RESEARCH NEWS

Circular economy – better recycling of paper packaging

Sealing Paper Packaging without Adhesives

Paper packaging offers a number of advantages over its plastic counterparts: It has a high recycling rate, lower CO_2 emissions, and lower disposal costs. However, it cannot yet be sealed without adhesives or layers of plastic – a disadvantage for manufacturing and recycling processes. In the PAPURE project, four Fraunhofer institutes are developing a laser-based process that enables completely adhesive-free paper packaging.

Since plastic packaging accounts for a large fraction of plastic waste, the demand for environmentally friendly packaging options is increasing. One material that is becoming more and more popular as a sustainable alternative to plastic is paper. However, the problem is that sealing paper packaging requires additives such as adhesives or plastic. These additives contaminate the paper, complicate the recycling process, and reduce the quality of the recycled material. This poses a significant challenge to the otherwise established and efficient paper recycling process. In the PAPURE project, the Fraunhofer institutes for Applied Polymer Research IAP, for Material and Beam Technology IWS, for Process Engineering and Packaging IVV and for Machine Tools and Forming Technology IWU are looking to improve recyclability by sealing paper packaging without any additives. The institutes are pooling their expertise to develop a sealing process using laser treatment to modify the paper so that it can then be sealed directly with a heat sealing process. The project focuses on analyzing various papers and characterizing materials (Fraunhofer IAP), laser-based surface modification (Fraunhofer IWS), developing an innovative sealing system (Fraunhofer IVV), and establishing an industry-oriented demonstrator (Fraunhofer IWU). A laboratory-scale manufacturing unit is being built at Fraunhofer IWU in Dresden that replicates the process for manufacturing a typical packaging material.

Paper composition affects adhesive properties

In the first step, Fraunhofer IAP researchers are characterizing coated and uncoated papers for packaging applications as well as printer papers and cardboard to determine whether they are suitable for sealing without the application of further additives. Roughly three dozen types of paper are available for selection. Special attention is given to determining the hemicellulose, cellulose, and lignin content of the paper. These have a significant effect on the adhesive properties of the materials and the quantity and composition of the resulting cleavage products (reaction products from laser treatment). Analytical methods such as scanning electron microscopy (SEM), high-

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performance anion exchange chromatography (HPAE) and X-ray photoelectron spectroscopy (XPS) are used to analyze the chemical composition and morphology of the different papers before laser treatment and of the subsequent reaction products. Fraunhofer IAP research scientist Robert Protz: "An excessive proportion of inorganic compounds, such as talc and calcium carbonate, has a negative effect on the adhesive properties and bond strength of the seams. It can also be said that thicker papers are more suitable for binder-free sealing." The researchers were able to show that thicker standard papers available on the market and used for producing items such as disposable paper cups and other food packaging can be used for the sealing process.

Functionalizing paper with CO lasers

In the next step, Fraunhofer IWS researchers irradiate the surface of the paper with a carbon monoxide laser (CO laser), which rapidly heats the paper, converting its primary components – lignin, hemicellulose, and cellulose – into short-chain compounds in a controlled process. This innovative process step is what enables adhesive-free sealing of the paper. After irradiation, fusible cleavage products remain on the paper surface and seal under heat and pressure without any additional material. "By irradiating the paper with a CO laser, we create refusible, sugar-like reaction products that we use instead of the synthetic materials or adhesives that would otherwise be required to seal the paper by the heat sealing process. In this way, we are essentially producing our own adhesive in the form of the cleavage products," says Volker Franke, Group Manager Laser Micro Processing at Fraunhofer IWS in Dresden. "After laser treatment, we have succeeded in using heat sealing, an established thermal contact process, to bond two layers of paper with heat and pressure."

Bond strength defines seam quality

The project partners at Fraunhofer IVV are developing the necessary sealing system for processing laser-treated papers with fusible cleavage products. To achieve this, the researchers are accounting for the effects of material properties, laser parameters and the properties of the fusible reaction products on bond strength based on data already recorded by the teams at Fraunhofer IAP and Fraunhofer IWS. They are also testing the extent to which bond strength and leak-tightness can be improved by using suitable sealing parameters and tool geometries and are transferring the results to a packaging solution with the goal of achieving seam properties suitable for the market. "Bond strength determines how difficult it is to tear open or to open packaging," explains Fabian Kayatz, research scientist and project coordinator at Fraunhofer IVV in Dresden. "By measuring mechanical stability under different types of loads (shear test, T-peel test), we can demonstrate the effects of laser parameters and sealing parameters on the bond strength of the seams. Crucial sealing parameters are sealing time, sealing temperature, sealing pressure, and tool geometry. Fiber direction also plays a role, i.e., the orientation of the material relative to the sealing tool." Marek Hauptmann, head of the joint project, adds: "We are essentially striving for a bond strength that is higher than the interply adhesion of the paper layers. We are already achieving good bonds in

the shear tests. We can easily lift 20 kilograms with a seal that is only two centimeters long and three millimeters wide."

Adhesive-free sealing integrates into existing production

At Fraunhofer IWU in Dresden, a laboratory-scale modular paper processing manufacturing unit is currently being developed that replicates the process for manufacturing a flat four-sided bag – commonly used for packaging – in a roll-to-roll process. The primary focus of the work is developing and integrating a laser and a sealing module into the approximately six-meter-long, one-meter-deep and two-meter-high industrial-type demonstrator. The adhesive-free sealing process is being adapted based on sensors proven in industry (including image and moisture sensors) and a digital twin with a trained data model. The surface of the paper web running continuously through the plant is first irradiated with the CO laser, producing the cleavage products mentioned above. A second paper web is then fed in, joined with four seams using a combined sealing and punching tool in a heat-sealing process, and is then punched out to form a bag. The heat generated during the sealing process activates the cleavage products, causing the two paper webs to bond together. In the future, a seal seam measurement system installed in the pilot plant as a quality control measure will record real-time changes in seal seam quality, enabling rapid adjustment of laser and sealing parameters. Fraunhofer IWU research scientist Christer-Clifford Schenke: "Our goal is to produce ten packages per minute on the pilot system by the end of the project in September 2026."

Presentation at Interpack 2026

The practical, modular demonstrator shows that the process can be integrated into existing production processes in the future. Both the laser module and the sealing tool can be implemented separately in production. This makes the process especially attractive for packaging machine manufacturers, packaging material producers and packagers. The integration of PAPURE technology enables companies in this industry to position themselves as pioneers in the field of "green packaging." Together with interested companies from the packaging and food industries, as well as paper manufacturers and mechanical engineering firms, the project partners intend to further develop the plant for large-scale production. Fraunhofer researchers will be presenting the potential applications of this technology and showing how the system works at the Interpack 2026 trade show from May 7 to 13 in the Technology Lounge of the German Machinery and Equipment Manufacturers Association (VDMA) in Düsseldorf (Hall 4, Booth C54).

Project website: https://www.papure.fraunhofer.de/

Fig. 1 Process for sealing a laser-modified paper web without additives

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Fig. 2 Demonstrator plant with integrated Papure laser module

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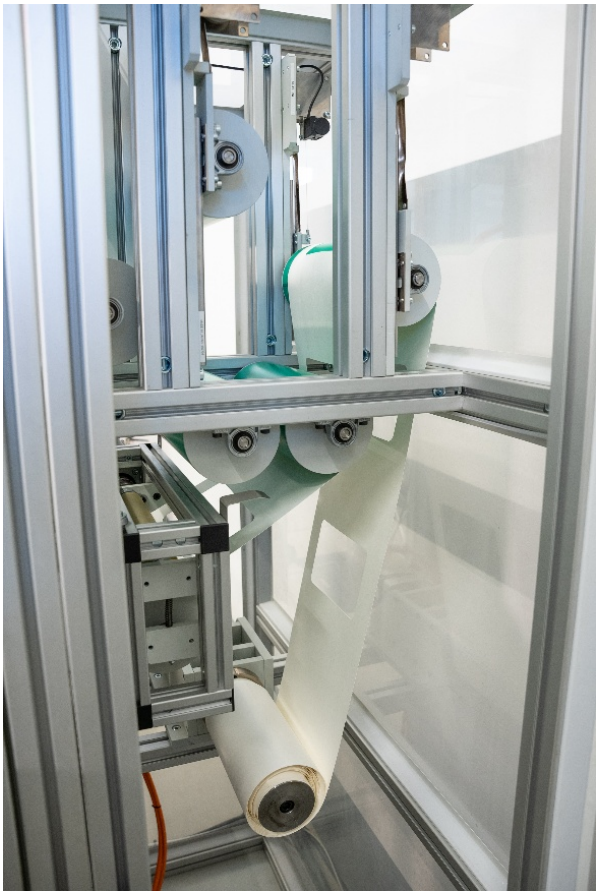

Fig. 3 Paper reel downstream of the sealing module. The cutouts for the four-sided bags are clearly visible.

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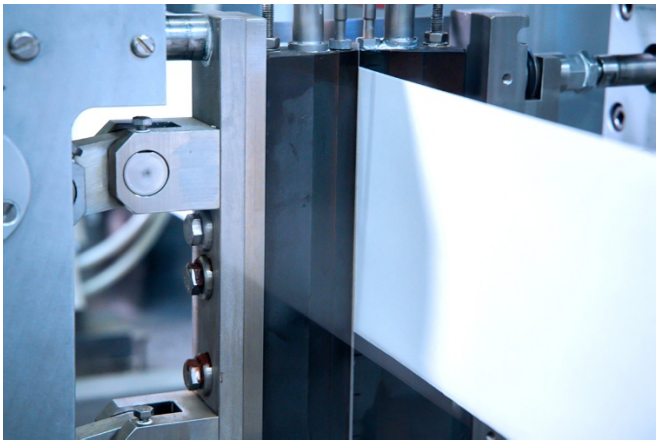

Fig. 4 Sealing a paper web by heat contact sealing

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Fig. 5 Sealed paper bag packaging

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