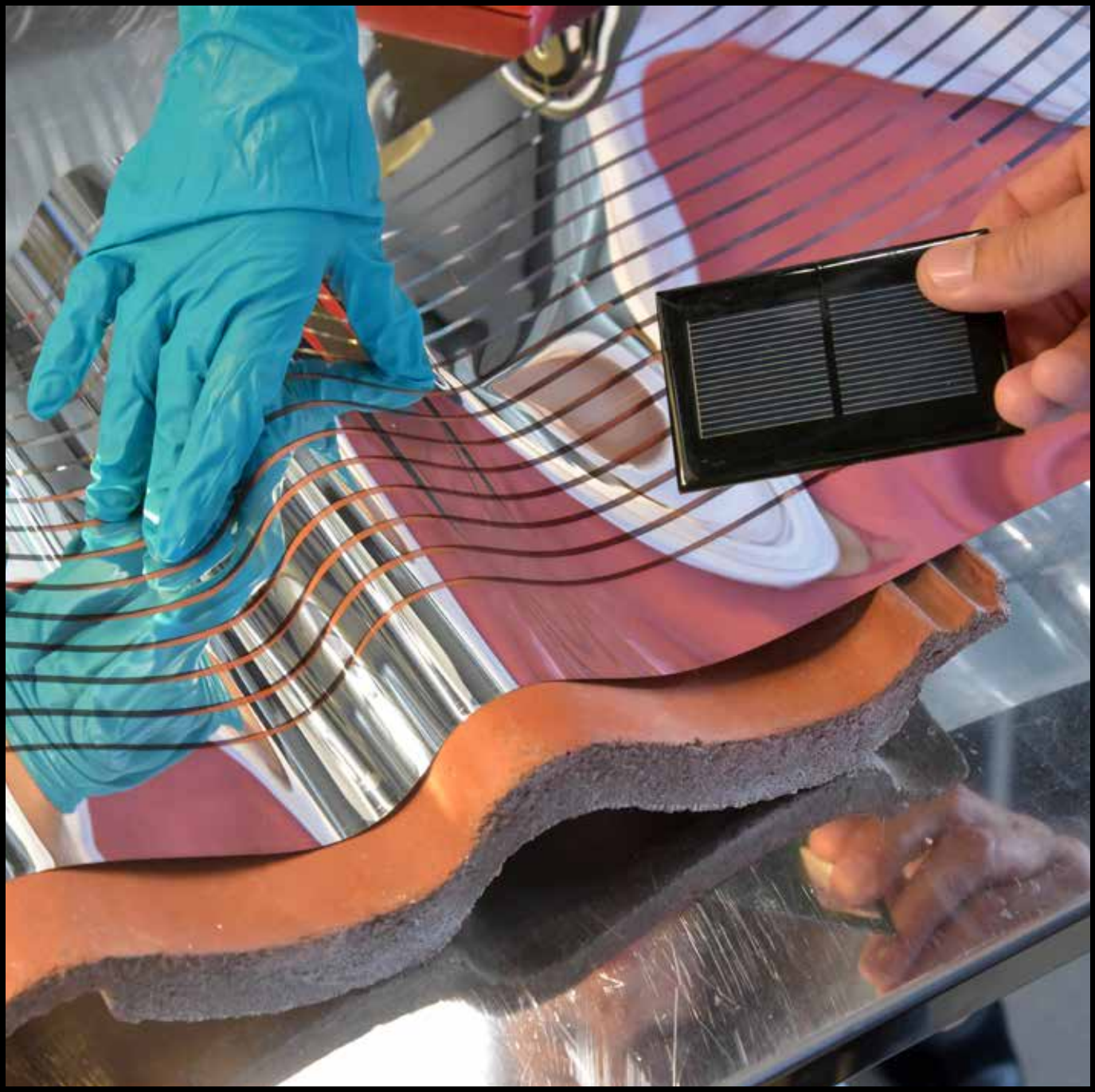


RollFlex R2R Innovation Centre

Interreg
Deutschland - Danmark

EUROPEAN UNION

The Southern Denmark Growth Forum

rollflex
R2R innovation centre

AN INNOVATIVE R2R PRODUCTION FACILITY

Roll-to-roll (R2R) processing is the process of printing materials (conducting, semi-conducting, coating) on thin substrates such as flexible glass or a thin plastic or structured film. The manufactured products include electric components such as flexible electronics and (organic) light-emitting diodes or solar cells.

- **Advantages:** Main advantages of R2R-fabricated products are mechanical flexibility, lightness, high throughput at low production costs, and semi-transparent properties.

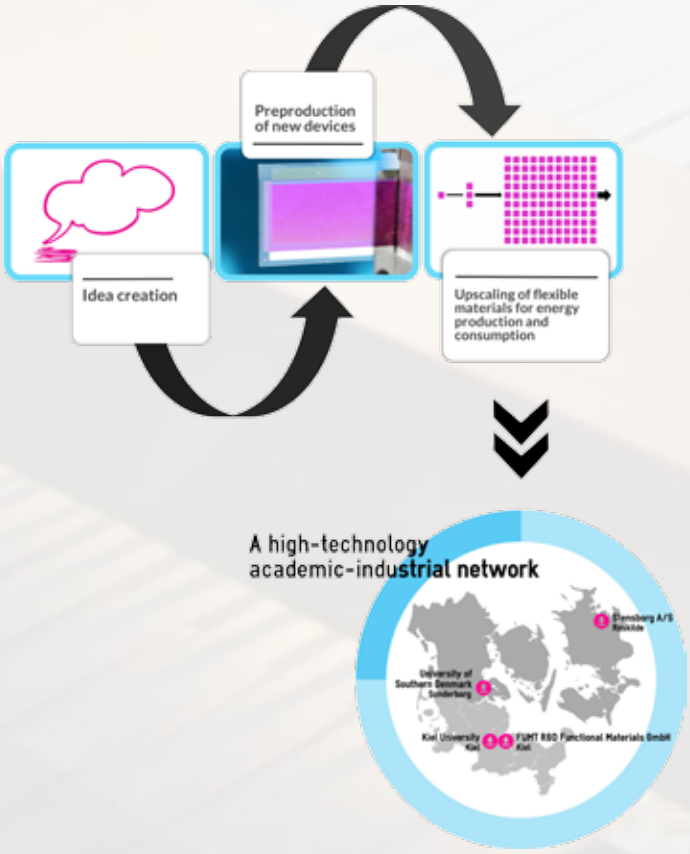
- **Applications:** R2R-fabricated products can be used within a wide range of product areas. Significant examples of potential markets are the sectors of lighting, display, photovoltaics, and labelling.

Beginning 2016, the Mads Clausen Institute established a new R2R production facility. This facility holds potential for research and production in the area of flexible and printed electronics, new materials, and solar cells.

The R2R production facility is part-financed by Interreg Deutschland-Danmark and Syddansk Vækstforum via the RollFlex project, which is a roll-to-roll project innovation centre that focuses on the development and the production of flexible and sustainable energy solutions in terms of energy generating and energy efficient devices using roll-to-roll technology. This Danish-German cross border project has a budget of 2.7 MEUR and is running from 2016 to 2019.

Partners

- University of Southern Denmark, Mads Clausen Institute (lead partner)
- Christian-Albrechts-Universität zu Kiel, Faculty of Engineering
- FUMT R&D Functional Materials GmbH
- Stensborg A/S, Roskilde

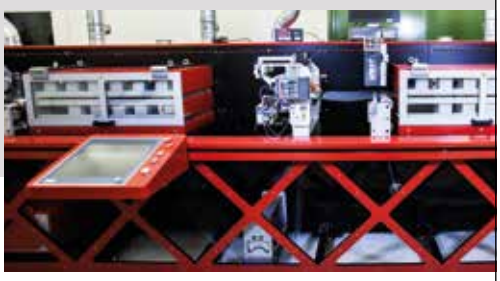


www.rollflex.eu

Printed aluminum back electrode, MCI

Beginning 2016, the Mads Clausen Institute established a new R2R production facility. This facility holds potential for research and production in the area of flexible and printed electronics, new materials, and solar cells.

Horst-Günter Rubahn
Director at MCI



FOM
TECHNOLOGIES

FOM Technologies provide device processing and test equipment and analytical lab management software for functional materials R&D in thin-film solar cells, energy applications, batteries and material research in general.

- Dedicated equipment for R&D material device development
- Material development for roll-to-roll processing
- Low material consumption – flexible and rigid substrates
- Slot-die coating using our Mini Roll Coater, Compact Sheet Coater or Solar X3 roll-to-roll system
- High-precision coating using the µPrecision Coater
- Small batch sheet processing to large-scale roll-to-roll processing
- Fluidic distribution system – temperature controlled 5-120°C
- Mercury Lab Management Software organizing and optimizing the R&D process
- Heated and cooled slot-die systems
- Custom made equipment for dedicated research application

Made by researchers for researchers. Applied in the development of perovskites PV, OPV, CIGS, LEC, OFET, adhesive lithography, super capacitors, batteries, fuel cells and nano-material among others.

FOM Technologies is a spin-off company from DTU. For more information please visit
www.fomtechnologies.com

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FOM Technologies - Enabling material research

Mini Roll Coater

A NEED FOR R2R PROCESSING

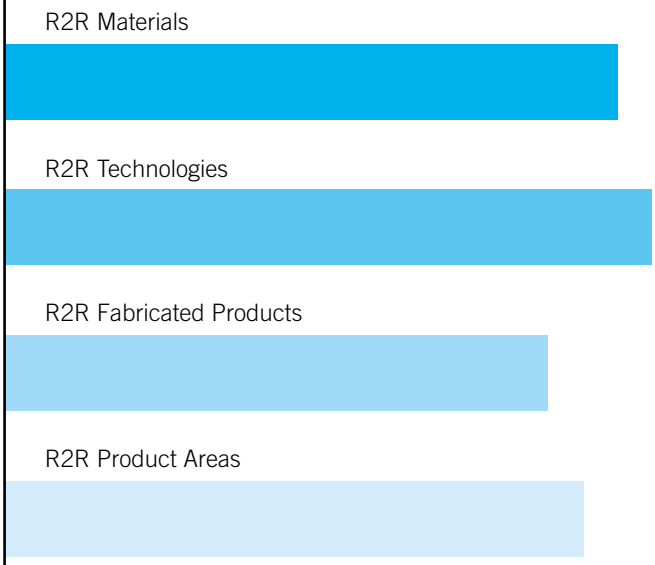
R2R processing benefits
- Companies
- Universities
- Research institutions

Within:

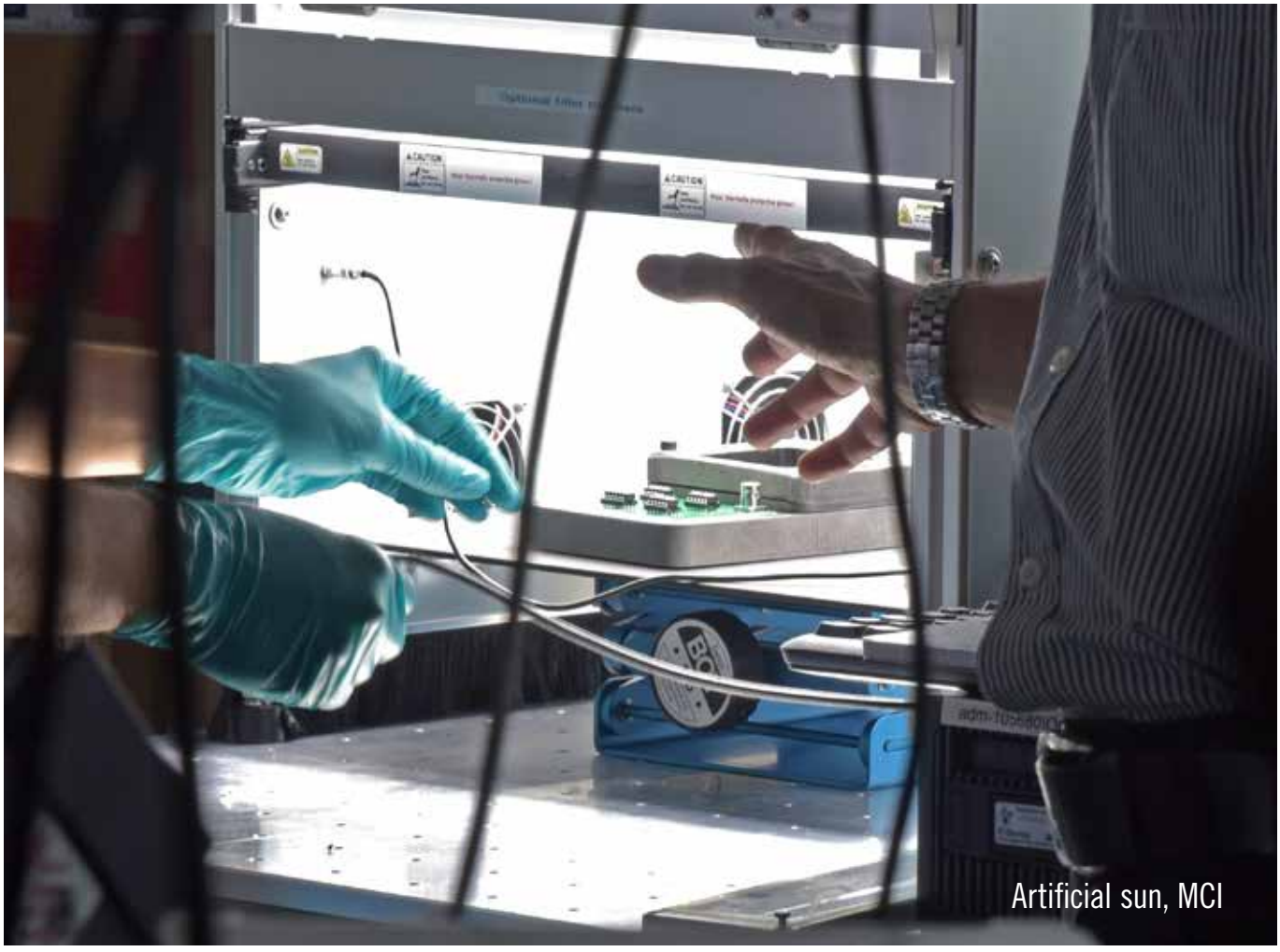
Processing
- Materials and technologies

Applications
- R2R processing for new products
- Use of R2R-processed products in the production line

In the region Denmark/Schleswig-Holstein and Hamburg, 140 companies are related to R2R production technology. From those, about 25% use R2R technology at present or will use it in the future, within:



Source: DSN Need Analysis R2R, May 2016.



Artificial sun, MCI

Technology at the Mads Clausen Institute (MCI)

The R2R facility at MCI combines large-scale vacuum sputter deposition (7 magnetrons) with slot die coating, nanoimprint lithography, lamination, and other standard R2R processing equipment. This opens up for new products and also allows for the use of R2R technology in the whole innovation cycle, from basic science over (student) projects to product development.

Processing materials

- Plastic films and foils
- Structured films
- Metallic nanoparticles
- Nanowires
- Organics
- Oxides
- Transparent encapsulation barriers
- Nitrides

Processing technologies

- Slot die coating
- Nanoimprint lithography
- Sputter deposition
- Liquid phase deposition
- Lamination
- Advanced control systems
- In-situ inspection

Products

- Organic solar cells
- Organic light-emitting diodes
- Artificial muscles
- Flexible sensors

Product areas

- Lighting
- Photovoltaics
- Robotics and wearables

The main scientific goal of the R2R facility is to understand and improve the upscaling process of revolutionary new energy devices such as organic solar cells and organic light-emitting transistors.

Structured silicon wafer, MCI

Technology at Kiel University (CAU)

The Chair for Integrated Systems and Photonics has extensive research experience in the area of nanostructured organic optoelectronics. At CAU, structure concepts for the enhancement of device efficiency will be investigated theoretically, and prototypes will be built and tested on a small-scale at the Kieler Nanolaboratory, identifying optimal device configuration for R2R applications.

Modelling
- Simulation methods: Finite element method (FEM), finite-difference time-domain method (FDTD), transfer matrix method (TMM)
- Optical behaviour of nanostructured waveguides
- Absorption phenomena in organic and inorganic thin-film layers

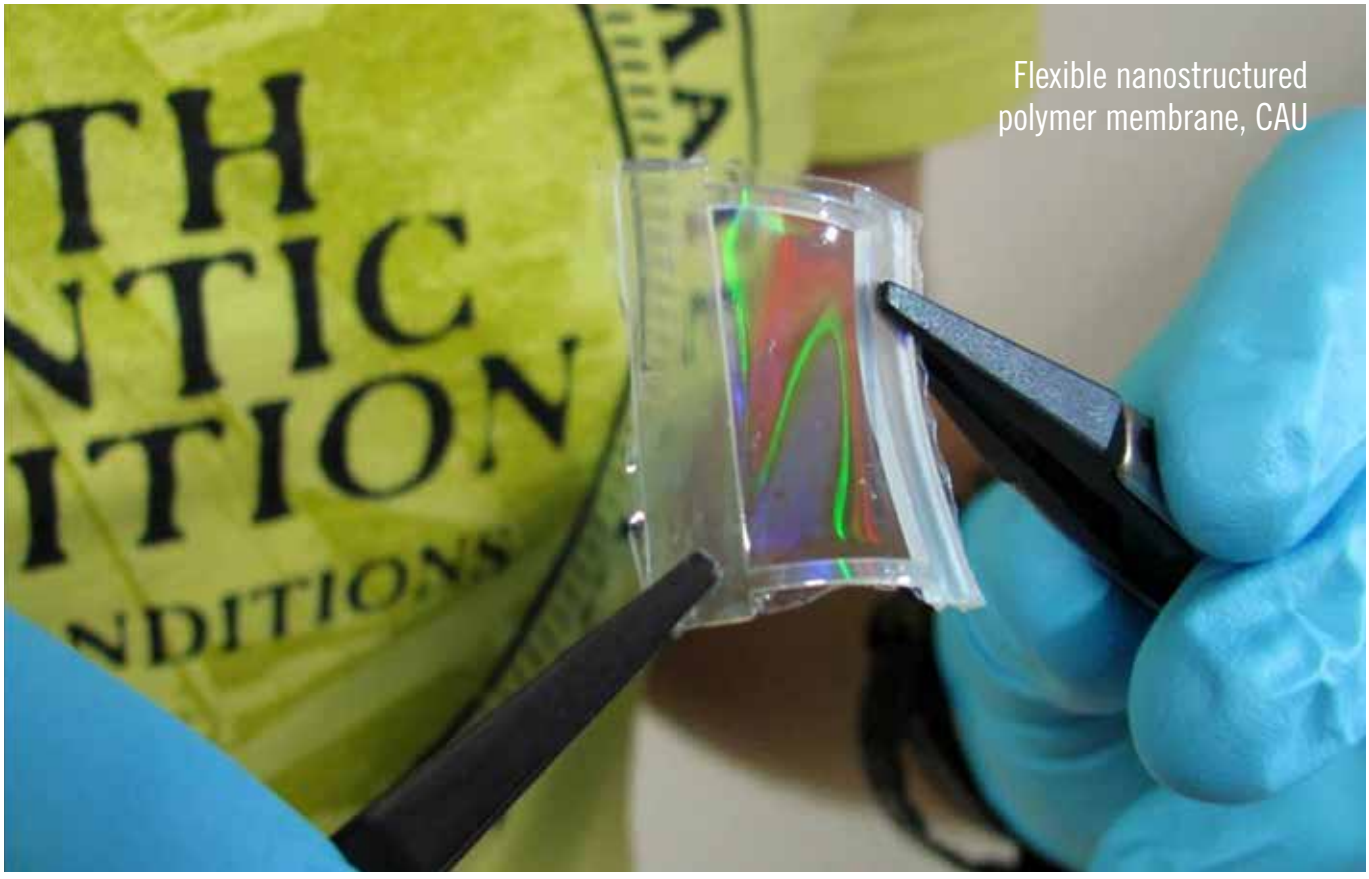
Processing materials
- Plastic films and foils
- Organics
- Oxides
- Metals
- Structured surfaces
- Nanoparticles
- Transparent encapsulation barriers

Processing technologies
- UV nanoimprint soft lithography
- UV lithography
- Thermal vapour deposition
- Thin-film spin-coating under nitrogen atmosphere
- Chemical surface functionalization

Products
- Organic light-emitting diodes
- Organic photodetectors
- Nanostructured waveguides/photonic crystal slabs
- Optical biosensors/lab-on-chip systems
- Optical thin-film filters
- Cantilevers
- Pressure sensors

Product areas
- Lighting
- Sensing

The main scientific goals at CAU are to design nano- and microstructures for enhanced energy efficiency and light steering, and to integrate these structures into R2R processed organic optoelectronic devices.



Flexible nanostructured polymer membrane, CAU

Laboratory setup, FUMT

Technology at CAU/FUMT R&D Functional Materials GmbH

FUMT works on basic research and development as well as industry client-oriented product development. Most of the product solutions are generic blocks of and for new products. FUMT acts as a bridge between science and economy and its benefit to the customer is innovative technology by enhanced function.

In the product development of FUMT, one of the business units involves products containing functionalized microparticles. FUMT has special knowledge about the effects of microstructured particles on the enhancement of polymer composites. Due to their concave shape, these particles are called Core-Spike-Particles (CSP®).

FUMT created its own brand CSP and conducts production of polymers including these microparticles. CSP composites (CSPC) can be used as surface coatings for highly stressed areas and also for special modified castings.

For the processing in different varieties, FUMT developed special equipment to produce CSP-based materials. One of the most investigated types of these CSP is tetrapodal zinc oxide (T-ZnO), which can be used in a great number of varieties.

For the R2R development, the light-scattering behaviour of T-ZnO should be used in the OLED devices to modify absorption and reflection in order to increase the coupling efficiency. FUMT has made investigations together with CAU to use T-ZnO as an enhancer in polymers like silicone, thermoplastics, and others. A polymer dispersion containing T-ZnO can be used in the coating procedure to build scattering foils.

In the RollFlex project, the process should be upscaled and combined with other necessary steps to build a large-scale OLED panel.

Technology at Stensborg A/S

Stensborg A/S has world-class expertise and more than 15 years of experience in industrial mass fabrication of micro- and nanostructures for optical applications via roll-to-roll printing technology.

The company manufactures custom roll-to-roll/roll-to-plate UV-NIL (Nano Imprint Lithography) machines for the production of micro-and nanostructured foil and plate products using a unique, patented Holoprint® technology. Stensborg also produces custom foils on in-house production machines. Additionally, customers are supported with mastering, imprinting plates, and speciality resins.

The unique imprinting method allows for imprint of nano- and microstructures onto a wide variety of substrates at high speeds, and the process can be fully integrated with other printing or imprinting processes (R2R NIL technology).

Main technology attributes include

- Super-sharp structure definition
- Low-cost in house production, suitable for millions of m² imprinting
- Speeds up to 60 m/min
- In-register image structure printing or wallpaper structure
- Ability to print on flexible as well as solid substrates, transparent and opaque
- Optimized UV resins for 20 nm-100 micron feature sizes
- Long-run polymer imprinting plates

The roll-to-roll facilities include an ISO7 cleanroom that contains state-of-the-art equipment for the development and production of equipment and prepress materials for industrial mass production of nano- or microstructures.

Stensborg has developed fast light curing resins as imprint materials and master templates optimized for usage in the process. Stensborg has a palette of master template imprint materials as well as UV-curing resins for, e.g., flexo, slot or ink-jet applications.

The planned RollFlex project outcome will become an important resource for innovation and R&D activities contributing to enhance competitiveness on the regional and global markets for structured functional foils. The project goal is to seek a production upscaling of the developed micro- and nanostructures to be used in company technology.

HoloPrint insert into R2R setup, Stensborg

> The planned RollFlex project outcome will become an important resource for innovation and R&D activities contributing to enhance competitiveness on the regional and global markets for structured functional foils.

Jan Stensborg, CEO & founder

INNOVATION

Idea creation

Relevant ideas for R2R production must come from either company or fundamental scientific interests within upscaling technologies. Both FUMT and Stensborg A/S continuously strive to improve their product portfolio via open discussion of groundbreaking ideas. At the universities, ideas are channelled along R2R-relevant lines such as to improve structural properties of the foils, new device architectures, or increased use of green materials.

The Mads Clausen Institute hosts an Innovation Lab, which is a central unit to foster the collaboration with existing and potential network partners, such as relevant companies in the border region. This will be achieved through creativity and innovation workshops, which generate a basis for output related to the project and the companies' specific competences.

Additionally, the Innovation Lab represents an accelerator for technological entrepreneurial ventures, both during the project lifetime and afterwards.

Processes

- Roll-to-roll sputtering processes to mass produce metal and metal-oxide thin-films
- Roll-to-roll slot die coating for printing of semiconducting and conductive inks and polymers
- Roll-to-roll lamination of encapsulation foils for device packaging
- Roll-to-roll nanoimprint lithography (NIL) to mass produce micro- and nano-scale structures
- Mass production of semiconducting micro- and nano-structures
- Production of templates to assist the roll-to-roll NIL production
- Production of UV-curable resin products useful for optical lithography and roll-to-roll NIL

Products

The range of products that can be manufactured by R2R processing is broad. Examples for such products can be found at, e.g., Stensborg and FUMT:

Stensborg
Our business is the production of products with micro- and nanostructured surfaces. Such functional surfaces are offered as ready-made components or as custom-tailored solutions.

Examples are
- Nano-imprinting of optical verification devices (OVD) and holograms
- High volume, lab-on-a-chip
- Flexible solar cell production
- Nano- and micro-structured imprint templates
- UV-curable resins
- Tailored high-refractive-index materials
- R2R and R2P machines

FUMT
FUMT R&D is engaged in the development of modified materials for rotor blades on windmills, friction reduction on band conveyors, bio-corrosion resistance coatings for submarine use, biocide-free coloured coatings as substitute for paintings, etc. In addition, FUMT offers surface structuring by modified etching to enlarge mechanical strength and adhesion on metal surfaces (aluminium, titan, etc.).

APPLICATIONS

Flexible Solar Cells
In recent years, there has been tremendous progress in the development of novel organic solar cells, which, due to their appealing features such as low cost, mechanical flexibility, low weight, and ease of integration, are considered as future candidates for the solar energy market. New scientific and engineering methods for improving both power conversion efficiency and device lifetime are constantly pursued in the endeavour of lifting the technology to a commercialization stage.

Organic light-emitting diodes (OLED)
Production of OLEDs is interesting because they enable a better contrast ratio with a wider view angle compared to classic LCDs., and they are energy saving since no background lighting is necessary. Another important aspect is that OLEDs are made of organic materials that can be deposited in flexible substrates such as polyethylene terephthalate (PET) to produce flexible screens. The roll-to-roll process could enable their mass production and reduce the production costs significantly.

DEAP materials
Dielectric Electroactive Polymers (DEAP) are material systems, which produce large strains upon the application of a voltage on the electrodes that sandwich the DEAP film. The DEAP technology therefore transforms electrical energy into mechanical work and vice versa. The DEAP technology can be utilized in a vast number of actuator and sensor applications, useful for new, flexible, smart products that can be produced from roll-to-roll technology.

Education
The R2R facility is integrated into the curricula for engineering students at both CAU and SDU, providing a stimulating learning environment and teaching up-to-date competences from photonic components to optoelectronics and integrated systems.

In addition, the RollFlex project will have a strong focus on educational activities – also externally – via continuing education courses for local and regional company employees. The courses will expand from engineering and lab courses on roll-to-roll production technology to courses that contain device theory and development, for example on the organic light-emitting and solar cell devices developed in the project. The course activities will also include a course on high-tech business venturing that focuses on the commercialization of developed products and that is held in collaboration with relevant companies. Online courses will be available to expand the range of potential students and other interested people for these courses.

PROJECTS

Webcoater (in the back), MCI

Although newly established, the R2R facility can rely on support from a number of other national and international projects besides the RollFlex project:

THINFACE: A PhD training initiative for the design of next-generation energy devices with the aim to develop high performance OPV through integration of novel nanostructures and metal-oxide interlayers. This international EU network (ITN) is running from 2013 to 2017, is funded by around €1m on R2R-related topics, and has partners from, e.g., University Milano-Bicocca, Technical University of Graz, University Pierre & Marie Curie, University Autonoma De Madrid and CIC NanoGUNE.
www.thinface.eu

SDU2020: Production of next-generation energy devices. The network runs from 2014 to 2017, is funded by about €1m and includes partners from the Department of Physics, Chemistry and Pharmacy at SDU as well as the Department of Biochemistry and Molecular Biology (Membrane Biophysics and Biophotonics Group) at SDU.

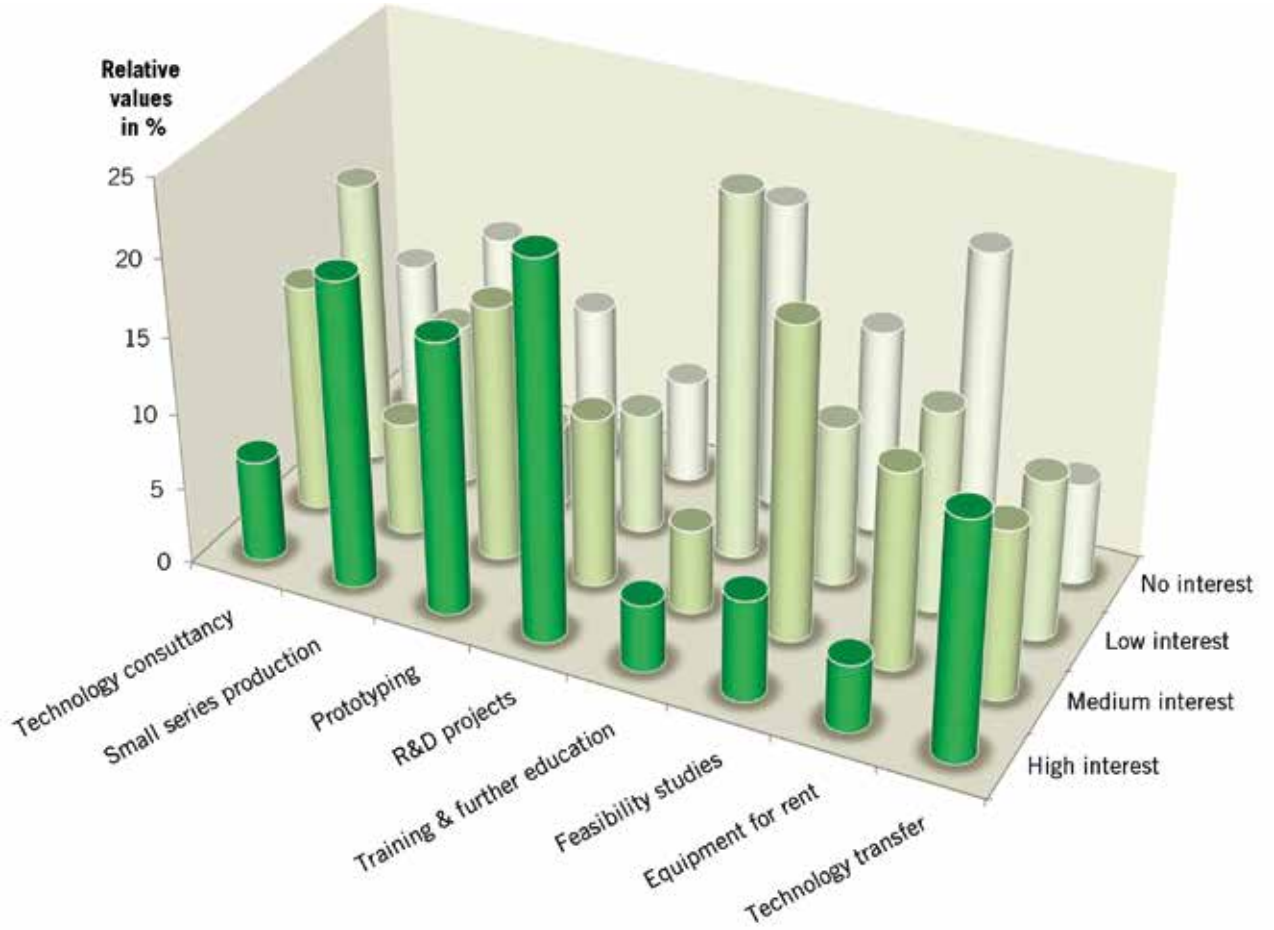
SunTune: High-efficiency solar cells by spectral transformation using nano-optical enhancement. The network duration is from 2015 to 2019 with a RollFlex-related funding of about €100,000 and partners from the Department of Physics and Astronomy/ Interdisciplinary Nanoscience Center (iNANO) and the Department of Engineering at Aarhus University, DTU Mechanical Engineering, Technical University of Denmark (DTU), International Solar Energy Research Center, Konstanz, as well as Racell – Saphire Group and EnergiMidt A/S.

CompliantPV: Mechanical and photochemical stabilization of flexible organic solar cells. The network runs from 2017 to 2019, is R2R-funded by around €360,000 and has partners from SDU, Technical University of Denmark (DTU), as well as from the Institute of Materials Research and Testing in Berlin.

Stabil-O: Stabilization of organic solar cells by ternary blending active layers with stabilizing additives. Stabil-O is a network running from 2015 to 2017 with a total funding of around €300,000 and with partners from the National Institute of Standards and Technology and the Eberhard Karls Universität Tübingen.

FUTURE POTENTIAL

R2R processing has an obvious economic growth potential. The relevance of the specific service needs fulfilled by the new R2R processing facility is indicated in the graph below:



Source: DSN Need Analysis R2R, May 2016.

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