has developed an absorber layer in the field of solar thermal systems with an absorption ratio of 94% and a thermal emissivity of less than 10% at an operation temperature of 200°C. The technology and pilot equipment were successfully transferred to the industrial customer.

On 9 December 2013, the Board of the Fraunhofer-Gesellschaft decided to carry out the integration of the Fraunhofer COMEDD in the Fraunhofer FEP. The integration involves challenges and opportunities. Through the synergies in the field of thin-film technologies and organic electronics, it is possible to offer new solutions for customers and thus, to enter new markets. The first steps in this direction have already been made with the establishment of the cluster FLEET (Flexible Electronics Encapsulation Technologies Dresden).

Enjoy reading this report and we are looking forward to your comments and questions!

Prof. Dr. Volker Kirchhoff *Dr. Nicolas Schiller*

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COLLABORATION AND MEMBERSHIPS

Thin film technology is used in a number of rapidly developing markets. We collaborate with both national and international partners in order to improve the competitive position of our customers and our institute and to promote successful development work.

INDUSTRY PARTNERS

Fraunhofer FEP collaborated in 2013 with approx. 50 national and international industrial partners.

RESEARCH PARTNERS

- University of Virginia USA
- Beijing Institute of Aeronautical Materials
- National Institute for Materials Science Japan
- Korean Institute of Industrial Technology

FRAUNHOFER COOPERATIONS

- Fraunhofer Group for Light & Surfaces
- Fraunhofer Battery Alliance
- Fraunhofer Photocatalysis Alliance
- Fraunhofer Polymer Surfaces Alliance POLO
- Fraunhofer Cleaning Technology Alliance
- Research Alliance Cultural Heritage
- Fraunhofer Cluster Nanoanalytics Dresden

ACADEMIC COOPERATIONS

- Technische Universität Dresden – Institut für Festkörperelektronik
- Westsächsische Hochschule Zwickau
- Hochschule für Technik und Wirtschaft Dresden (HTWD)

MEMBERSHIPS

- Europäische Forschungsgesellschaft Dünne Schichten EFDS e. V.
- Organic Electronics Saxony e. V. (OES)
- Silicon Saxony e. V.
- Dresden-concept e. V.
- AMA Fachverband für Sensorik e. V.
- Bundesverband mittelständische Wirtschaft (BVMW)
- Deutsche Gesellschaft für Galvano- und Oberflächentechnik e. V.
- Kompetenznetz Industrielle Plasma-Oberflächentechnik INPLAS e. V.
- Kompetenzzentrum Maschinenbau Chemnitz/Sachsen e. V. (KMC)
- Netzwerk »Dresden – Stadt der Wissenschaft«
- Verband der Elektrotechnik – Bezirksverein Dresden e. V. (VDE)
- Verband deutscher Maschinen- und Anlagenbau e. V. (VDMA)
- IVAM e. V. Fachverband für Mikrotechnik
- International Council for Coatings on Glass ICCG e. V.
- Arbeitskreis Glasig-kristalline Multifunktionswerkstoffe
- Europäische Forschungsgesellschaft für Blechverarbeitung e. V.
- International Irradiation Association

THE FRAUNHOFER-GESELLSCHAFT

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 67 institutes and research units. The majority of the more than 23,000 staff are qualified scientists and engineers, who work with an annual research budget of 2 billion euros. Of this sum, more than 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

www.fraunhofer.de

THE INSTITUTE IN FIGURES

Funding

The institute had a very remarkable fiscal year. Due to successful acquisition, the Fraunhofer FEP was able to generate € 7.0 million through direct orders from industry. This corresponds to an increase in economic return of 10 percent when compared to the previous year. Profits in the amount of € 5.0 million were generated with public projects, sponsored by the federal government and the Bundesländer. The major share thereof in the amount of € 4.1 million was raised by publicly sponsored projects together with medium-sized companies sponsored by the Saxonian State Ministry of Science and Art and the Saxonian State Ministry of Economy, Labour, and Transport. The share of external profits from projects implemented in cooperation with industry, the public, and other customers, i.e. the share of external funds, therewith was 79 percent and corresponds to a volume of € 12.8 million. This way, the ambitious goals for 2013 were exceeded. The basic consumption of funds for the operating budget was € 3.3 million.

The profits generated in the reporting period are divided as follows:

- income from industry (contract research with industry) — € 7.0 million
- public funding (contract research funded by the federal government) — € 0.9 million
- public funding (contract research funded by the Länder) — € 4.1 million
- EU and other funding — € 0.8 million

Total expenditure

The overall expenditure from the operating and investment budget amounted to € 17.6 million. During the period under consideration, € 1.5 million, thereof € 0.6 million from the central strategic fund, were invested in equipment and infrastructure. These investments serve to continue business activities and in particular for implementing ongoing research projects and simultaneously guaranteeing future research work. The share of personnel expenses amounted to € 8.1 million, corresponding to 50 percent of the operating budget in the amount of € 16.2 million. The material cost was € 7.5 million.

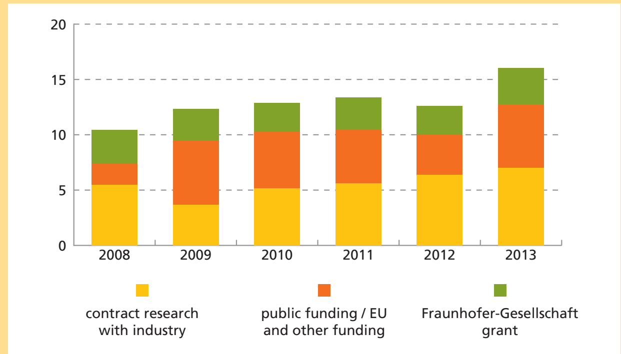
Workforce

In the past year, 141 employees, thereof 13 trainees, and additionally 28 degree candidates/interns, as well as 95 research assistants worked at the institute. Out of the 62 scientifics, 10 scientists also worked on their PhD topics. The share of women among the scientists was 18 percent. In the past year, our personnel strategy again focused on training of young scientists. By assigning attractive topics for diploma, bachelor and PhD, highly motivated scientists were able to successfully obtain their degree.

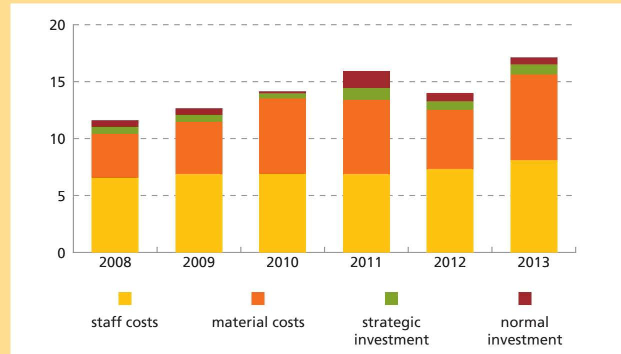
The field of technical talent we focused again on targeted vocational training in cooperation with the respective technical schools in 2013. In this area, the Sächsische Bildungsgesellschaft Dresden is our long-term partner for training of physics laboratory assistants. We would like to thank the Chamber of Industry and Commerce of Dresden and all institutions that provided and provide an essential contribution to the success of our trainees. Moreover, we would also like to thank the employees of our institute who, along with their main activities, always guarantee the proper vocational training of our future employees with huge personal commitment.

By the end of 2013, 2 new trainees started their apprenticeship with the institute. Thus, 13 trainees are currently being trained: two BA students, one materials tester, six physics laboratory assistants, one industrial mechanic, one electrician, one IT specialist and one office management assistant.

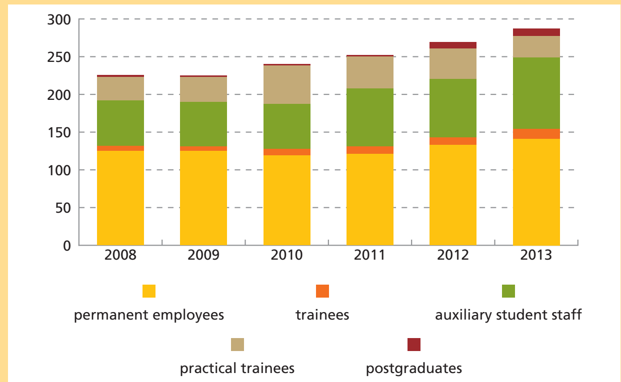
1 *Operating budget (in million euros)*



2 *Investment and total costs (in million euros)*



3 *Fraunhofer FEP workforce*



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FRAUNHOFER GROUP FOR LIGHT & SURFACES

Competence by networking
Six Fraunhofer institutes cooperate in the Fraunhofer Group Light & Surfaces. Co-ordinated competences allow quick and flexible alignment of research work on the requirements of different fields of application to answer actual and future challenges, especially in the fields of energy, environment, production, information and security. This market-oriented approach ensures an even wider range of services and creates synergetic effects for the benefit of our customers.

Core competences of the group
- surface and coating functionalization
- laser-based manufacturing processes
- laser development and nonlinear optics
- materials in optics and photonics
- microassembly and system integration
- micro and nano technology
- carbon technology
- measurement methods and characterization
- ultra precision engineering
- material technology
- plasma and electron beam sources

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www.light-and-surfaces.fraunhofer.de

Fraunhofer Institute for Electron Beam and Plasma Technology FEP
Electron beam technology, sputtering technology, plasma-activated high-rate deposition and high-rate PECVD are the core areas of expertise of Fraunhofer FEP. The business units include vacuum coating, surface modification and treatment with electrons and plasmas. Besides developing layer systems, products and technologies, another main area of work is the scale-up of technologies for coating and treatment of large areas at high productivity.
www.fep.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT
With more than 350 patents since 1985 the Fraunhofer Institute for Laser Technology ILT develops innovative laser beam sources, laser technologies, and laser systems for its partners from the industry. Our technology areas cover the following topics: laser and optics, medical technology and biophotonics, laser measurement technology and laser materials processing. This includes laser cutting, caving, drilling, welding and soldering as well as surface treatment, micro processing and rapid manufacturing. Furthermore, the Fraunhofer ILT is engaged in laser plant technology, process control, modeling as well as in the entire system technology.
www.ilt.fraunhofer.de

Fraunhofer Institute for Applied Optics and Precision Engineering IOF
The Fraunhofer IOF develops solutions with light to cope foremost challenges for the future in the areas energy and environment, information and security, as well as health care and medical technology.
The competences comprise the entire process chain starting with optics and mechanics design via the development of manufacturing processes for optical and mechanical components and processes of system integration up to the manufacturing of prototypes. Focus of research is put on multifunctional optical coatings, micro- and nano- optics, solid state light sources, optical measurement systems, and opto-mechanical precision systems.
www.iof.fraunhofer.de

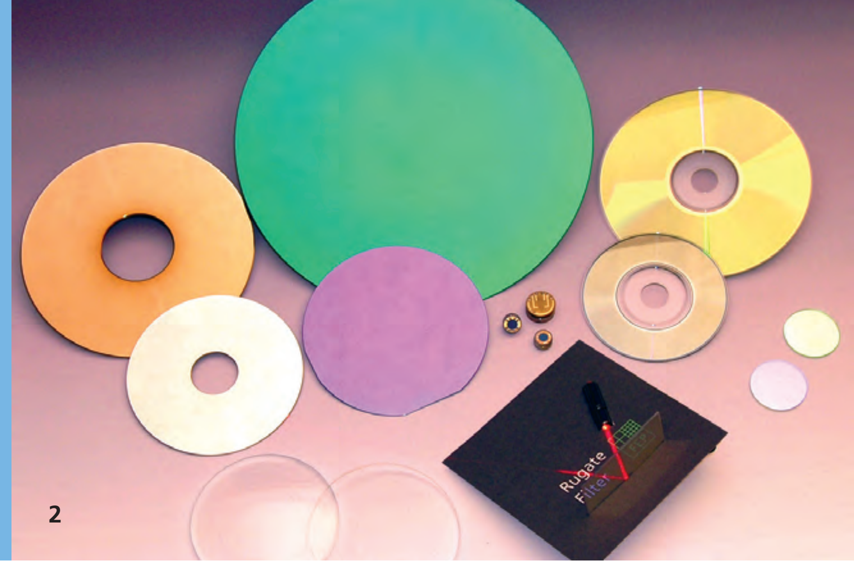
Fraunhofer Institute for Physical Measurement Techniques IPM
Fraunhofer IPM develops and builds optical sensor and imaging systems. These mostly laser-based systems combine optical, mechanical, electronic and software components to create perfect solutions of robust design that are individually tailored to suit the conditions at the site of deployment. In the field of thermoelectrics, the institute has extensive know-how in materials research, simulation, and systems. Fraunhofer IPM also specializes in thin-film technologies for application in the production of materials, manufacturing processes and systems.
www.ipm.fraunhofer.de

Fraunhofer Institute for Surface Engineering and Thin Films IST
As an industry oriented R&D service center, the Fraunhofer IST is pooling competencies in the areas film deposition, coating application, film characterization, and surface analysis. Scientists, engineers, and technicians are busily working to provide various types of surfaces with new or improved functions and, as a result, help create innovative marketable products. The institute’s business segments are: mechanical and automotive engineering, aerospace, tools, energy, glass and facade, optics, information and communication, life science and ecology.
www.ist.fraunhofer.de

Fraunhofer Institute for Material and Beam Technology IWS
The Fraunhofer Institute for Material and Beam Technology is known for its innovations in the business areas joining and cutting as well as in the surface and coating technology. Our special feature is the expertise of our scientists in combining the profound know-how in materials engineering with the extensive experience in developing system technologies. Every year, numerous solution systems have been developed and have found their way into industrial applications.
www.iws.fraunhofer.de

RESEARCH NEWS

RESEARCH NEWS

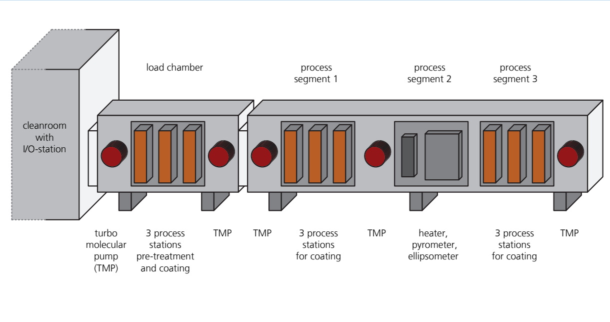


PreSensLine – NEW COATING EQUIPMENT FOR MANUFACTURING LARGE-SCALE PRECISION COATINGS

At Fraunhofer FEP, new coating equipment, PreSensLine, was recently brought into operation for depositing large-scale precision coatings. The system provides a range of options for precision adjustment and for making specific variations to coating properties. It is equipped with process components developed by Fraunhofer FEP and modules for in situ monitoring.

High precision coatings are required for a large number of applications in optics, sensor technology and electronics as well as in energy and medical technology. In Fraunhofer FEP's »Precision Coating« division, we are developing pulse magnetron sputtering processes and magnetron PECVD processes to apply high-quality coatings and coating systems, that have optical, electrical, acoustic and magnetic properties, at a high coating rate and with a low number of defects. Such coatings can be manufactured with precise layer thicknesses and highly reproducible coating properties using dynamic coating techniques. A combination of precise, adjustable processes, which remain stable over long periods, with an exact substrate movement and optical, in situ monitoring is needed to manufacture these coatings.

4 *PreSensLine system design*



Based on this, Fraunhofer FEP conceptually designed new coating equipment where also large substrates can be coated. The PreSensLine equipment allows a range of simple to complex coating systems to be deposited on large and heavy substrates.

The system was developed in cooperation with the VON ARDENNE GmbH company and first put into operation in 2013. It is equipped with coating technology from Fraunhofer FEP: square magnetrons (RM800), pulsed energy supply (unipolar/bipolar switching unit UBS-C2) and process control technology (process control unit PCU^{plus}).

PreSensLine consists of a large process chamber with a separate load chamber. In its current stage of expansion, the process chamber is equipped with two coating stations each with two RM800 sputtering sources and is also equipped with a station with a substrate heater (max. 400°C) as well as in situ measuring technology (pyrometric, optic). An inverse sputter-etcher (plasma treater RP800) can be used in the load chamber to pre-treat the substrate, and magnetrons can be used for adhesive layers.

The substrates are fixed on a substrate carrier and passed in front of the coating sources. Three types of carrier are available in order to meet complex requirements and to form various different layer specifications:

- Heavy-load carrier
  for coating of large and heavy substrates (max. 90 kg) up to 680 × 790 mm.
- Rotation carrier
  for coating of substrates of up to 545 mm in diameter (max. 50 kg) using rotary motion; a combination of rotating and linear movement allows improved layer thickness homogeneity
- Bias/heat carrier
  for coating using a DC or HF bias for substrates of up to 680 × 790 mm; also thermally insulated to allow the substrate to be heated up to 400°C.

Beside using a conventional support roller system in the load chamber, a precision drive mechanism has been installed into the process chamber to ensure a high level of precision. The mechanism itself is a vacuum linear drive mechanism developed by LSA GmbH onto which the carrier is placed. This precision drive mechanism allows speeds of up to 0.5 m/s to be reached with a positioning accuracy of ± 0.05% and a control accuracy of ± 0.025%.

Targets of 800 mm length are used for the RM800 sputtering sources. The sources developed at Fraunhofer FEP display the following properties:

- increased long-term stability and good use of the target material by using a target erosion related movable magnet system allowing the magnetic field strength and therefore the discharge conditions to remain constant
- reactively-guided processes with increased long-term stability by avoiding redeposition zones on the target and by using a hidden anode which is protected from a build-up of material deposits and thus from the effects of the so-called vanishing anode

1 *PreSensLine – pilot system for dynamic precision coating*
2 *Examples of application for precision coating*
3 *Integrated package with DRM 400, UBS-C2 and PCU^{plus}*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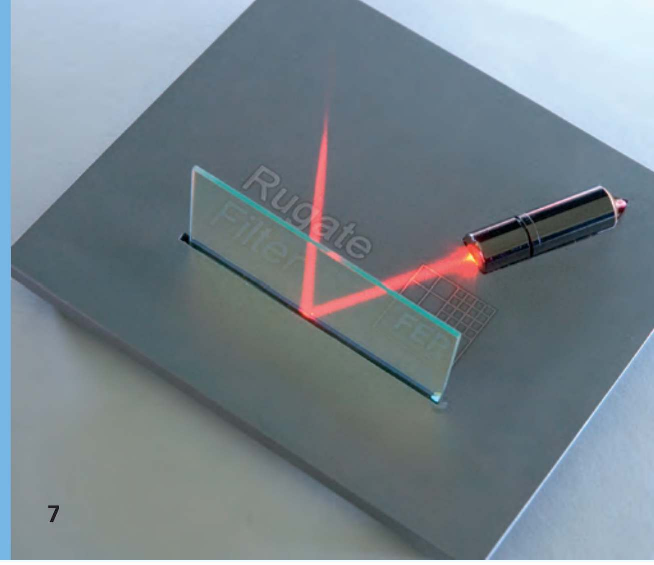
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8

- high process stability by introducing integrated pressure and flow measurement and control of inert and reactive gas inlet

Combined with the pulsed energy supply (UBS-C2), Fraunhofer FEP process control technology (PCU^{plus}) and fully automatic process control software, the RM800 sputtering sources can be used universally in different fields of application. Metal coatings as well as dielectric coatings can be deposited at high coating rates. This technology opens up new degrees of freedom in regard to influencing and optimising layer properties and therefore also allows coatings with more complex property profiles to be created for new applications. The energy input used onto the growing layer can be adjusted by selecting the pulse mode in such a way that substrates sensitive to temperature can be coated using a lower energy input while highly dense layers can be produced using a high energy input. By combing unipolar and bipolar pulse modi, even additional requirements for the layer to have a very low mechanical stress, can be met – something which is not possible with other technologies.

When forming several layers, the coating stations are operated without interruption and the carrier oscillates the substrates between the coating sources. Alternating low refractive (SiO_2) and high refractive layers (e.g. Al_2O_3, TiO_2, Ta_2O_3, HfO_2, Nb_2O_5) are thus deposited for optical coating systems, for example. Thickness uniformity has been optimised for surface areas of 500 mm × 700 mm and comes to approximately ± 1%. In future, uniformity values are expected to be better than ± 0.5% across homogeneous areas of 550 mm × 750 mm.

To adjust coating properties for single layers or coating systems precisely, PreSensLine has been fitted with modules which implement in situ monitoring. A pyrometer has been fitted to control the temperature of the substrate after pre-heating or after the coating process. So that spectral, optical properties, such as transmission or reflection, can be determined, an ellipsometer and an integrating sphere are used. This allows layer thicknesses to be determined in situ thus significantly speeding up the optimisation process of optical coating systems in particular. By taking intermediary measurements after each individual layer or even after sub-layers have been deposited means that the layer thickness for the next coating can be adjusted, if necessary.

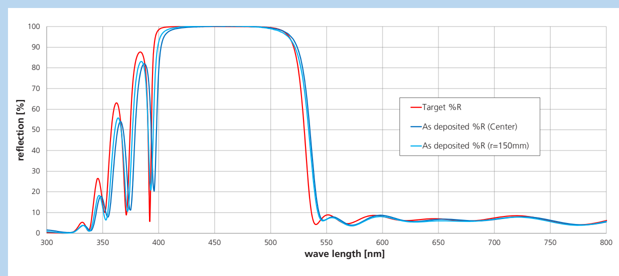
This new coating equipment forms the technological basis for creating highly precise and complex coating systems on large surfaces for use in laser optics, spectroscopy, display, lithography, medicinal technology, photovoltaics or sensors, amongst other things. The focus of precision coating is thus on the accuracy of the properties required (e.g. optical or electrical), high reproducibility, low defect density, low amount of roughness on the layers and good stability under extreme operating conditions.

Some examples of applications already tested using PreSensLine are:

- precision optical interference coating systems for large dichroic filters and special anti-reflection layers for 3D displays made from high (Nb_2O_5) and low refractive (SiO_2) single layers with deviations of <± 1% in regard to layer uniformity and reproducibility (see fig. 8 and 9);
- polishable layers for lithographic applications with excellent layer adhesion, a high coating speed and very low defect density;
- electrical insulation layers for sensors built into components with an electric strength of up to 800 V, a high coating speed for depositing layers of up to 8 µm thick with low defect density, high electric resistance and good layer adhesion on different substrate materials;
- sensory layers for gas and humidity sensors made from mixed oxide materials by co-sputtering different target materials with a wide range of variation in the material's ratio.

PreSensLine enables large surfaces to be coated precisely which are then highly efficient in applications used in optics, sensors and electronics. To achieve this, PreSensLine uses innovative coating technology based on optimised Fraunhofer FEP key components combined with sophisticated coating equipment as well as precision drive mechanisms and in situ monitoring. Thanks to additional degrees of freedom provided by Fraunhofer FEP technology, further new applications with highly complex layer property profiles are expected to be availed of in the future.

9 Dichroic filter: Comparison of the spectral reflection trend of target function and the deposited layer system in the middle and at the boarder [r=150] of the substrate; deviation of <1% in case of multi-layer system out of 20 single layers



5 Plastic spectacle lenses with and without anti-reflection layer system

6 Square magnetron

7 Rugate filter for narrow-band laser reflection

8 Dichroic filter with reflection in blue spectral range

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HEALTHY SEEDS – AN INTERNATIONAL CHALLENGE!

Since its foundation, Fraunhofer FEP has been involved in developing and marketing of environmentally-friendly methods for seed disinfection with accelerated electrons, and has been very successful so far. New foci for research reflect the seed industry's current global situation.

At the start of the year, Fraunhofer FEP held the symposium „15 YEARS OF ELBE SEED – A SAXON INVENTION ON ITS WAY TO SUCCESS" celebrating 15 years since electrons have been used to treat seeds industrially. Speakers from research, development and agriculture were able to explain in an extraordinary way to those interested what kind of potential this environmentally-friendly technology possesses and how, in the last few years in particular, the demand for electron-treated seeds in Germany has increased greater than production capacity. After striving for years to have this technology accepted by those in agriculture, this is a very positive development. The question experts are asking now, where did this boom come from?

One factor has certainly been that of partnering with innovative companies within the seed industry – these companies have acted as a catalyst for the growing acceptance. Another crucial factor, however, has been the increasing diffusion of plant diseases across the world due to global trade and climate change. Fewer and fewer systematic agents used to protect plants are able to counteract the risk of infection since the number of licenses awarded is barely rising due to safety concerns and pathogens' resistance to agents is increasing. The search for alternatives is already under way across the world. In these conditions, interest in treating seeds using electrons is increasing as a means of using physics to protect plants. And this is not purely a German phenomenon. In order to test how suitable Fraunhofer FEP technology would be for large seed markets and in order to prepare to enter the market, Fraunhofer FEP is able to draw on Fraunhofer internal funds as part of a PROFIL project. As a result, preparatory tests are being carried out with Chinese and Indian partners. However, these tests are not simply about testing the effect of the treatment by analysing pathogen spectra, soil conditions and climate effects, but are also about understanding the structure of the seed market as well as regulative and research activities.

In connection with this, an Indian delegation made their first visit to Fraunhofer FEP at the end of January 2013. The delegation spent an intense period acquainting themselves with the possibilities electron treatment can offer. Under the direction of the Fraunhofer Representative Office India, delegates from the University of Agricultural Sciences, Bangalore and several other agricultural universities from the federal state of Karnataka, plus a few industrial companies, discussed the benefits of working together with Fraunhofer FEP. The subject was rated as being so important that Fraunhofer received an invitation to speak at the XIII. ISST National Seed Seminar 2013 – INNOVATIONS IN SEED RESEARCH AND DEVELOPMENT in Bangalore. As the only foreign attendee at the conference, Fraunhofer FEP had the opportunity to present electron treatment to a varied audience. At the same time, the seminar provided a comprehensive overview of the current status of seed treatment and problems in India. The challenges associated with providing enough food for the population are enormous. 17% of the global population has to be provided with food using 3% of the world's land surface and 4% of the world's water reserves. The Indian seeds market is the fifth largest in the world with a turnover of approximately 2 billion dollars every year. However, only approximately 25% of the seeds needed are produced in controlled conditions and distributed as certified seeds due to a lack of infrastructure. Everything else results from uncontrolled production which is of a lower quality. On the other hand, research of a highly academic nature is being carried out into plant protection. However, it will be highly difficult to make this relevant in practice when considering the structure of the market. However, those involved in Indian agriculture have stated that they aim to become competitive on an international level and to rise to the position of a seeds exporter.

Given this context, Fraunhofer FEP needed to rethink the direction its development will take in electron treatment technology. Entering the Indian market can only be achieved through making small, yet inexpensive, laboratory equipment. There is great demand for such equipment both at universities and research institutes as well as in local, firmly decentralised seed treatment, though for the latter, the equipment would have to be slightly modified. This kind of technology only has a chance in Indian conditions if the equipment is designed to be robust and simple. Nevertheless, the market is enormous. Since 2009, Fraunhofer FEP has been constantly active in developing the market in China. While the seeds market there is similar in size to the Indian market, the structures are entirely different. Introducing a new procedure in plant protection to the market is made tedious due to the market's centralised structure which has many levels of responsibility that are

1 *Electron-treated seed, natural and healthy*

2 *Over 65 visitors hearing about this technology at the ELBE-SAAT symposium*

3 *Visit from scientists and industrial representatives from the Indian federal state of Karnataka as part of the PROFIL project ASeet*

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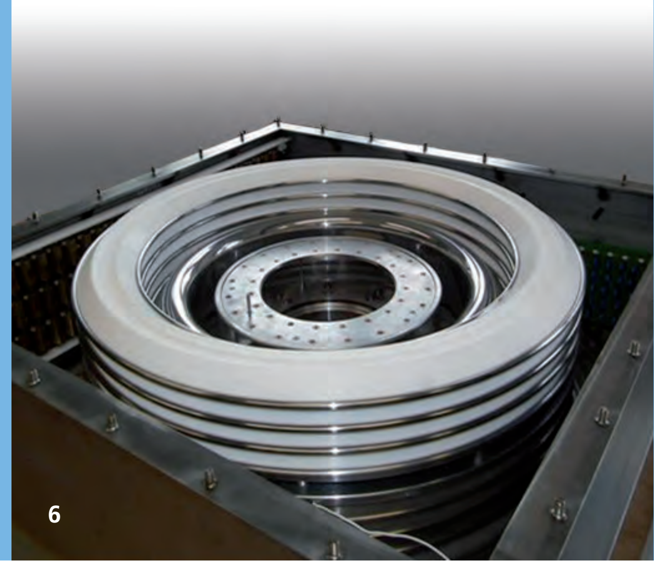

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often difficult for us to understand. Fraunhofer FEP has found a dedicated partner in the Shandong Academy of Sciences (SDAS) in Jinan which works with them on aptitude tests for the treatment process under the climate and soil conditions present in the Shandong province and which also provides contact to the seeds industry. In August 2013, SDAS organised a workshop in Jinan on treating seeds using electrons at which Fraunhofer FEP and SDAS were able to present their first set of joint results to a large audience made up of researchers, but also of government bodies, seed producers and seed treatment machinery manufacturers. Although the framework conditions differ greatly to those in India, one can also draw the conclusion that small laboratory equipment, or modular units with a small output, are certainly the focus of potential users.

The workshop took place alongside the 10th ICPP International Congress of Plant Pathology in Beijing. Fraunhofer FEP was also at the conference to present seed treatment using electrons. More than 1600 visitors from 80 countries discussed the current, global problems associated with plant protection, not just those affecting seeds. The conference itself only takes place every five years. Besides having a basic understanding of how plant diseases spread and are transmitted, a major issue was the effect of climate change and reducing the amount of chemical pesticides used. The majority of the conference was given over to how these problems can be solved by altering the genes in the seeds themselves or by modifying common combinations of agents. Other alternatives are scarce. It is precisely in this context that Fraunhofer FEP is introducing its electron treatment technology, something which consequently attracted everyone's attention across the international floor. However, the conference also showed that the considerable gaps in our understanding of the concomitant effects associated with seed electron treatment urgently need to be filled in. The fact that treated seeds germinate faster, grow fast initially on the field and are more resistant to pathogens in the soil was something that could often only be observed, but not explained. That is a topic for the FEP to research further together with expert partners from the Technical University of Dresden, the Julius Kühn Institute and other research centres. Knowing more about any other plant physiological effects of electron treatment can open up a new range of applications for this kind of technology.

As we were able to demonstrate, efforts to make healthy seeds the basis for productive agriculture by effectively protecting plants are increasing across the world, because a growing population along with a decrease in arable land presents the need to safeguard food production with enormous challenges. In this situation, the BMELV has decided to sponsor a large project to establish a consortium at Fraunhofer FEP to develop seed treatment technology using accelerated electrons. Glatt Ingenieurtechnik GmbH, BayWa AG and Nordkorn Saaten GmbH will be laying the foundations together with the FEP for a new, compact and modular generation of equipment as part of a project entitled „ResaatEl – resource-conserving seed treatment using new, cost-effective electron treatment units". A newly developed toroidal electron source (fig. 6) from Fraunhofer FEP will allow seeds to be treated for the first time by only using one electron source to significantly reduce the space required for the unit.

The Fraunhofer FEP pilot unit already available to treat seeds using electrons is designed to treat large throughput volumes of up to 30 t/h. BayWa AG and Nordkorn Saaten GmbH have been producing certified seeds using this pilot unit since 2011 and have marketed them under the E-PURA® brand. Another Fraunhofer FEP seed treatment unit is set to go into operation in 2014 at Nordkorn Saaten GmbH at their site in Güstrow. However, the past has also shown that there are only a few seed treatment sites which are actually able to use this high throughput efficiently. But the new generation of units is opening up a considerably larger field of applications for small and medium-sized seed producers. An objective which has also been acknowledged on an international level. For this reason, the joint project will also make a significant contribution to commercialising the technology better.

Another field of work is in using electrons to treat small quantities of highly-priced fine seeds such as vegetable and flower seeds. In this connection, Fraunhofer FEP started its preliminary development stage in 2013 which will go into the experimental stage in 2014. Challenges arise in both handling such differently shaped seeds and in entering the electron dosage required in a targeted and steady way.

For the E-processes department, 2014 is a year especially given over to treating seeds in an environmentally-friendly way using accelerated electrons. Fraunhofer FEP will be able to continue to pave the way in this sector of technology by grouping together all activities and carrying out joint projects with other expert partners both nationally and abroad.

4 *Award for the presentation given at the XIII. ISST National Seed Seminar*
5 *High yield thanks to electron-treated seeds, documented for more than 10 years via regular field tests*
6 *Toroidal source during assembling*

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz

ptble

Sponsorship for the project was provided by the Federal Ministry for Food, Agriculture and Consumer Protection (BMELV) as a result of the resolution made by the German Federal Parliament. Project management is carried out via the Federal Institute for Agriculture and Food (BLE) as part of the programme to promote innovation.

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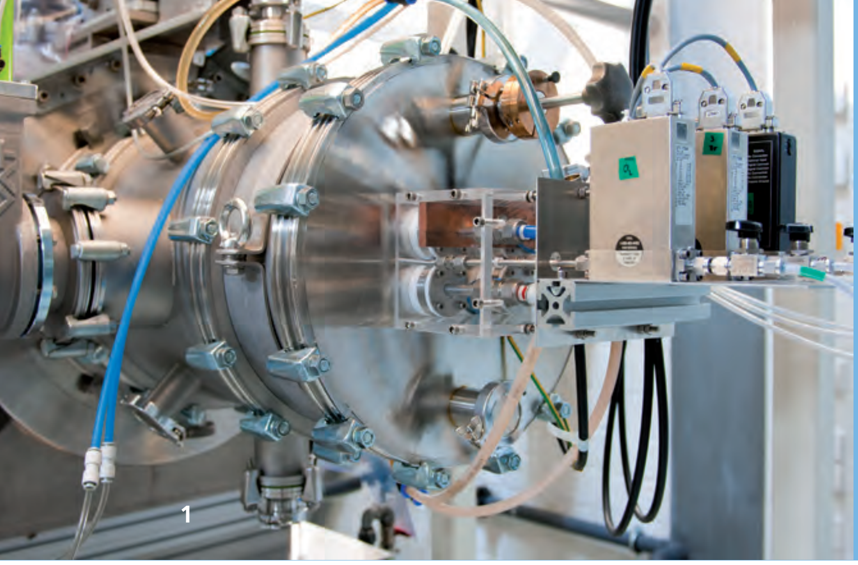
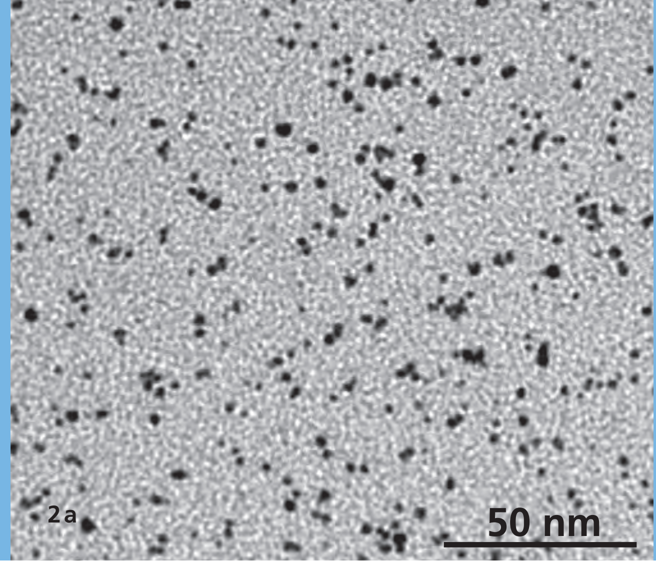
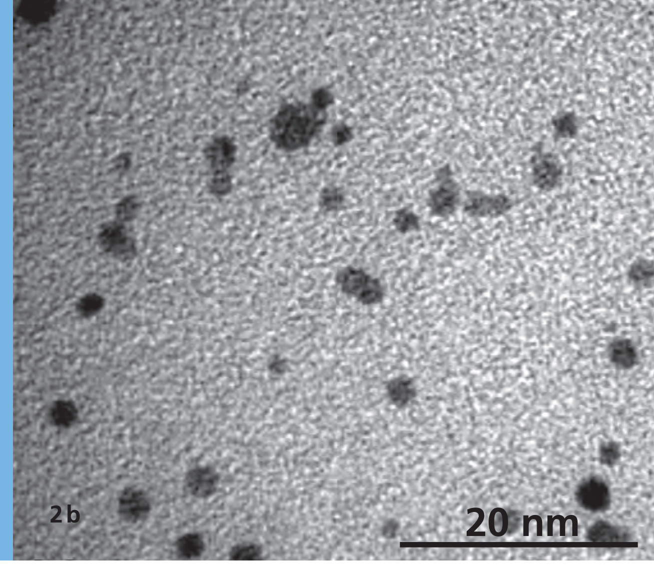






ENHANCED PHOTOCATALYTIC ACTIVITY OF TiO_2 THIN FILMS BY PT NANOPARTICLES DEPOSITION

A plasma-based process using a modified gas flow sputter (GFS) source, which allows the production of nanoparticles in a vacuum environment, is described. The equipment was successfully used for the deposition of Pt nanoparticles on thin films of TiO_2 in order to improve its photocatalytic activity.

Metal nanoparticles (NPs) deposited on a semiconductor photocatalyst like the TiO_2 act as traps for photogenerated electrons, reducing the electron-hole recombination rate and enhancing its photoactivity. Among the available approaches, the gas flow sputtering (GFS) process for plasma generation of metal NPs is very promising, because it allows the synthesis of large quantity of particles with well-defined physical properties and their deposition directly on surfaces in a vacuum process.

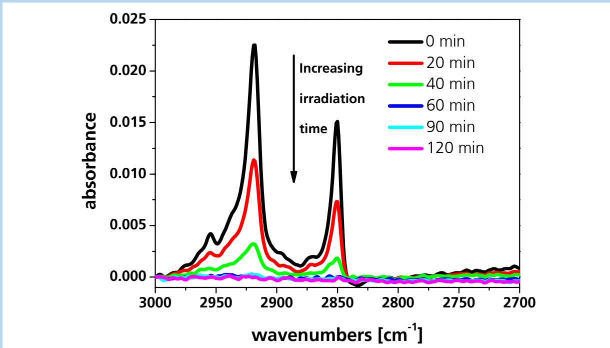
The GFS process is a hollow cathode glow discharge with a high gas flow. In inert gas atmosphere, plasma is ignited between two parallel metal targets (cathode) and the chamber wall (anode) (Fig. 1). Due to the geometry of the hollow cathode, the secondary electrons emitted from the targets are here confined and can efficiently ionize the gas atoms creating a high-density atomic vapor. An Ar gas flow forced through the cathode enables effective transport of the sputtered atoms into an aggregation zone. There they first thermalize by collisions with the buffer gas, and then condense to form nanoparticles or clusters, which are deposited on the substrate at high deposition rates. Because the gas stream efficiently cools the atomized particles, the substrate temperature remains low and the coating of thermally sensitive substrates is possible. By introducing reactive gases, compound NPs can also be formed. The size of the particles can be adjusted between 2 and a few tens of nanometers by changing the pressure in the aggregation zone or by tuning the discharge power.

One of the applications was the deposition of Pt NPs on TiO_2 thin films in order to improve the photocatalytic activity of the semiconductor. For this investigation, the NPs were deposited on two types of substrates: float glass coated with TiO_2 thin films by reactive pulse magnetron sputtering (PMS) and commercial photocatalytic glass. A discharge power of 3 kW and a pressure in the aggregation region of approx. 50 Pa were employed. Two series of experiments were conducted by sputtering for 3 (Fig. 2) and 5 seconds to deposit different amount of NPs.

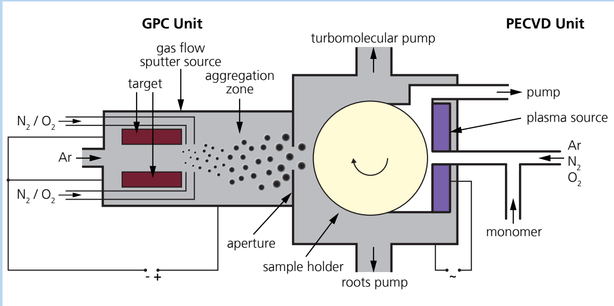
Thereafter water contact angle measurements were performed on the samples during irradiation with UV-A light in order to check their photo-induced superhydrophilic properties. Moreover, self-cleaning properties of the photocatalysts were evaluated by tracing the decomposition of thin films of stearic acid (SA), that were deposited on the TiO_2-coated glasses by spin-coating. The decomposition of the SA was assessed through infrared absorption spectroscopy, by monitoring the disappearance of the typical SA bands in the region 2700–3000 cm^{-1} (Fig. 3). The integrated area under the peaks is used to calculate the decomposition rate.

It was observed that the presence of Pt NPs greatly enhances the self-cleaning and photo-induced superhydrophilic properties of TiO_2 thin films for very small amounts of loaded metal (only 3 sec deposition time). On the contrary, a higher deposition time (5 sec) was detrimental for the photocatalytic activity of the TiO_2. This is attributed to an excessive coverage of the semiconductor surface by the NPs, which can limit the quantity of light reaching the TiO_2.

3 Photocatalytic decomposition of stearic acid by a TiO_2 layer (PMS) coated with Pt nanoparticles (3 seconds deposition time). FTIR absorption spectrum measured before (0 min) and after UV-A irradiation after certain time intervals (20...120 min; $P_{UV\text{-}A}$=1.5 mW/cm²)



4 Vacuum deposition system composed of a gas phase condensation (GPC) unit for nanoparticles production (left) and a PECVD unit which enables the incorporation of the particles into organic matrix materials (right)



1 LB nano

2 TEM pictures of Pt nanoparticles deposited on carbon grids using the following sputtering parameters:
power discharge 3 kW,
Ar flow 0.75 slpm,
sputtering time 3 sec.
(one sample with two different magnifications)

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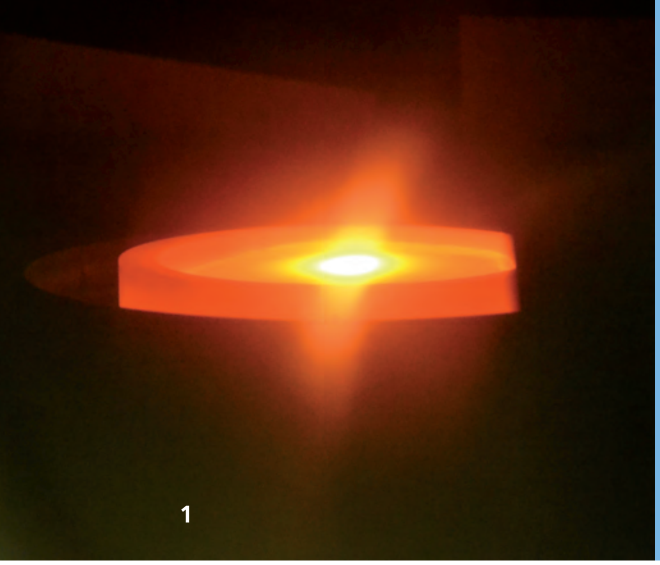
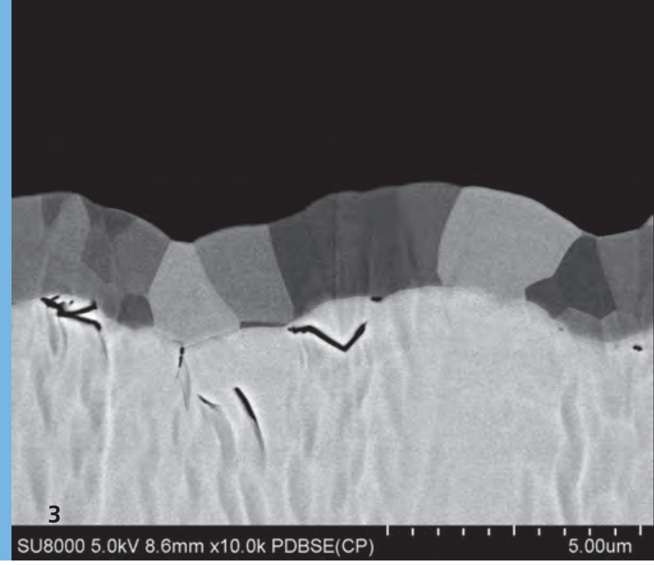
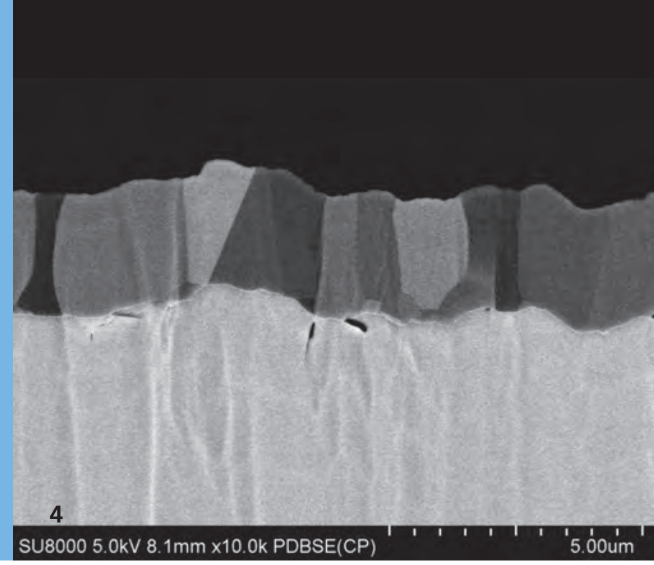






COST-EFFICIENT HIGH-RATE METALLISING FOR HETERO-JUNCTION SOLAR CELLS

Hetero-junction cells constitute a promising method of establishing high cell efficiencies in the photovoltaics market [1]. Currently, the cells are characterised by efficiencies of more than 21% [2,3]. At the Fraunhofer FEP, a related, cost-efficient metallisation step is being developed.

The selected approach to the solution consists of applying the high-rate electron beam evaporation for aluminium metallisation of the rear cell contact. For this, different crucibles – water-cooled, cold and ceramic, hot crucibles – should be tested and the deposited layers should be evaluated. Fig. 1 illustrates a ceramic crucible during practised aluminium evaporation. Fig. 5 demonstrates that, regarding the two tested crucible variants, evaporation with stationary coating rates in the target at range of 100 – 200 nm/s are possible. The required energy for the ceramic crucible is lower by a factor of 3 to 4, which is the reason for the specific interest in this type of crucible.

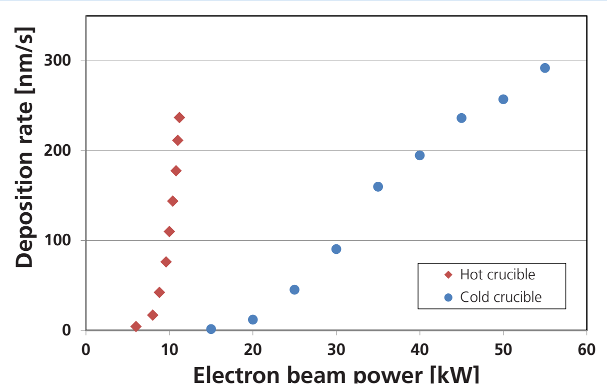
Despite the high coating rate and the low thickness of the silicon wafers of less than 200 µm, the temperature limit of 200°C must not be exceeded due to material-related reasons when the aluminium layers with a thickness of one micrometer are deposited. The temperature curve of the wafer during aluminium evaporation in Fig. 6 illustrates that this general condition is also complied with.

The structures of the layers show a very compact crystalline structure (see Fig. 3 and 4). This was expected for evaporation from the cold crucible. Fortunately , ceramic crucible materials were found that make this possible. These compact layers are characterised by specific electrical resistances corresponding to the values for aluminium bulk material, the values are at least, only exceeded by 10% using the ceramic crucible. The most important prerequisite for using the evaporated layers to tap the current generated in the solar cell at the lowest possible losses is met this way.

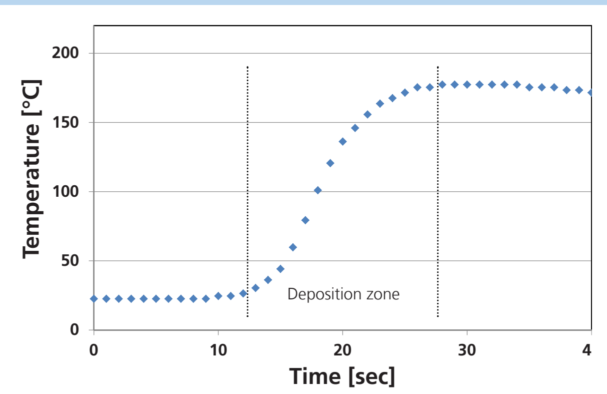
The efficiency analysis performed demonstrates that the developed high-rate metallisation is capable of providing a 100 MW product line and must be estimated with a portion of costs of less than 0.03 Euro per Watt peak. The general project goal of providing a cost-efficient alternative for sputtering regarding the metallisation of the hetero-junction cells is accomplished.

The further analyses within the framework of the joint research project with Roth & Rau AG address the comprehensive analysis of the processed hetero-junction cells, further analyses for optimising the materials for the ceramic crucibles, as well as the long-term stability of the aluminium high-rate metallisation.

5 *Stationary aluminium deposition rate as a function of the electron beam power*



6 *Heating of the wafer during aluminium evaporation*



[1] *Lachenal et al.: High Efficiency Silicon Heterojunction Solar Cell Activities in Neuchatel, Switzerland; 25th EUPVSEC (2010), p.1272*

[2] *Strahm et al.: Silicon Heterojunction Solar Cells on Thin Large Area Substrates: The Route towards Low Electricity Generation Cost; 28th EUPVSEC (2013)*

[3] *Taguchi et al.: 24.7% Record Efficiency HIT® Solar Cell on Thin Silicon Wafer; 28th EUPVSEC (2013)*

1 *Aluminium evaporation from hot crucible*

2 *Wafer based solar cell*

3 *Structure of the aluminium layer evaporated from a cold crucible*

4 *Structure of the aluminium layer evaporated from a hot crucible*

The project was funded by the European Union and the Free State of Saxony.
Funding reference: 100095132

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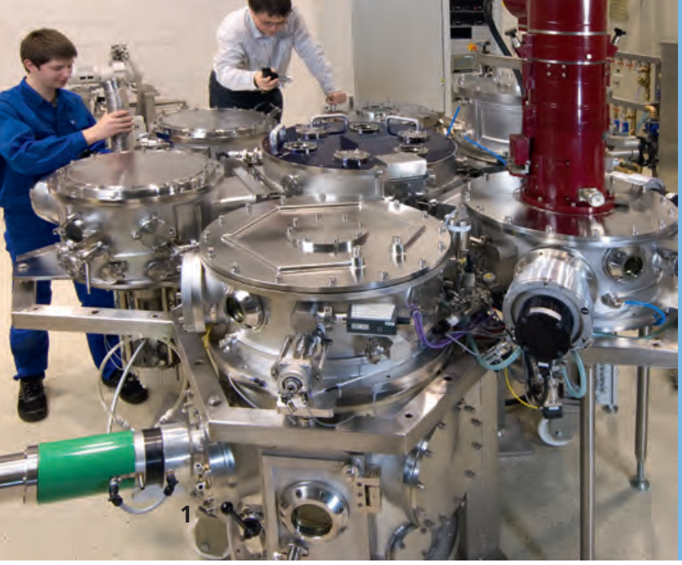
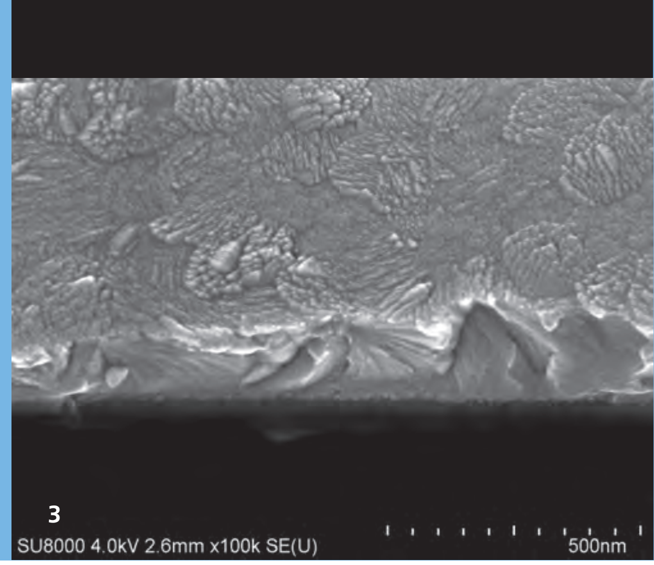
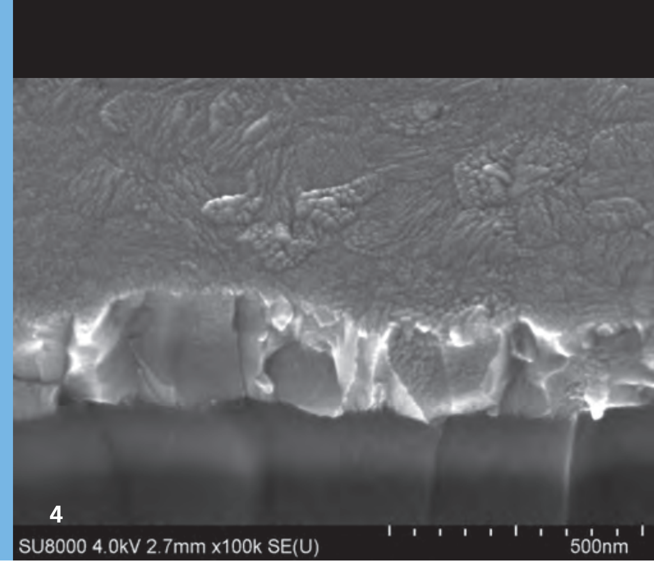






ELECTRON BEAM RAPID THERMAL ANNEALING OF TRANSPARENT CONDUCTIVE OXIDES

Rapid thermal annealing of coated surfaces with an electron beam is a new process in the field of thin-film technology. Applying this technology to transparent conductive oxides is a very promising method. The conductivity levels achieved on glass by means of these films exceed the values possible when tempering conventionally.

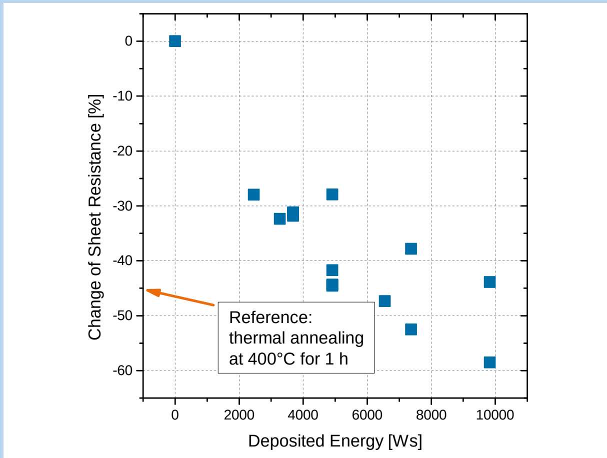
Flexible optoelectronic devices have a promising future. Foldable displays and ultra-light solar cells are the two most important applications currently emerging. Regarding the anticipated broad launch of these products, several technical requirements must be met. Work is being done world-wide to fulfil these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

Transparent conductive oxides, specifically the valuable indium tin oxides (ITO), constitute an important class of materials for this purpose. Transferring this coating technology to polymer substrates is a challenge. The substrate materials should not be heated excessively during coating. However, this is a prerequisite for achieving high levels of film quality. The key to solving this problem is heating the film for a short period of time using a pulsed application of energy. This way, the surface is heated to a high temperature without excessively heating the sensitive substrate. This technology was already tested using laser and UV impulse lights. Experiments were conducted at the Fraunhofer FEP aiming at using the electron beam for rapid thermal annealing. When compared to the other two methods, the electron beam emits the major part of its energy only a couple of hundred nanometres below the surface. This reduces the thermal tensions between the layer and the substrate which is the essential advantage when implementing this technology.

As an example, Figure 5 illustrates the effect of the electron beam on the film resistance of an ITO-coated glass surface. The thickness of the ITO film was 230 nm. The electron beam was used with an acceleration voltage of 10 kV in order to scan a glass surface of 8 cm × 8 cm. A simulation program was used in order to estimate the temperature of the film which reached a value of 600°C for a short period of time. However, the temperature pulse only lasted a few milliseconds causing the substrate to heat only slightly. The figure illustrates the clear connection between the amount of heat applied by the electron beam and the change of the layer resistance when compared to the initial value. In the best case, the layer resistance was reduced by 60%. This clearly exceeds the reference value when heating the coated glass to a temperature of 400°C for 1 hour, corresponding to a conventional annealing process. This example illustrates: the treatment of ITO-coated surfaces with an electron beam is a powerful method for optimising transparent electrodes. The reduction of the necessary annealing time from one hour to a few minutes is already an essential advantage. Regarding temperature-sensitive substrates, another advantage includes the fact that the applied heat can be limited almost entirely to the film. In contrast to rapid thermal annealing using the laser or UV lights, the distribution of the applied heat in the layer can be adjusted advantageously in a targeted manner by adjustment of the acceleration voltage of the electron beam.

In the next step, the technology will be advanced and optimised for rapid thermal annealing of coated polymer substrates (e.g. polymer films). The challenge at the transition from glass to polymer substrates is to apply the largest possible amount of heat to the film while simultaneously applying the least possible amount of heat to the substrate. This development work is supported by a powerful simulation program. In the medium term, the goal is to verify this technology on a roll-to-roll system and to render this technology usable for the industry by means of pilot projects. In fact, we are looking for partners from industry already in the current development phase.

5 Change of the layer resistance of a 230 nm thick ITO layer on glass at the application of an electron beam (10 kV)



1 Cluster system »ERICA« for complex coating and patterning process in vacuo

2 Electron beam in vacuo

3 REM image ITO tempered on glass

4 REM image ITO non-tempered on glass

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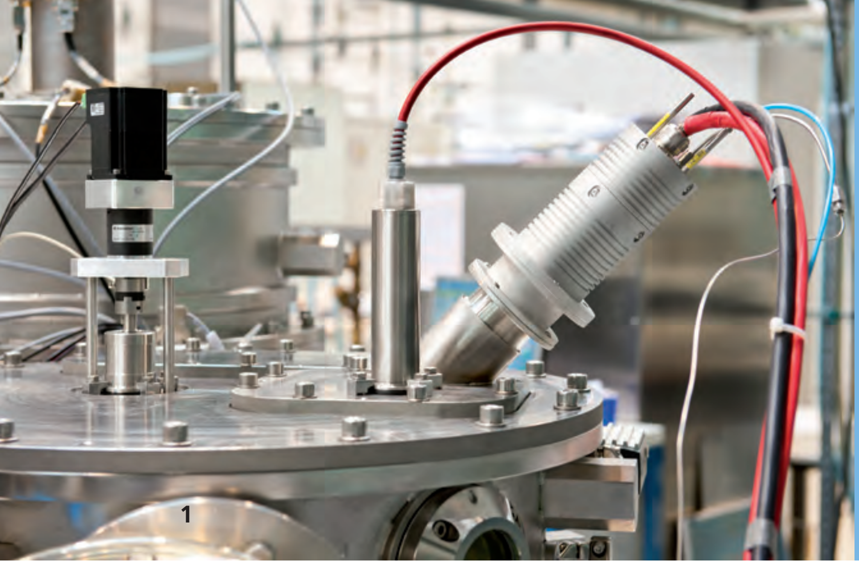

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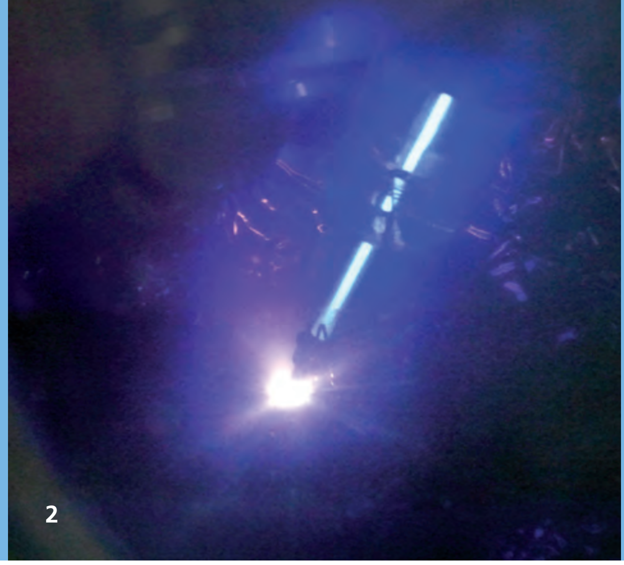

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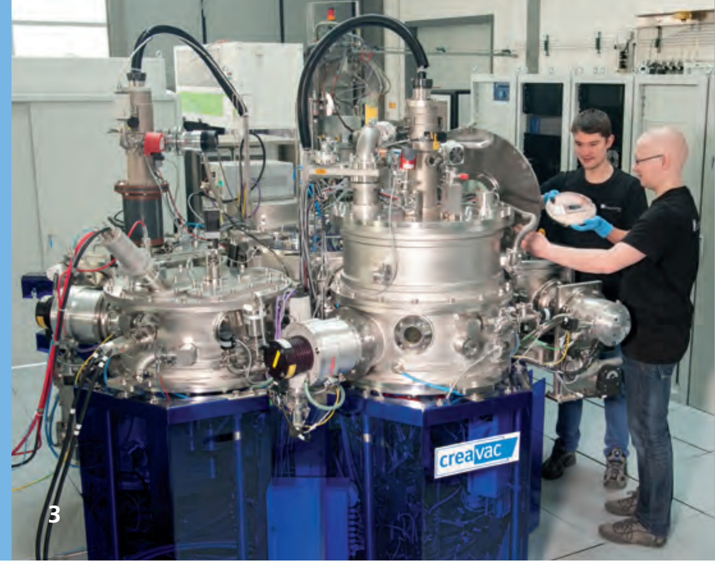

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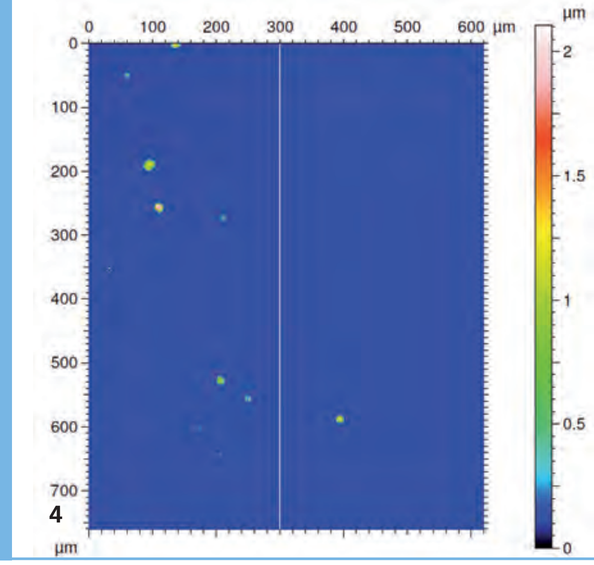

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PULSED ELECTRON BEAM DEPOSITION – A NEW COATING METHOD AT THE FRAUNHOFER FEP

At the Fraunhofer FEP, the use of a new highly intense, pulsed electron beam source opens new possibilities regarding the defined deposition of dense, as well as adhering thin layers and layer systems of a broad range of materials, especially on thermally unstable substrates.

With the new Pulsed Electron Beam Deposition (PED) method, a new field of work has been developed at the Fraunhofer FEP. A pulsed electron beam with a very high power density $\geq 10^8$ W/cm² is applied locally to a target and allows for an ablation of the target material, i.e. the surface of the matter to be evaporated is heated locally for a few nanoseconds to an extent that the state of material abruptly switches from solid to gaseous and moves towards the substrate as a directional vapour flow.

When compared to alternative Pulsed Laser Deposition (PLD), this method is characterised by low system costs. An essential feature of the process includes its high variability – nearly all materials (both electrically conductive and insulating materials) may be ablated. Microparticles during layer formation can be prevented by optimising the process parameters.

One particularity of the method includes the formation of a dense discharge plasma. It increases the energy of the ablated particles to several 10 eV and thus to a higher energy level than during electron beam evaporation or sputtering, for example. This positively influences the properties of the growing layers so that the substrate temperature can be kept low. Therefore, the growing of adhering, dense layers are also made possible on temperature-sensitive substrate materials – such as plastic, for example.

As opposed to the classic electron beam evaporation process, the target to be evaporated remains solid when using PED. The advantage is that this allows for homogeneously depositing alloys in the proper stoichiometric ratio, because there is no accumulation of the components that are difficult to evaporate due to the avoidance of a molten bath. With the help of defined energy pulses, the coating rate can furthermore be adjusted in a targeted manner.

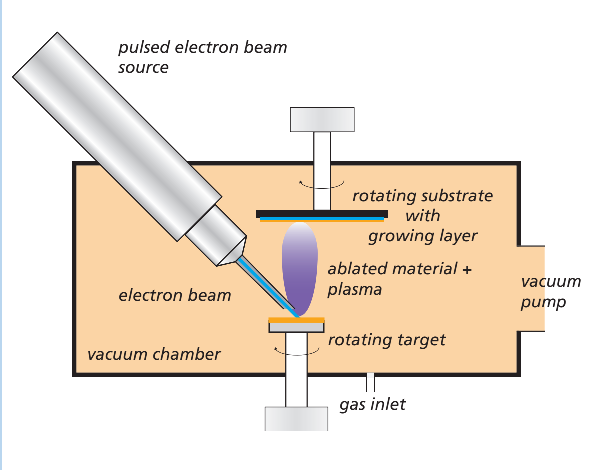
Moreover, reactive process control is possible by adding the corresponding gases. As a result, there are numerous different application possibilities such as the production of hard material layers, decorative layers, or transparent, conductive oxide layers. Further possible fields of application can be found in the field of flexible displays and in the thermoelectric sector. In order to coat industrially relevant substrate dimensions and to increase the rate, several PED sources may be combined.

At the Fraunhofer FEP, a coating system from Organic Spintronics srl was integrated into the existing vacuum cluster plant »ERICA« and the deposition of thin metal and semi-conductor layers was examined in process chains for photovoltaic applications. Furthermore, promising tests regarding the deposition of transparent conductive oxide layers were conducted. The first tests were intended to develop a general understanding of the PED process, as well as to demonstrate the principle suitability of the method for different applications.

5 Process parameters

Acceleration voltage:	up to 20 kV
Chamber pressure:	10^{-5} … 10^{-2} mbar
Extracted energy per pulse:	~1 J
Repetition rate:	0 … 100 Hz
Power density:	~10^8 W·cm^{-2}
Act. power density on substrate at 100 Hz:	~10^{-2} W·cm^{-2}
Typical layer thickness per pulse:	0.001 … 1 nm
Static deposition rate:	0.1 … 100 nm·s^{-1}

6 Process scheme PED



1 PED system on the vacuum cluster plant »ERICA«

2 PED process: effect of the intensive electron beam on a target

3 Cluster system »ERICA« for complex coating and patterning processes in vacuo

4 Surface profiles (White light interferometry) of silicon layers deposited by PED. Selecting suitable process parameters can significantly reduce quantity and size of occurring microparticles (left: unoptimized, right: optimized)

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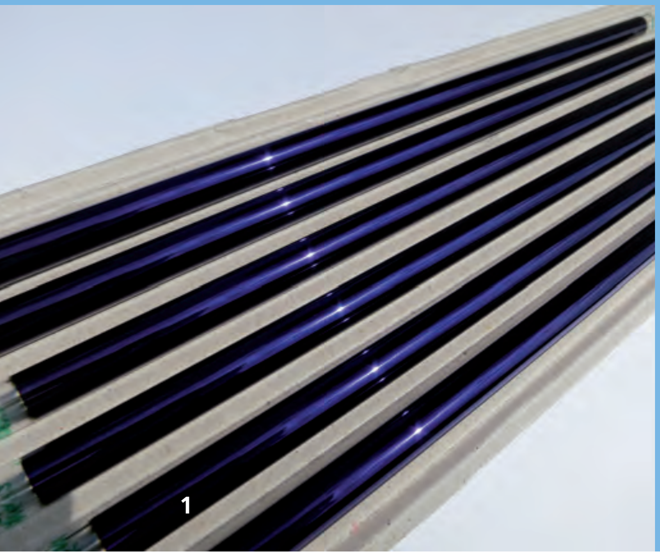
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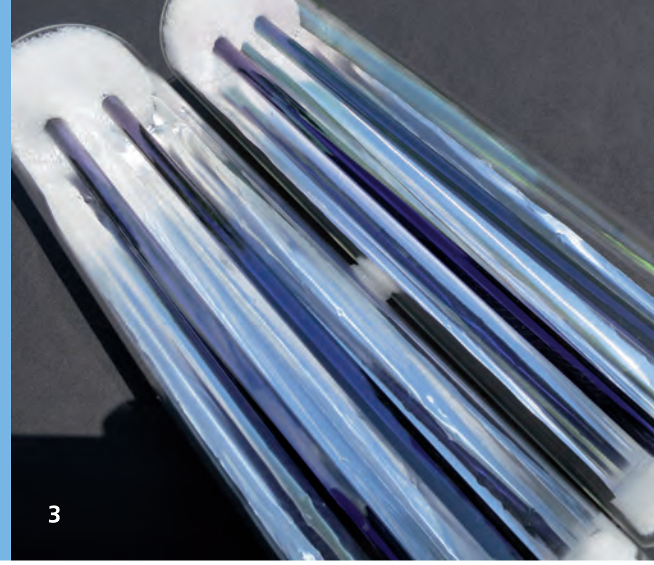
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LAYER SYSTEMS FOR HIGH-PERFORMANCE SOLAR TUBE COLLECTORS

Along with photovoltaics, solarthermics has a huge potential for sustainably using renewable sources of energy. The prerequisite for developing this potential includes high-temperature solar collectors able to guarantee perennial loading and withdrawal cycles in connection with low-loss energy storage.

Although the direct conversion of sunlight to usable thermal energy, also referred to as solarthermics, can already look back on a long development history, it is currently experiencing a development burst that, according to many experts, will lead to a significant expansion of its field of application.

Traditional solar collectors are operated with water as a transport medium and work at temperatures of about 100°C. However, it is not possible to combine them with Zeolith thermal storage systems capable of emitting the thermal energy stored during summer in the winter, since these require loading temperatures in excess of 200°C.

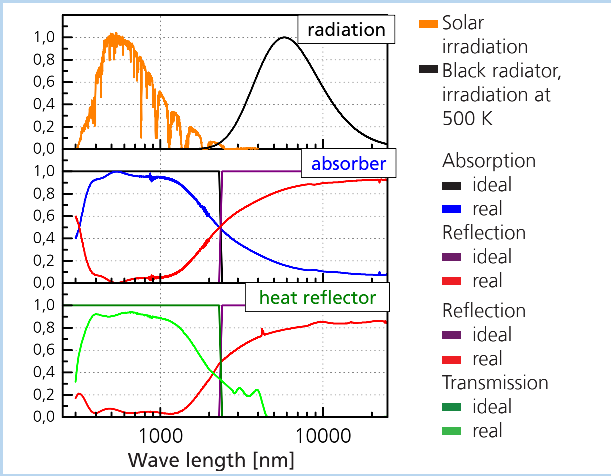
The technical implementation of solar collectors for operating temperatures of 200 – 250°C first and foremost requires a reduction of the irradiation losses increasing with the fourth power of the temperature. On the one hand, effective measures may include the advanced optimisation of the absorber layer system towards low IR irradiation. On the other hand, the transition to a vacuum tube design with an additional intermediate tube and an IR-reflecting coating deposit offers huge potential for increasing the overall efficiency of the collector for high temperatures.

The absorber layer system developed at the Fraunhofer FEP is based on the principle of a multi-layer absorber consisting of alternating deposits of metal (Cr, Mo) and dielectric (Al_2O_3, Si_3N_4) layers with an adapted thickness and achieves a degree of solar absorption of 94% at a degree of thermal emission of less than 10% (at an operating temperature of 200°C). The layer adhesion is outstanding and the predicted ageing resistance is sufficient even at increased application temperatures. Tempering tests 72 hours at 500°C, what corresponds to a service life of more than 30 years at a temperature of 200°C, conducted in this regard did not result in any measurable changes of the layer properties.

When compared to the absorber, complementary requirements exist for the necessary second layer system, the heat or IR reflector: while the first must absorb in the visible wavelength range and reflect in the infrared wavelength range, the latter should combine high optical transmission in the visual range with high reflection in the infrared range. This is achieved by transparent conductive layers based on metals (Ag) or oxides (ITO, AZO) that must additionally be equipped with adapted diffusion barriers and anti-reflection layers. The easier technical controllability, as well as the lower manufacturing costs argue in favour of metal-based systems at this point, while the better long-term stability is a decisive advantage of the oxide-based systems up to now. However, current development work gives reason to expect more progress in this field.

During the development of the depositing processes (reactive and non-reactive magnetron sputtering) the focus was on the simplicity and reliability of the technologies (no complex process control necessary), as well as on the largest possible fault tolerance of the layer stacks (regarding thickness deviations of the individual layers). In collaboration with the mechanical engineering company Götz Lamm & Co. OHG Metalltechnik Großenhain, a pilot plant was designed, built up, and commissioned in this regard, which will deliver the first samples of coated absorber and reflector tubes shortly. The glass blowing company Horst Müller Berlin is responsible for further processing and completing these samples to become demonstrator components so that the first high-performance collectors will be available for evaluation in the near future.

5 Incident and irradiated energy spectrum (top), as well as spectral characteristics of absorber (middle) and heat reflector (bottom) adjusted to the aforementioned



1 Coated absorber tubes
2 ILA 750 – vertical in-line sputter plant
3 Collector models
4 UNIVERSA – pilot plant for 3D coating using pulse magnetron sputtering

Europa fördert Sachsen.
EFRE
The project was funded by the European Union and the Free State of Saxony.
Funding reference: 100072533

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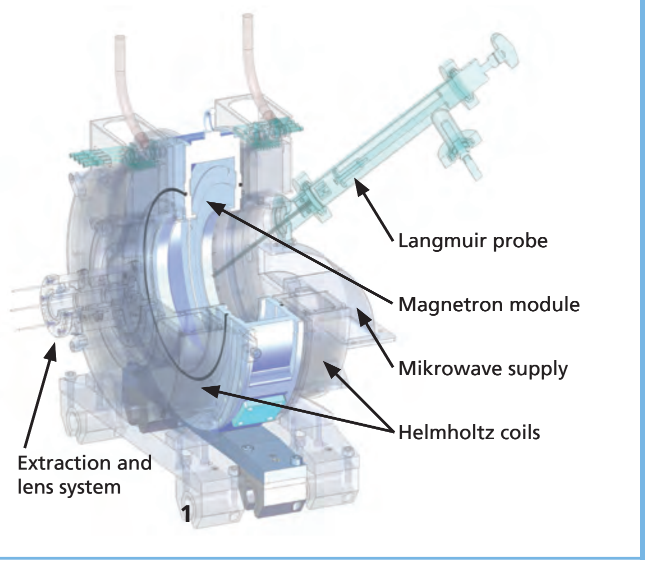

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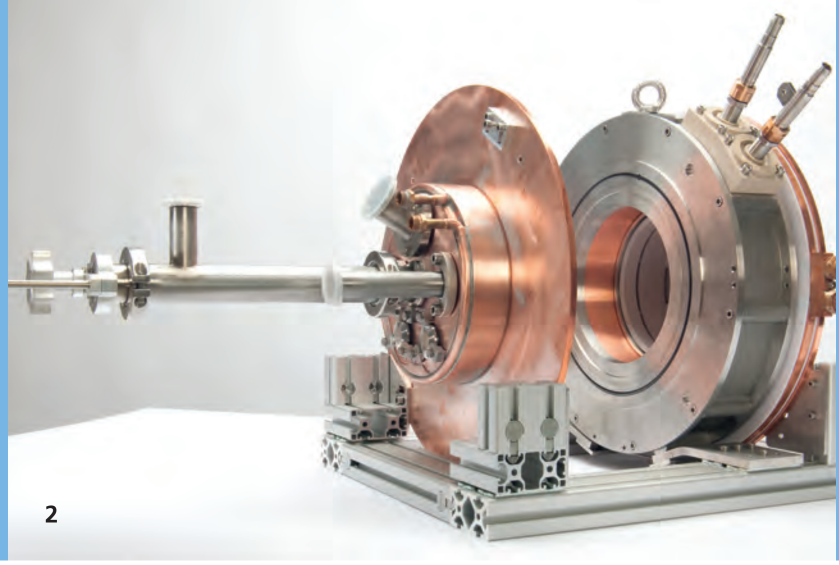
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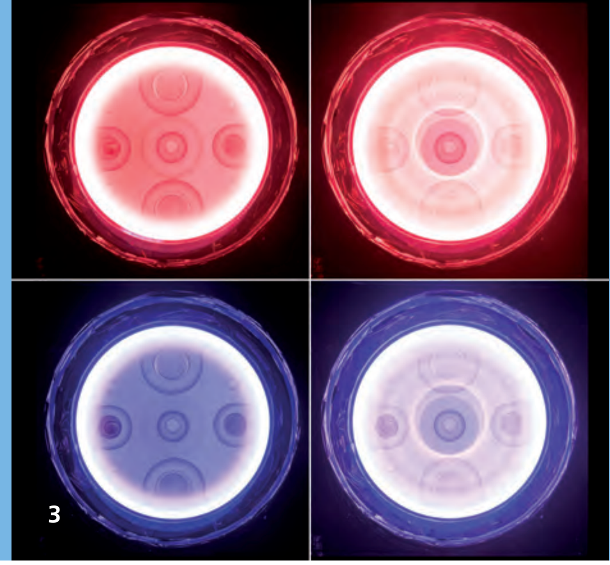
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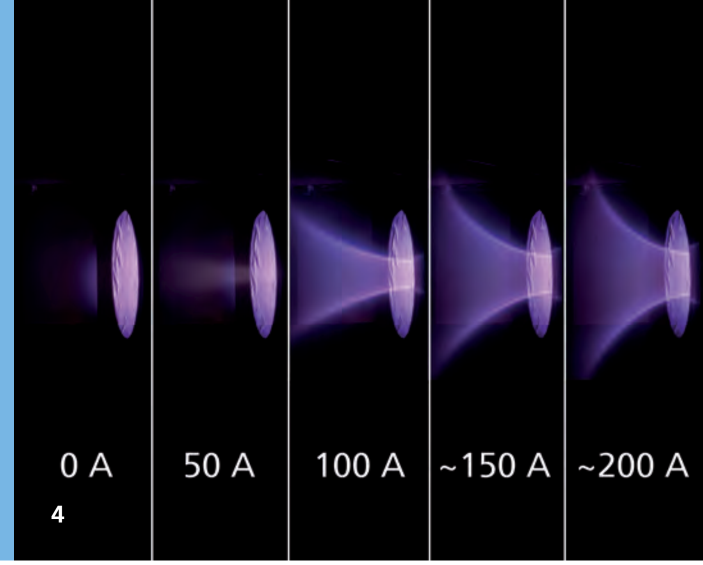

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LOADING AN ECR SOURCE USING SPUTTERING TO IMPLANT Al^{+} IONS

Doping is a significant process step for photovoltaic cells within regard to quality, efficiency and costs. None of the doping processes currently used in PV technologies meet all of the requirements sufficiently. New technologies need to be developed.

The motivation for developing a technological basis for a doping process that uses Al ion implantation arises from the fact that this technology allows to carry out two essential doping stages for silicon photovoltaics for both wafer-based and thin-film techniques:

- the (selective) emitter profile for n-type PV cells and
- the (local) back surface field profile for p-type PV cells.

For crystalline solar cells, n-type silicon would usually be the best material since it is not subject to ageing caused by a light-induced build-up of boron-oxygen complexes, unlike p-type Czochralski silicon. Plus, it displays a higher charge carrier lifetime.

In principle, high-amperage ECR ion sources[1] with subsequent ion optics suitable for generating broad beams enable a high-grade implantation of Al ions on large processing widths – of up to two meters in future. The particular challenge is in loading the ECR plasma/ECR resonator chamber with aluminum. A magnetron sputtering source meets all of the requirements (especially regarding beam purity) placed on the technology at comparatively moderate purchasing and operating costs, and has no limitations. A „magnetron ECR ion source" of this kind, MECRIS[2], has been created in partnership with DREEBIT GmbH (Dresden) (fig.1).

Developing the „magnetron sputtering source" module at Fraunhofer FEP in the shape of a hollow cylinder (target width 50 mm, radius 100 mm/sputtering direction: inward radial) required particular careful alignment with the structure of the ECR resonator. This is because:

- exact magnetic fields have to be defined for both the microwave resonator as well as for the sputtering source. These fields have to be as free from interaction as possible.
- electrical fields are needed for the sputtering source and for extracting ions from the resonator. These electrical fields have to be sufficiently free from interaction.

These requirements could be met during the construction phase with the help of numeric simulation (COMSOL). The loading of the immediate ionization volume (spheroid) in the middle of the resonator was ensued simultaneously.

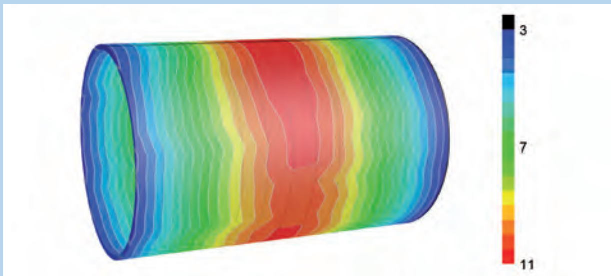
The magnetron sputtering source (fig. 2) is subjected to an extensive analysis. The following properties are determined:

- space-resolved coating rate (fig. 5) and/or integral load rate (fig. 6) and three-dimensional densities of Al atoms
- electron temperature and density using a partly automated double Langmuir probe

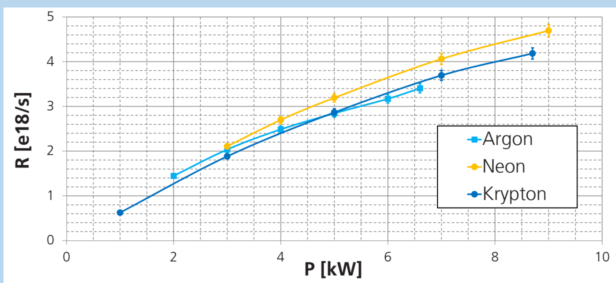
Numerous process parameters are varied, e.g. magnetron power, type (fig. 3) and pressure of the process gas, to create a basis for an operation of the MECRIS, which is most efficient and long term stable too. Further, the influence of target erosion and the coil current in the Helmholtz coils (fig. 3 and 4) on the operating parameters is determined.

As predicted, the magnetron sputtering source is able to generate a sufficient load rate of > 10^{18} Al atoms per second even at a medium power density (> 4 W/cm²). This rate is needed to provide the integral Al ion current of 30 mA that will be required from the completed MECRIS in the future.

5 Space-resolved coating rate r [nm/s] for process parameters: 5 kW/Ar 1 Pa/no coil current



6 Integral Al atom load rate R in dependence of power and type of gas



[1] *ECR: Electron Cyclotron Resonance*
[2] *MECRIS: Magnetron ECR Ion Source*

1 3D section of high current ECR ion source MECRIS (Fraunhofer FEP magnetron highlighted) © DREEBIT GmbH
2 Fraunhofer FEP cylinder magnetron with analytical equipment on a special flange
3 Sputtering plasma; front view (left without, right with coil current resulting in higher plasma density)
above: Neon process gas
below: Argon process gas
4 Sputtering plasma (argon process gas); side view from left to right: increasing coil current (0 … maximum)

The project was funded by the European Union and the Free State of Saxony.
Funding reference: 100106678

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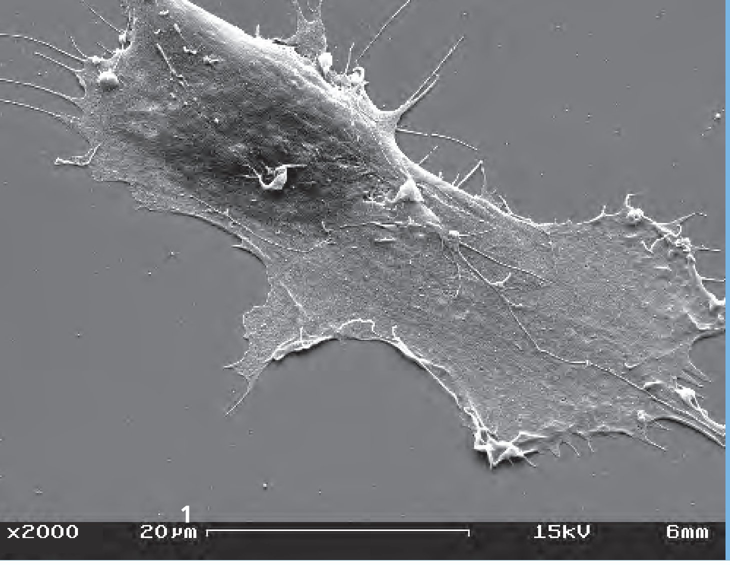

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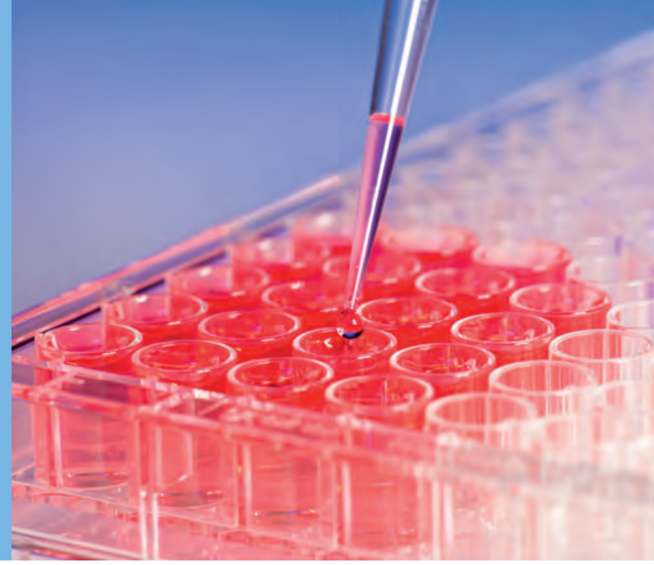



2

DEVELOPMENT OF BIOFUNCTIONAL, STERI-LISATION-RESISTANT DLC LAYERS

DLC coatings are to be modified with the help of low-energy electron beam technology. The intended field of application is medical engineering, hence durability of the coatings and sterilisation resistance, as well as possible improvement of biocompatibility are assessed.

Over the course of the past years, diamond-like carbon (DLC) established strongly in the field of medical applications (Fig. 2). In this, the very good friction/gliding properties, high hardness values, as well as good biocompatibility are particularly advantageous.

Due to the amorphous structure of DLC, the material can be characterised by properties of diamond *and* graphite [1]. In this, the hybridisation condition of the carbon atoms (sp^2 hybridised and/or sp^3 hybridised), as well as the hydrogen content of the coating are decisive. These parameters vary depending on the deposition method.

Within the framework of an SMWK-sponsored cooperation project, the group »Medical Applications« of the Fraunhofer FEP and Europ Coating GmbH, address the modification of DLC as well as material-related and biological assessment of these coatings.

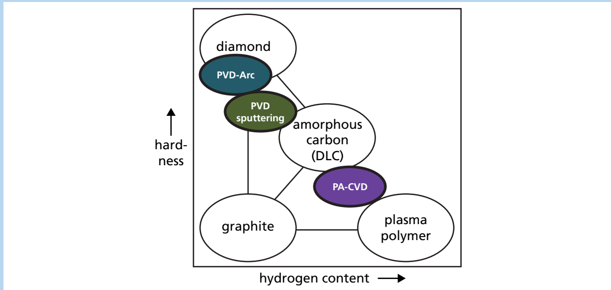
By using different deposition methods (PA-CVD, PVD sputtering, and PVD-Arc methods), Europ Coating GmbH deposites DLC layers with varying properties (Fig. 3). These layers are then modified by low-energy electron beam treatment at the Fraunhofer FEP. It is intended to improve the mechanical durability and the biofunctionality thus increasing the marketability of the modified surfaces in the field of medical applications.

The electron beam modification is expected to result in a changed layer durability with the power of enhancing sterilisation resistance of the coated surfaces. In order to assess this, a practice-oriented sterilisation regime (preliminary treatment 1M NaOH, followed by steam sterilisation) was developed and the layers were subjected to a total of 80 sterilisation cycles. The results demonstrated that stable DLC layers can be created both by PVD-Arc and by PVD sputter deposition.

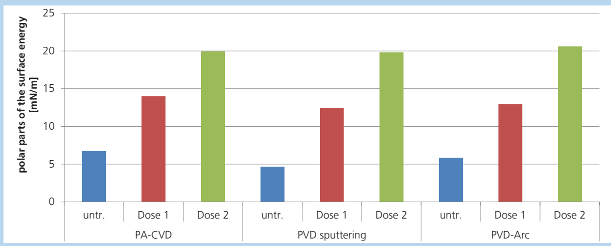
The characterisation of the electron beam modified DLC layers was performed with the help of contact angle measurement and surface energy calculation whereby the energetic properties of the layers were determined. The calculation of the dispersive and polar parts of surface energy showed that the polar parts increase with rising electron beam dose (Fig. 4), which correlates with a change of the relation between sp^2 and/or sp^3 hybridised carbon atoms. The biological interactions may also be influenced positively by increasing the polar parts.

Initial cytological results revealed that all of the coatings show a good biocompatibility (Fig. 1). The cell vitality on the coatings was also increased slightly compared to the standard (Fig. 5). The biofunctionality of the DLC coatings is to be advanced further by means of electron beam modification.

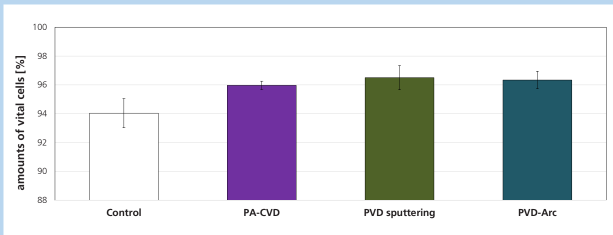
3 *Classification of the deposition methods used for DLC*



4 *Polar parts of the surface energy of unmodified and electron beam treated DLC layers*



5 *Amount of vital connective tissue cells on the different DLC coatings*



[1] *Mertz, K.W., Jehn, H.A.; Praxishandbuch moderne Beschichtungen: Advanced Surface Coatings, Hanser Fachbuchverlag 2001, S. 261*

1 *Spreading cell on biocompatible surface*

2 *Microsurgical instruments*

Freistaat Sachsen
Staatsministerium für Wissenschaft und Kunst

Funded by the Saxon State Ministry for Higher Education, Research and the Arts
Funding reference: 100106122

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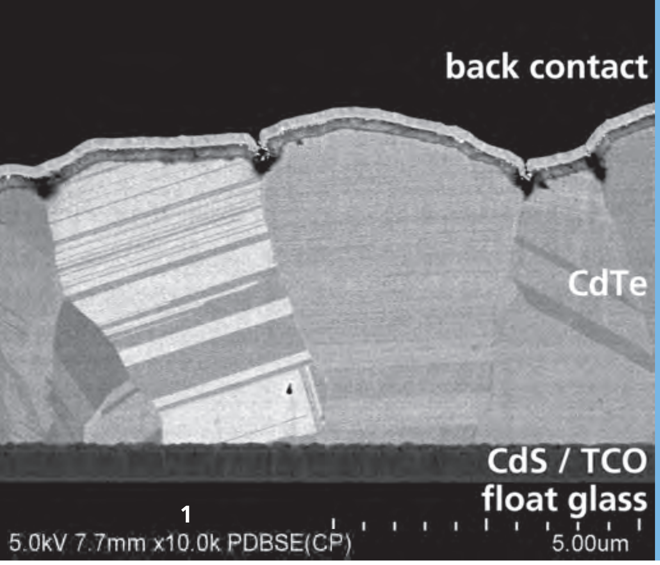
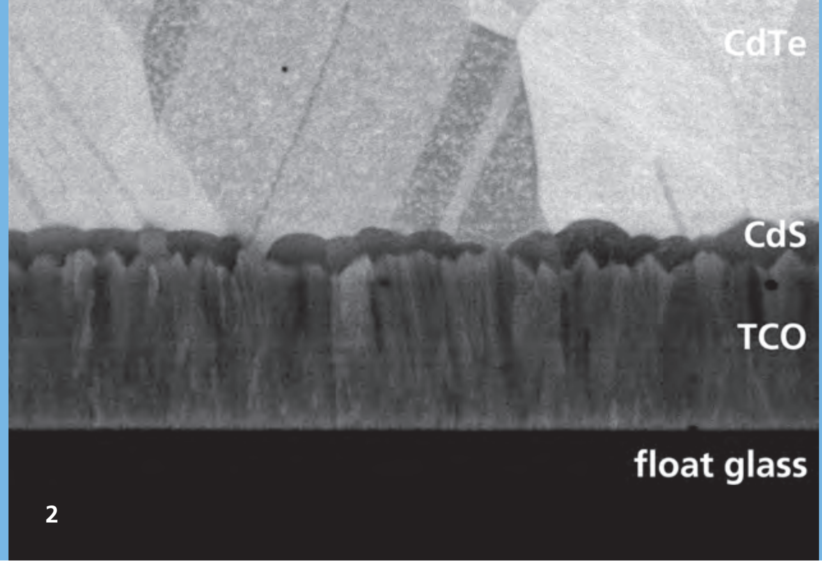
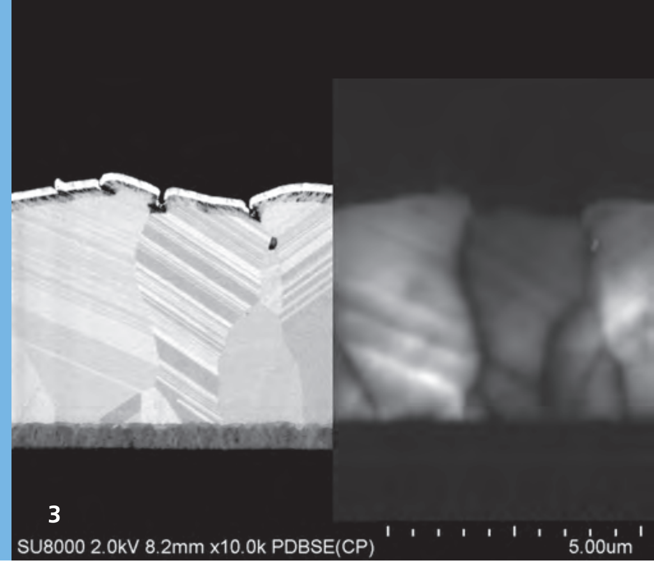
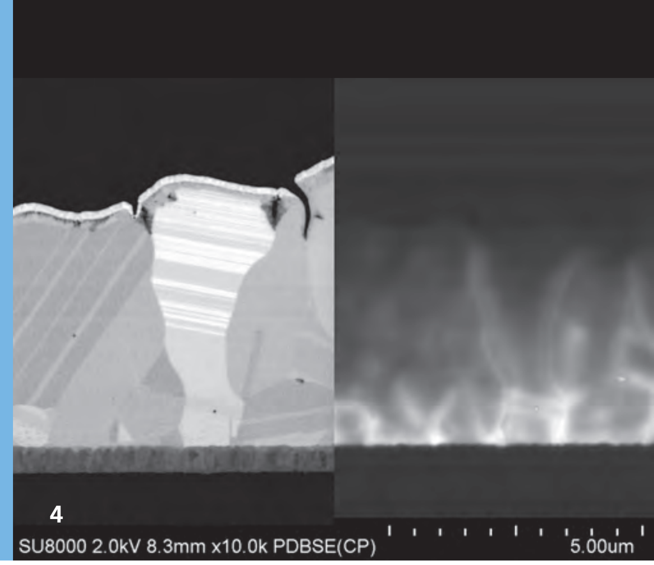








ANALYTIC INVESTIGATIONS OF CdTe THIN FILM SOLAR CELLS

Within the framework of an industrial project with CTF Solar GmbH, we were able to continue the hitherto successful work regarding process and technology development for CdTe thin film solar cells in 2013. In this, analytic examinations provided an important contribution.

With the help of field emission scanning electron microscopy (FE-SEM) investigations of ion-polished cross-sections, microstructure and interfaces can be investigated with high resolution using the crystal orientation and atomic number contrast. In this regard, figures 1 and 2 illustrate a solar cell in superstrate configuration with float glass substrate, TCO front contact, thin n-conductive CdS layer, p-conductive CdTe absorber layer, and metal rear contact as an overview image and at high magnification.

Diffusion and grain growth processes at the interface between the CdTe and the CdS layers during the thermal chlorine activation treatment are of particular interest. Due to the diffusion of sulphur into the CdTe layer and or tellurium into the CdS layer the band gap of both materials can be influenced and thus also the absorption behaviour. Simultaneously, a reduction of the CdS layer thickness causes an increase of the quantum efficiency in the short wavelength range. However, grain growth of the CdS crystallites or CdS layers that are too thin may also cause the formation of pores in the layers reducing the values for the open circuit voltage and the fill factor of the solar cell. Therefore, the processes must be optimised to such that the CdS layer is as thin as possible, but the properties of the pn transition do not deteriorated simultaneously.

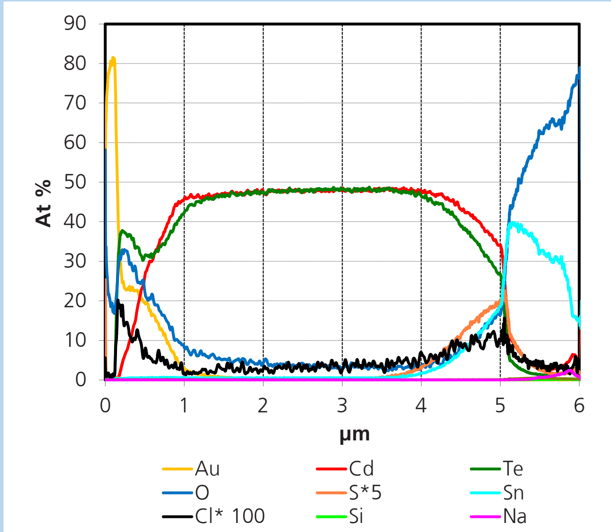
Additional information on the pn junction and the chlorine activation treatment can be obtained by measuring the electron beam-induced conductivity (EBIC). In so doing, the EBIC signal distribution is measured simultaneously with the electron-microscopical imaging. The results of these investigations have shown that only a weak EBIC signal and an inhomogeneous signal distribution can be measured prior the chlorine activation treatment (Fig. 3). While a significant EBIC signal is already detected inside individual CdTe crystallites, other crystallites still seem completely dark. The CdTe grain boundaries themselves, and all areas near the grain boundaries exhibit no EBIC signal. Accordingly, the areas near the grain boundaries have the effect of strong recombination centres for the generated charge carriers and therefore do not provide any contribution to the measured EBIC signal.

On the contrary, a significant change regarding the distribution of the EBIC signal can be detected after an activation treatment (Fig. 4). The areas near the grain boundaries are now characterised by a signal that is clearly higher as in the centre of the crystallites. Completely dark crystallites without EBIC signals are no longer detected. This result can be interpreted as a direct proof of the passivation of areas near the grain boundaries by the chlorine activation treatment.

Furthermore, the chlorine diffusion may be investigated by determining chemical depth profiles with the help of glow discharge optical emission spectrometry (GD-OES). Regarding this, figure 5 illustrates the depth profile of a CdTe solar cell with gold rear contact. On the surface of the CdTe layer, a tellurium accumulation and a partial oxidation can be detected. The chlorine content in the CdTe is in the range of 0.03 to 0.2 at.- % with clearly present maximum values on the layer surface and on the interface to the CdS.

The analytical results help enhancing the understanding regarding the influence of process parameters on the structure and the electrical properties of the CdTe thin film solar cell. The latest news regarding record efficiencies of the CdTe thin film solar cell of 19.0 and 19.6% performed by First Solar and GE Global Research furthermore demonstrate that there still is potential for further progress.

5 Chemical depth profile of a CdTe thin-layer solar cell determined with glow discharge optical emission spectrometry (GD-OES)



1 FE-SEM figure of the ion-polished cross-section of a CdTe thin film solar cell

2 FE-SEM figure of the interface between TCO, CdS, and CdTe layer at higher magnification

3 FE-SEM figure of a CdTe thin film solar cell in the crystal orientation contrast (left) and related EBIC signal distribution prior to the activation treatment (right)

4 FE-SEM figure of a CdTe thin-film solar cell in the crystal orientation contrast (left) and related EBIC signal distribution after the activation treatment (right)

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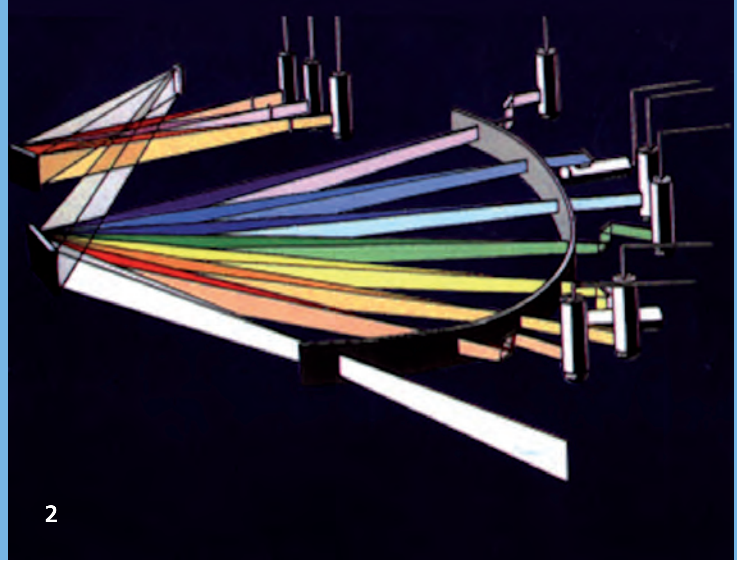
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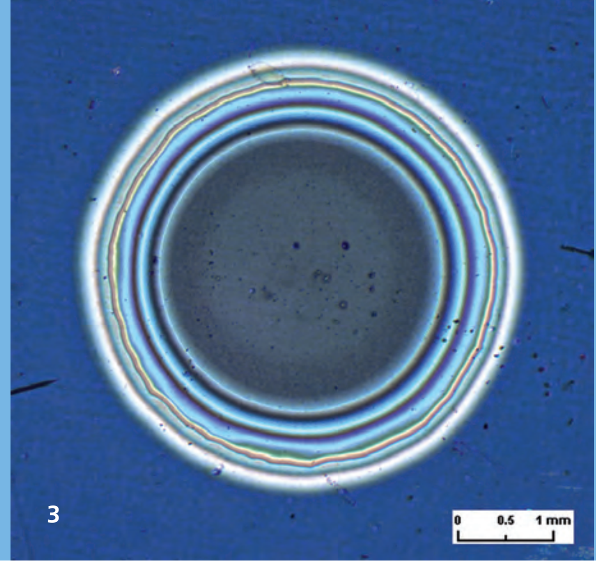

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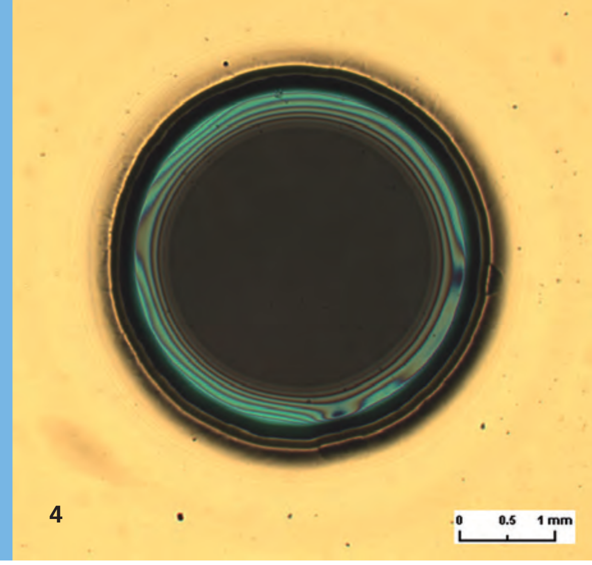

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ANALYSIS OF CHEMICAL DEPTH PROFILES BY RF GLOW DISCHARGE SPECTROMETRY

By investing in a new RF glow discharge spectrometer GD-Profiler 2 (HORIBA Jobin Yvon), it was possible to significantly enhance the analytic possibilities at the Fraunhofer FEP regarding the analysis of chemical depth profiles.

The application of an RF glow discharge with optical emission spectrometry (RF-GD-OES) allows the analysis of chemical depth profiles on electrically conductive and non-conductive samples. For the analyses, the sample is sputtered on a spot diameter of 4 mm, atom layer by atom layer. In the electrical field of the glow discharge, the plasma causes an excitation of the sputtered atoms causing collisions with high-energy electrons or with meta-stable argon gas atoms. Upon excitation to a higher level of energy, the absorbed energy is emitted in one or several steps as discrete optical spectral lines when returning to the initial level. The light intensity of the optical emission lines of the different elements is then registered as a function of time in a spectrometer. Through calibration with certified reference materials, the measured qualitative intensity-time profiles can be used to calculate quantitative chemical depth profiles.

The device installed at the Fraunhofer FEP (Fig. 1) disposes of 45 selected optical emission lines of different chemical elements, including hydrogen. In order to analyse the emission lines, a polychromator with a holographic grid and a spectral range of 110 to 620 nm is used (Fig. 2). Additionally, it is possible to analyse additional optical emission lines with the help of a monochromator or to document the entire emission spectrum sequentially. The detectors are sensitive photomultipliers with a high dynamic range for concentrations of 1 ppm to 100%.

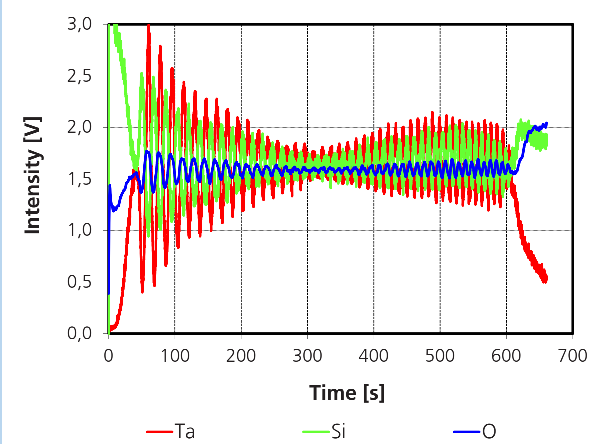
In order to achieve the best possible depth resolution, the sputter parameters must be selected in such a way that the sputter crater is as flat as possible. This can largely be achieved by optimising the parameters sputter performance and pressure. The analysis of the craters is performed by additional measurements with a profilometer.

By using a pulsed RF discharge, it is also possible to analyse temperature-sensitive samples such as coated polymer foils or even coatings on glass substrates, whereby the thermal stress for the samples can be reduced to an extent that any damage to the samples can be avoided (Fig. 3 and 4).

This way, we are now able to analyse coatings regarding their chemical depth profile on all substrates used at the Fraunhofer FEP such as metal band, glass, silicon, and even on polymer foils. Another advantage of the RF-GD-OES analyses typical for the method includes very high sputter rates of several micrometers per minute allowing for the quick analysis of chemical depth profiles of deeper layers. Despite the high sputter rates, depth resolutions of a few nanometres can be achieved for thin layers. For many elements, the lower limit of detection is 1 ppm.

Up to now, typical fields of application for RF-GD-OES analyses at the Fraunhofer FEP include optical layer systems, layers designed for photovoltaics, sliding bearing layers, wear resistant layers, and anti-corrosion layers. Figure 5 illustrates an RF-GD-OES depth profile of an optical Rugate filter with very good depth resolution of the silicone oxide and tantalum oxide gradient layers as an example.

5 Chemical depth profile of a Rugate filter determined by RF glow discharge spectrometry (RF-GD-OES)



1 RF glow discharge spectrometer GD-Profiler 2 (HORIBA Jobin Yvon)

2 Analysis of the optical emission lines using a polychromator

3 RF-GD-OES analysis spot on sun protection system on PET foil

4 RF-GD-OES analysis spot on optical filter on glass substrate

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HIGHLIGHTS

HIGHLIGHTS

1

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FRAUNHOFER LOUNGE

In 2013, the Fraunhofer Lounge was dedicated to social developments and controversial political decisions arising from the elections in September.

Twelfth Fraunhofer Lounge:
How much truth and risk can Germany take?
Necessary remarks on self-contentment of an industrial nation

Uncomfortable truths - for example, in the debate about energy policy, demographics, infrastructure, or other fields – are a tough act to follow in our country. The style of our public debates generates a risk aversion that is becoming more and more critical for the competitiveness and the future of Germany as an industrial location.

How much truth and risk can Germany take? Necessary remarks regarding the complacency of an industrial nation – this was the topic of the 12th Fraunhofer Lounge on the winter's eve of 14 March 2013 in the Fraunhofer FEP.

Dr. Michael Inacker, assistant executive editor of Wirtschaftswoche and managing editor of the Handelsblatt's editorial office in Berlin explained the meaning of »merciless fall« on that evening – Inacker uses this term to refer to the attitude towards politicians and top earners whose misconduct resulted in the destruction of their reputation and professional career. The topic referred to the editorial article for Handelsblatt from 20 December 2012, within the framework of which Dr. Michael Inacker describes our society as a society »without any margin of error and compassion« and criticises the attitude towards the German top staff members.

The evening was presented by the host Mr. Wolfgang Genczler, regional director Saxony/Thuringia of the MERKUR BANK. During the evening, he challenged and at the same time agreed with the core statement of the evening that we as a society often lose sight of proportionality and that there is hardly any chance of rehabilitation. Thereafter, the participants had the chance to take up the issue again and to enjoy beverages and snacks in discussions accompanied by live piano music.

Thirteenth Fraunhofer Lounge:
Are medium-sized companies the motor for innovation?
Perspectives in economic policy during the new legislative period

The coalition talks are in progress and there is still a certain level of uncertainty which simultaneously generates an inner social anxiety to learn more about the future. In Germany, many organisations and people deal with the question of what comes next: companies, research organisations, employees, students. The German people have cast their vote and decided in favour of familiar structures that are, however, not compatible with current development. This is the opinion of Oswald Metzger, commentator on politics and current affairs and political maverick associated with the SPD, the Bündnis 90/Die Grünen and more recently the CDU. Oswald Metzger was a guest at the 13th Fraunhofer Lounge on 24 October 2013 in the Fraunhofer FEP.

In his speech, he described his view of the precarious pension policy and the disastrous cooperation with EU states encumbered with debts. For many audience members, his statement that there was no german politician who was able to maintain the market economy was an assertion and revelation all at once. Boiled down to the essence: we all live in a country that is short sighted and spends far too much. Mr. Metzger polarises.

The soft comments of the evening's host, Uta Deckow-Kindermann, editor for regional politics with the Mitteldeutscher Rundfunk, did not really mitigate the conditions described either.

The discussion about photovoltaics, which was existential for many attending guests, continued with beverages and snacks after the end of the official discussion. The question now is how the current government can be convinced to invest more money on research on renewable energy instead of coming up with new subsidy mechanisms?

WEBSITE

www.fep-lounge.de

1 Host Wolfgang Genczler, Dr. Michael Inacker, and head of the institute Prof. Dr. Volker Kirchhoff (from left to right)

2 Oswald Metzger talking to the host Uta Deckow-Kindermann

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THE PRO FLEX CONFERENCE IS GAINING SIGNIFICANCE

136 visitors from 21 countries took part in the pro flex conference 2013 which took place from 24 to 25 September 2013 at Fraunhofer FEP. The significant interest shown by Japanese companies was particularly striking. Global players also made use of the opportunity to share the latest developments in „coating flexible materials" with one another.

The pro flex conference is supported by the „Flexible Products" department at Fraunhofer FEP. The department's activities include, amongst others, developing and piloting encapsulation technologies in roll-to-roll processes. In this context, the department works very closely with members of the FLEET cluster (Flexible Electronics Encapsulation Technologies Dresden). The cluster concentrates on developing encapsulation technologies to reach industrial and series maturity.

Encapsulation technologies are highly relevant for the development of flexible electronics. Flexible electronic components can be integrated into other objects such as clothing or packaging. This in turn is interesting for areas such as medicine or security, e.g. as regards sensors which monitor bodily functions and send data in good time to care personnel. But even flexible solar cells or light fixtures provide several new areas for application. Encapsulation is needed to protect active components in electronics from humidity and oxygen.

For this reason, one of the key issues of the conference was in applying roll to roll technologies and using them to develop barrier layers to encapsulate flexible products. The future of flexible electronics depends greatly on the development of barrier films. Single stages in this process, such as the quality of the substrate, process stability or reproducibility, still present a great challenge. Various organisations presented their approaches to deal with it.

Moreover, those participating in the conference had the opportunity to compare between roll-to-roll PECVD (plasma-enhanced chemical vapour deposition), ALD (atomic layer deposition) or PVD (physical vapour deposition) through presentations given on different technologies in order to find the best process methods for their application. To achieve the functions needed for coated films, the properties of individual materials are taken into account as well as combinations of materials.

This time great attention was paid to coating of flexible glass. Flexible glass can be used in various ways in electronics since it is a material which combines the best properties of glass and plastics. However, there are still some remaining hurdles in the processing stages of this material which the research community is attempting to overcome.

Right at the heart of many presentations was the question of how to minimise the defects on substrates. And there are many different ways of doing this. Fraunhofer COMEDD, for example, is taking the approach whereby defects are selected and where those which do not affect the end product are disregarded right from the start. Kobe Steel Ltd Japan is developing ways of minimising defects by using a multi-layer system. Still, there is demand for an online method of analysis with which defects of up to 1 µm and the quality of the substrate can be determined in a cost-effective way.

Thanks to the pro flex conference, Fraunhofer FEP succeeded in strengthening its position within the »Flexible Products« area and in creating sustainable contacts within Europe and beyond.

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ANHANG

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ANHANG

NAMEN, DATEN UND EREIGNISSE

NAMES, DATES AND EVENTS

MITGLIEDSCHAFT IN GREMIEN

A. Arnold
- International Council for Coatings on Glass ICCG e. V.
- Netzwerk »Dresden – Stadt der Wissenschaft«

H. Bartzsch
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS)
- Silicon Saxony e. V.

J. Fahlteich
- Fraunhofer-Allianz Polymere Oberflächen POLO

P. Frach
- Fraunhofer-Allianz Photokatalyse
- AMA Fachverband für Sensorik e. V.
- Deutsche Gesellschaft für Galvano- und Oberflächentechnik e. V. (DGO)
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS) Fachausschuss »Oberflächen und Beschichtungen in der Bio- und Medizintechnik«
- Photonic Net

F. Hoyer
- Fraunhofer Social Media Netzwerk

V. Kirchhoff
- Bundesverband mittelständische Wirtschaft (BVMW)
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS)
- Fraunhofer-Verbund Light & Surfaces

H. Klostermann
- Kompetenznetz Industrielle Plasma-Oberflächentechnik, AG Neuartige Plasmaquellen und Prozesse, INPLAS
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS) Fachausschuss »Funktionalisierung von Kunststoffen«

G. Mattausch
- Informationstechnische Gesellschaft (ITG) des VDE: Fachausschuss 8.6 »Vakuumtechnik und Displays«
- Organizing Committee der »EBEAM – International Conference on High-Power Electron Beam Technology«
- Organizing Committee der »International Conference on Electron Beam Technologies – EBT«

C. Metzner
- Kompetenzzentrum Maschinenbau Chemnitz/Sachsen e. V. (KMC)

W. Nedon
- Forschungsallianz Kulturerbe FALKE

F.-H. Rögner
- Fraunhofer-Allianz Reinigungstechnik

N. Schiller
- Technical Advisory Committee der »Annual Technical Conference« der »Society of Vacuum Coaters – SVC«
- Fraunhofer-Allianz Batterien
- Organic Electronics Saxony e. V. (OES)
- Co-Chair of Board for AIMCAL Web Coating & Handling Conference

C. Wetzel
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS) Fachausschuss »Oberflächen und Beschichtungen in der Bio- und Medizintechnik«
- Netzwerk ProAnatomie
- Netzwerk Sachsen Textil

J. Wieczoreck
- WCMS Fachbeirat

O. Zywitzki
- Dresdner Fraunhofer-Cluster Nanoanalytik (DFCNA)

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Method for the Production of an Ultra Barrier Layer System
FEP 183
Dr. C. Charton, Dr. M. Fahland, Dr. N. Schiller, S. Straach, M. Krug

JP 5150626 B2
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FEP 214
Dr. G. Mattausch, J.-S. Liebig, L. Klose, Prof. V. Kirchhoff, Dr. J.-P. Heinß, H. Flaske

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Transparent plastic film for shielding electromagnetic waves and method for producing a plastic film of this type
FEP 215
Dr. M. Fahland, T. Vogt, Dr. N. Schiller, W. Schönberger, Dr. S. Günther, Dr. J. Fahlteich

EP 2 087 503 B1
Vorrichtung zum Vorbehandeln von Substraten
FEP 220
Dr. H. Morgner, Prof. C. Metzner, Dr. B. Scheffel, L. Klose, Prof. V. Kirchhoff, Dr. J.-P. Heinß

JP 5349455 B2
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FEP 239
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JP 5355150 B2
Licht erzeugendes Wandelement
FEP 245
Prof. V. Kirchhoff, Dr. T. Kopte, J. Kubusch

EP 2 288 646 B1
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Prof. V. Kirchhoff, Dr. T. Kopte, J. Kubusch

EP 2 468 915 B1
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Dr. H. Bartzsch, P. Pötschick, Dr. P. Frach, Dr. M. Fahland, C. Gottfried

VORTRÄGE

F.-H. Rögner
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Symposium 15 Jahre ELBE SAAT
Fraunhofer FEP
Dresden, Germany
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M. Junghähnel
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Ilmenau, Germany
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H. Morgner
Plasmaaktivierte, reaktive Elektronenstrahlbedampfung
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C. Metzner
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Dresden, Germany
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M. Fahland
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J. Fahlteich
Ultra-High Barriers for Encapsulation of flexible Displays and Lighting Device
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04. – 05.Juni 2013

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F.-H. Rögner
Electron treatment - enhancing safety in food production
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Advanced cost effective and sustainable low-emittance coatings based on titania for improved long wave radiation reflection in window applications
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Tampere, Finland
11. – 15. Juni 2013

J. Fahlteich
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M. Maicu
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Elektronen – so vielseitig wie ein Schweizer Taschenmesser!
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Jinan, Shandong, China
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G. Gotzmann, J. Beckmann, B. Scholz, U. Herrmann, C. Wetzel
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ThGOT Thementage Grenz- und Oberflächentechnik gemeinsam mit dem 9. Thüringer Biomaterial-Kolloquium
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Novel Techniques and Tools for the Plasma-activated Electron Beam high-rate Deposition of dense Zirconia coatings
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Suzhou, China
09. – 10. September 2013

M. Fahland
Roll-to-roll deposition of optical coatings using magnetized midfrequency powered plasma processes
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09. – 13. September 2013
H. Klostermann, F. Fietzke, B. Krätzschmar
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H. Bartzsch, S. Barth, D. Glöß, P. Frach, T. Herzog, G. Suchaneck, J. Juuti
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ZVO Oberflächentage
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J.-P. Heinß
Crystallization of thin silicon layers by using axial electron beam sources
Workshop „Polycrystalline growth of Si – new insights from experiment and modeling“
Karlsruhe, Germany
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H. Bartzsch
Reaktive Magnetron-Sputtertechnologien für Anwendungen in der Elektronik und Sensorik auf industriellem Niveau
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Abscheidung dünner TiO_2 und Nb_2O_2 Schichten mittels Puls-Magnetron-Sputtern vom keramischen Rohrtarget
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M. Junghähnel
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C. Wetzel
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J.-P. Heinß, P. Lang
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C. Wetzel
Untersuchungsmodell zur Testung biophysikalischer Therapiegeräte
5. CIT Forschungs-Workshop
Hamburg, Germany
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F.-H. Rögner, C. Kleemann
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N. Schiller
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ANHANG

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ANHANG

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537. Wilhelm and Else Heraeus Seminar
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26.–28. Juni 2013

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537. Wilhelm and Else Heraeus Seminar
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M. Maicu
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J. Schönfelder
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MASTERARBEITEN

K. Bedrich
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Technische Universität Bergakademie Freiberg
Fakultät für Chemie und Physik, Arbeitsgruppe Photovoltaik

N. Chen
Characterization of Piezoelectric Energy Harvesters under Dynamic Load
Technische Universität Dresden
Institut für Festkörperelektronik

I. Mehrez-Koch
Transparente Barriereschichtsysteme auf flexiblen Substraten hergestellt mittels Atomlagenabscheidung und reaktivem Sputtern
Westsächsische Hochschule Zwickau
Fachbereich Physikalische Technik / Informatik

C. Süß
Aluminium-Metallisierung für eine Silizium-Photovoltaik-Labortechnologie
Westsächsische Hochschule Zwickau
FB Physikalische Technik, Studiengang Mikrotechnologie

L. Qin
Untersuchungen zur Beeinflussung der Elektronenstrahlführung in einer Folienbedampfungsanlage mittels eines elektromagnetischen Ablenksystems
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Lehrstuhl Mikroelektronik

S. Weller
Passivierung für einen Si-PV-Laborprozess
TU Bergakademie Freiberg
Fakultät für Werkstoffwissenschaften,
Institut für Elektronik- und Sensormaterialien

M. Friedemann
Elektrische und optische Eigenschaften von dotierten Zinkoxid-Schichten mit Aluminium und Titan
TU Chemnitz
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A. Karutz
Ermittlung des Einflusses der Nanophotonentechnologie® auf in vitro-Zellkulturen
Internationales Hochschulinstitut Zittau
Studiengang Biotechnologie und Angewandte Ökologie

C. Jorsch
Spezifizierende Untersuchungen der antimikrobiellen Wirksamkeit von Ag/Cu-Misch-Schichten auf der Basis von Modellmedien
Internationales Hochschulinstitut Zittau
Studiengang Biotechnologie und Angewandte Ökologie

J. Beckmann
Untersuchung zur Elektronenstrahlmodifikation von DLC-Schichten und deren Auswirkung auf die Sterilisationsfestigkeit
Hochschule für Technik und Wirtschaft Dresden
Fakultät Maschinenbau/Verfahrenstechnik, Studiengang Chemieingenieurwesen

DIPLOMARBEITEN

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Technischen Universität Dresden
Fakultät Maschinenwesen

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J. Hou
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Technischen Universität Berlin
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A. Schmidt
Aufstellungskonzept für eine Pilot-Anlage des Fraunhofer FEP unter besonderer Berücksichtigung der Forschungslogistik
Hochschule für Technik und Wirtschaft HTW Dresden
Fakultät Maschinenbau/Verfahrenstechnik
Studiengang Produktionstechnik

BACHELORARBEITEN

T. Treuholz
Einrichten einer Hochvakuumanlage für die Abscheidung amorpher Siliziumschichten mittels Axial-Elektronenstrahlverdampfung
Technische Hochschule Wildau
Fachbereich Ingenieurwesen/Wirtschaftsingeneurwesen
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Proverb oHG

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VDD AG
Weststraße 60
09603 Großschirma OT Siebenlehn