Fraunhofer FEP

FRAUNHOFER INSTITUTE FOR ORGANIC ELECTRONICS, ELECTRON BEAM AND PLASMA TECHNOLOGY FEP

ANNUAL REPORT 2014/15

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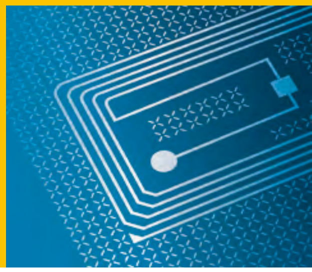
2014/15





CONTENTS

GENERAL PART

RESEARCH NEWS






HIGHLIGHTS

APPENDIX

1

FOREWORD

Dear readers,

With this annual report we would like to thank all our partners and customers as well as employees for a successful 2014.

The integration of Fraunhofer Research Institution for Organics, Materials and Electronic Devices COMEDD into Fraunhofer FEP was a special occasion of the last year. In this process it was important to establish a uniform organizational structure. We would like to thank all our employees for a positive mindset during this time. Due to integration, the name of the institute was changed into Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP. The new name allows for activities in organic electronics.

The integration will take place within three years. We would like to use this time to develop new technologies, processes and products in organic electronics.

In the meantime, we are especially pleased that established technologies at Fraunhofer FEP are of great interest for our customers. The half of our industry revenues were achieved through the projects in the area of electron beam.

On the European level, Fraunhofer FEP has managed to secure participation in three projects including two projects in the area of microelectronics „LOMID" (Large Cost-effective OLED Microdisplays and Their Applications) and „ADMONT" (Pilot Line for the Production of Semiconductor Chips with Extended Functionalities) and a Marie-Skłodowska-Curie project „NANOLAPS" for the development of plasmonic thin-film composites.

Research on flexible glass belongs to the recent activities at Fraunhofer FEP. On the one hand, flexible glass was successfully used for OLED encapsulation and substrate. On the other hand, experimental developments for treatment of flexible glass by sputtering with a subsequent flash lamp annealing were carried out. The know-how gained through these activities can be now transferred with partners into new products.

1 *Deputy Director Dr. Nicolas Schiller, Director Prof. Dr. Volker Kirchhoff and Deputy Director Dr. Uwe Vogel (f.l.t.r.)*

The department „Medical Applications" has proved within the Foundation grant (*Stiftungspromotion*) of Jessy Schönfelder the possibility to sterilize biological tissue with electron beam. In the medium to long term, it is possible to treat with this technology biological materials and implants that were not sterilizable until now.

Through the investment into the new coating equipment NOVELLA, it is now possible to use the high-rate coating for 3-D components at Fraunhofer FEP.

In 2014, the extension of the research campus at the Fraunhofer Research Center for Resource-saving Energy Technologies (RESET) were continued. Since 2014 the center is housing equipment for precision coating that can be used for large-area deposition of precision layers.

Frauhofer FEP supports with its technologies national and international activities for protection of cultural heritage. Within the symposium „*Schadstoffe in Museen*" (Harmful Substances in Museums) on July 2, 2014 a „Memorandum of Understanding" on cooperation between the Fraunhofer Society with Research Alliance Cultural Heritage, Dresden State Art Collections (*Staatliche Kunstsammlungen Dresden*) and Saxon State and University Library Dresden (SLUB) was signed. Through the memorandum the project partners hope to draw attention of representatives of the local government to the importance of „Preservation", and start joint activities on preservation of cultural heritage.

In this report you will find further information about the applied research in each division at Fraunhofer FEP.

Enjoy reading our report and see you soon at our institute!

Prof. Dr. Volker Kirchhoff

ORGANIZATIONAL STRUCTURE

GENERAL MANAGEMENT

Director: Prof. Dr. Volker Kirchhoff
Deputy Directors: Dr. Nicolas Schiller | Dr. Uwe Vogel

FLEXIBLE ORGANIC ELECTRONICS

Head: Dr. Christian May
S2S Organic Technology: Dr. Christian May
Organic Cleanroom: Maik Schober
R2R Organic Technology: Dr. Stefan Mogck

MICRODISPLAYS AND SENSORS

Head: Dr. Uwe Vogel
Organic Microelectronic Devices: Dr. Olaf Hild
Process Integr. Microdisplays & Sensorics: Dr. Karsten Fehse
Microdisplay Cleanroom: Mario Metzner
Organics Micro-Patterning: Dr. Olaf Hild
IC and System Design: Bernd Richter

ELECTRON BEAM

Head: Prof. Dr. Christoph Metzner
Electron Beam Processes: Frank-Holm Rögner
Coating of Sheets & Metal Strips: Prof. Dr. Christoph Metzner

PLASMA

Head: Dr. Torsten Kopte
Coating of Flat Substrates: Dr. Torsten Kopte
Medical Applications: Dr. habil. Christiane Wetzel
Coating of Components: Dr. Heidrun Klostermann

FLEXIBLE PRODUCTS

Head: Dr. Nicolas Schiller
Flexible Products: Dr. Nicolas Schiller

PRECISION COATING

Head: Dr. Peter Frach
Static Deposition: Dr. Hagen Bartzsch
Dynamic Deposition: Dr. Daniel Glöß

MATERIALS ANALYSIS

Head: Dr. Olaf Zywitzki

SYSTEMS

Head: Henrik Flaske
Cooperation: Steffen Kaufmann
Prototyping: Rainer Zeibe
Electronic Development: Dieter Leffler
Mechanic Development: Henrik Flaske

ADMINISTRATION

Head: Veit Mittag

CROSS DEPARTMENTS

Marketing: Ines Schedwill
Corporate Communications: Annett Arnold
Quality / Knowledge Management: Sabine Nolting
Protective Rights / Contracts / Library: Jörg Kubusch
Team Assistance: Annett Nedjalkov
Technical Management: Gerd Obenaus
Information Technology: Roberto Wenzel

ADVISORY BOARD

MEMBERS OF THE ADVISORY BOARD

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Christoph Zimmer-Conrad	Saxon State Ministry of Science and the Arts

GUEST MEMBERS

Dr. Alexander Kurz	Fraunhofer-Gesellschaft, Human Resources, Legal Affairs and IP Management
Dr. Patrick Hoyer	Fraunhofer-Gesellschaft, Institute Liaison
Dr. Hans-Ulrich Wiese	Former Board Member of the Fraunhofer-Gesellschaft

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 2014 with approx. 50 national and international industrial partners.

RESEARCH PARTNERS

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

FRAUNHOFER COOPERATIONS

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

ACADEMIC COOPERATIONS

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

MEMBERSHIPS

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

THE FRAUNHOFER-GESELLSCHAFT

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

At present, the Fraunhofer-Gesellschaft maintains 66 institutes and research units. The majority of the nearly 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2 billion euros. Of this sum, around 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

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

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

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

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

www.fraunhofer.de

THE INSTITUTE IN FIGURES

Funding

The integration of the two cost centers FEP-061 and COMEDD-162 began in the financial year 2014. Fraunhofer FEP is presented as a single institute in the following outline.

Development of total expenditures

Total expenditures for operating expenses and investments were € 25.8 million. In the period under review, € 2.3 million of this amount were invested in equipment technology and infrastructure, with € 1.1 million coming from the central strategy fund. These investments were made for the support of the business areas, especially the realization of ongoing research projects, and also for the support of future research. Personnel costs amounted to € 12.6 million, which corresponds to 53 percent of the operating budget of € 23.4 million. The cost of materials was € 8.9 million.

The institute can look back on a noteworthy financial year. In the project work segment, very high-volume industrial projects and the demanding deadlines with numerous grant projects posed special challenges. Thanks to successful acquisitions, Fraunhofer FEP was able to generate € 8.3 million through direct industry orders. Revenues of € 7.4 million were generated from public projects subsidized by the federal and state governments. Out of this amount, the largest proportion at € 4.8 million came from publicly funded projects in cooperation with SMEs, subsidized by the Saxony State Ministry for Science and Art and the Saxony State Ministry for the Economy, Employment and Transport. The ratio of external revenues from projects with industry as well as public and other customers – the third-party funds ratio – was therefore at 69 percent with a volume of € 17.2 million. € 6.1 million of core funding was consumed by the operating budget.

The revenues generated in the reporting period are allocated to the cost centers as follows:

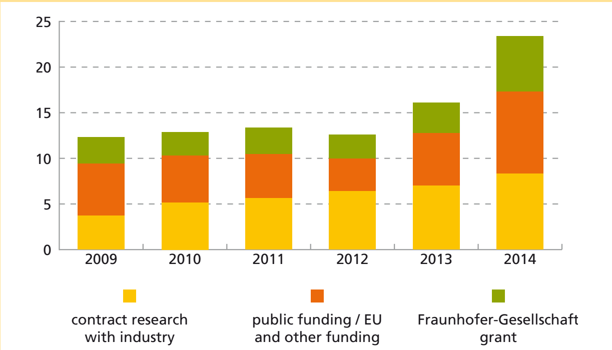
	061	**162**
▪ Industry revenues (contract research with industry)	€ 6.5 million	€ 1.8 million
▪ Public revenues (federal contract research)	€ 1.3 million	€ 1.3 million
▪ Public revenues (state contract research)	€ 4.0 million	€ 0.8 million
▪ EU and other revenues	€ 0.8 million	€ 0.8 million

Employee development

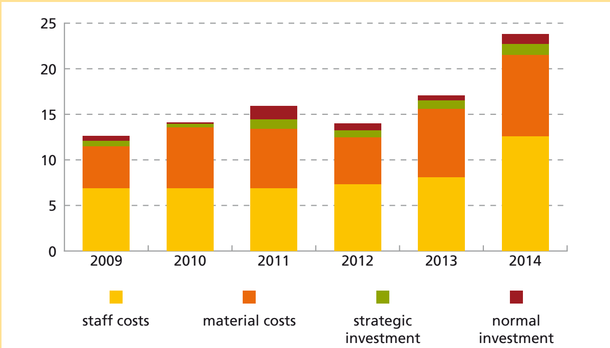
The institute employed 193 people in the past year, 9 of which were trainees, as well as 40 interns and 103 scientific assistants. Of the 94 employees who were employed as scientists, 12 were working on their doctoral topics in addition. The proportion of women in the scientific segment was 24 percent. Training of young scientists continued to define our personnel strategy priorities in the past year. By assigning attractive diploma, bachelor and doctoral topics, we helped highly motivated scientists to graduate successfully. Systematic technical training of young people continued in the year 2014 with apprenticeships in cooperation with the respective vocational schools. Here our trustful partner for training physics laboratory assistants is the Sächsische Bildungsgesellschaft Dresden. We would like to thank the Dresden Chamber of Industry and Commerce and all institutions who played a major part in the success of our trainees.

Our thanks also goes to the employees of our institute, who consistently ensure the professional training of our future employees with great personal dedication, in addition to their primary responsibilities.
One new trainee started his apprenticeship with the institute by the end of 2014. We therefore have now 9 trainees including one BA student, four physic laboratory assistants, one industrial mechanic, one electronic engineer, one IT specialist and one office clerk.

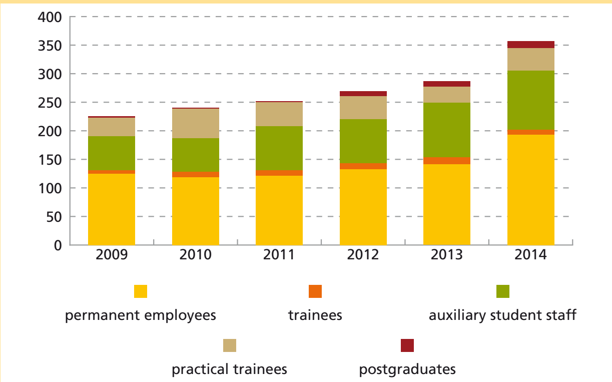
1 *Operating budget (in million euros)*



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



3 *Fraunhofer FEP staff*



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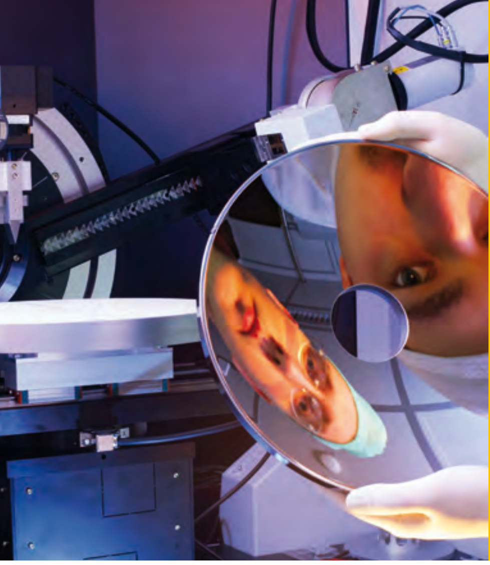

FRAUNHOFER GROUP FOR LIGHT & SURFACES

Competence by networking

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

Core competences of the group

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

Contact

Group Chairman	Group Assistant
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Phone +49 3641 807-201	Phone +49 3641 807-207

www.light-and-surfaces.fraunhofer.de

Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP

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

www.fep.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT

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

www.ilt.fraunhofer.de



Fraunhofer Institute for Applied Optics and Precision Engineering IOF

The Fraunhofer IOF develops solutions with light to cope foremost challenges for the future in the areas energy and environment, information and security, as well as health care and medical technology.

The competences comprise the entire process chain starting with optics and mechanics design via the development of manufacturing processes for optical and mechanical components and processes of system integration up to the manufacturing of prototypes. Focus of research is put on multifunctional optical coatings, micro- and nano- optics, solid state light sources, optical measurement systems, and opto-mechanical precision systems.

www.iof.fraunhofer.de

Fraunhofer Institute for Physical Measurement Techniques IPM

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

www.ipm.fraunhofer.de

Fraunhofer Institute for Surface Engineering and Thin Films IST

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

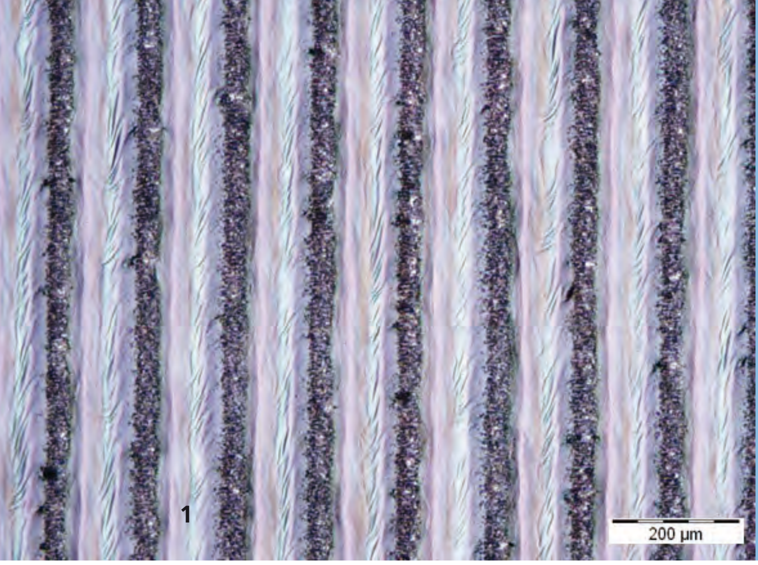
www.ist.fraunhofer.de

Fraunhofer Institute for Material and Beam Technology IWS

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

www.iws.fraunhofer.de

RESEARCH NEWS



NOVEL METHOD FOR THE PRODUCTION OF THIN SILICON WAFERS

As thin as possible silicon wafers produced without sawing (kerfless) are required for various applications, especially in photovoltaics. This first thin crystalline silicon layers have been successfully produced on wafers using electron beam technology.

The active zone of silicon wafers used for electronics is usually just a few micrometers thick. This makes the production of thin wafers interesting for numerous applications (microelectronics, photovoltaics).

The current process of cutting the wafers from the monocrystal using a wire saw is limited to a minimum thickness of approximately 120 µm. It creates an interference layer which not only needs to be subsequently removed but also results in more than 50% cutting waste of the expensive monocrystal material.

This is why we have tested an alternative technology concept based on electron beam technology. It allows monocrystalline silicon layers to be produced on a monocrystalline substrate in the first phase.

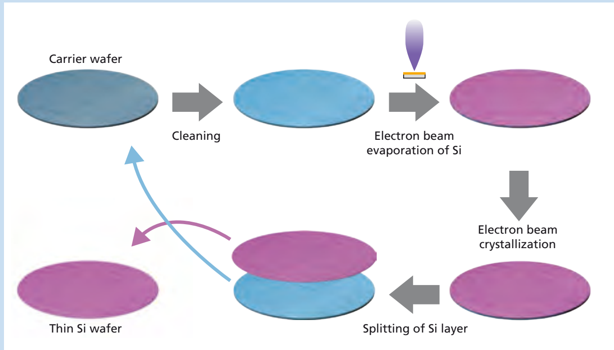
The novel method is based on the approach of producing the silicon wafer from a vapor phase deposition silicon layer which is subsequently crystallized. In this process, the crystal information for the vapor phase deposition layer is formed by an underlying monocrystalline substrate, e.g. a silicon or sapphire wafer. The substrate wafer is subsequently split off, cleaned and reused (Fig. 3). The electron beam as the energy source is applied in three process steps: for the in-situ cleaning of the carrier substrate, the vapor phase deposition of the silicon layer and the crystallization. We utilize the following advantages of the electron beam:

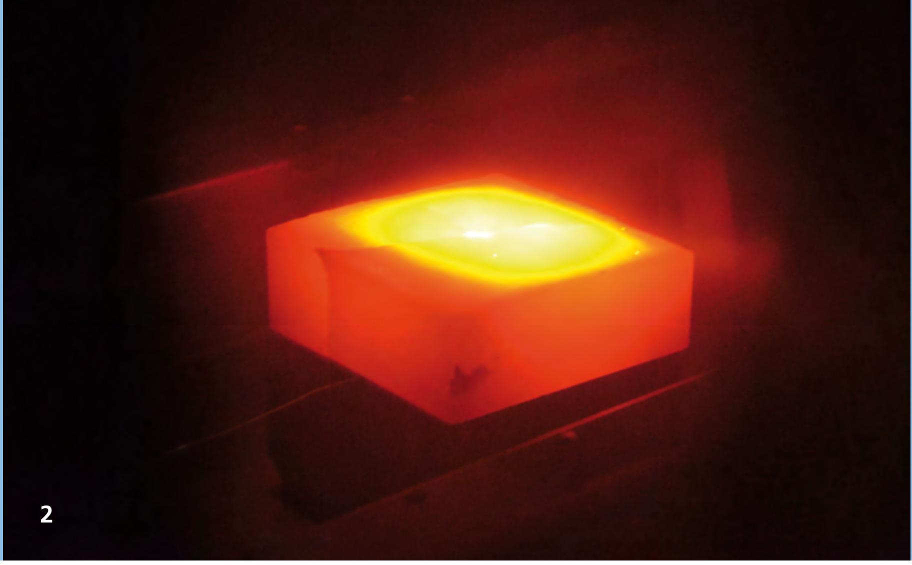
- The electron beam and the surrounding high-vacuum chamber are nearly free of contaminants.
- The electron beam can be used with a high energy density.
- Inertia-free and fast deflection and highly precise control of the electron beam are possible.

Therefore it is predestined for fast process speeds. Not only does it ensure high productivity, it also makes a defined energy distribution during processing possible.

After the carrier substrate is cleaned in a wet-chemical process common in the semiconductor industry, ultra-fine cleaning

3 *Schematic for the fabrication steps of the proposed new technology*





in-situ in the vacuum follows to remove contaminants. This is required for the later low defective transfer of the crystal information into the silicon layer being crystallized. Here the etching effect can be realized by sublimation of the surface layers, or by an electron beam-induced chemical reaction with high purity hydrogen. Both effects were investigated in a master's thesis [1]. The electron beam was moved across the surface of the carrier substrate in a line pattern (Fig. 1). With a very rapidly deflected, well-focused electron beam, a removal rate of 10 nm/s has been achieved. This establishes the basis for a highly productive, contamination-free and low defect, in-situ ultra-fine cleaning process. Further work is now focusing on laminar stock removal.

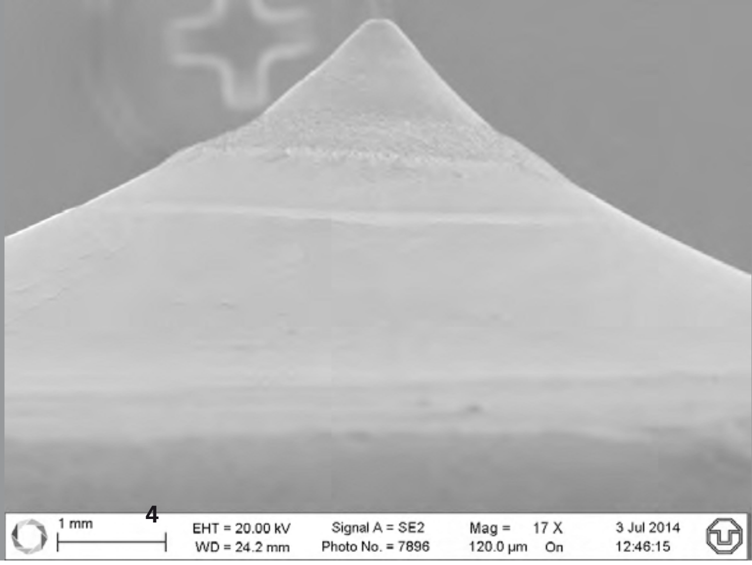
In the second process step, a silicon layer is deposited onto the pre-cleaned carrier substrate. Here the following requirements need to be met:

- Large-scale depositing of thick silicon layers (>10 µm) with a high deposition rate (>300 nm/s)
- Ensuring extremely high layer purity
- Application of the silicon as an amorphous layer, since monocrystalline areas would interfere with subsequent crystallization and form a multicrystalline layer

Once again, the three characteristics of the electron beam identified above apply. Three evaporation configurations were tested to ensure high purity during vaporization:

a) Conventional evaporation of solar grade polysilicon from a water-cooled copper crucible
b) Evaporation of solar grade polysilicon contactless from a large copper crucible, so that only a small part of the evaporation material is melted and contact of the silicon melt with the crucible wall or bottom is avoided
c) Crucible-free evaporation of rod-shaped electronic grade silicon mono-crystals

1 *(100) Si surface after 500 process scans with electron beam induced etching (EBIE)*
2 *Heated mc Si block during evaporation*



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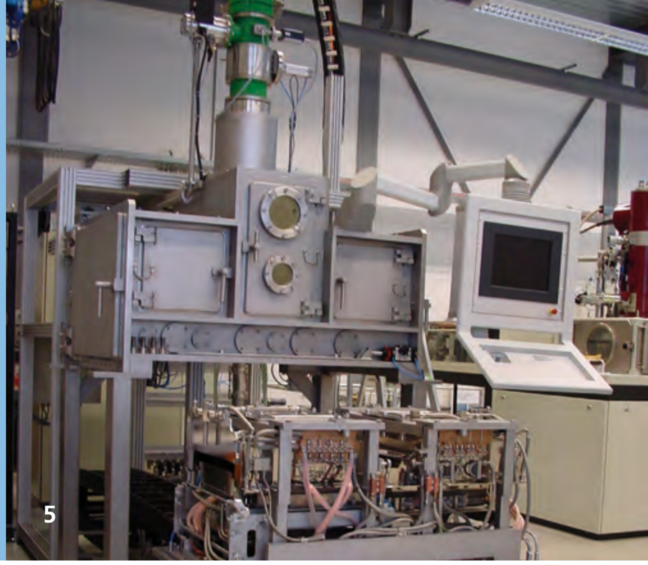
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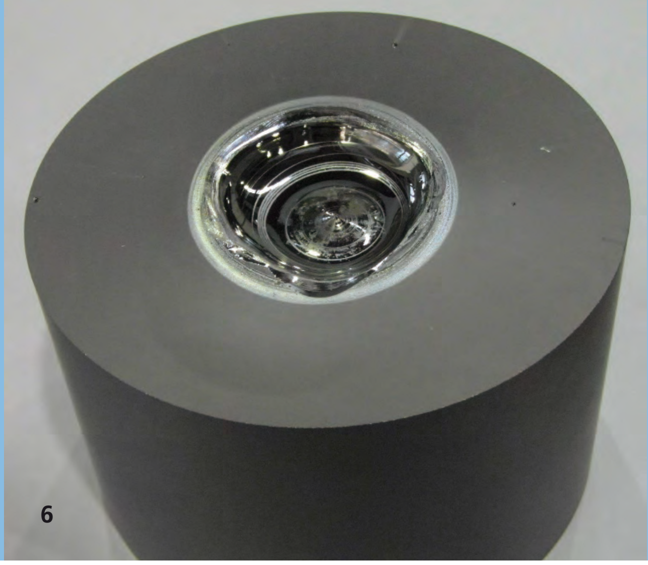
With the third method (c) produced layers of the highest purity are produced [2]. For evaporation without a crucible, the biggest challenge is heating the brittle silicon rod. With the help of simulation calculations, a regime was developed to increase the electron beam power step by step and simultaneously adjust the electron beam deflection. This adjustment made it possible to slowly heat the silicon rod to the evaporation temperature without bursting (Fig. 8). Challenges with this method were to achieve a stable, high evaporation rate, and to avoid leakage of the melt from the top of the rod. Evaporation without a crucible is beneficial for the evaporation rate as well. Since there is no direct cooling contact with a crucible, the electron beam power is used more effectively for evaporation. Deposition rates up to 300 nm/s were demonstrated (Fig. 9). Further work is aimed for realizing 1 µm/s. This has established the foundation for long-term, stable, large-scale vapor phase deposition for the economical deposition of thick, high purity silicon layers. Maintaining a substrate temperature <450°C ensured that purely amorphous silicon layers were deposited.

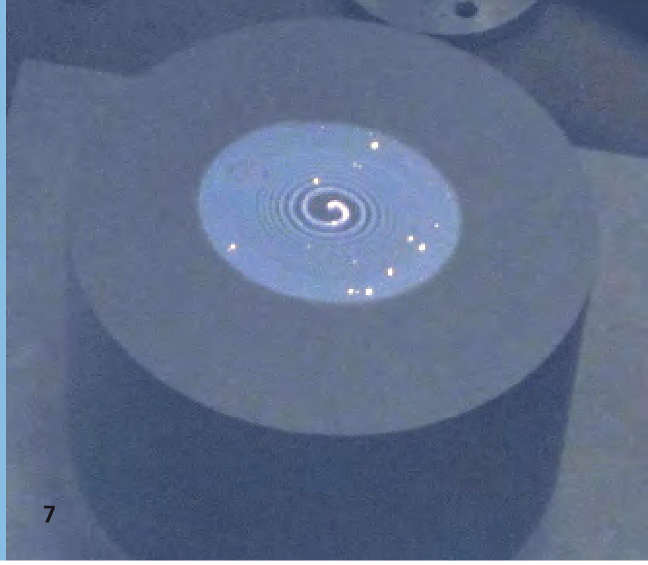
Studies of electron beam crystallization were then performed with thick amorphous silicon layers that were deposited onto a monocrystalline carrier substrate. The electron beam was moved over the surface of the silicon layer in a line pattern. Suitable control of the electron beam within a multidimensional parameter space was achieved. This demonstrates that it is possible to crystallize the silicon layer with the electron beam so that the crystal information can be transferred from the carrier substrate into the deposited silicon layer that its mono-crystalline growth is successfully achieved. Figure 10 shows a silicon layer of about 7 µm that was crystallized on an area of 6 × 6 mm^2 with the electron beam. The red color in the EBSD map identifies the crystal orientation which is identical with the substrate underneath. This proves that the desired overall concept is technically feasible. In particular, it shows that the layers are of sufficient purity and that the boundary layer between the carrier substrate and silicon layer is also clean enough that the crystal information can be transferred with low defect density.

Economic efficiency is of crucial importance for the introduction of this novel method to produce thin silicon wafers. Based on knowledge of the individual process steps, the total cost for producing the wafers and the cost per Wp were estimated and reflected into the predicted costs. Costs of 0.36 US$ per Wp are expected for 2017 [3]. With the transfer of our proposed technology, we estimate the costs of less than 0.10 Euro per Wp. Therefore, we believe our proposed solution also has excellent long-term cost advantages, compared to competitive other known kerfless process approaches.

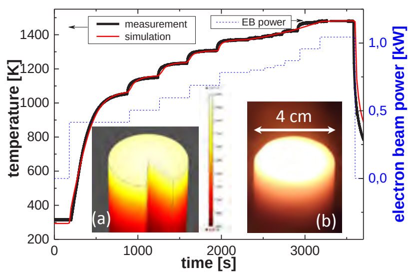
The demonstrated studies were financed by funds from the European Union, the Free State of Saxony (project: 100102018) and Fraunhofer FEP in-house research. We would like to thank Dr. E. Hieckmann, Dresden Technical University for carrying out the EBSD studies.

We now look forward to industrial partnerships to implement the technical/technology basis we have developed in the overall concept or also for other possible applications.



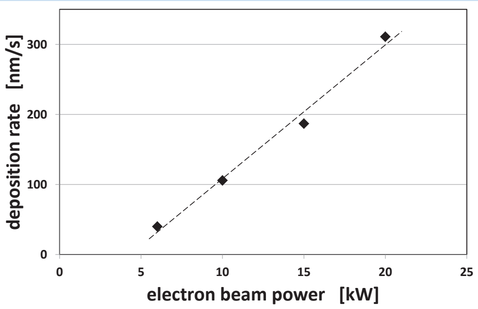


8 *Measured (bold black line) and FEM-simulated (thin red line) temperature of the Si rod top face vs. time during heat up at different electron beam power (blue dashed line)*

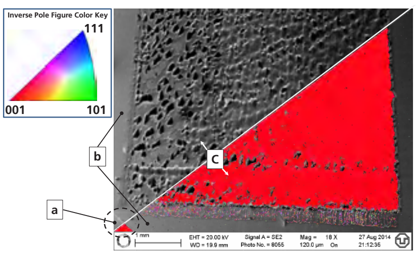


a) Simulated temperature field
b) photo of the hot Si rod

9 *Silicon deposition rate vs. electron beam power for the crucible-free setup*



10 *Electron beam crystallized area of a Silicon layer*



a) (100) Si substrate
b) a-Si layer on substrate
c) electron beam crystallized Si layer on substrate

SEM image at low magnification (top left) overlayed with the corresponding EBSD data map (bottom right). The color indicates the crystal orientation, shown in the inverse pole figure color key. At transparent regions no crystal orientation could be evaluated.

[1] *E. Bodenstein : M.Sc.Thesis, University of Technology Dresden, May 2014*

[2] *S. Saager, M. Ben Yaala, J.-P. Heinß, Chr. Metzner, B. Pfefferling, D. Temmler: High-Rate Deposition of Si Absorber Layers by Electron Beam Evaporation and First Electron Beam Crystallization Tests; In Proceedings of 29th European Photovoltaic Solar Energy Conference, Amsterdam, 2014, 1900-1903*

[3] *M. A. Green: Silicon Wafer-based Tandem Cells: The ultimate Photovoltaic solution?; In Proceedings of 28th European Photovoltaic Solar Energy Conference, Paris, 2013, 7 - 10*

4 *SEM image of a cone shaped Si crystal after solidification of Si melt*

5 *ELMASCAN – electron beam processing equipment of the Fraunhofer FEP*

6 *Si single crystal rod with solidified melting pool after evaporation*

7 *Si single crystal rod with electron beam scan layout during heating up*

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2

DEPOSITION PROCESS AND STRUCTURE ANALYSIS OF PIEZOELECTRIC ALUMINUM-SCANDIUM-NITRIDE LAYERS

By reactive pulse magnetron sputtering of an aluminium and a scandium target of a Double Ring Magnetron DRM 400 the Al/Sc ratio in $Al_XSc_{1-X}N$ layers can be systematically varied. The effect of chemical composition and structure on piezoelectric properties is analysed.

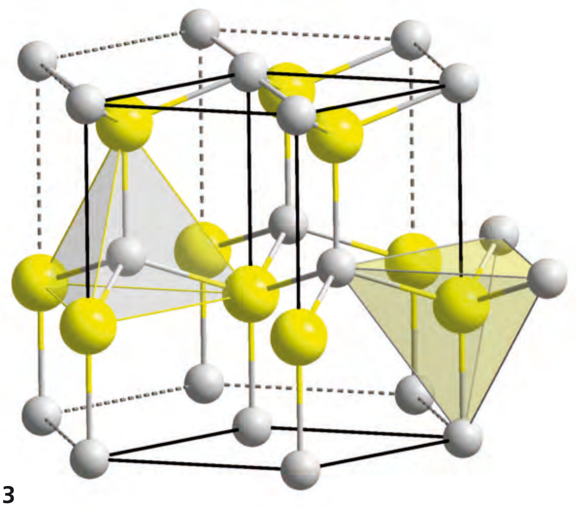
Piezoelectrics are materials that deform when an electrical voltage is applied or that produce a separation of charge under the application of mechanical force. They are used in many different fields of application, for example as frequency filters in telecommunication. Aluminum nitride (AlN) is a widely used piezoelectric material in this field. Its piezoelectric activity comes from its wurtzite structure (Fig. 3). Additional fields of application such as micro-energy harvesting, for example for self-sufficient sensors, are increasingly gaining importance as well.

AlN exhibits a number of advantages compared to other piezoelectric materials, such as lead-zirconate-titanate (PZT). Here, the long term stability, mechanical properties, substitution to lead according to the EU RoHS directive and compatibility with common microelectronics production processes can be emphasized. However, a disadvantage of AlN compared to other piezoelectric materials is the relatively low piezoelectric constants d_{33} and d_{31}. However, by doping the layers with scandium, the piezoelectric properties can be improved significantly by up to 400%.

The deposition processes for AlN and $Al_XSc_{1-X}N$ were carried out at Fraunhofer FEP using a stationary coating setup with the double ring magnetron DRM 400 developed at the institute (see Fig. 1). By superimposing the two discharges, the dual-ring arrangement of the targets makes it possible to deposit the layers on large surfaces (max. diameter 200 mm / 8 ") and homogenously at the same time (Fig. 5). Very high deposition rates can also be realized through suitable process control, which is of great importance for industrial use in particular.

The aluminum-scandium-nitride layers ($Al_XSc_{1-X}N$) were produced by means of reactive co-sputtering of metallic Al and Sc targets in an argon-nitrogen atmosphere. By using metallic Al and Sc targets, it was possible to vary the layer composition, that is the Al:Sc ratio in the layers, by means of the output ratio. Deposition rates of up to 200 nm/min were achieved for piezoelectric $Al_XSc_{1-X}N$ layers. The piezoelectric charge constant d_{33} reached values up to 28 pC/N (Fig. 8).

Examinations using FE scanning electron microscopy (FE-SEM) and X-ray diffraction (XRD) are used to clarify how the structure of these $Al_XSc_{1-X}N$ layers changes with increasing scandium integration and how the piezoelectric properties can be influenced as a result.
Depending on the scandium content, the $Al_XSc_{1-X}N$ layers exhibit the hexagonal wurtzite structure with a tetrahedral coordination (Fig. 3) or the cubic rock salt structure with octahedral coordination (Fig. 4).



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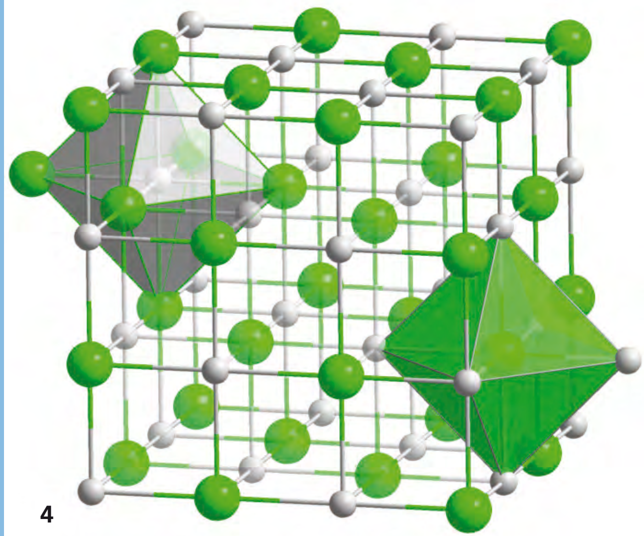

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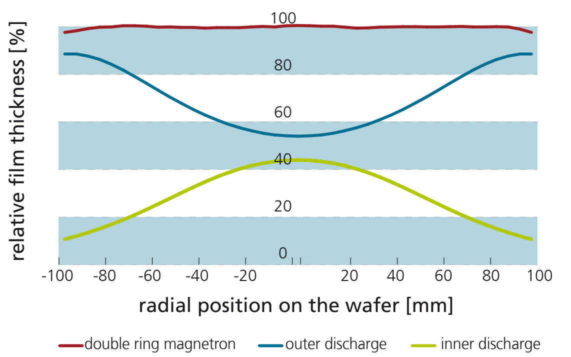
As with pure AlN, the existence of piezoelectric properties is bound to the polar c-axis of the hexagonal wurtzite structure. Electric charges can be observed when mechanical strain acts in the direction of the polar c-axis (direct piezoelectric effect). The cubic rock salt structure on the other hand has a centrosymmetric structure without a polar axis, so that no piezoelectric properties develop for this structure.
For a scandium content below 50%, the wurtzite phase with (001) texture primarily occurs while the cubic phase with rock salt structure is detected above 50%. Both phases exhibit a positive mixing enthalpy according to theoretical calculations, and are therefore metastable with an inherent existing driving force for separation. The structure examinations have, however, revealed that complete separation can be avoided under the non-equilibrium conditions during magnetron sputtering.

The $Al_xSc_{1-x}N$ layers with wurtzite structure exhibit a columnar structure according to FE-SEM examinations, which in turn exhibits a higher density of lattice defects with increasing scandium incorporation (Fig. 6). Changes in the lattice parameters could also be proven through X-ray diffraction. The incorporation of scandium on aluminum sites leads to a

5 *Film thickness distribution of the DRM 400*

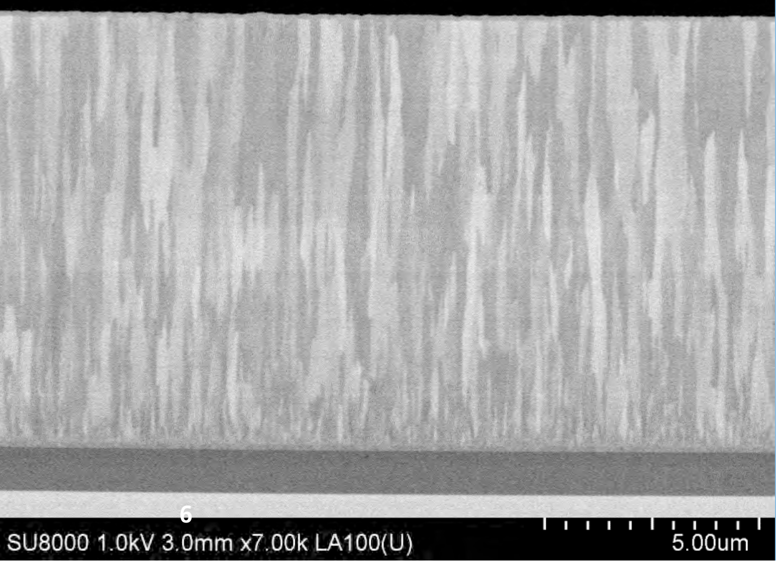


1 *Double ring magnetron DRM 400*

2 *Cluster 300 experimental plant for stationary magnetron sputtering*

3 *Hexagonal wurtzite structure with tetrahedral coordination and polar c-axis*

4 *Cubic rock salt structure with octahedral coordination and centrosymmetric structure*



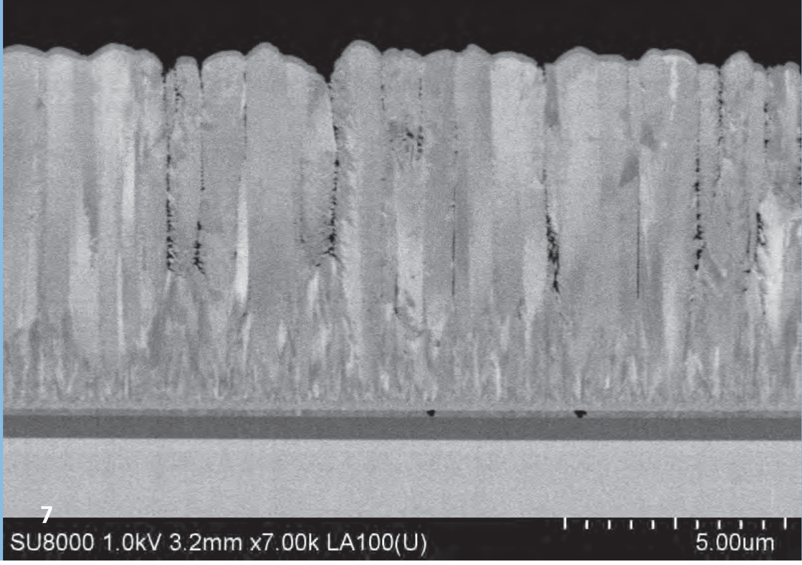
distortion of the tetrahedral coordination with nitrogen. The c/a-axis ratio of the hexagonal wurtzite phase decreases from 1.6 for a pure AlN layer to 1.27 for a $Al_XSc_{1-X}N$ layer with 43% scandium. In the range of 40 to 43% scandium, the decomposition into an aluminum-rich and a scandium-rich wurtzite phase could be proven by XRD.

The structural changes occurring with the increasing scandium content also lead to a weakening of the bonding and therefore a decrease in the modulus of elasticity. Through measurements with nanoindentation technique, a decrease was noted in the modulus of elasticity from 340 GPa for AlN to 190 GPa for $Al_XSc_{1-X}N$ with a scandium content of 43% (Fig. 9). Both effects – weakening of the bonding and the decrease in the modulus of elasticity – lead to an increase in the piezoelectric charge constant for $Al_XSc_{1-X}N$ and a drastic improvement of the piezoelectric properties by up to 400% compared to pure AlN.

At a scandium content above 50%, the cubic rock salt structure with centrosymmetric structure is proven, so the piezoelectric properties are lost entirely. The modulus of elasticity of the cubic phase is about 380 GPa. Significantly larger crystallites, which are approximately 1 µm wide, are discernible in the FE-SEM images, which means the layers simultaneously exhibit a greater surface roughness (Fig. 7).

The optimum piezoelectric properties with a high piezoelectric charge constant d_{33} of up to 28 pC/N are achieved with a scandium content between 35 and 43%. This is one of the highest values for nitride semiconductors. Influencing the energy of particle bombardment through the selection of the pulse mode and pulse parameters in pulse magnetron sputtering with the double ring magnetron DRM 400 and the pulse unit UBS-C2 of Fraunhofer FEP is essential for achieving these favorable piezoelectric properties.

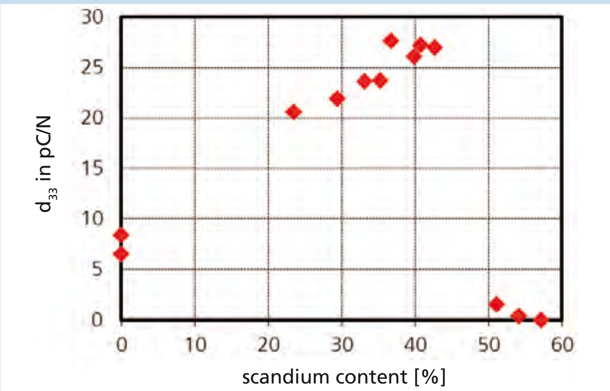
Based on the principle of co-sputtering two different targets, there is currently still a composition gradient across the coating area. Therefore, the homogeneity of the precipitated layers is to be improved in a next step through the use of a different target configuration.



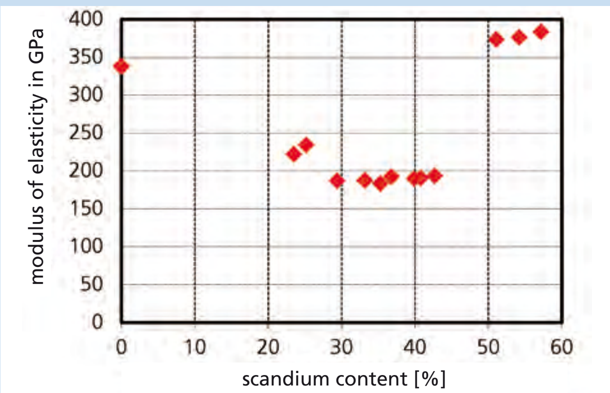
6 *FE-SEM image of a $Al_xSc_{1-x}N$ layer with hexagonal wurtzite structure (23.5% Sc)*

7 *FE-SEM image of a $Al_xSc_{1-x}N$ layer with cubic rock salt structure (51.1% Sc)*

8 *Piezoelectric coefficient d_{33} of the $Al_xSc_{1-x}N$ layers depending on the scandium content*



9 *Modulus of elasticity of the $Al_xSc_{1-x}N$ layers depending on the scandium content*



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1

DAV 20-2 – DIGITAL DEFLECTION AMPLIFIER FOR THE WIDE-ANGLE DEFLECTION OF ELECTRON BEAMS

The development of a powerful, compact, digital deflection amplifier permits space-saving integration into the beam guidance concept of the Fraunhofer FEP electron beam gun for the wide-angle deflection of electron beams

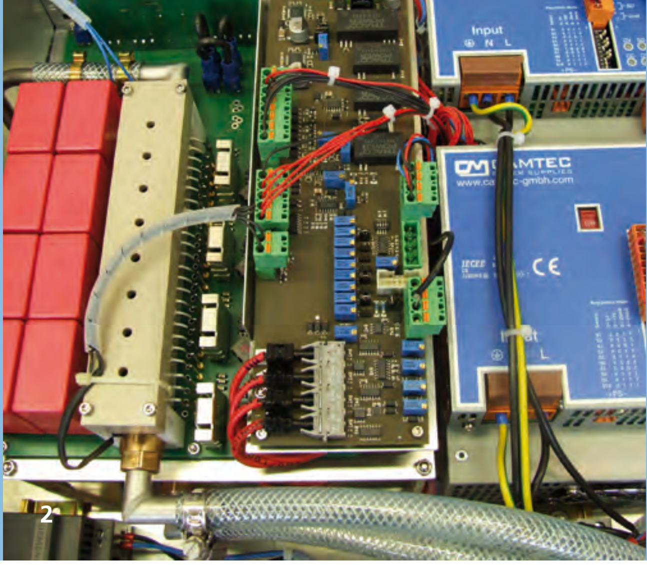
In the field of electron beam technology, the development of complex beam guidance modules is among the competencies of Fraunhofer FEP in addition to developing customer-specific system solutions for electron beam sources. Electron beam systems and corresponding beam guidance technologies are developed for applications in melt metallurgy and high-rate PVD, enabling guidance of high-power electron beams with deflection frequencies up to 20 kHz and deflection angles of ±45°. Here the key to success is the individually coordinated interplay of low-inductive, hyperbolic deflection coils with the DAV 20-2, a digital deflection amplifier conceived especially for applications with fast electromagnetic wide-angle electron beam deflection systems.

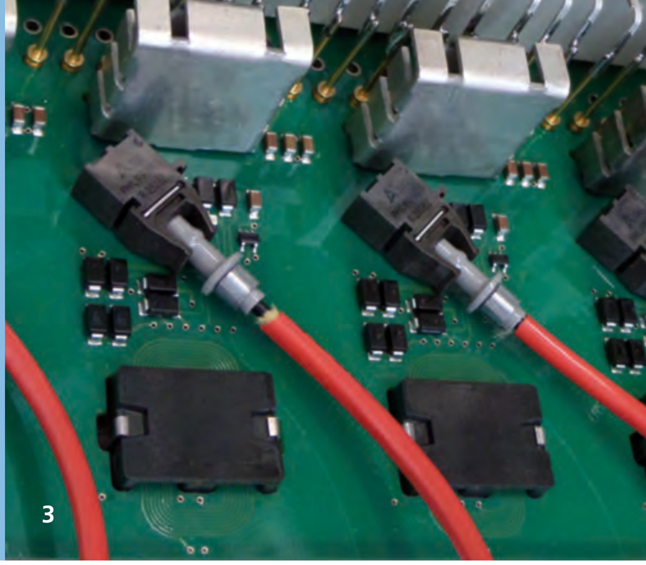
The DAV 20-2 digital amplifier is a two-channel broadband power amplifier and was developed according to the class D principle. Analog input signals are transformed into high-frequency digital switching signals through a pulse width modulator. These signals in turn drive a switching stage which is constructed as a full-bridge circuit. At the output of the full-bridge circuit, a pulse width modulated bipolar voltage is then available which is transformed into a current proportional to the input signal by the integrated characteristic of the inductive load (Fig. 4). In order to supply the required signal bandwidth of 0 Hz (DC) ... 20 kHz with an adequate signal quality, an effective pulse frequency of the power switching stage of up to 500 kHz is required. The pulse frequency imposes the highest requirements on the power switching stage. The entire switching topology of the DAV 20-2 transforms a control voltage of 0 ... ±10 V to a load current of 0 ... ±20 A and supplies an output voltage of ≤400 V to operate inductive loads.

In the interaction between specific configured deflection coils, with inductivities in the range of 50 ... 250 µH, guidance of the electron beam was proven with frequencies up to 20 kHz and deflection angles of ±45° (Fig. 5).

This was only achieved by using highly modern SiC-MOSFET and their integration into an innovative cooling management system.

Only the high power density, low switching losses at a high switching frequency and the high electric strength of the SiC-based MOS transistors used make it possible to achieve the required performance parameters. High energy efficiency results in >90% effectiveness in the entire work range of the DAV 20-2. This makes it possible to reduce the size of the DC power supplies, optimize cooling and therefore the development of a compact, cost-effective and very powerful device in the 19-inch 4HE format.



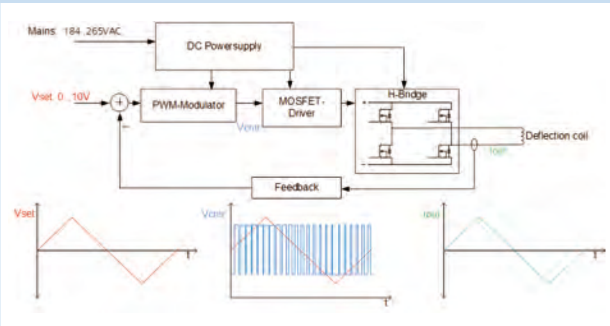


1 *Digital deflection amplifier DAV 20-2*

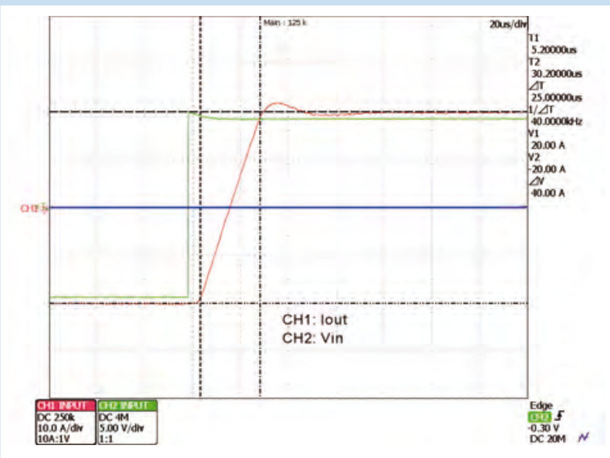
2 *Compact design through a modular set-up*

3 *Fail-safe control of power transistors*

4 *Basic mode of operation of the deflection amplifier DAV*



5 *Step response of the load current -20A → +20A on a low inductive Fraunhofer FEP deflection coil*



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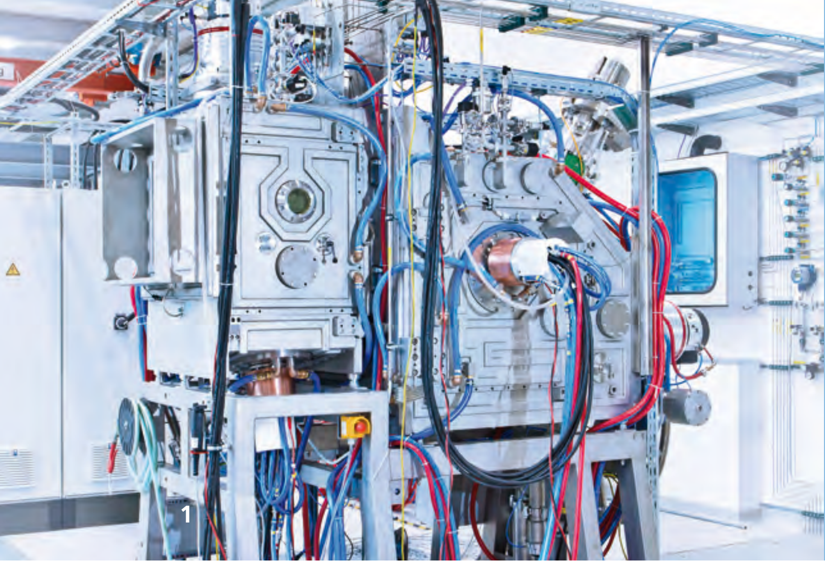
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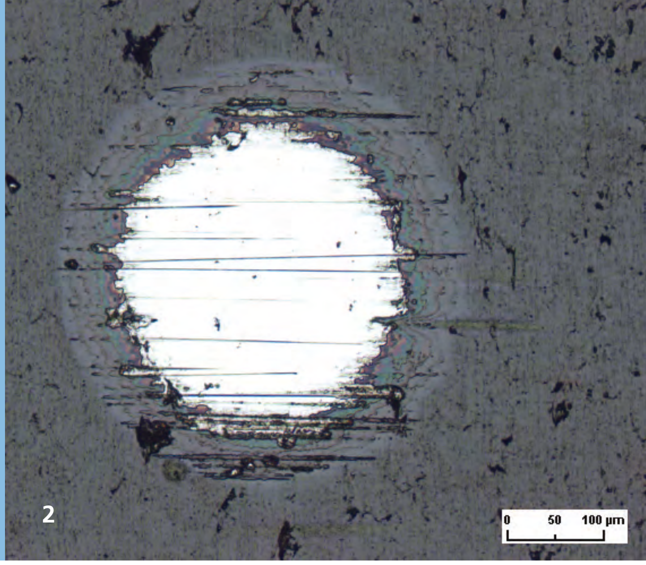


2

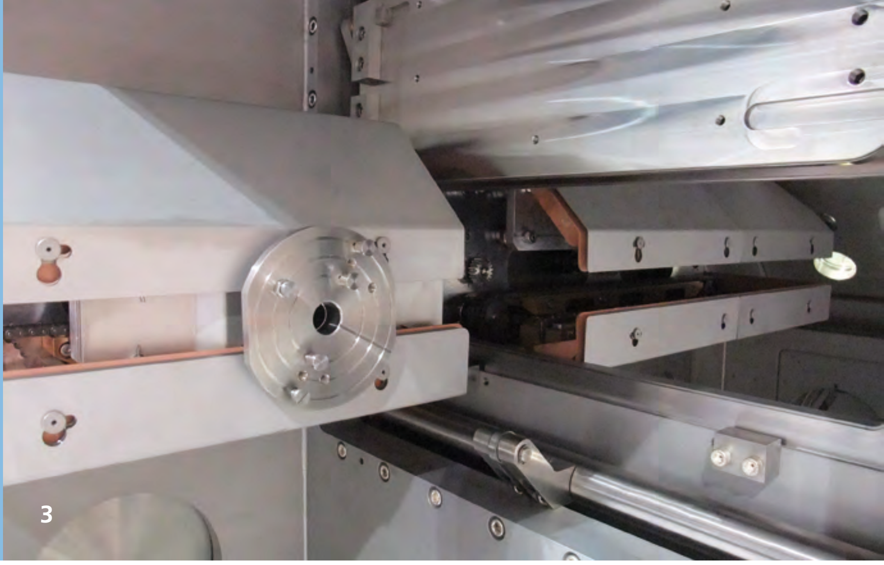
NOVELLA – A NEW PLATFORM FOR THE HIGH-RATE COATING OF COMPONENTS

With the NOVELLA system, Fraunhofer FEP has a platform for the efficient high-rate electron beam evaporation of 3D components available for the first time. Fraunhofer FEP engineers and equipment manufacturers brainstormed in order to realize a new system concept with a sophisticated substrate transport.

Coatings play an essential role in the development of technologies to conserve resources and improve efficiency. They are increasingly conquering the fields of mechanical engineering and plant construction, where the coating of components with three-dimensional geometries is required more and more often in the course of functional optimization. In order to meet economic constraints, this requires efficient system concepts and coating processes that are able to realize complex movement sequences in order to apply coating systems to moving parts with high deposition rates and the most even possible distribution.

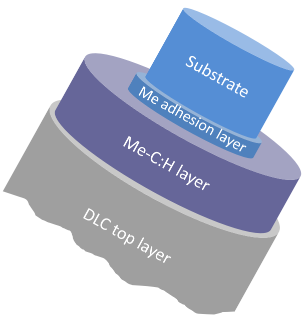
Fraunhofer FEP in cooperation with the equipment manufacturing partner Creavac has designed a corresponding platform, which is intended to accomplish the challenge for all coating technologies available at Fraunhofer FEP. Therefore, it can serve as a demonstration system for a variety of industrial coating processes. The result appears unimposing compared to other tunnel machines, but it packs a punch: In the NOVELLA system, individual substrates with dimensions up to ∅ 150 mm × length 300 mm and a weight of up to 20 kg can be fed into the coating chamber and discharged from it, without having to ventilate the processing chamber or interrupt the coating process. This allows R&D tests with the variation of specific process parameters and otherwise entirely constant conditions to be performed more efficiently compared to conventional batch systems. The chamber principle also supports the sequential coating of numerous substrates in series, and therefore comes close to a continuous flow tunnel machine which can be realized for the treatment of large lots in an industrial production chain.

Plasma-activated electron beam evaporation, magnetron sputtering and plasma-activated chemical vapor deposition are the coating techniques used. These high-rate technologies constitute a challenge for substrate transportation, which has to be very well shielded against parasitic layer formation and has to withstand temperatures of up to 500°C on the substrate carrier. The diversity of the available technologies makes it possible to realize combination coatings in a direct process sequence. They are required to protect components against premature mechanical wear as well as chemical and thermal degradation, and to minimize frictional losses in moving systems in order to make them more efficient. The application conditions for the coated components keep on getting more challenging, since effectiveness is maximized by higher temperatures and higher pressures or components with a reduced weight that have to withstand the same loads. Components and coatings have to be tailored to each other in order to stand up to these new loading conditions. With a given component, this often means that a coating system has to be realized with several individual layers or a graded



structure. For example, the favorable friction characteristics of carbon-based layers can be utilized with maximum benefit by realizing a layer structure consisting of a priming layer, transition and bearing layer containing carbon which provides certain failsafe running functions, and a DLC top layer with a very low friction coefficient (see Fig. 4). Such a structure was produced through the combination of plasma-activated electron beam vaporization and plasma-activated chemical vapor deposition. Figure 2 shows a calotte grinding through such a layer system which was deposited at a rate of approximately 1200 nm/min, here still on a stationary substrate. Realizing such layer systems on rotating components on the NOVELLA system is aimed to demonstrate the future performance of high-rate electron beam vaporization as well as related combination technologies and to illustrate the feasibility of implementation in industrial production processes.

4 *Me–Me-C:H–DLC layer stack on 3D substrate (schematic)*



1 *The NOVELLA system*

2 *Calotte grinding through a layer structure according to Figure 4*

3 *Transport system*

Europa fördert Sachsen.
EFRE
Europäischer Fonds für regionale Entwicklung
Gefördert aus Mitteln der Europäischen Union

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2

REFINEMENT OF ITO ON ULTRA-THIN GLASS BY FLASH LAMP ANNEALING

Glass becomes elastic and flexible at a thickness lower than 200 µm, which is comparable to the thickness of copy paper. This ultra-thin, flexible substrate material opens up a wide range of applications in electronics, sensors, display technology as well as architectural glazing.

For the above listed applications, transparent conductive oxides on flexible glass are of special interest. In order to increase the conductivity and transmittance of indium tin oxide (ITO) as transparent conductive electrode material, Fraunhofer FEP is studying short-time annealing methods for the efficient processing of flexible glass.

Conventional furnace annealing methods heat up the entire substrate and are often very time-consuming and energy-intensive. Novel short-time annealing methods with pulse times in the millisecond range are faster and more energy-saving. Only the film on the surface is heated while the bulk of the substrate remains cold.

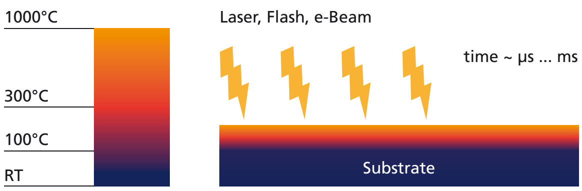
Flash lamp annealing (FLA) is one of these short time annealing methods. To implement it, Xenon lamps are used to generate light flashes. The pulse duration and energy density of the flash is used to vary the temperature at the surface and the penetration depth into the film and the substrate. The effect of FLA depends on the energy absorption of the film and the substrate, the thermal capacity and the thermal conductivity. FLA treatments were carried out on 150 nm thick ITO films. The films were deposited on 25 × 30 cm² flexible glass by magnetron sputtering at room temperature in the inline coating machine ILA 750 and exhibited a sheet resistance of 25 Ω after coating. In cooperation with DTF Technology GmbH, the ITO layers were annealed in a dynamic FLA process and showed a sheet resistance of 14.5 Ω after treatment with a homogeneity of ±5% over the entire area. In addition to significantly reducing the sheet resistance, the absorption of the layer was also reduced so that transmittance in the visible range increased to more than 81%. The resistivity is reduced because of an increase in carrier density. The achieved results are comparable to those of conventional thermal treatment in a furnace at 300°C for 15 minutes.

Through the reduction of absorption of the ITO thin films after FLA treatment, there is nearly no further influence on an already annealed film upon repeated treatment with the same energy density. This self-limiting process enables the homogenous treatment of large surfaces and the use of the technology on inline roll-to-roll systems.

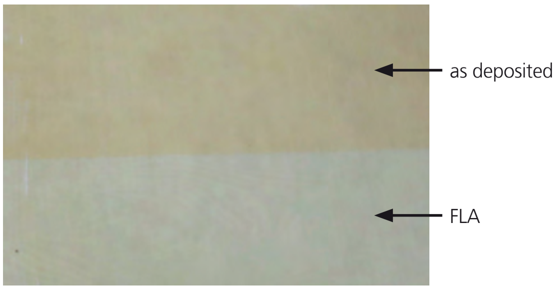
Continuing the investigations and further optimization of the FLA process is planned for other TCO materials as well. Furthermore, the suitability of the process for temperature-sensitive substrates such as plastic panels and polymer webs will be studied.

3

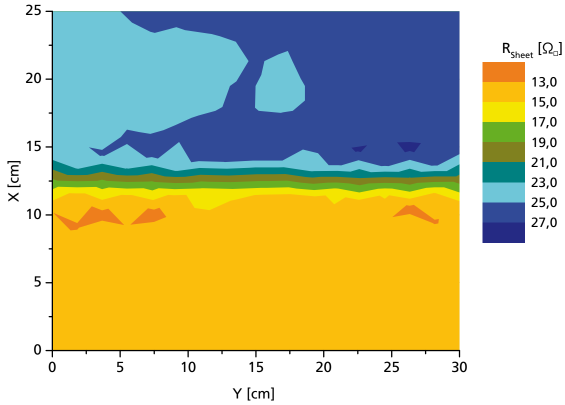
4 *Temperature distribution in the substrate by using short time annealing processes*



5 *ITO-coated thin glass (upper section untreated, lower section after FLA)*



6 *Surface resistivity of ITO-coated thin glass (upper section untreated, lower section after FLA)*



1 *ILA 750 – Vertical in-line sputtering plant*

2 *Improved sheet resistance and transmittance of ITO thin film after FLA*

3 *Ultra-thin flexible glass*

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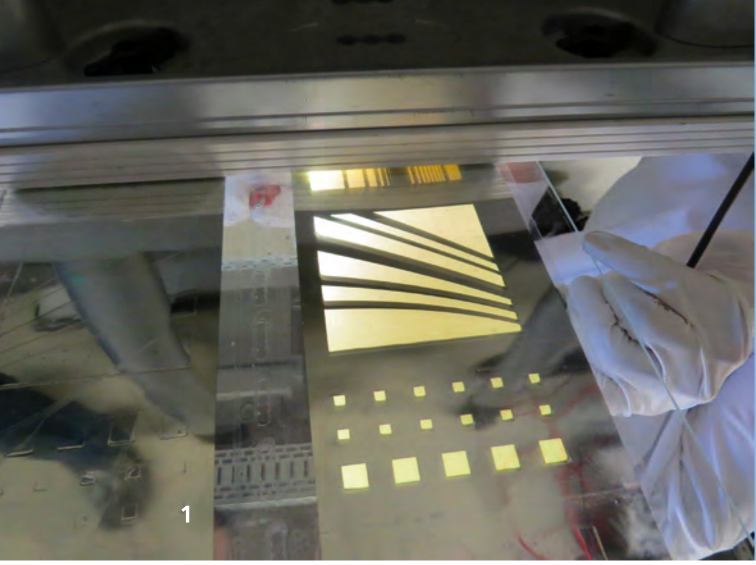

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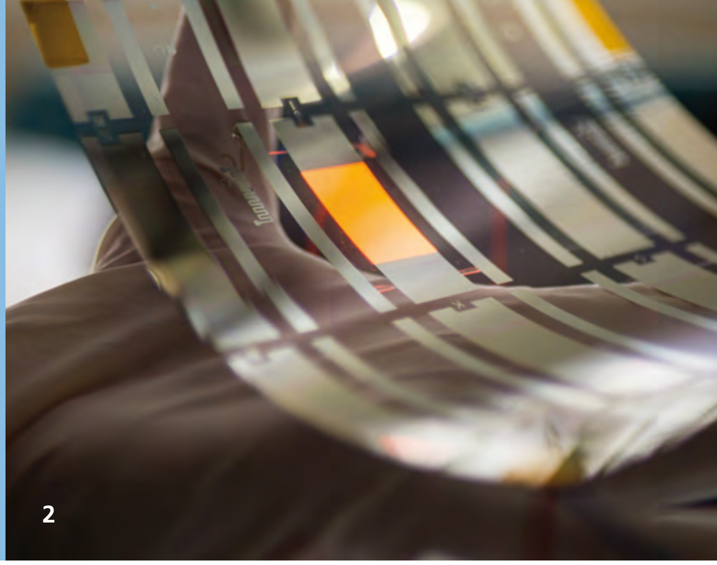


2

FLEXIBLE ULTRA-THIN GLASS – A NEW, ATTRACTIVE SUBSTRATE FOR OLED LIGHTING

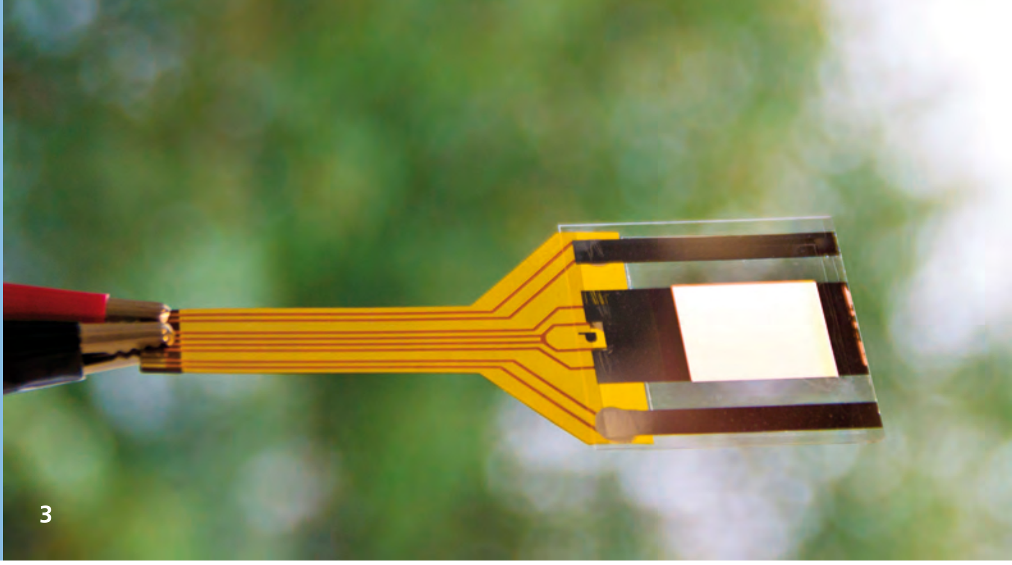
Organic light-emitting diodes (OLEDs) on flexible substrates offer unique possibilities for lighting. In addition to their attractive appearance and integration possibilities, there is another important aspect: The substrates on which they are processed, such as very thin and flexible glass.

OLEDs have special features that distinguish them significantly from other light sources. While incandescent lamps, energy-saving lamps and also classical LEDs are point light sources, OLEDs emitt light on their entire surface. With very low energy consumption, they make transparent light sources possible, which can also be applied to flexible and bendable substrates. The related lighting options and design possibilities have played a crucial role in driving significant efforts for the development of OLED lighting technologies worldwide. Over the last five years, developments have proven the technical feasibility of this vision in the form of initial, flexible demonstrators.

Leading lighting manufacturers have set up pilot production capacities for OLED for lighting on rigid glass substrates in the meantime. However, significant market penetration in general lighting will only be achieved when, on the one hand, the currently high production costs for OLED illuminants are reduced and, on the other hand, new application and design fields which could not be served to date are tapped. The combination of the special design characteristics – flatness and flexibility – with cost-efficient production methods represents OLED as a promising alternative to the established lighting technologies – also from an economic perspective. Various substrate types such as barrier-coated polymer films or thin metal foils are available for the demonstration of flexible OLEDs. Both substrates have significant disadvantages, for example the existing unsatisfactory water vapor barrier and the roughness of the surface. Now a virtually ideal substrate is available with the increasing supply of flexible, ultra-thin glass. Key features include the excellent barrier, smooth surface, high level of light transmission and the ability to deposit highly transparent, conductive materials. However, the high risk of breakage due to improper handling is a disadvantage.

Last year, Fraunhofer FEP has developed processes for OLED elements on the basis of sheet-to-sheet processing and roll-to-roll processing on flexible glass. The integration of OLED elements onto flexible glass is a major step towards achieving the required lifespan of the elements. Fraunhofer FEP has made major progress towards increasing the availability of flexible OLEDs on ultra-thin glass, gaining worldwide attention. Special contacting methods were also developed to enable control and integration.

Fraunhofer FEP works in close contact with the manufacturers of ultra-thin glass in order to continue driving this technology. The participation at trade fairs as LOPE-C and Lighting Japan deserve special mention, where demonstrators with flexible glass rolls “G-Leaf” from Nippon Electric Glass Co. Ltd. were presented.



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New opportunities are offered as a result of skillful integration of flexible glass in signage and lighting systems on any kind of surface for buildings, furniture, packaging, automotive or medical applications. Especially it is relevant for curved surfaces considering a long OLED lifetime which is comparable to the lifetime of elements on rigid glass.

The further improvement of contacting and the reliability of the elements will be the main R&D areas for the near future. The integration of highly conductive metal lines in the elements constitutes a key technology for the production of OLEDs on the basis of small molecules. Improving the reliability and contacting of such elements will be a focal point of future efforts.

Federal Ministry
of Education
and Research

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1 *Large-scale bottom-emitting OLED on flexible glass (10 × 10 cm²) processed with roll-to-roll technology*
2 *OLED on thin glass processed with sheet-to-sheet technology*
3 *OLED on thin glass with bonded flex ribbon cable connection for secure contacting and integration*

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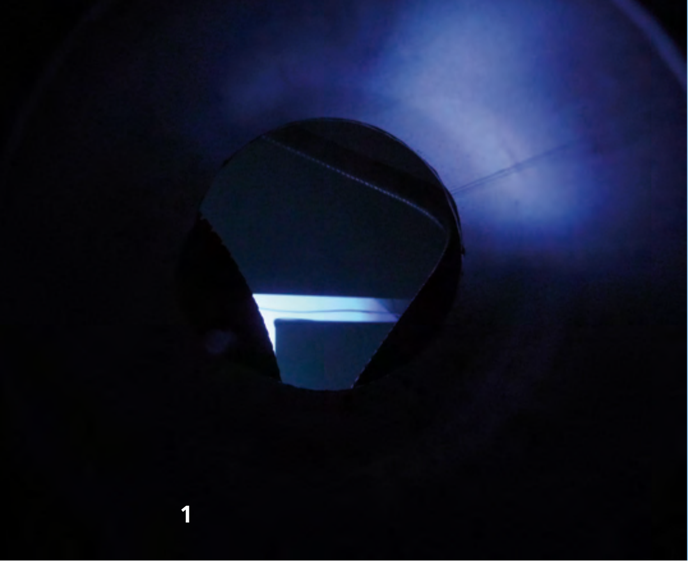

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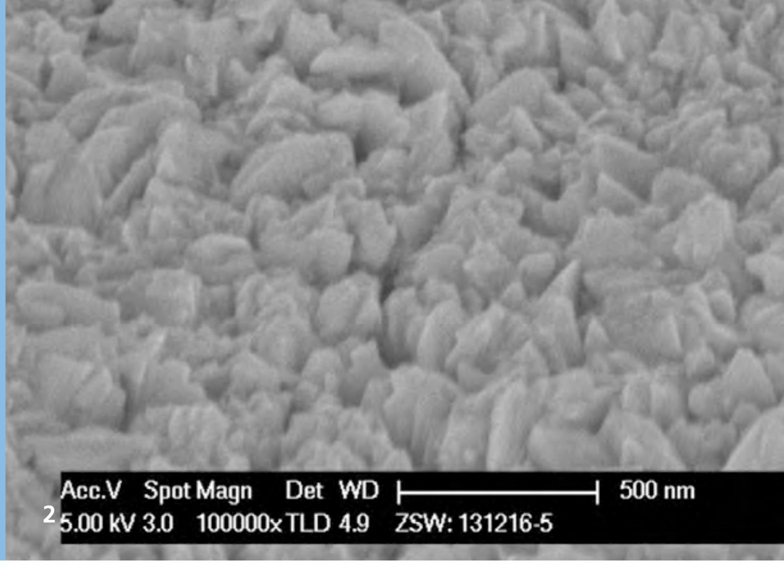


2

PLASMA-ACTIVATED DEPOSITION OF CIGSe-BASED PHOTOVOLTAIC ABSORBER LAYERS

Plasma-activated CIGSe deposition was attempted for the first time in a project initiated by the Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) (German Center for Aviation and Aerospace): Flexible CIGSe Thin Film Solar Cells for Aerospace – PIPV 2. The project objective was the production of lightweight solar cells on thin plastic films that perform under the space conditions.

The application of thin film solar cells in aerospace solar generators of the next generation opens up new possibilities for future spacecraft. Even though the efficiency factor of CIGSe cells is significantly lower than today's crystalline aerospace solar cells, they have a number of unique advantages. The deposition of thin film solar cells on flexible substrates enables the transition to flexible module structures with more than three times the specific output (W/kg) and packing volume (W/m^3) compared to the wafer-based systems used in the past. CIGSe thin film solar cells also set themselves apart with extremely high radiation hardness, which could make their use possible on obits that were previously unattractive due to their radiation intensity.

The efficiency factor of vapor phase deposition CIGSe solar cells has been continuously increased to 21.7% so far (current record ZSW [1]). Relevant optimization parameters for high efficiency factors are the grain structure, Ga-gradient and grain orientation as well as doping the absorber with sodium and potassium, the process temperature and the processing duration.

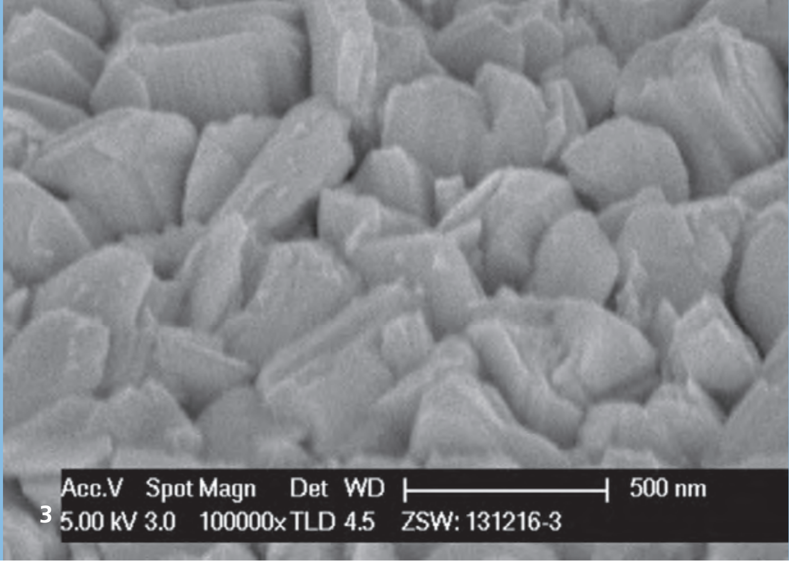
The limited temperature resistance of the polyimide polymer substrates at approximately 400°C to 450°C, compared to 550°C to 600°C for coating glass substrates, represents a limit on the growth conditions of the CIGSe absorber layer.

Fraunhofer FEP has many years of experience in the use of high-density plasma for activating the condensing vapor in vacuum deposition processes, e.g. with hollow cathode arc discharge plasmas. Here the proven effects of the plasma are:

- Plasma-activated evaporation makes it possible to overcome the porous and columnar structures of materials with a high melting point and in a reactive process, even at high coating rates.
- The formation of crystalline phases can take place at lower temperatures.
- The activation (excitation, ionization, dissociation, increased kinetic energy) of the vapor and gas particles in the process increases the chemical reactivity.

In close cooperation with the Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (Center for Solar Energy and Hydrogen Research Baden-Württemberg) (ZSW), Fraunhofer FEP (subcontractor) modified a hollow cathode arc discharge plasma source and integrated it into the second stage of a two-stage coating process for the absorber layer. The scientific studies of plasma-activated CIGSe deposition were conducted under supervision of the ZSW with the following key results:

- In the aggressive selenium atmosphere of the CIGSe coating chamber, the hollow cathode arc discharge plasma source works for a long time with no disruptions.



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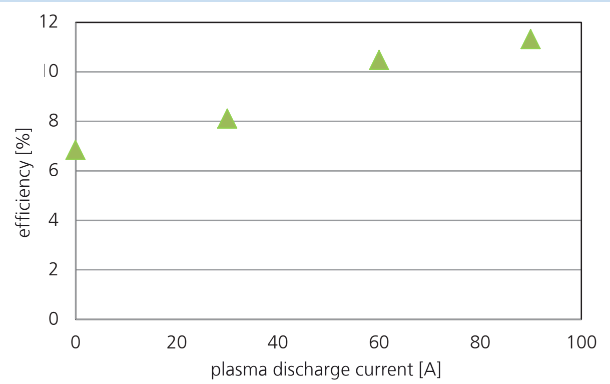
- Plasma activation has a clear influence on the structure of the CIGSe absorber layers and electronic characteristics of the solar cell (Figure 2, 3 and 5).
- The increase in reactivity under plasma activation was proven by the RFA and XRD measurements and SNMS depth profiles.
- The increase in cell efficiency with growing plasma activation could be determined under certain parameter conditions (Figure 5).

Initial results of plasma-supported CIGSe deposition reveal a promising potential for plasma activation in absorber deposition. Further activities are planned in a subsequent project. To improve productivity, the reactivity during layer formation is to be increased significantly through strong plasma activation of the Se-reactive gas component.

5 *Change of the efficiency of CIGSe solar cells with increasing plasma activation*



[1] P. Jackson, D. Hariskos, R. Wuerz, O. Kiowski, A. Bauer, T. M. Friedlmeier, and M. Powalla: Properties of Cu(In,Ga)Se2 solar cells with new record efficiencies up to 21.7% Phys. Status Solidi RRL, 1–4 (2014) / DOI 10.1002/pssr.201409520

[2] S. Langendorf, S. Brunner, K. Zajac: Design and Testing of a Flexible Solar Generator for On-Orbit Verification Mission; Proceedings of the 13th European Conference on Spacecraft Structures, Materials & Environmental Testing; ESA SP-727; 2014

Project: Flexible CIGSe thin film solar cells for aerospace – PIPV 2

We would like to express our thanks to all partners of the project consortium, in particular the colleagues at ZSW Stuttgart for their close and constructive cooperation.

1 *Plasma in the coating chamber*

2 *Structure of the CIGSe crystallites, SEM topography, no plasma activation (© ZSW)*

3 *Structure of the CIGSe crystallites, SEM topography, plasma activation with 100 A discharge current (© ZSW)*

4 *Aerospace application: unrolled solar generator (© HTS)[2]*

Bundesministerium
für Wirtschaft
und Technologie

DLR

ZSW

Federal Ministry of Economics and Technology and Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR)
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FORSCHUNGSALLIANZ KULTURERBE – ASSOCIATION WITH NEW DRESDEN PARTNERS

On 2 July 2014 the Forschungsallianz Kulturerbe ceremonially associated itself with the Staatliche Kunstsammlungen Dresden and Sächsische Landesbibliothek – Staats- und Universitätsbibliothek Dresden with the objective of bundling and supplementing competencies as well as realizing synergy effects.

More than 130 experts from Germany, Austria, Belgium and Switzerland met in the palace chapel of the Dresden residential palace on 2 July 2014 for a symposium "Hazardous Substances in Museums". The technical conference organized by Fraunhofer FEP was a joint event of Forschungsallianz Kulturerbe founded in 2008, Staatliche Kunstsammlungen Dresden (SKD) and Sächsische Landesbibliothek – Staats- und Universitätsbibliothek Dresden (SLUB). In the course of the symposium, existing cooperation of Forschungsallianz Kulturerbe with SKD and SLUB was made official. In doing so, Forschungsallianz Kulturerbe followed the suggestion made back in the summer of 2012 by the Saxony State Minister for Science and Art, Ms. Professor Sabine von Schorlemer.

Signing the Memorandum of Understanding in the presence of the State Minister marked the event's ceremonial conclusion. The Fraunhofer-Gesellschaft was represented by its President Mr. Professor Dr. Reimund Neugebauer, who thereby officially assumed the patronage for Forschungsallianz Kulturerbe. The Leibniz-Gemeinschaft (Leibniz Association) was represented by its speaker Mr. Professor Dr. Stefan Brüggerhoff and the Stiftung Preußischer Kulturbesitz (Prussian Cultural Heritage Foundation) by its Vice President Mr. Professor Dr. Günther Schauerte. Director General Mr. Professor Dr. Hartwig Fischer signed for SKD and Mr. Dr. Michael Vogel, Saxony State Representative for the Preservation of Archives and Libraries, signed for SLUB. The technical conference was made possible through financial support from the Deutsche Bundesstiftung Umwelt (DBU) (German Federal Environmental Foundation). Ms Dr. Johanna Leissner (Fraunhofer Brussels, Speaker of Forschungsallianz Kulturerbe) and Mr. Dr. Paul Bellendorf (DBU) welcome the symposium participants and opened the event. "Forschungsallianz Kulturerbe was happy to follow the suggestion of the State Minister!" said Johanna Leissner. She herself had successfully worked with SKD in a project of Fraunhofer ISC Würzburg to measure hazardous substances in the Grünes Gewölbe (Green Vault). Now she expects broader interdisciplinary cultural research with synergy effects through the association. Paul Bellendorf emphasized that "Hazardous Substances in Museums" is a highly relevant topic that will gain even more importance in the future. Projects in this field have been subsidized by the DBU for more than 20 years already and the foundation wants to expand, support and actively attend to this subject area in the coming years. Mr. Professor Dr. Hartwig Fischer also stressed the importance of "preservation" for museum institutions. This requires knowledge of possible sources of damage and the related hazards that museum objects and employees may be exposed to. "The exchange of experiences between the humanities and natural sciences is essential here and this association is an important step, also in regards to making the public aware of this topic." Mr. Dr. Michael Vogel expects future cooperation with Forschungsallianz Kulturerbe

to result in innovative processes for the cost-effective and lasting restoration of fragile assets in archives and libraries. Mr. Professor Dr. Reimund Neugebauer recognized the broad range of technology know-how among the participating Fraunhofer institutes and stated his willingness to support demand-based developments for SKD and SLUB with Fraunhofer means. Mr. Professor Dr. Stefan Brüggerhoff and Mr. Professor Dr. Günther Schauerte used several examples to illustrate how effective cooperation with partners of Forschungsallianz Kulturerbe has been in the past. They stated their high expectations for the association. Ms. Professor Sabine von Schorlemer reminded those in attendance that our monuments and cultural assets constitute humanity's memory and knowledge repository, making it our obligation to preserve them for posterity. She herself made a very important contribution in this regard by seeking dialog with representatives of the EU Commission and EU Parliament in Brussels. She explained the important role of cultural research for innovation and growth in Europe. In the course of well-grounded discussions, she managed to have cultural research accepted into the EU research and innovation program Horizon 2020, thereby effectively securing an economic basis for Forschungsallianz Kulturerbe.

The technical element of the symposium was met with widespread agreement. All presentations as well as information on the exhibits, which were presented as part of a small exhibition, are compiled in a companion booklet and will be available for download in PDF format at *www.forschungsallianz-kulturerbe.de*.

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RESET – THE FIRST STEP HAS BEEN TAKEN

Far-reaching decisions of great significance led to a project description on 30 June 2008 to found a centre with the name "Fraunhofer Research Center for RESsource-conserving Energy Technologies (RESET)" in Saxony. Now this research center is going up on the plot of land at Bodenbacher Straße 38.

The center is being developed under the auspices of the three institutes FEP, IKTS and IWS represented at the site of Fraunhofer-Institutszentrum Dresden (IZD). Formerly dedicated to urban use and now transferred to the Fraunhofer-Gesellschaft, the lot at Bodenbacher Straße 38 is 1.7 ha in size.
A project-specific development plan was prepared as a first important step to establish a suitable general framework. Among other things, a fact emerged during this process that proved defining for the future. The grade of the lot in its original form combined with the requirements of the city planning office only permitted a building structure that is not compatible with research facilities housing the test equipment typical for FEP. The usable room height would simply have been too low. "Going down" was the only solution. Therefore the site had to be excavated by approximately two meters so the eaves height of the future buildings according to the development plan corresponds to those of the neighbors' adjacent buildings. Approved in 2010, this plan now serves as a guideline for development and the construction of the entire campus. It is intended to ensure that structures and building services that meet the requirements of research logistics are created.

The green light for construction work on the site was given in the year 2010 with the conversion of a former vehicle hall into a technical center. Leaving the shell of the existing building while nevertheless making it usable as a research facility was the objective. Therefore the building was gradually expanded downwards by 2 meters. Pillar by pillar, always a new, complicated foundation – a masterful engineering feat!

The 500 m² laboratory hall is the main element of this building. A partly accessible media duct recessed in the floor runs down the middle. It supplies all test equipment with coolant water, vacuum, electricity etc. from below, so there is no risk of collisions. The clean room that divides the space is another special feature of the laboratory hall (purity ISO 5). This further improves the building's functionality for scientists. The research equipment can now be "docked" directly on the clean room to use it for many different purposes (as a lock, for preparation, evaluation etc.).

In parallel to the reconstruction of the first building, a new structure is being erected on the campus for the three institutes (financed with the help the European Regional Development Fund (ERDF) as well as funding from the federal government and the state of Saxony). The FEP building (~850 m² usable space) is the southernmost in a group of three similar architecture modules – technology center buildings with a semibasement.
In keeping with the research center's name RESET, ecology and sustainability were accorded a high priority in regards to the technical equipment of the new FEP building, e.g. with the installation of a 1,200 m² geothermal heat exchanger under

the building's entire floor plate. Installing a cooling unit was not necessary as a result. This surface heat exchanger draws "cold" from the ground and thereby provides the cooling medium for the air conditioning units in the FEP building (in summer). In the winter "ground heat" is used to preheat the exterior air. The main air conditioning system in the FEP building is another innovative detail. Next to EC fans, an exhaust air scrubber with a high-efficiency heat exchanger is installed here as well. This scrubber cools the exhaust air in summer (adiabatic) and the heat exchanger transfers the recaptured "cooling" energy to the supply air. Process heat generated during the research process (in the coolant water) is also used in the air conditioning system to preheat the exterior air (in winter). Another noteworthy factor is that all lighting in the FEP technical center was realized on a LED basis (including dimming).

A second step to expand the campus will follow. Here one of the sub-projects is to add a laboratory and office level on top of the semibasement. Initial planning for this has already commenced. However, erecting the heart of the campus with the central FEP building sized at ~4,000 m² (foundation and technical center halls) is being left to the end – quasi as the "Vision 2020".

A big thank you to the state capital of Dresden with all its offices for their constructive support as well as the excellent team of architects (msp Architekten, Landschaftsarchitektur Petzold) and specialist engineers (ISP Scholz, Ingenieurbüro Scheibner, DERU Planungsgesellschaft, Zibell Willner & Partner). It was truly enjoyable teamwork which served the common good.

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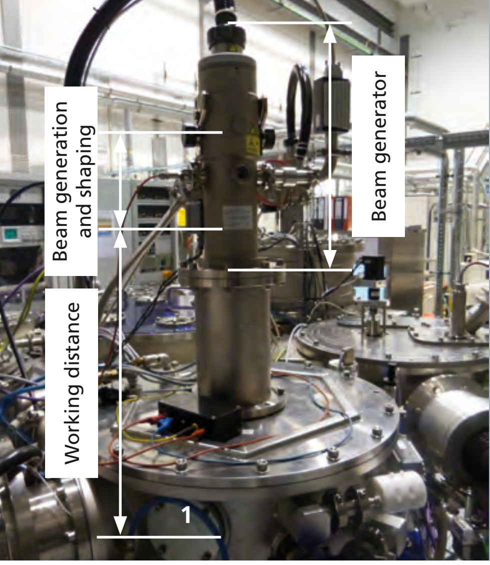

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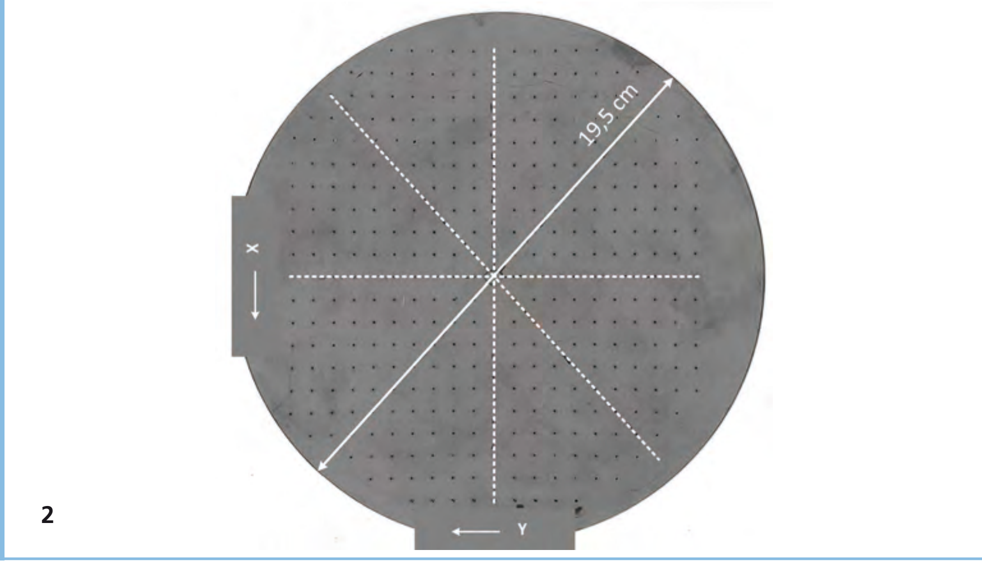

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FAST AND PRECISE ELECTRON BEAM MICROMACHINING

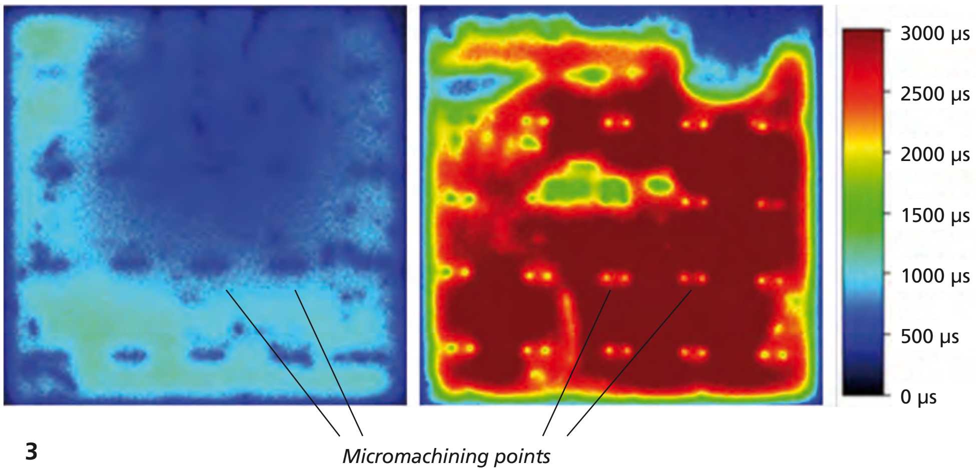
In the course of a collaborative project between FOCUS electronics GmbH and Fraunhofer FEP, the fundamentals of optimized electron beam machining for large-scale micro-structuring applications and surface treatment were developed.

Micromachining – defined as precision cutting, removing, joining and modifying of structure sizes in the micrometer range – plays an important role in industrial fabrication. Here, the laser is an established tool: It is used for example for structuring and contacting of solar cells, and for welding stents in a micrometer range for medical technology. On the other hand, the "electron beam" is a tool which is not as well-known to date although it has been used for many years for special applications such as lithography and microwelding of sensors. The main applications of the electron beam, however, included the macroscopic welding, melting and vaporization of metals as well as material analysis. Due to its special physical characteristics, the electron beam is also very well suited for micromachining of large surfaces, and opens up novel application possibilities in this field. Compared to laser, it offers advantages for structuring of optically transparent as well as thick layers. Inertia-free beam deflection using electromagnetic fields makes very high process speeds possible.

In the "EMICPRO" project, FOCUS electronics GmbH and Fraunhofer FEP are conducting fundamental research in order to further develop the potential of the electron beam for micromachining in microsystems technology and for surface and thin film technology. From a process technology perspective, major challenges are generally associated with these applications: producing small structures on substrates that are as large as possible, precisely and quickly with good productivity, without unnecessarily influencing the surrounding substrate areas.

A key requirement for the production of microstructures is the ability to bundle beam energy on a correspondingly small point. Especially with compact beam sources and large distances between the beam source and substrate, this imposes stricter requirements for the focus diameter (Figure 1). The conditions for generating the beam in the cathode system play an essential role here. Through structural changes and the use of new cathode materials, beam diameters of approximately 100 µm with a working distance of about 50 cm have been realized. These diameters were measured at acceleration voltages of 50 kV and beam currents of up to 10 mA.

To meet the high productivity requirements, a new and highly dynamic beam deflection system was designed which, thanks to its low inductance, makes very high deflection frequencies (up to 92 kHz large signal triangle function) possible at deflection angles of up to ± 10°. Its special design ensures that the programmed deflection patterns are transferred without distortion. With a reduction of the deflection speed, the deflection range can be expanded to as much as ± 20°. When the electron beam is focused on the center of the specimen, the power density is reduced at the edges of the processing



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area with these large angles, because, despite of the large depth of focus, the focal plane lies above the surface. With the implementation of an additional, dynamic electromagnetic lens, tracking of the focal position according to the current deflection angle has been successfully accomplished, thereby realizing consistent results in the entire processing window (Figure 2).

Another important aspect of micro-structuring with the electron beam is preventing damage to adjacent areas, for example electronic assembly parts in microelectronics. The electron beam usually operates continuously. In this mode, it jumps from one to the next working position very quickly so that it moves over the intervening areas of the substrate at a very high speed of several kilometers per second, making the beam exposure time extremely short. A new pulse technology that successfully turns the beam current on and then off again for a microsecond or more, with rise times of approximately 200 ns has also been realized. In this mode, the stream of electrons only flows to the substrate when the working position is reached. This allows surface damage to be avoided, especially on highly sensitive substrates, which was confirmed in the course of the project "EMICPRO" (Figure 3).

Project partners:
FOCUS electronics GmbH, Leipzig
Fraunhofer FEP, Dresden

1 *Experimental beam source in trial operation with extended working distance*

2 *Square point grid in sheet steel, 50 kV, 3 mA, working distance 50 cm*

3 *Charge carrier life time measurement on highly passivated solar silicon with 40 micromachining points arranged in pairs (Left: continuous beam, right: pulsed beam current); our warmest thanks to Roth & Rau AG for taking the measurements*

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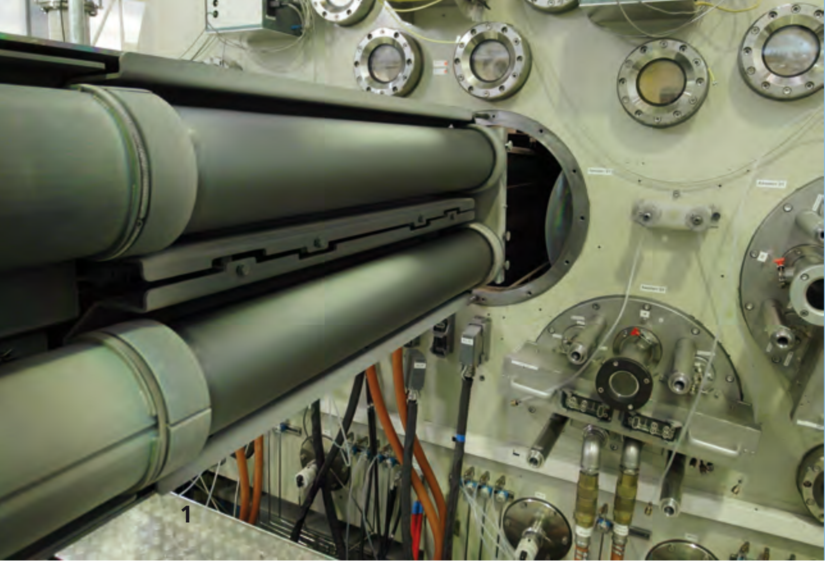

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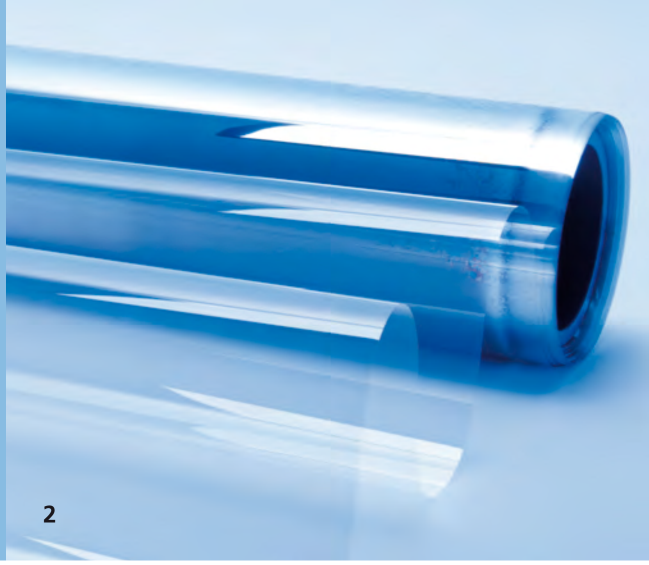


2

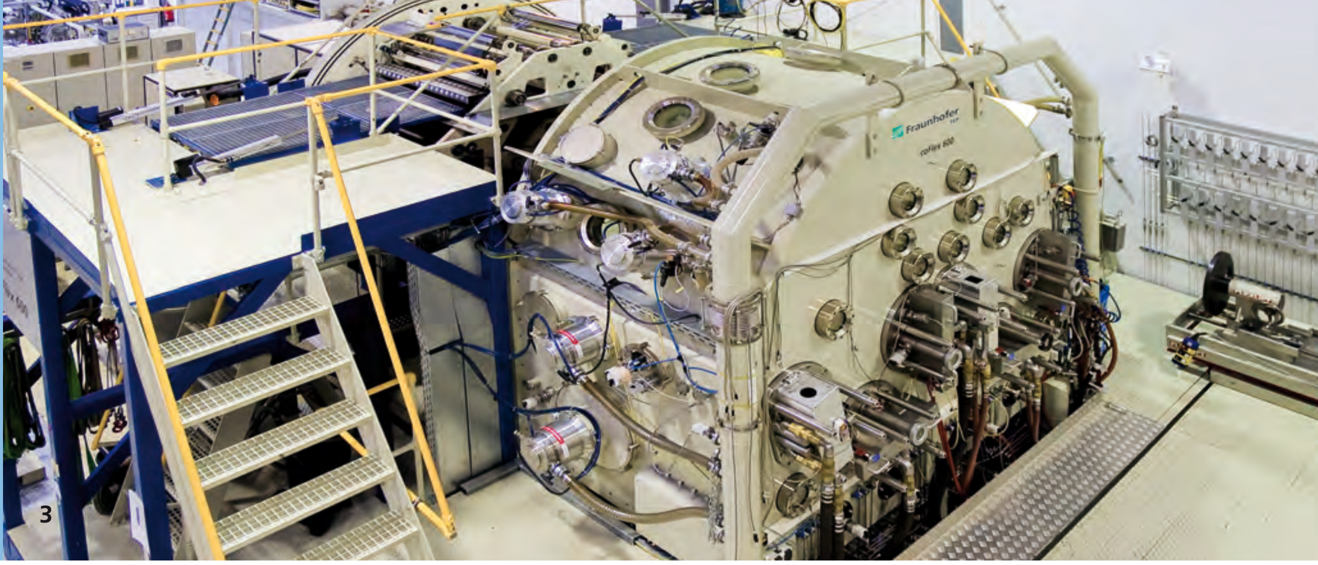
ROLL-TO-ROLL COATING WITH ROTATABLE MAGNETRONS

In the course of the OPTIPERM-V project, Fraunhofer FEP introduced new rotatable magnetron processes funded by the SMWK in cooperation with the project partner VON ARDENNE. It allows the precipitation of oxynitride layers in various compositions. With the help of this new technology, polymer films have been successfully enhanced to produce extremely low water vapor permeation values.

In 2013 a major modernization was realized on the *coFlex® 600* roll-to-roll sputtering system, which is 15 years old in the meantime. Three modules for sputtering with rotatable magnetrons were implemented with the support of the company VON ARDENNE. This technology has become more and more popular in recent years. It makes coating processes less expensive, supports longer production cycles and, in particular, makes it possible to precipitate coatings of high quality with a low rate of defects. The latter feature was also the trigger for the first joint research project between Fraunhofer FEP and VON ARDENNE on the new technology platform. It is well known that a low rate of defects is a crucial feature for the quality of water vapor barrier layers on polymer films. This is important for various trendsetting products in organic electronics. Flexible solar cells need these layers, as does polymer-based surface lighting. This makes the deposition of such layers, in particular using a rotatable magnetron particularly attractive.

The undertaking was subsidized by the Saxony State Ministry for Science and Art (SMWK) as part of the OPTIPERM-V project. Here, the focus was on the material aluminum oxynitride (AlO_XN_Y). A suitable coating technology first had to be developed. The new modules were connected to the i-PULSE® series sputter power supplies. These devices are a part of the in-house development from Fraunhofer FEP and have been used for reactive sputtering processes for years. Precisely controlling the process gas supply is crucial for optimizing deposition as well. All of this previous knowledge was supplied by Fraunhofer FEP. It the OPTIPERM-V project, it was shown that the stoichiometry of the AlO_XN_Y layers, in particular the ratio of oxygen and nitrogen, can be adjusted in very wide ranges through precise process control. Using the rotatable magnetron also permits long-term stable behavior without a major process drift. Ultimately, it was even possible to prove that a significant increase in the deposition rate is possible, since the heat load on the substrate is lower thanks to the new modules compared to the coating equipment used in the past.

The project partners put this technology expertise in use by investigating a wide variety of layer compositions and testing the suitability of the layers in regard to their use as permeation barriers. In the end, a composition has shown an outstanding embodiment of the desired characteristics. After applying a layer with a thickness of just 50 nanometers using the optimized composition, water vapor permeation was successfully reduced to a value of 0.005 g m^{-2} d^{-1}. This corresponds to a reduction of three orders of magnitude compared to the uncoated original substrate. These layers also exhibited an outstanding optical quality, which is of high importance for applications in opto-electronics in particular.



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This successful beginning will be further developed in a subsequent project. Here, the focus will be on transferring the results obtained so far to larger deposition dimensions, enabling the equipment manufacturer VON ARDENNE to produce tailor-made machines for potential customers all over the world.

However, this intensive cooperation with VON ARDENNE should not diminish the fact that the new technology platform on the *coFlex® 600* is available to other project partners as well. The previously mentioned outstanding optical properties and the great variety of possible layer materials represent fascinating options for many different potential new developments.

1 *Rotatable magnetron*
2 *Coated roll of polymer film*
3 *coFlex® 600 – roll-to-roll pilot sputter roll coater*

Freistaat Sachsen
Staatsministerium für Wissenschaft und Kunst

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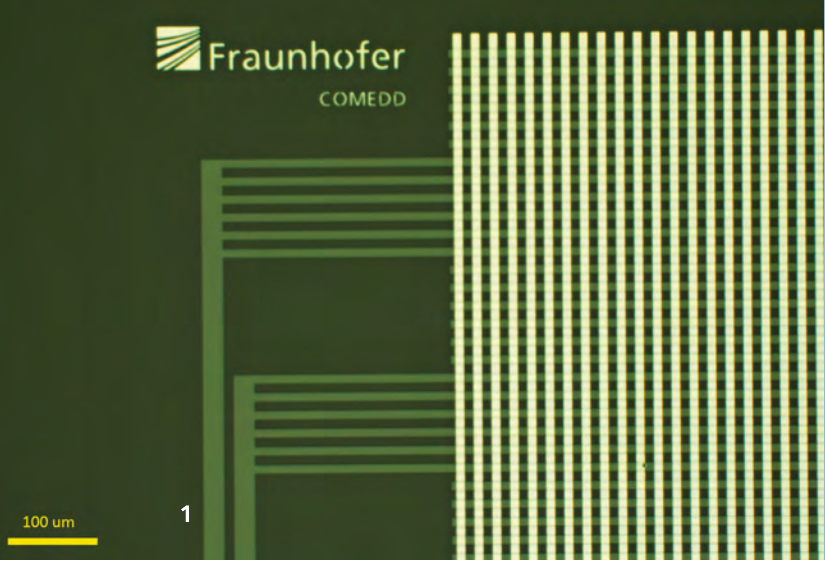
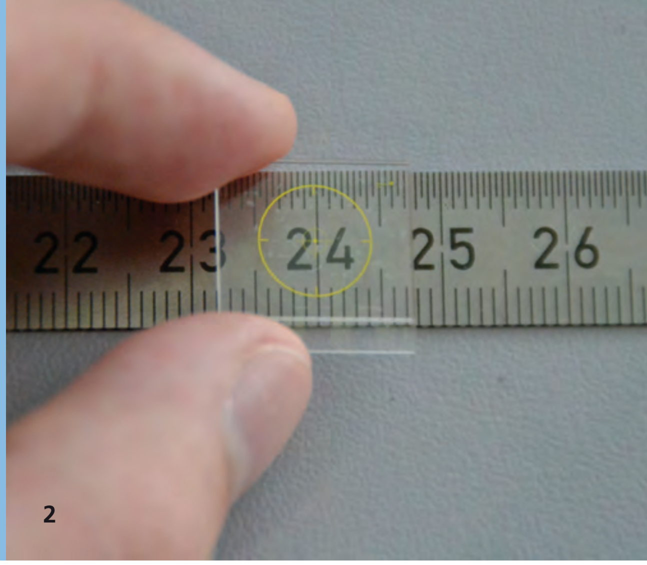




ATTRACT PROJECT: "OLED MICRODISPLAY FABRICATION BY ORTHOGONAL PHOTO-LITHOGRAPHY (OLITH)"

"Fraunhofer Attract" is an internal program that enables brilliant external scientists to conduct application-oriented research at a Fraunhofer institute for the strategic development of new competencies. With OLITH, extremely minute structures have been efficiently produced for high-resolution OLED microdisplays.

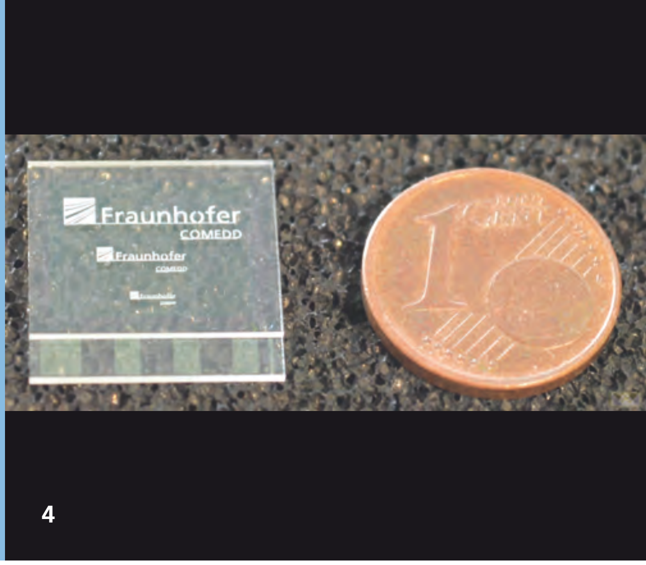
Currently, only shadow masks are being used for the structuring of organic semiconductor materials for industrially produced OLED displays. This makes it possible to pattern certain areas of the substrate for evaporation processes in vacuum systems. Structures up to ≥ 50 µm can be realized. While this is sufficient for today's displays used for example in cell phones (< 500 ppi), it is not adequate for microdisplays where pixel sizes below 10 µm have to be realized so that they can be integrated into optically enlarging near-to-eye systems. Color filters are currently being used in the production of such small pixel sizes. They spectrally separate the white light of an OLED into its R, G, B components as shown in figure 5. This leads to inadequate display characteristics in regards to brightness and contrast, since about 2/3 of the light generated is lost through absorption and because the use of white light implicitly limits the color space. The illustration also shows that direct structuring of monochrome OLEDs overcomes these problems and that improved display characteristics can be achieved.

OLITH pursues a new approach for direct OLED structuring in the form of orthogonal photolithography. The hydrophobic and lipophobic properties of special fluorinated solvents and photoresists, that mix neither with water nor with organic solvents, are used here (figure 6).

In contrast to using conventional photochemicals, this guarantees that the OLED materials are chemically unaltered and functional after the patterning process. As with standard photolithography, the photoresists are cross-linked with UV light and used as a patterning mask in etching or lift-off processes. Structure sizes below 1 µm can be realized.

During the project duration various OLED material systems were evaluated in regards to compatibility with orthogonal photolithography and the technology was integrated into the existing production line at Fraunhofer FEP. The structuring of OLED stacks in different colors was realized by means of orthogonal photolithography and a concept for full-color displays without color filter was developed.

Figure 7 shows the OLED layer sequences that were developed. They combine polymers (red and green emitters) that can be applied under exposure to air and structured by means of orthogonal photolithography as well as vacuum-processed materials (blue emitters) that can only be coarsely structured using shadow masks.



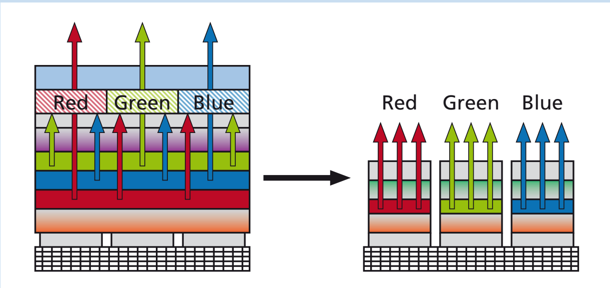
1 *OLED display (10 µm resolution) produced with OLITH*

2 *OLED test structure produced with OLITH*

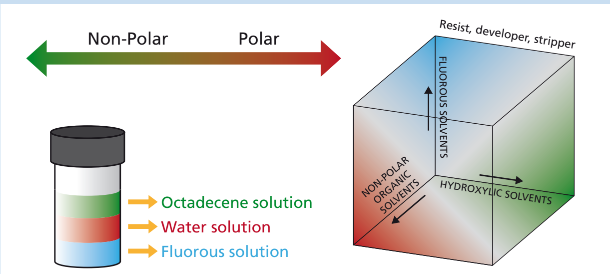
3 *Clean room with OLED microdisplay production line*

4 *OLED logos produced with OLITH*

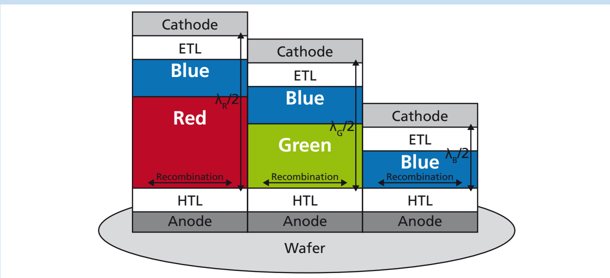
5 *Left: Conventional approach showing white OLED consisting of red, green and blue emitting layers & color separation by color filters. Right: Separately structured R, G, B pixels*



6 *Phase separation between organic, aqueous and fluorinated solvents*



7 *OLED layer sequence for the realization of micro-structured RGB pixels in microdisplays*



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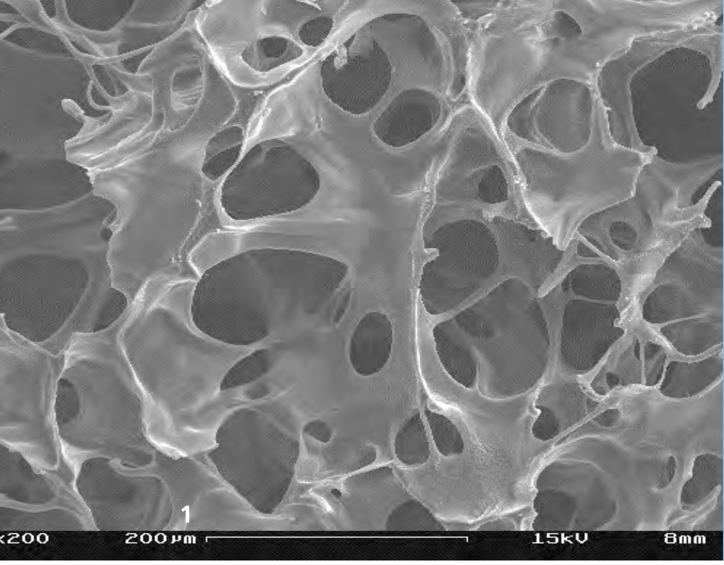
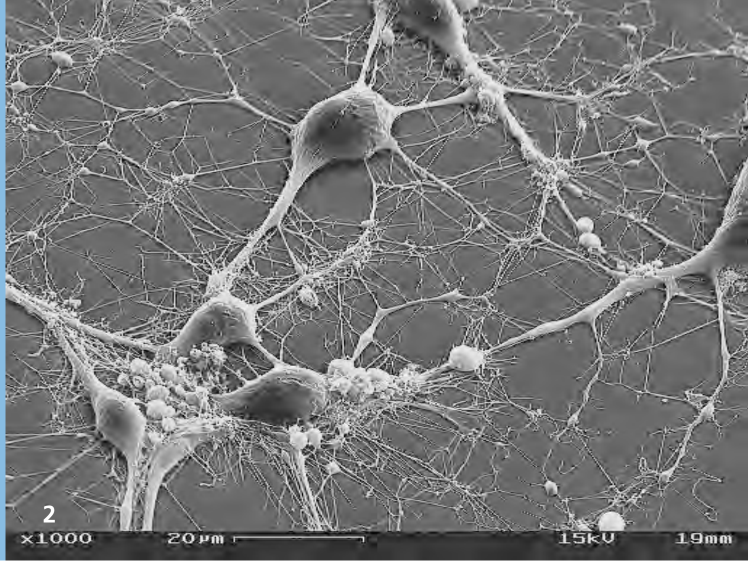




CRITICAL POINT DRYING – A PREPARATION METHOD WITH GREAT POTENTIAL

A wide range of investigation methods for product and technology developments as well as services is available in the biomedical laboratory unit. In order to perfect the technical know-how for the visualization of the biological analysis spectrum, a preparation methodology has been established which not only has great potential but is truly enjoyable as well.

For the staff of the Medical Applications workgroup, evaluating scanning electron microscope images of biological preparations has always been a problem, because SEM microscopy takes place in a vacuum and evaporation, shrinkage and crack formation can occur during preparation. However, in order to ensure high-quality imaging, it is important to fix the biological structures at the time of sample collection and to suppress all functional processes in a sample.

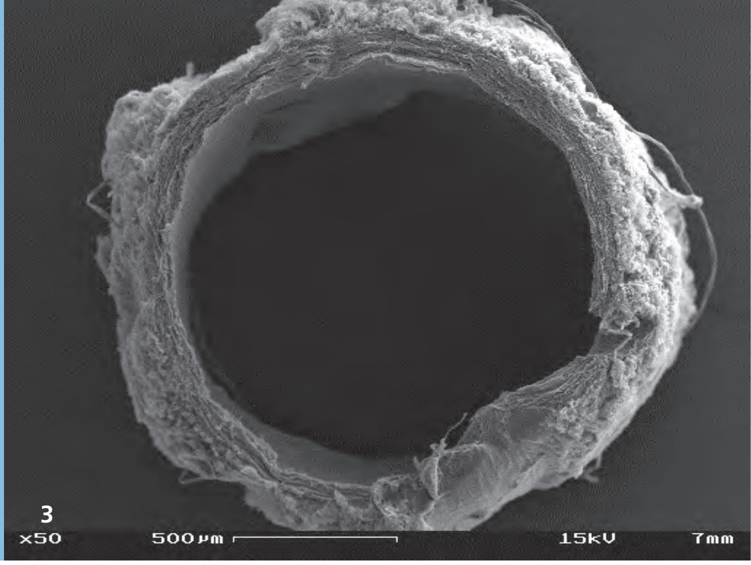
The company LEICA Microsystems GmbH took on this challenge and developed a device (LEICA EM CDP300) that not only refines the preparation method, but also revolutionizes the imaging accuracy.

The benefit is that the water contained in biological samples is initially exchanged for ethanol before this is replaced by supercritical carbon dioxide. Since the CO_2 starting at a critical temperature of 304.2 K and a critical pressure of 72.9 atm behaves simultaneously like a liquid and a gas, no phase limit is crossed and the biological samples retain their natural form.

In the establishment of critical point drying (CPD), the experimental focus was on optimizing the exchange processes with the variation of exchange fluids and the number of exchange cycles as well as their speed. Another focal point was in the area of sample preparation. Fixing and dehydration in particular had to be adjusted to meet specific requirements. Figure 4 and 5 illustrate how well this can be accomplished.

The great potential of CPD benefits the established technologies of Fraunhofer FEP in the field of surface treatment/coating as well as sterilization and biofunctionalization by means of electron beam treatment. In concrete terms, the imaging of antimicrobial effects of embedded silver/copper particles and their controlled permeation, cell healing effects due to the light of favorable radiation, the influence of TCO layers (e.g. indium-tin-oxide (In_2O_3:Sn, ITO) and aluminum doped zinc oxide (ZnO:Al, AZO)) on in-vitro cell cultures as well as the biofunctionality of switchable surfaces is possible among other things. Furthermore, CPD is suitable for non-biological but vacuum-sensitive products and substrates, e.g. plastic, textiles, leather and paper, and for hydrogels and cryogels.

Critical point drying is a process that requires little effort, with fast and reproducible results – a preparation method with great potential that is also enjoyable and fun to implement.

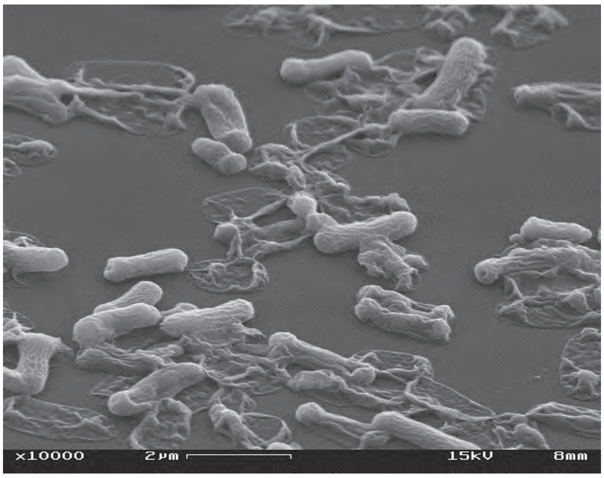


1 *Cryogel (SEM image 200x)*

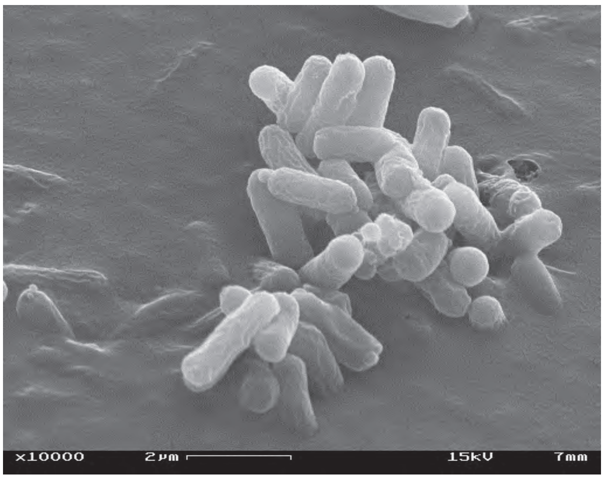
2 *Damaged fibroblasts for studies of the cell damage healing effect (SEM image 1000x)*

3 *Sterilization model: rat aorta (SEM image 50x)*

4 *E.coli with conventional preparation technique (SEM image 10,000x)*



5 *E.coli with CPD preparation technique (SEM image 10,000x)*



CONTACT

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HIGHLIGHTS

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FRAUNHOFER FEP EXTENDS ITS PORTFOLIO

Thanks to the integration of Fraunhofer COMEDD we are able to develop together with our customers processes, process components and corresponding applications in organic electronics.

Since 1st July 2014, Fraunhofer FEP and Fraunhofer COMEDD have been operating under one roof as the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP. The new name underscores the fact that the competencies of both institutions have converged and highlights the importance of organic electronics in the region.

Professor Volker Kirchhoff, director of the institute, is pleased about the new possibilities: "Compared to the previous FEP focus on technologies and processes, COMEDD is also aimed at components and applications. In the field of barrier films for flexible organic components for example, I expect significant progress thanks to the experience of COMEDD. However, the OLED microdisplays can also benefit from the many years of work in the field of process technology and the market relationships of Fraunhofer FEP."

The current core competencies of Fraunhofer FEP include electron beam applications, sputtering, plasma-activated high-rate vapor deposition, high-rate PECVD and technologies for organic electronics as well as IC and system design.

The entire value chain from the technology to the product is represented by these competencies. Products in the electronics, sensor technology, optics, transportation, biomedicine, smart building, environment and energy sectors in particular are addressed. However, the main focus is on new solutions for flexible electronics intended to open up entirely new possibilities: individual lighting concepts, roll-up or folding mobile phones, intelligent building management and eye-controlled communication and data transmission.

The integration will take place within three years. The cooperation is now organized through concrete projects, which initially focus on new structuring technologies for OLEDs (organic light-emitting diodes) and the encapsulation of organic components. Developing new processes, especially in these fields, will give our customers a significant head start in the field of organic electronics.

On the topic of encapsulation, both groups are currently researching the benefits of flexible glass. The material combines the properties of glass and plastic and could be ideal as a permeation barrier. However, some processing challenges still have to be overcome along the way. The stability of the material is yet to be studied in greater detail as well.

Beyond that, the scientists are investigating the effects of OLED light on living cells. Fraunhofer FEP has the perfect infrastructure for this development: the "Medical Applications" department for example has been researching the biocompatibility of surfaces with living cells for a long time and the

"Flexible Organic Electronics" department is successful in the development of flexible OLEDs. Together they can incorporate the positive effect of OLED light on people, which is perceived as pleasant, into novel lighting concepts.
Sterilization via electron beam on OLED-on-silicon sensors developed at Fraunhofer FEP is also conceivable for use in biomedical applications. The scientists are convinced that they will be able to continue offering novel developments to customers and partners through the combined competencies going forward.

Dr. Uwe Vogel, deputy director of the institute and division director "Microdisplays and Sensors" emphasizes: "The merger of COMEDD and FEP is a groundbreaking step for future Fraunhofer developments and activities in Dresden on the one hand and for organic electronics at the site in Saxony on the other hand. New approaches and research focal points – for example for flexible electronics – can be addressed more effectively as a result. Preceding long-term joint projects between FEP and COMEDD – for example in the development of roll-to-roll technology for flexible organic lighting – resulted in significant successes. This already constitutes a good basis for future cooperation. The employees know each other and networks already exist. We at COMEDD highly value the open and professional manner of FEP employees in the course of this integration."

Customers and partners can continue to work with their existing contacts in all technical fields. In addition, they will benefit from a more complete and expanded selection of services.

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ICCG10 – THE INTERNATIONAL CONFERENCE ON COATINGS ON GLASS AND PLASTICS

Experts for glass, display and high-tech coatings gathered in Dresden during June of 2014. More than 400 international participants discussed the industry trends.

Among the numerous events held with Fraunhofer FEP in 2014, ICCG10 is last year's highlight. Fraunhofer FEP had the honor of organizing and shaping this rotating international conference jointly with the international program committee of the ICCG. The conference with subsequent industrial exhibition was held from 22 to 26 June 2014 at the MESSE DRESDEN exhibition site.

This technology and user-oriented conference brought experts from science and industry to Dresden, who are actively engaged in the field of large-area coating on glass and plastics. Innovative functional and surface coatings, the selection of materials for them and application-oriented layer properties were the focal points of the conference.

To start off the 10th ICCG conference, renowned international scientists and representatives of industrial companies analyzed market developments for functional surface coatings and revealed new technology trends for product development.

The organizers succeeded in bringing more than 400 participants from over 26 countries to Dresden. During the week of the conference, the latest developments as well as technologies for plasma and surface coating in a vacuum or under atmospheric pressure were presented and discussed by international experts. Numerous representatives of users were among the participants as well.

The focal points for this conference were chosen as follows by the program committee: electrochromic coatings, switchable mirrors, ALD, large-area PECVD, flash lamp annealing, flexible glass and barrier technologies. Special emphasis was also placed on products such as CIGS and OLED, functional textiles, energy-efficient buildings and flexible electronics.

The conference was accompanied by a top-class industrial exhibition with 34 companies and Fraunhofer FEP actively presenting their expertise. The institute which itself was represented with nine conference segments was therefore able to illustrate the technologies that were presented with exhibits directly on site.

ICCG10 was an excellent presentation venue for Fraunhofer FEP. In addition to establishing contacts with scientific partners, relationships with existing customers were further strengthened and concrete projects were begun.


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Overview of presentations given by the institute:

Short Courses:

- Pre-treatment, handling and cleaning of thin and flexible substrates
  Dr. Stefan Mogck, Fraunhofer COMEDD

Session 1-8:

- Reactive Sputtering in Roll-to-Roll Coating Machines using Rotatable Magnetrons
  Dr. Matthias Fahland, Fraunhofer FEP
- Low Pressure Plasma Treatment For Curing Hybrid Layer Systems
  Dr. Daniel Glöß, Fraunhofer FEP
- Glass meets flexibility – Challenges in manufacturing of thin films on flexible glass
  Dr. Manuela Junghähnel, Fraunhofer FEP
- Co-sputtering of rugate filters of reduced loss and roughness
  Kerstin Täschner, Fraunhofer FEP
- Roll-to-Roll OLED fabrication on transparent barrier film
  Dr. Stefan Mogck, Fraunhofer COMEDD

Poster Session (recognized with the Best Poster Award):

- Improvement of the electrical and optical properties of ITO thin films on ultra-thin glass by flash lamp annealing
  Stephanie Weller, Fraunhofer FEP

Additional contributions:

Panel Discussion:
Dr. Nicolas Schiller, Fraunhofer FEP
Dr. Christian May, Fraunhofer COMEDD
Co-authors Session S3-04:
Stephan Barth, Fraunhofer FEP
Dr. Daniel Glöß, Fraunhofer FEP
Dr. John Fahlteich, Fraunhofer FEP
Dr. Peter Frach, Fraunhofer FEP

WEBSITE

www.iccg10.de

1 *Presentation of the Best Poster Award to Stephanie Weller by Dr. Johannes Strümpfel, Local Vice Chairman*

2 *Lounge at the industrial exhibition*

3 *Presentations in Saal Hamburg*

4 *Accompanying industrial exhibition*

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PHOTONICS ACADEMY 2014

The Photonics Academy 2014 was held at Fraunhofer COMEDD from 23rd to 28th March 2014 under the motto "We seek the best for the new dimension of light – organic LEDs".

The Photonics Academy – an initiative of the Federal Ministry for Education and Research, the Fraunhofer-Gesellschaft and the industry associations Spectaris, VDMA and ZVEI – is intended to offer career prospects for young people in the world of light. Students had the opportunity to immerse themselves in the world of photonics for one week. This practical week-long event will be held annually at rotating Fraunhofer institutes with a different focus every year.

Excursions to companies, meetings with company managers, practical experiments, soft skills workshops, presentations by accredited experts and a varied supporting program awaited the participants. They had the opportunity to network with like-minded individuals and photonics experts from science and industry.

The third event of this kind was hosted by Fraunhofer COMEDD (part of Fraunhofer FEP since July 1st, 2014) in Dresden. In 2014 it was dedicated to organic electronics, especially organic light-emitting diodes (OLEDs). At the end of March 30 students from all over Germany gathered in Dresden under the motto "The new dimension of light: organic LEDs". Excursions took them among other things to the company Novaled, a 2001 spin-off from the institute which is now one of the world's leading companies in the field of OLED technology with a specialization in OLED materials. On the practice day, the participants were even able to build organic light-emitting diodes themselves at Fraunhofer COMEDD. They gained important insights into the corresponding characterization of the resulting components. The technology of OLED microdisplays was examined as well and the participants had the chance to try out various smart glasses in which these displays are used.

Many participants were still searching for the appropriate major. A lot of them were enthusiastic about organic electronics after they were familiarized with the possibilities of organic semiconductors for light, augmented reality with microdisplays and flexible electronics. During the various company visits (Heliatek, Infineon, OSRAM OS, Novaled, VON ARDENNE, 3D-Micromac) they also gained fascinating insights into the industry. They had the unique opportunity to ask questions about launching a career in the organics sector to company managers and HR staff in a relaxed atmosphere during a "Meet the Experts" evening.

A varied supporting program including a scenic tour through Dresden and a sports evening was also part of the practical week-long event, which ended with the presentation of certificates to the participants by representatives from politics, science and industry at the LED and OLED manufacturer OSRAM OS in Regensburg.

3

1 *Photonics Academy 2014 at Fraunhofer COMEDD*

2 *Participants during practical investigations under the instruction of scientists*

3 *Certificates were awarded to the participants by Dr. Frank Schlie-Roosen (BMBF), Dr. Ulrich Steegmüller (OSRAM), Ines Schedwill (Fraunhofer COMEDD)*

WEBSITE

www.photonik-campus.de/studium/photonik-akademie

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ANHANG

ANHANG

NAMEN, DATEN UND EREIGNISSE
NAMES, DATES AND EVENTS

MITGLIEDSCHAFT IN GREMIEN

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

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

J. Fahlteich
- Fraunhofer-Allianz Polymere Oberflächen POLO
- Technical Advisory Committee der Web Coating Session der Society of Vacuum Coaters (SVC)

P. Frach
- Fraunhofer-Allianz Photokatalyse
- AMA Fachverband für Sensorik e. V.
- Deutsche Gesellschaft für Galvano- und Oberflächentechnik e. V. (DGO)
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS)
  Fachausschuss »Oberflächen und Beschichtungen in der Bio- und Medizintechnik«
- Photonic Net
- Bundesverband mittelständische Wirtschaft (BVMW)
- Silicon Saxony e. V.
- Verband der Elektrotechnik – Bezirksverein Dresden e. V.

D. Glöß
- Dresdner Fraunhofer-Cluster Nanoanalytik

M. Hoffmann
- Dresdner Fraunhofer-Cluster Nanoanalytik

M. Junghähnel
- Technical Advisory Committee Emerging Technologies der Society of Vacuum Coaters (SVC)
- Program Committee Member (ICCG)
- Deutsche Glastechnische Gesellschaft/Deutsche keramische Gesellschaft DGG-DKG, Mitglied AK Glasig-kristalline Multifunktionswerkstoffe

F. Hoyer
- Fraunhofer Social Media Netzwerk

V. Kirchhoff

- Bundesverband mittelständische Wirtschaft (BVMW)
- Europäische Forschungsgesellschaft Dünne Schichten e. V. (EFDS)
- Fraunhofer-Verbund Light & Surfaces
- Organic Electronics Saxony e. V. (OES)
- DRESDEN-concept e. V.

H. Klostermann

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

G. Mattausch

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

C. May

- VDMA - Organic Electronics-Association

C. Metzner

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

W. Nedon

- Forschungsallianz Kulturerbe FALKE

F.-H. Rögner

- Fraunhofer-Allianz Reinigungstechnik
- International Irradiation Association

N. Schiller

- Advisory Board der AIMCAL Web Coating & Handling Conference Europe
- Fraunhofer-Allianz Batterien
- Organic Electronics Saxony e. V. (OES)
- Fraunhofer-Allianz Polymere Oberflächen POLO
- Energy Saxony e. V.

U. Vogel

- Fraunhofer-Verbund Mikroelektronik
- Silicon Saxony e. V.

C. Wetzel

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

J. Wieczoreck

- WCMS Fachbeirat

O. Zywitzki

- Dresdner Fraunhofer-Cluster Nanoanalytik (DFCNA)

ANHANG

PATENTE

DE 103 24 556
Erteilungsbeschluss
Katodenzerstäubungsverfahren
FEP 180
Dr. H. Bartzsch, Dr. P. Frach, C. Gottfried, K. Goedicke, S. Lange

DE 103 47 989 B4
Verfahren zum Stabilisieren des Verdampfens mittels Schiffchenverdampfer
FEP 185
Dr. T. Wünsche, K. Goedicke, S. Straach, Dr. F. Fietzke

TW I401336 B1
Beschichtungsverfahren und Vorrichtung mittels einer plasmagestützten chemischen Reaktion
FEP 248
Dr. M. Fahland, T. Vogt, Dr. S. Günther, Dr. J. Fahlteich, W. Schönberger, A. Schönberger

JP 5538361 B2
Transparentes Barriereschichtsystem
FEP 250
Dr. N. Schiller, Dr. W. Schönberger, Dr. J. Fahlteich, Dr. M. Fahland

DE 10 2009 019 422 B4
Verfahren zum Erzeugen eines Plasmas mittels eines Magnetrons
FEP 257
Dr. F. Fietzke, Dr. H. Klostermann, B.-G. Krätzschmar, R. Blüthner

US 8,878,422 B2
Device for producing an electron beam
FEP 281
Dr. G. Mattausch, Dr. P. Feinäugle, Prof. V. Kirchhoff, D. Weiske, H. Flaske, R. Zeibe

EP 2 633 543
Erteilungsbeschluss
Vorrichtung zum Erzeugen eines Elektronenstrahls
FEP 281
Dr. G. Mattausch, Dr. P. Feinäugle, Prof. V. Kirchhoff, D. Weiske, H. Flaske, R. Zeibe

DE 10 2013 111 650
Erteilungsbeschluss
Vorrichtung zum Erzeugen beschleunigter Elektronen
FEP 310
Dr. G. Mattausch, Dr. P. Feinäugle, Prof. V. Kirchhoff, F.-H. Rögner, J. Kubusch, S. Weiß, S. Schmidt, F. Ender, St. Kaufmann

US 8,766,286 B2
Organic opto-electric device and a method for manufacturing an organic opto-electric device
F49432 COMEDD
J. Amelung

VORTRÄGE

C. May
Flexible OLED Lighting – Status and Outlook
3rd China International OLEDs Summit
Shanghai, China
20. – 21. Januar 2014

C. May
New possibilities for automative lighting by flexible OLED
15th International Conference Intelligent Automotive Lighting
Frankfurt, Deutschland
27. – 29. Januar 2014

B. Beyer
Aktivitäten zur Standardisierung im FP7-Projekt GLADIATOR
Nationaler Informationstag der NKS NMBP
Düsseldorf, Deutschland
06. Februar 2014

U. Vogel, B. Richter, K. Fehse, P. Wartenberg, J. Baumgarten, A. Zakhidov
OLED-on-Silicon Microdisplays:
Technology for interactive Eyeglasses, and beyond
Electronic Displays Conference
Nürnberg, Deutschland
25. – 27. Februar 2014

H. Klostermann
Oberflächenfunktionalisierung mittels Elektronenstrahl- und Plasmatechnik
Forum „Metal meets Medical" der Messe METAV
Düsseldorf, Deutschland
11. – 15. März 2014

N. Schiller
Beschichtung und Oberflächenbehandlung von Kunststofffolien im Vakuum: Technologien und Anwendungen
Workshop "Oberflächenbeschichtungen: Aufbau und Funktion"
Materials Valley e. V.
Hanau, Deutschland
13. März 2014

H. Morgner, C. Metzner, O. Zywitzki
High-rate deposition of SiO_x-layers using hollow cathode arc discharge plasma sources
72nd IUVSTA Workshop "Plasma-assisted Vapour Deposition of Oxide Based Thin Films and Coatings"
Schloss Seggau, Österreich
06. – 12. April 2014

B. Scheffel, C. Metzner, T. Modes
Spotless arc activated high-rate depositionof titanium dioxide coatings onto metal strip
72nd IUVSTA Workshop "Plasma-assisted Vapour Deposition of Oxide Based Thin Films and Coatings"
Schloss Seggau, Österreich
06. – 12. April 2014

C. Metzner, H. Morgner, B. Scheffel, H. Klostermann, F. Fietzke
Decorative colored coatings on metal strips
VacuumTechExpo
Moskau, Russische Föderation
15. – 18. April 2014

E. Schwuchow, H. Morgner, O. Zywitzki, C. Metzner
Technology chain for CdTe thin-film solar cells
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J. Fahlteich, S. Günther, S. Mogck, O. Miesbauer, S. Amberg-Schwab, K. Noller, C. Boeffel, N. Schiller
Roll-to-Roll Technologies for Ultra-high Permeation Barriers and OLED Encapsulation
24th Finetech Japan
Tokio, Japan
16. – 19. April 2014

O. Zywitzki
Untersuchungen an Paradetextilien aus der Zeit Augusts des Starken
Dresdner Seniorenakademie –
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Dresden, Deutschland
24. April 2014

C. Metzner, B. Scheffel, G. Mattausch, T. Modes
Plasma-activated High-rate Deposition of Titanium Dioxide Coatings by Electron Beam, Spotless Arc and Dual Crucible Technology
41st International Conference on Metallurgical Coatings and Thin Films, ICMCTF
San Diego, USA
28. April – 02. Mai 2014

F. Fietzke, B.-G. Krätzschmar
Ionized Sputtering with a Pulsed Hollow Cathode Magnetron
41st International Conference on Metallurgical Coatings and Thin Films, ICMCTF
San Diego, USA
28. April – 02. Mai 2014

M. Junghähnel, M. Fahland, B. Meyer, K. Bedrich
Recent Developments of Ultrafast Electron Beam Treatment of Transparent Conductive Films
57th Annual SVC – Society of Vacuum Coaters – Technical Conference
Chicago, USA
03. – 09. Mai 2014

M. Junghähnel, S. Garner, T. Preußner, S. Günther, P. Chimo
Large area sputteringof dielectric and infrared blocking layer stacks on flexible glass
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Chicago, USA
03. – 09. Mai 2014

D. Glöß, M. Maicu, R. Schmittgens, D. Hecker, P. Frach, G. Gerlach
Synthesis and Deposition of Metal Nanoparticles by Gas Phase Condensation Process
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Chicago, USA
03. – 09. Mai 2014

C. May
OLED – a Next Generation Flexible Lighting Technology for Automotive and Further Transportation Applications
57th Annual SVC – Society of Vacuum Coaters – Technical Conference
Chicago, USA
03. – 09. Mai 2014

J. Fahlteich, S. Günther, M. Fahland, S. Mogck, T. Wanski
Transparent Barriers for Flexible Electronics: Where do we go?
57th Annual SVC – Society of Vacuum Coaters – Technical Conference
Chicago, USA
03. – 09. Mai 2014

U. Vogel
Germany's NEXT Top Glasses – more than eyes can see
NEXT Berlin – Leading. European. Digital
Berlin, Deutschland
05. – 06. Mai 2014

J. Fahlteich, S. Günther, M. Fahland, S. Mogck, T. Wanski
Rolle-zu-Rolle Technologien für transparente Funktionsfolien für die organische Elektronik
VDI-Konferenz „OLED in der Beleuchtung"
Frankfurt am Main, Deutschland
15. – 17. Mai 2014

J. Brückner
Rolle-zu-Rolle Fertigung von TCM auf flexiblen Substraten – Chancen und Herausforderungen
EFDS-Workshop "Transparente leitfähige Materialien (TCO/TCM) – Festkörperphysikalische Grundlagen und Technologien"
Dresden, Deutschland
14. Mai 2014

B. Beyer
Graphen - Eigenschaften und mögliche Anwendungen
EFDS-Workshop "Transparente leitfähige Materialien (TCO/TCM) – Festkörperphysikalische Grundlagen und Technologien"
Dresden, Deutschland
14. Mai 2014

C. May
Einführung in die OLED-Herstellungsverfahren
VDI-Konferenz "OLED in der Beleuchtung"
Frankfurt am Main, Deutschland
15. – 16. Mai 2014

C. May
Grundlagen und Status der OLED-Technologie für die Beleuchtung
VDI-Konferenz „"OLED in der Beleuchtung"
Frankfurt am Main, Deutschland
15.–16. Mai 2014

S. Richter, M. Törker, A. Richter
Slot-die coated HIL integrated in VTE OLEDs
6th International Symposium Technologies for Polymer Electronics
Ilmenau, Dresden
20.–22. Mai 2014

A. Weidauer
Elektronenbehandlung von Saatgut – eine bewährte Pflanzenschutzmaßnahme mit Potential
Saatguthandelstag 2014
Burg Warberg, Deutschland
22.–23.Mai 2014

J. Brückner
New possibilities for automotive lighting by flexible OLED
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25. Mai 2014

J. Fahlteich, S. Günther, M. Fahland, N. Schiller, S. Mogck, T. Wanski
Ultra-high permeation barriers and functional films for large-area flexible electronics
LOPE-C
München, Deutschland
26.–29. Mai 2014

F.-H. Rögner, G. Mattausch
A novel electron beam source for simplified irradiation of 3D-shaped surfaces
New Approaches to Food Irradiation through the use of Electron Beams and X rays
IAEA Headquarter, Wien, Österreich
27.–28. Mai 2014

B. Beyer, W. Tress, K. Leo
Small Molecule Organic Solar Cells with Ternary Absorption Layers – A Study to evaluate the origin of Voc
EMRS Spring Meeting
Lille, Frankreich
26.–30. Mai 2014

A. Zakhidov, M. Schober, K. Fehse, O. R. Hild, U. Vogel
Orthogonal Photolithography for high-resolution OLED microdisplay and micro signage applications
International Symposium on SID Display Week
San Diego, USA
01.–06. Juni 2014

U. Vogel
Bi-directional OLED Microdisplays: Components & Systems for Data Glasses
International Symposium on SID Display Week
San Diego, USA
01.–06. Juni 2014

U. Vogel
Bi-directional OLED Microdisplays for Eye-tracking Interactive Data-Glasses
International Symposium on SID Display Week
San Diego, USA
01.–06. Juni 2014

J. Hesse
OLED: Neue Anwendungen in der Beleuchtung
LED- und OLED Praxisforum
Würzburg, Deutschland
02.–03. Juni 2014

N. Schiller, M. Fahland, J. Fahlteich, S. Günther, C. Steiner, S. Straach
R&D for the vacuum web coating industry: sensing new development topics
AIMCAL Web Coating & Handling Conference 2014
Cascais, Portugal
08.–13. Juni 2014

G. Mattausch, B. Zimmermann, F. Fietzke, J.-P. Heinß, B. Graffel, F. Winckler, F.-H. Rögner, C. Metzner
Gas discharge electron sources – Proven and novel tools for thin-film technologies
Electron Beam Technologies – EBT 2014
Varna, Bulgarien
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M. Dietze
Sterilisationsmethoden und deren Einfluss auf aluminiumoxidbeschichtete Verpackungsfolien
Berufsakademie Sachsen, Staatliche Studienakademie Riesa, Studiengang Labor- und Verfahrenstechnik

J. Bartsch
Elektronenstrahl-Abscheidung und -Kristallisation von Siliziumschichten
Hochschule für angewandte Wissenschaften München,
Fakultät für angewandte Naturwissenschaften und Mechatronik,
Studiengang Physikalische Technik

F. Achilles
Entwicklung einer Kompetenzmatrix und Ableitung von Handlungsempfehlungen zum Einsatz als Managementinstrument zur zielgerichteten Personalbedarfsplanung in der Fraunhofer-Einrichtung COMEDD
Hochschule für Technik und Wirtschaft Dresden

MASTERARBEITEN

E. Bodenstein
Elektronenstrahl-induziertes Trockenätzen im Druckbereich <10^{-3} mbar
TU Dresden, Fakultät Elektrotechnik und Informationstechnik,
Studiengang Nanoelectronic Systems

M. Hahmann
Untersuchungen zur Biokompatibilität von elektronenstrahl-modifiziertem Kollagengewebe
Internationales Hochschulinstitut Zittau,
Studiengang Biotechnologie und angewandte Ökologie

T. Fischer
Advanced transparent anode concepts including slot-die coating process steps for application in organic electronic devices
TU Chemnitz, Fakultät für Naturwissenschaften

DIPLOMARBEITEN

E. Schwuchow
Untersuchungen zur Abscheidung von CdTe- und CdS-Schichten in Dünnschichtsolarzellen im Temperaturbereich um 300 °C
TU Chemnitz, Fakultät für Naturwissenschaften,
Professur für Halbleiterphysik

M. Förster
Charakterisierung der Prozess- und Schichteigenschaften von co-gesputtertem Niob-dotierten Titanoxid
TU Dresden, Fakultät Maschinenwesen, Institut für Werkstoffwissenschaft

B. Pfefferling
Herstellung von Al-Si-Kontakten durch direktes Ultraschall-Bonden von Al-Bonddraht auf einkristallinem Silizium
Hochschule für Technik und Wirtschaft Dresden, Fakultät Elektrotechnik

J. Jungius
Abscheidung hochreiner Siliziumschichten durch Elektronenstrahlaufdampfen
TU Dresden, Fakultät Maschinenwesen, Institut für Fertigungstechnik

J. Portillo
Esterilzacióne de Instrumental Médicio Mediante haz de Electrones
Universität von Zaragossa, Spanien

H. Voigt
Untersuchung der Elektroenergieversorgung für ein induktives Verdampfungsverfahren
Hochschule für Technik und Wirtschaft Dresden, Fakultät Elektrotechnik

DISSERTATIONEN

P. Pötschick
Magnetron-aktivierte plasmachemische Dampfphasenabscheidung von amorphen und mikrokristallinen wasserstoffhaltigen Siliziumschichten
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