CONTENTS

GENERAL PART

Foreword | 4
Organizational Structure | 6
Our Advisory Board | 7
Collaboration and Memberships | 8
The Fraunhofer-Gesellschaft | 9
The Institute in Figures | 10
Fraunhofer Group for Light & Surfaces | 12

RESEARCH NEWS

PreSensLine – new coating equipment for manufacturing large-scale precision coatings | 16
Healthy seeds – an international challenge! | 20
Enhanced photocatalytic activity of TiO₂ thin films by Pt nanoparticles deposition | 24
Cost-efficient high-rate metallising for hetero-junction solar cells | 26
Electron beam rapid thermal annealing of transparent conductive oxides | 28
Pulsed Electron Beam Deposition – a new coating method at the Fraunhofer FEP | 30
Layer systems for high-performance solar tube collectors | 32
Loading an ECR source using sputtering to implant Al⁺ ions | 34
Development of biofunctional, sterilisation-resistant DLC layers | 36
Analytic investigations of CdTe thin film solar cells | 38
Analysis of chemical depth profiles by RF glow discharge spectrometry | 40

HIGHLIGHTS

Fraunhofer Lounge | 44
The pro flex conference is gaining significance | 46

ANNEX

Names, Dates and Events | 50
Contact | 58
Editorial notes | 60
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!
ORGANIZATIONAL STRUCTURE

GENERAL MANAGEMENT
Acting Director
Prof. Dr. Volker Kirchhoff
Deputy Director
Dr. Nicolas Schiller

ADMINISTRATION
Head of Administration
Veit Mittag

CROSS DEPARTMENTS
Secretariat / Library
Annett Nedjalkov / Mandy Schreiber
Scientific Assistants
Dr. Mania Mehältäubl | Anastasiya Zagorni
Marketing / PR / Corporate Communications
Annett Arnold
Protective Rights
Jörg Kubusch
Material Characterization
Dr. Olaf Zywitzki
Quality and Technical Management
Wolfgang Nedon
Information Technology
Roberto Wenzel

DIVISION ELECTRON BEAM
Division Director: Prof. Dr. Christoph Metzner
Coating of Sheets and Metal Strips
Prof. Dr. Christoph Metzner
Electron Beam Processes
Frank-Holm Rögner

DIVISION PLASMA
Division Director: Dr. Torsten Kopte
Coating of Flat Substrates
Dr. Torsten Kopte
Medical Applications
Dr. habil. Christiane Wetzel
Coating of Components
Dr. Heidrun Klostermann

DIVISION FLEXIBLE PRODUCTS
Division Director: Dr. Nicola Schiller
Flexible Products
Dr. Nicola Schiller

DIVISION PRECISION COATING
Division Director: Dr. Peter Frach
Static Deposition
Dr. Hagen Bartzsch
Dynamic Deposition
Dr. Daniel Göß

DIVISION SYSTEMS
Division Director: Henrik Flaske
Development of Mechanics
Dieter Weiske
Development of Electronics
Dieter Leffler
Prototyping / Cooperation
Rainer Zeibe / Steffen Kaufmann

OUR ADVISORY BOARD

MEMBERS OF THE ADVISORY BOARD
Dr. Ulrich Engel  |  Chairman of Advisory Board
RD’in Dr. Annerose Beck  |  Saxon State Ministry of Science and the Arts,
Prof. Dr. Richard Funk  |  Head of Division Federal-State-Research Institutions
Prof. Dr. Gerald Gerlach  |  Chair of Advisory Board

GUEST MEMBERS
Dr. Alexander Kurz  |  Former Board Member of the Fraunhofer-Gesellschaft
Dr. Patrick Hoyer  |  Fraunhofer-Gesellschaft, Institute Liaison
Dr. Hans-Ulrich Wiese  |  Fraunhofer-Gesellschaft, Human Resources, Legal Affairs and IP Management
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 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
- Westfälische Hochschule Zwickau
- Hochschule für Technik und Wirtschaft Dresden (HTWD)

MEMBERSHIPS

- Europäische Forschungsgesellschaft Dünn Schichten EFDS e. V.
- Organic Electronics Saxony e. V. (OES)
- Silicon Saxony e. V.
- AMF-Fachverband für Sensorik e. V.
- DARKE – „Deutscher Arbeitgeberverband der Hochschulen“
- Fraunhofer Battery Alliance
- Fraunhofer Photocatalysis Alliance
- Fraunhofer Cluster Nanoanalytics Dresden

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.

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
- income from industry (public funding) € 0.9 million
- income from industry (public funding funded by the federal government) € 4.1 million
- income from industry (public funding funded by the Länder) € 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 scientists, 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.
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
- Carbon technology
- Measurement methods and characterization
- Ultra precision engineering
- Material technology
- Plasma and electron beam sources

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 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 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

Contact
Group Chairman: Prof. Dr. Andreas Tünnermann
Group Assistant: Susan Oxfart
Phone +49 3641 807-201
Phone +49 3641 807-207

www.light-and-surfaces.fraunhofer.de
PreSensLine – new coating equipment for manufacturing large-scale precision coatings

Healthy seeds – an international challenge!

Enhanced photocatalytic activity of TiO₂ thin films by Pt nanoparticles deposition

Cost-efficient high-rate metallising for hetero-junction solar cells

Electron beam rapid thermal annealing of transparent conductive oxides

Pulsed Electron Beam Deposition – a new coating method at the Fraunhofer FEP

Layer systems for high-performance solar tube collectors

Loading an ECR source using sputtering to implant Al⁺ ions

Development of biofunctional, sterilisation-resistant DLC layers

Analytic investigations of CdTe thin film solar cells

Analysis of chemical depth profiles by RF glow discharge spectrometry
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.

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 x 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 x 790 mm; also thermally insulated to allow the substrate to be heated up to 400°C.

Besides 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.
Combined with the pulsed energy supply (UBS-C2), Fraunhofer FEP process control technology (PCU®) 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 combining 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 (SiO₂) and high refractive layers (e.g. Al₂O₃, TiO₂, Ta₂O₅, HfO₂, Nb₂O₅) 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 (Nb₂O₅) and low refractive (SiO₂) 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.

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 (Nb₂O₅) and low refractive (SiO₂) 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.
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 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.

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
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 faster 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 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.

For the F-processes department, 2014 is a year especially given to treating seeds in an environmentally-friendly way using accelerated electrons. Fraunhofer FEP will be able to continue to commercialise the technology better. Overall, 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.

The Fraunhofer FEP pilot unit already available to treat seeds using electrons is designed to treat large throughputs 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.

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.

CONTACT

Frank-Holm Rögnér
Phone +49 351 2586-242
frank-holm.roegner@fep.fraunhofer.de
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 photocactivity. 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 sputtered atoms into an aggregation zone. There they first thermalize by collisions with the buffer gas, and then...
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 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.

\(^{11}\) Lachenal et al.: High Efficiency Silicon Heterojunction Solar Cell Activities in Neuchâtel, Switzerland; 25th EUPVSEC (2010), p.1272
\(^{12}\) Strahm et al.: Silicon Heterojunction Solar Cells on Thin Large Area Substrates: The Route towards Low Electricity Generation Cost; 28th EUPVSEC (2013)
\(^{13}\) Taguchi et al.: 24.7% Record Efficiency HIT® Solar Cell on Thin Silicon Wafer; 28th EUPVSEC (2013)

CONTACT

Dr. Jens-Peter Heinß
Phone +49 351 2586-244
jens-peter.heinss@fep.fraunhofer.de

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

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.

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 fulfill these requirements. One particular challenge is the production of suitable transparent electrodes. These components must have a very high current load capacity.
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 ≥ 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.
**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 (AlO_x, SiN_x) 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 aging 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 Metaltechnik 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.

---

**CONTACT**

**Dr. Fred Fietzke**  
Phone +49 351 2586-366  
fred.fietzke@fep.fraunhofer.de

**EUROSOLAR**  
The project was funded by the European Union and the Free State of Saxony.  
Funding reference: 100072533

---

**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**

---

**5 Incident and irradiated energy spectrum (top), as well as spectral characteristics of absorber (middle) and heat reflector (bottom) adjusted to the aforementioned**
LOADING AN ECR SOURCE USING SPUTTERING TO IMPLANT Al⁺ IONS

Doping is a significant process step for photovoltaic cells with 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:

1. the (selective) emitter profile for n-type PV cells and
2. 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 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 via the Helmholtz coils (target type of gas); side 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 ECR source (fig. 2) is subjected to an extensive analysis. The following properties are determined:

1. space-resolved coating rate (fig. 5) and three-dimensional densities of Al atoms
2. electron temperature and density using a partly automated double Langmuir probe
3. these fields have to be sufficiently free from interaction.

The 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 ensured simultaneously.

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

1. space-resolved coating rate (fig. 5) and/or integral load rate (fig. 6) and three-dimensional densities of Al atoms
2. electron temperature and density using a partly automated double Langmuir probe
3. the (selective) emitter profile for n-type PV cells and
4. 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 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 via the Helmholtz coils (target type of gas); side 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 ECR source (fig. 2) is subjected to an extensive analysis. The following properties are determined:

1. space-resolved coating rate (fig. 5) and three-dimensional densities of Al atoms
2. 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 > 10⁴ 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.
DEVELOPMENT OF BIOFUNCTIONAL, STERILISATION-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 (sp² hybridised and/or sp³ 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 deposits 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 sp² and/or sp³ 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.

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 deteriorate 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 to 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 demonstrates that there still is potential for further progress.

CONTACT
Dr. Olaf Zywitzki
Phone +49 351 2586-180
olaf.zywitzki@fe-p.fraunhofer.de
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 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.

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.

CONTACT
Dr. Olaf Zywitzki
Phone +49 351 2586-180
olaf.zywitzki@fep.fraunhofer.de
The pro flex conference is gaining significance
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?
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.

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.

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.

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.

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
ANHANG

M. Fahland
Deposition technologies for functional coatings on polymer substrates
VacuumTechExpo 2013, 8th International exhibition of vacuum machines, equipment and technologies
Moscow, Russia
16.–18. April 2013

W. Schönberger
Precision coatings on industrial scale: requirements, implementa-
tion, application
VacuumTechExpo 2013, 8th International exhibition of vacuum machines, equipment and technologies
Moscow, Russia
16.–18. April 2013

B. Schaffel, T. Modes, C. Metzner
Spotsless arc activated high-rate deposition using novel dual crucible technology for titanium dioxide coatings
56th Annual Technical Conference, SVC – Society of Vacuum Coaters
Rhode Island, USA
20.–25. April 2013

S. Günther, M. Fahland, J. Fahliche, B. Meyer, S. Strauch, N. Schiller
High-rate low pressure PECVD for barrier and optical coatings
56th Annual Technical Conference, SVC – Society of Vacuum Coaters
Rhode Island, USA
20.–25. April 2013

M. Junghähnel, T. Kopte
Advanced cost effective and sustainable transparent conductors based on lantha for large area applications
56th Annual Technical Conference, SVC – Society of Vacuum Coaters
Rhode Island, USA
20.–25. April 2013

C. Metzner, B. Schaffel, O. Zwetzk
High-rate PECVD with metal strip magnetron for hard and other functional coatings
40th ICMTF – International Conference on Metallurgical Coatings and Thin Films
San Diego, USA

M. Junghähnel, T. Kopte
Cost effective large area sputtering of transparent conductive TIO2:NB by using rotatable magnetron systems with oxidic targets
13th International Symposium on Transparent Oxide and Related Materials
TiO2:Nb by using rotatable magnetron systems with oxidic targets
13. Mai 2013

J. Fahliche
Ultra-High Barriers for Encapsulation of Flexible Displays and Ligh-
ting Device
SID 2013 – International Symposium
Society for Information Display, Display Week 2013
Vancouver, Canada
19.–24. Mai 2013

M. Fahland, B. Meyer, S. Günther, M. Junghähnel
Elektronenstrahlbehandlung zur Optimierung von transparenten leitfähigen Beschichtungen
IFDS Workshop „Transparent leitfähige Materialien (TCO / TCN) – Neubegründungen und Technologien“
Dresden, Germany
04.–05. Juni 2013

M. Junghähnel, F. Fietzke
Innovative Herstellungsvorgehen zur Hochleistungsbeschichtung von transparenten leitfähigen Materialien
IFDS Workshop „Transparent leitfähige Materialien (TCO / TCN) – Neubegründungen und Technologien“
Dresden, Germany
04.–05. Juni 2013

F.-H. Röger
Elektrotron treatment - enhancing safety in food production
XIII ECT National Seed Seminar 2013
Bangalore, India
08.–11. Juni 2013

M. Junghähnel, T. Kopte
Advanced cost effective and sustainable low-emittance coatings based on lantha for improved long wave radiation reflection in window applications
QPD Finland 2013 – Glass Performance Days
Tampere, Finland
11.–15. Juni 2013

J. Fahliche
Ultra-High Barriers for Encapsulation of Flexible Displays and Ligh-
ting Device
LOPE-C 2013 – Large-area Organic Printed Electronics
München, Germany

M. Maicu
Photocatalytic Properties of TiO2 Thin Films Modified by Ag and Pt Nanoparticles Synthesized by Gas Flow Condensation Process
4th International Conference on Semiconductor Photochemistry
Prag, Czech Republic
23.–27. Juni 2013

M. Junghähnel
Physikalische Dampfabscheidung von Dünnichtschichten, Basisprozess und ihre reaktiven Varianten
OTTI Fachforum Schichten auf Glas
Regensburg, Germany

J. Fahliche
Vacuum Deposited Functional Films for Flexible Electronics
6th International Symposium on flexible electronics – ISTOE 2013
Thessaloniki, Greece
06.–11. Juli 2013

S. Barth, H. Bartzsch, D. Göbl, P. Frach, T. Herzog, S. Walters, H. Hauer
Sputter deposition of stress controlled piezoelectric AlN and AlSiN films for ultrasonic and energy harvesting applications
2013 IEEE International Ultrasonics Symposium
Prag, Czech Republic
21.–25. Juli 2013

F.-H. Röger
Elektrotron – so vielklick wie ein Schweizer Taschenmesser!
Sage der Wissenschaften am BIZ Radebeul 2013
Dresden, Germany
27. Juni 2013

F.-H. Röger
Electron treatment of seed – an effective, environmental friendly, physical plant protection measure
CEIP – 10th International Congress of Plant Pathology
Peking, China
25.–30. August 2013

F.-H. Röger
Sterilization by low Energy Electrons – A Possibility of safe Producti-
on for Food, Food and Medicine
Workshop at SDAS
Jinan, Shandong, China
31. August 2013

G. Gottzmann, J. Beckmann, B. Schub, U. Hermann, C. Weitze
Entwicklung biofunktionaler, Diamond-Like Carbon (DLC) Schichten
THGDT + Unternehmen Grenz- und Oberflächenforschung gemeinsam mit dem 9. Thüringer Biomaterial-Kolloquium
Zusammen, Germany
03.–05. September 2013

V. Kischhoff, C. Metzner, G. Mattausch
Novel Techniques and Tools for the Plasma-activated Electron Beam high-rate Deposition of dense Zirconia coatings
8th AUSD Symposium China 2013
Suzhou, China
09.–10. September 2013

M. Fahland
Roll-to-roll deposition of optical coatings using magnetized midfre-
quency powered plasma processes
19th PC – International Vacuum Congress
Paris, Frankreich
09.–13. September 2013

H. Klottermann, F. Fietzke, B. Kirchhoff
Deposition of mixed oxide coatings by pulsed reactive co-sputtering
19th PC – International Vacuum Congress
Paris, Frankreich
09.–13. September 2013

C. Metzner, B. Schaffel, H. Morgen, O. Zwetzk
Neue nachhaltige Vakuumbeschichtungen auf metallischen Platten
und Bändern
ZVD Oberflächen
Dresden, Germany
18.–20. September 2013

J.-R. Heid
Crystalization of thin silicon layers by using axial electron beam sources
Workshop „Polycrystalline growth of Si – new insights from experiment and modeling“
Karlsruhe, Germany
19.–20. September 2013

H. Bartzsch
Reaktive Magnetron-Sputtertechnologien für Anwendungen in der Elektronik und Sensorik auf industrieller Ebene
B. Innovationstag
Dresden, Germany
25. September 2013

O. Zwetzk, T. Modes, H. Morgen, C. Metzner, B. Spich, H. Spich, C. Dovc, V. Krzto, L. Dovč, S. Fazlakhin
Effect of chlorine activation treatment on EBIC signal distribution of cadmium telluride thin film solar cells
28th European Photovoltaic Solar Energy Conference and Exhibition PVSEC
Paris, France
30. September –04. Oktober 2013

B. Schaffel, C. Metzner, O. Zwetzk
Plasmaaktivierte Hochratenbeschichtung für dünne YSZ-Feststoffelek-
trolyte
V2013 Vakuumbeschichtung und Plasmaoberflächentechnik
Dresden, Germany
14.–17. Oktober 2013
V2013 Vakuumbeschichtung und Plasmaoberflächentechnik

Sputtern vom keramischen Rohrtarget

03. November 2013

C. Wetzel

27. Oktober 2013

Charleston (South Carolina), USA

Konferenzbeitrag in Proceedings

AIMCAL Web Coating & Handling Conference 2013

Ensuring of high deposition rates by increasing of cooling efficiency

J.-P. Heinß, P. Lang

14. Oktober 2013

Dresden, Germany

Workshop Translations-Forschung in der Gewebemedizin

Möglichkeiten zur Verbesserung einzelner Gewebe-Banking-Prozesse

M. Junghähnel

14. Oktober 2013

Dresden, Germany

(V2013 Vakuumbeschichtung und Plasmaoberflächentechnik)

Schüttgut

Aluminium-basierte PVD-Schichten für den Korrosionsschutz von Metallen

F. Fietzke, B. Krätzschmar

14. Oktober 2013

Dresden, Germany

Struktur und Eigenschaften von CdTe-Dünnschicht-Solarzellen

C. Drost, V. Krishnakumar, S. Frauenstein

O. Zywitzki, T. Modes, C. Metzner, B. Siepchen, B. Späth

14. Oktober 2013

Dresden, Germany

Abscheidung dünner TiO₂und Nb₂O₅Schichten mittels Puls-Magnetron-Sputtern

T. Preußner, G. Hüttl, R. Blüthner, T. Kopte

14. Oktober 2013

Dresden, Germany

ANHANG ANHANG


30. Oktober 2013

21. Oktober 2013

17. Oktober 2013

ISOS-6, 6th International Summit on Organic Photovoltaic Stability

J. Fahlteich, C. Steiner, S. Winkler, M. Fahland, S. Günther, N. Schiller

09. Dezember 2013

Hanau, Germany

Materialforum, Umicore AG & Co. KG

Plasmatechnologie - Beschichtung von flexiblen Kunststoffen und Metallbändern

T. Roch, M. Bieda, A. Lasagni, M. Beckmann

17th IMRP – International Meeting on Radiation Processing

F.-H. Rögner, C. Kleimann

New E-Beam sterilization concept - a highly efficient way to sterilize on demand at health care processes in hospitals, medical centers and geriatric care

17th IMRP – International Meeting on Radiation Processing

Shanghai, China

05. – 08. November 2013

F.-H. Rögner, G. Mattausch

A novel Electron Beam Source for simplified irradiation of 3D-shaped surfaces

17th IMRP – International Meeting on Radiation Processing

Shanghai, China

05. – 08. November 2013

N. Schiller

Plasmatechnologie - Beschichtung von flexiblen Kunststoffen und Metallbändern

Materialforum, Umicore AG & Co. KG

Hanau, Germany

09. Dezember 2013

J. Fahlteich, C. Steiner, S. Winkler, M. Fahland, S. Günther, N. Schiller

Ultra-High Permeation Barrier Films for the Encapsulation of Flexible Electronic Devices

EBS 5th, 6th International Summit on Organic Photovoltaic Stability

Chambéry, France

11. Dezember 2013

M. Fahland

Antirefleksbeschichtung von Kunststofffolien im Vakuum

Galvano technik Nr. 2, 2013

S. 286-293

B. Schefiel, T. Modes, C. Metzner

Spotless arc activated high-rate deposition using novel dual crucible technology for titanium dioxide

Proceedings of 13th International Conference on Plasma Surface Engineering, PSE 2012

Garmisch-Partenkirchen, Germany


p. 14 – 17

O. Zywitzki, T. Modes, C. Metzner, B. Siepchen, B. Späth

Quality assessment of corneal storage media and their components

Graefes Arch Clin Exp Ophthalmol, CORNEA

vol. 114, 2013, p. 163-158

M. Jouannic, D. Thierry

Real-time monitoring of indoor air corrosivity in cultural heritage institutions with metallic electrical resistance sensors

Studies in Conservation

Vol. 58, No. 2, 2013, p. 117 – 128

F.-H. Rögner

Behandlung von Saatgut mit Elektronen

ACKER plus

Vol. 07, 2013, Seite 38 – 41

J. Schönfelder, M. Valtrik, L. Kreis, R.H.W. Funk, K. Henkmann, C. Wetzel

Quality assessment of corneal storage media and their components

Graefes Arch Clin Exp Ophthalmol, CORNEA


online: 22. Oktober 2013

F. Fietzke, B. Krätzschmar

Aluminium-basierte PVD-Schichten für den Korrosionsschutz von Schüttgut

V2013 Vakuumbeschichtung und Plasmaoberflächentechnik

(DIndustrieausstellung & Workshop-Woche)

(Dresden, Germany)

14. – 17. Oktober 2013

M. Junghähnel

Advanced Glass Refinement by Thin Films - Trends and Challenges of Thin Film Technologies for Windows and Facade Glasses

Proceedings of 13th International Conference on Plasma Surface Engineering, PSE 2012

Garmisch-Partenkirchen, Germany


p. 64 – 57

P. Frach, C. Gottfried, F. Fietzke, H. Klostermann, H. Bartosch, D. Güß

High Power Density Pulse Magnetron Sputtering – Process and Film Properties

Proceedings of 13th International Conference on Plasma Surface Engineering, PSE 2012

Garmisch-Partenkirchen, Germany


p. 40 – 83

B. Zimmermann, F. Fietzke, H. Klostermann, J. Lehmann, F. Munnik, W. Möller

High rate PECVD of a-C:H coatings in a hollow cathode arc plasma

Proceedings of 13th International Conference on Plasma Surface Engineering, PSE 2012

Garmisch-Partenkirchen, Germany


p. 392 – 394

S. Günther, M. Fahland, J. Fahlteich, B. Meyer, S. Straach, N. Schiller

High rate low pressure plasma-enhanced chemical vapor deposition for barrier and optical coatings

Thin Solid Films

Vol. 532, 2013, p. 44 – 49

T. Prosek, M. Kouril, M. Dubu, M. Taube, V. Hubert, B. Schefiel, Y. Degros, M. Jouannic, D. Thierry

Real-time monitoring of indoor air corrosivity in cultural heritage institutions with metallic electrical resistance sensors

Studies in Conservation

Vol. 58, No. 2, 2013, p. 117 – 128

T. Paul, B. Hützl, R. Blüthner, T. Korte

Abheizung dünner TiO₂und Nb₂O₅Schichten mittels Puls-Magnetron-Sputtern vom keramischen Rohrtarget

V2013 Vakuumbeschichtung und Plasmaoberflächentechnik

(DIndustrieausstellung & Workshop-Woche)

(Dresden, Germany)

14. – 17. Oktober 2013

O. Zywitzki, T. Modes, H. Margner, C. Metzner, B. Siepchen, B. Späth, C. Droit, V. Kränzle, S. Frauenstein

Struktur und Eigenschaften von Céfas-Dünnschicht-Solarzellen

V2013 Vakuumbeschichtung und Plasmaoberflächentechnik

(DIndustrieausstellung & Workshop-Woche)

(Dresden, Germany)

14. – 17. Oktober 2013

F. Fietzke, B. Krätzschmar

Aluminium-basierte PVD-Schichten für den Korrosionsschutz von Schüttgut

V2013 Vakuumbeschichtung und Plasmaoberflächentechnik

(DIndustrieausstellung & Workshop-Woche)

(Dresden, Germany)

14. – 17. Oktober 2013

C. Wetzel

Möglichkeiten zur Verbesserung einzelner Gewebe-Banking-Prozesse

Workshop Translations-Forschung in der Gewebemedizin

(DIndustrieausstellung & Workshop-Woche)

(Dresden, Germany)

17. Oktober 2013

J.-F. Held, P. Lang

Ensuring of high deposition rates by increasing of cooling efficiency

ARACAL Web Coating & Handling Conference 2013

Konferenzbeitrag in Proceedings

Charleston (South Carolina), USA

27. – 30. Oktober 2013

C. Wetzel

Untersuchungsmodell zur Testung biophysikaler Therapiegärte

S. IT Forschungs-Workshop

Hamburg, Germany

03. November 2013
R. Würz, F. Kessler, H. Morgner, S. Saager
Influence of hollow cathode plasma activation on the growth of Cu(In,Ga)Se2 thin films

B. Zimmermann, F. Fietzke, G. Mattausch
Hollow cathode arc enhancement in reactive PVD processes on the growth of Cu(In,Ga)Se2 thin films

M. Maicu
Preparation and Characterization of Photocatalytically Active TiO2 Thin films by a Gas Flow Sputtering Process
3rd European Symposium on Photocatalysis JEP 2013 Portoroz, Slowenien 25.–29. September 2013

Sputter deposition of stress controlled piezoelectric ADN and AISiN films for ultrasonic and energy harvesting applications
6. Airportseminar Dresden, Germany 06. November 2013

J. Schönfelder
Einfluss der Nanophotonentechnologie® auf Keratinozyten in vitro
Medica Düsseldorf, Germany 23. November 2013
**KONTAKT | CONTACT**

**Adresse | Address**

Fraunhofer-Institut für Elektronenstrahl- und Plasmatechnik FEP
Winterbergstraße 28
01277 Dresden, Deutschland

www.fep.fraunhofer.de
info@fep.fraunhofer.de

**Internationale Vertreter | International Representatives**

Japan | Dr. Koichi Suzuki
Tokyo, 154-0004, Japan | 510, Spacia Sangenchaya | Nibankan | 2-14-6, Taishido, Setagaya-ku

China | Oliver Wang
10C, Block V Neptunus Mansion | Nanyou Rdd Nanshan District | Shenzhen 518054

Indien | Umesh Bhagwat
S.U.N. Media Ventures Pvt. Ltd. | 1, Gnd Floor, Krishna Kunj, Ashok Nagar Cross Road No 3 | Kandivili East, Mumbai 400101

Südafrika | Thomas Schaal
Esa-Meridian consulting (pty.) Ltd. | 25 Tahiti Close | 7975 Capri Village | Fish Hoek / Cape Town