World's first organic photovoltaic cell made from recycled polypropylene

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World´s first organic photovoltaic cell on a film made of recycled polypropylene from drink pouch packaging material. Credit: OET Organic Electronics Technologies P.C.

The partners of the EU project FlexFunction2Sustain have committed themselves to create a network for innovative solutions for sustainable

and smart products powered by nano-functionalized paper and plastic in order to support SMEs, start-ups and industries in the development and market launch of pioneering products. After the first two years, a number of promising results and prototypes have emerged and will be presented at the Conference for Industrial Technologies IndTech 2022 in Grenoble, France, June 27–29, 2022. Among them, a recently finalized highlight: the first working organic photovoltaic cell on recycled plastics.

Recently, participants from all over the world met at the Stockholm+50 Environment Summit and emphasized the urgency in moving forward quickly with environmental and climate protection measures. The littering of our planet and its oceans is progressing inexorably. A main driver for plastic waste is packaging materials, which are needed to extend the shelf life of food or to protect delicate products and pharmaceuticals from damaging environmental influences. In addition, smart packaging opens up many new and useful possibilities thanks to flexible electronics. In the future, short-life packaging materials for medicines, for example, will be equipped with flexible electronics to monitor medication intake or track sensitive products during their delivery route.

Recycling of plastics and using recycled material for packaging is an important cornerstone on the road to greater environmental protection and reducing plastic waste. To replace such composite and multilayer materials that are not recyclable or degradable, novel polymer compositions (bio-based and/or biodegradable) and adapted product designs are being discussed as a solution approach. In smart packaging, the electronics must also be considered in a more environmentally friendly way and, for example, designed to be recyclable and produced by using recyclates. A number of startups and innovative companies have created concepts for sustainable flexible and smart packaging products.

Gathering 19 partners from research, universities and industry throughout Europe, FlexFunction2Sustain aims at supporting small and medium-sized companies in bringing innovative concepts and ideas for products based on nanofunctionalized plastic and paper surfaces and membranes to market. The FlexFunction2Sustain Network—an Open Innovation Testbed (OITB) for nanofunctionalization technologies—offers comprehensive services to support innovation, e. g. from material and product design, technology and product development, small batch production to the sourcing of development funds.

Two years of FlexFunction2Sustain: What has emerged?

During its first two years, the consortium established an association which purpose is to structure and exploit the OITB member´s service portfolio. Hence, through this association the partnership plans to deliver an easy, fast-track access to the OITB facilities and services to SMEs, start-Ups and industry. To ease the commercialization process, the customer gains access to the OITB through a Single Entry Point (SEP) sales and project management entity. An SEP consults the customer in the selection of appropriate technologies and coordinates all development work and interaction with the OITB members for the customer. FlexFunction2Sustain will establish regional contact points to provide the best possible user experience and to bring the OITB to the whole European single market.

First prototypes of novel, eco-friendly plastic and paper products were prepared and evaluated within different industrial use case scenarios. These included recyclable/compostable food and cosmetic packaging, membranes for water filters and diagnostics, smart plastic surfaces for automotive application, and biodegradable security and anti-counterfeiting labels.

Project coordinator Dr. John Fahlteich sums up: "We are proud to present the first working organic photovoltaic cell (OPV) on a recycled polypropylene substrate along with a whole range of technology demonstrators at IndTech 2022 end of June in Grenoble, France." Besides the OPV cell, several innovative product concepts will be shown including:—fully recyclable drink pouches,—optical features on biodegradable film,—innovative fresh food packaging made of semi-transparent paper—membrane based syringe filters for diagnostics and water filter applications.

Dr. Fahlteich continues: "At IndTech, FlexFunction2Sustain is embedded in a dedicated section of the exhibition presenting the innovations and services of 13 different Open Innovation Testbeds addressing a variety of technologies and applications ranging from biomaterials to nano-enabled surfaces towards eco-friendly and energy efficient solutions for building envelopes. A broad portfolio of technology solutions awaits SME and industry on site. We are looking forward to exchanging ideas and initiating projects with future partners from SME, Start-Ups and industry."

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The project partners Fraunhofer IVV and IPC Centre Technique Industriel de la Plasturgie et des Composites used recycled polypropylene (rPP)—recovered from a newly designed packaging material for recyclable drink pouches—mixed with virgin polyproypylene (vPP) to produce a substrate film for printed electronics at a recyclate content of 50%.

At Fraunhofer FEP, a transparent electrode—made of indium tin oxide (ITO)—was applied by means of roll-to-roll (R2R) vacuum coating with

magnetron sputtering with a specially adapted set of process and winding parameters. The result is impressive, since despite the recyclates used in the substrate, the ITO exhibited almost the same sheet resistance as achieved on pristine film substrates.

Organic Electronics Technologies P.C. (OET) in Greece then performed R2R slot-die coating to produce OPV cells, followed by an encapsulation step over the printing of the organic materials and the finalization of the OPV cells. Here, OET's researchers performed several trials on the coating parameters and finally succeeded in printing the functional OPV layers on the PP substrate made with 50% rPP recovered from drink pouch packaging material. As a result, the OPV was demonstrated to function as a device with a max efficiency of 1%.

OET's project manager Vasileios Kyriazopoulos: "The power conversion efficiency of approx. 1% is already sufficient to supply a wide range of single-use smart packaging productions with sufficient electrical power. Currently, OPV cells on commercially available substrates can achieve efficiencies above 8%, therefore, by improving the entire fabrication process, including film extrusion, layer design, printing and encapsulation, it is achievable to increase the efficiency of OPV cells printed on recyclable material, which is made with 50% rPP, by more than 5%."

This represents a first major step in the development of more environmentally friendly product designs and flexible electronics. In the future, products such as smart packaging, but also interactive magazines in the field of advertising or consumer electronics can be designed based on these initial developments. Thanks to flexible electronics such as an OPV cell on recycled material, tomorrow's products will be powered a little more environmentally friendly.

Of course, the initial results only point the way ahead. In the future, the

FlexFunction2Sustain consortium will work on improving the extrusion process for the recycled film. In addition, the development of a new layer design for improved surface quality is on the agenda. The OPV process also holds potential for improving drying temperatures and encapsulation strategies. All together leading to the perspective of reaching similar performances of flexible electronics as done on pristine, fossil-based plastic films.

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