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Lectures and Posters

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Book of Abstracts: Lectures and Posters

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Preliminary remarks

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President of the foundation AMK

A warm welcome to the international scientific conference polymertec26 on the campus of Merseburg University of Applied Sciences.

Following the successful polymertec event in 2024, we are once again looking forward to an in-person conference that continues the tradition of biennial cycles for this format. The conference motto, “Concepts for the Sustainability of Polymer Materials and Polymer Technologies,” reflects and further emphasizes the trends toward sustainability and the transformation of the chemical industry. We expect approximately 100 participants, with 48 presentations and 20 posters, all of which will contribute to the success of the event. We would like to express our sincere gratitude to everyone involved.

Our thanks also go to all organizers and colleagues for their dedication and creativity in preparing the conference. In particular, our non-university partners, in close cooperation with Merseburg University of Applied Sciences, played a decisive role in the conceptual design and operational implementation of the program, thereby helping us to create a high-caliber and attractive program for polymertec26.

Without the active support of our sponsors, such a conference would not be possible. Many thanks to everyone who has supported us both financially and in the implementation of the event.

We look forward to two days of scientific presentations and posters covering all areas of the polymer materials value chain.

This booklet contains a compilation of all abstracts of the presentations and posters. All authors also have the opportunity to publish the content of their presentations and posters in the journal “Macromolecular Symposia” following the conference.

As with previous events, polymertec26 aims to more closely link the broad spectrum of knowledge-oriented research, applied basic research, and technology-oriented research, and to serve as a bridge between academia and industry.

Supporting young researchers is particularly close to our hearts. Free admission to all lecture sessions for students of Merseburg University of Applied Sciences, as well as a prize for the best poster, are intended to support this effort.

On the evening of the first day of the event, guests will have excellent opportunities to expand their networks during an evening event in the historic part of Merseburg. The poster session will take place at the end of the first day of the event.

On behalf of the organizers—Merseburg University of Applied Sciences, the Fraunhofer Institute for Microstructure of Materials, the Institut für Polymerwrkstoffe e. V., the foundation Akademie Mitteldeutsche Kunststoffinnovationen, and our patron, the Minister for the Environment, Science, and Energy, Prof. Dr. Armin Willingmann—we wish everyone much success and enjoyment at the conference, as well as a wonderful time in the cathedral and university town.

Warm regards,

The Conference Organizing Committee
Valentin Cepus, Maik Feldmann und Katrin Reincke

Preliminary program of Polymertec 26

Day 1: 17/06/2026

Time	Session 1	Session 2
09:00 – 09:30	Registration	
09:30 – 10:00	**Opening**	
	Plenary Lectures	
10:00 – 10:40	C. Patermann (Former Program Director at the European Commission) *Industrial Bioeconomy – From global to national – Hype or reality?*	
10:40 – 11:20	I. Oehme (Umweltbundesamt Dessau-Roßlau, Germany) *The European packaging regulation (PPWR) – New impetus for the circular economy of packaging*	
11:20 – 11:50	**Industrial Show-Cases**	
11:50 – 12:40	Lunch break	
	Biobased and Biodegradable Polymers	**Resource Efficiency und Sustainable Processing Technologies**
12:40 – 13:10	**Session Key Lecture** A. Mautner (BOKU University, Tulln an der Donau, Austria) *Multiple recycling of polyhydroxyalkanoates and PHA–wood composites*	**Session Key Lecture** B. Strehmel, V. Strehmel (PhoSuMa Photonic & Sustainable Materials GmbH, Annaburg/Germany) *Light-mediated crosslinking of green monomers with photoinitiators of the next generation based on sustainable processing technologies*
13:10 – 13:30	B. T. Hiller, D. Krieg, M. Nase, F. Puch (Hochschule Hof, Germany) *Wine by-products as sustainable additives for biopolyesters – Feasibility, reliability, optimization & transferability*	M. Moneke, K. Grünheide, E. Stuckert, H. Hofmann (Hochschule Darmstadt, Germany) *Development of high-impact grass fiber polypropylene composites*
13:30 – 13:50	I. I. Kleiber, C. K. Falkenreck, J.-C. Zarges, M. Nase, H.-P. Heim (Hochschule Hof, Germany) *Correlative fracture surface analysis of filled TPS/PBS blends using optical microscopy and micro-CT*	B. Tillner, S. Wüstenhagen, I. Jahn, P. Hirsch, M. Feldmann (Fraunhofer Institut für Mikrostruktur von Werkstoffen und Systemen, Halle/Germany) *Processing and analysis of sustainable continuous fiber-reinforced thermoplastic composites based on polyethylene terephthalate and carbon fibers*
13:50 – 14:10	M. Walther (Universität Oldenburg, Germany) *Sustainable polybutylene succinate production from organic waste*	M. Moreno (Hochschule Merseburg, Germany) *TiO_2 and ZnO atomic layer deposition as a biointerface foundry for antiseptic, regenerative, and immunomodulatory chitosan and polyamide scaffolds*
14:10 – 14:40	Break	
	Biobased and Biodegradable Polymers	**Polymer Characterization, Polymer Testing and Material Modelling (Additive Manufacturing)**
14:40 – 15:10	**Session Key Lecture** P. Marques de Farias, M. Schmid (Hochschule Albstadt-Sigmaringen, Germany) *Hydrothermal engineering and stearoyl chloride grafting of babassu films for enhanced barrier performance*	**Session Key Lecture** J. Stampfl (Technische Universität Wien, Austria) *Heterogeneous photopolymers for additive manufacturing*
15:10 – 15:30	S. Lüneburg, S. Wüstenhagen, P. Hirsch, M. Feldmann (Sustainable Solutions GmbH, Leipzig/Germany) *Bio-based polybutylene succinate as a sustainable material alternative: From raw materials to textile applications*	R. Sattler, R. Zhang, R. Androsch, M. Beiner (Martin-Luther-Universität Halle-Wittenberg, Halle/Germany) *About strategies to improve the quality of 3D printed parts made from semi-crystalline polymers*
15:30 – 15:50	R. Merijs Meri, J. Zicans, R. Berzins, R. Berzina, I. Bockovs, Z. E. Ribens, I. Reinholds, A. Zarins, L. Avotina, A. Petrovs (Riga Technical University, Latvia) *Protein fibers for thermoplastic bio-based insulation materials*	O. Neudert, H. Asghari (GMBU e.V., Halle/Saale) *Development and characterization of EMI shielding and foamable electrostatic dissipative filaments for additive manufacturing*
15:50 – 16:20	Break	
	Biotechnological, Chemical and Material-related Recycling	**Polymer Characterization, Polymer Testing and Material Modelling (Additive Manufacturing)**
16:20 – 16:50	**Session Key Lecture** C. Burgstaller (Fachhochschule Oberösterreich, Wels/Austria) *Recycling of short-fibre-reinforced thermoplastics*	**Session Key Lecture** T. Koch, F. Chalupa-Gantner, A. Ovsianikov, M. Lunzer (Technische Universität Wien, Austria) *It doesn't always have to be micro: Mechanical and thermo-mechanical properties of 2 PP processed macroscopic specimen*
16:50 – 17:10	P. Hirsch, S. Wüstenhagen, M. Feldmann (Fraunhofer Institut für Mikrostruktur von Werkstoffen und Systemen, Halle/Germany) *Recycling of bio-based polybutylene succinate – Current challenges and future prospects*	A. Narayanan Ramakrishnan, I. Ries, J. G. Zhang, S. Schwan (Hochschule Merseburg, Germany) *Toolpath-driven finite element simulation with melt-pool-focused adaptive mesh refinement and thermal remapping for high-fidelity FDM modelling*
17:10 – 17:30	B. Gerets, K. Engelsing, R. Schlutter (SKZ – Das Kunststoff-Zentrum, Würzburg/Germany) *Characterization of the environmental stress-cracking behavior of low-density polyethylene blends and recycled materials*	A. Narayanan Ramakrishnan, I. Ries, H. Ban, S. Schwan (Hochschule Merseburg, Germany) *AI-guided predictive adaptive mesh for finite element simulation of fused deposition modelling*
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18:00 – 19:00	Break (no coffee)	
19:00	**Networking Event**	

Day 2: 18/06/2026

Time	Session 1	Session 2
08:30 – 09:00	Registration	
	Plenary Lectures	
09:00 – 09:40	B. von Vacano (Vice President, Plastics Circularity Research BASF) *Pathways to circularity – Technology, economic and societal dimensions of polymer recycling from an industry perspective*	
09:40 – 10:20	V.-M. Archodoulaki (Technische Universität Wien, Austria) *Challenges and limitations of mechanical recycling of polymers*	
10:20 – 10:40	Break	
	Biotechnological, Chemical and Material-related Recycling	**Polymer Characterization, Polymer Testing and Material Modelling**
10:40 – 11:10	**Session Key Lecture** F. Morales, G. Campos, C. Ramirez, C. Rosales, A. Costantino, M. J. Galante, E. Agaliotis, V. Pettarin (INTEMA, UNMdP/CONICET, Mar del Plata/Argentina) *Innovative engineering strategies to enhance polymer sustainability*	**Session Key Lecture** J. Jůza, I. Fortelný (Institute of Macromolecular Chemistry, Prague/Czechia) *Polymer blends compatibilization using block copolymers. Recent modifications and copolymer contents*
11:10 – 11:30	C. Doerffel, M. Schreiter, M. Spieler, T. Swoboda, M. Richter (Steinbeis Innovationszentrum Automation in Leichtbauprozessen, Chemnitz/Germany) *Ultrasonic separation for recycling of hybrid components*	M. Kernbach, D. V. Dao, Z. Evgrafova, J. Noetel, M. Krause (Hochschule Merseburg, Germany) *In-situ investigation of laser swelling in polymers*
11:30 – 11:50	R. Berzins, R. Merijs Meri, J. Zicans (Riga Technical University, Latvia) *Development of recycled polypropylene composites with naturally occurring rapeseed waste modified with cardanol derivates*	M. Kovář, E. Nezbedová (DMKtech s.r.o., Prague/Czechia) *The use of sandwich samples to estimate the lifetime*
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	Biotechnological, Chemical and Material-related Recycling	**Polymer Characterization, Polymer Testing and Material Modelling**
12:40 – 13:10	**Session Key Lecture** D. Heymel, S. Schröter, T. Rothgänger, M. Seitz (Hochschule Merseburg, Germany)	**Session Key Lecture** A. Zankel, C. Mayrhofer, M. Nachtnebel, H. Fitzek, H. Schroettner (Technische Universität Graz, Austria) *Advances in ultramicrotomy for the microscopical and electron-microscopical investigation of polymeric materials*
13:10 – 13:30	H. T. Nguyen, H. Schmidt, M. Gadara, S. Gramsall, P.-T. Miclea (Martin-Luther-Universität Halle-Wittenberg, Halle/Germany) *Microplastic analysis in medical devices and biological samples using Raman spectroscopy and microscopy*	D. Schüsler, M. Wendt, O. Mashkov, D. Clark, O. Stroyuk, B. Jäckel, I. M. Peters, C. Buerhop-Lutz, A. Mordvinkin (Fraunhofer Institut für Mikrostruktur von Werkstoffen und Systemen, Halle/Germany) *Quantitative non-destructive monitoring of water ingress into polymer laminates*
13:30 – 13:50	M. Seitz, V. Cepus, L. Kuhle, M. Klätte (Hochschule Merseburg, Germany) *Potential and evaluation of solvolytic and solvent-based processes for recycling*	M. Sgraja, U. Giese, V. Cepus, J. Meier (Deutsches Institut für Kautschuktechnologie, Hannover/Germany) *Pressure dependence of viscosity in SBR compounds*
13:50 – 14:10	A. Rawal, D. Singh, S. Pandey, S. Shukla, A. K. Maurya, H. Saraswat, V. Khatkar, A. Kukovecz, T. Sykes (Indian Institute of Technology Delhi, New Delhi/India) *Mechanistic insights of microplastic release through fibre fragmentation*	H. Braune, T. Schülein, M. Wilhelm, J. Krückel (Karlsruher Institut für Technologie, Germany) *Effect of polypropylene (PP) impurities on the crystallization kinetics and tensile behavior of high-density polyethylene (PE-HD)*
14:10 – 14:30	C. Sandten, M. Kreyenschmidt (Hochschule Münster, Steinfurt/Germany) *VOC analysis of polyether polyol polyurethane soft foams as a proxy for autoxidative degradation*	M. Volf, M. Kovář, E. Nezbedová (Czech Technical University in Prague, Czechia) *Service life of PE-HD pipe types: Accelerated tests vs. structural evaluation*
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15:30 – 15:50	M. Sturm, M. Hogg, K. Eissenberger, J. F. Lübben, M. Schmid (Universität Albstadt-Sigmaringen, Germany) *From residual biomass to high-performance PEF Packaging: Scale-up pathways and food-contact demonstrators*	J. A. Rodríguez Agudo, D. Oppen, J. Haeberle, M. Biermann, M. Schäffler, J. Läuger (Anton Paar Germany GmbH, Ostfildern/Germany) *New perspectives for functional materials: Axial-torsional dynamic mechanical analysis meets Raman spectroscopy*
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16:10 – 16:30	V. K. Minupala (Hochschule Merseburg, Germany) *Bio-based and natural fibre reinforced plastics as sustainable lightweight sandwich structures for urban electric vehicles*	M. Hammermeister, E. Stuckert, I. Kibet, J. Schmidt, J. Wieser (Hochschule Darmstadt, Germany) *Influence of bulk density distribution in a hopper on the flow behavior of talc*
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Institut für Polymerwerkstoffe e.V. (IPW), Merseburg

Akademie Mitteldeutsche Kunststoffinnovationen (AMK), Merseburg

Polymer Service GmbH Merseburg (PSM)

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Challenges and limitations of mechanical recycling of polymers

Industrial Bioeconomy – From global to national – Hype or reality?

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The industrial bioeconomy combines innovative biotechnologies, sustainable raw materials, and new business models to use resources more efficiently and reshape value creation. This presentation analyzes the development from global vision to national implementation and examines whether the current hype reflects actual levels of realization. Key questions include: What drivers are accelerating the bioeconomy (policy, investment, technological advances, circular economy)? What barriers hinder scalable implementation (technology, regulation, market structures, supply chains, investment risks)? Global trends—research pipeline, international collaborations, trade and sustainability standards—are weighed against national strategies, infrastructure, skills shortages, and local value creation. Using case studies from biofuels, bio-based materials, agro- and food value creation, as well as digital platforms for innovation and collaboration, the presentation illustrates how political frameworks, funding landscapes, and metrics (life cycle assessments, emission reduction, life cycle costs) influence feasibility. Finally, scenarios for short, medium and long terms are presented, and recommendations for action are given to policymakers, industry and research to create a more resilient, sustainable bioeconomy.

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Multiple recycling of polyhydroxyalkanoates and PHA–wood composites

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Bio-based and biodegradable plastics are a key component of the sustainable use of polymer materials. However, biodegradability is not necessarily a desired property for many applications, nor is it the primary or ideal end-of-life (EoL) scenario. Recycling, particularly of biopolymers based on renewable raw materials, can be an approach to keeping carbon in the cycle for as long as possible—acting as a carbon sink—before it ultimately returns to the natural carbon cycle. Here, we have examined in more detail the fundamental possibility of (thermo-mechanical) recycling of polyhydroxyalkanoates (PHAs), particularly PHA–wood composites.

Hydrothermal engineering and stearoyl chloride grafting of babassu films for enhanced barrier performance

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Babassu mesocarp (*Attalea speciosa*), a Brazilian agro-industrial byproduct containing ~85 % starch, represents a promising resource for bio-based packaging materials [1]. However, its intrinsic hydrophilicity limits its application in moisture-sensitive systems [2].

A dual bulk–surface engineering strategy was employed, combining hydrothermal treatment (autoclave: 121 °C, 15 min; thermomixer: 90 °C, 30 min) with stearoyl chloride esterification to tailor the cohesion and surface polarity of babassu-based films (BF) [3]. Four formulations were investigated: BF-NANG, BF-NAG, BF-ANG, and BF-AG, where NA/A denotes non-autoclaved/autoclaved and NG/G denotes non-grafted/grafted. BF-AG exhibited the highest numerical tensile strength (TS) (7.6 MPa) and Young's modulus (YM) (49.5 MPa); however, TS, YM, and elongation at break (EB) differences were not statistically significant. In contrast, grafting induced statistically significant surface modifications, with total surface free energy (γ) decreasing from ~42 mN/m (BF-NANG, non-grafted) to ~25 mN/m (BF-AG, grafted) (Table 1).

Table 1: Mechanical properties and surface free energy of BF-based films.

Sample	TS (MPa)	EB (%)	YM (MPa)	γ (mN/m)
BF-NANG	6.9 ± 0.6^{ab}	15.6 ± 2.9^{a}	45.4 ± 4.6^{a}	41.9 ± 4.0^{a}
BF-NAG	6.0 ± 0.2^{b}	15.9 ± 3.4^{a}	38.1 ± 6.4^{a}	24.7 ± 0.8^{b}
BF-ANG	5.7 ± 0.7^{b}	13.7 ± 2.1^{a}	40.8 ± 5.4^{a}	42.3 ± 3.6^{a}
BF-AG	7.6 ± 1.0^{a}	15.9 ± 0.9^{a}	49.5 ± 3.8^{a}	24.9 ± 0.6^{b}

Values sharing the same superscript letter within a column are not significantly different (Tukey's test, $p < 0.05$).

The water contact angle increased from ~70° to ~107° in grafted films, accompanied by a significant reduction in surface energy and vapor permeability. These results indicate that surface esterification governs moisture-barrier enhancement, whereas hydrothermal treatment primarily contributes to matrix densification. This dual-modification strategy provides a scalable pathway to moisture-resistant bio-based packaging materials with maintained mechanical integrity.

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Natural fiber-based cellulose source, and modifications effect on thermal, morphological, micromechanical, and adhesion properties of different polymer composites

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Natural fibers from various plant sources (such as *Girardinia diversifolia, Gossypium arboretum, Agave sisalana, Bambusa nutans,* etc.) were collected, and fiber surface modification was carried out by various methods. The various composition composites of micro- and nano-cellulose fibers were prepared with different petro- and bio-polymer matrices (such as polypropylene, ecoflex, urea formaldehyde, resorcinol formaldehyde, polyvinyl alcohol, starch, proteins, etc.). The composites were mainly prepared by cross-polymerization followed by curing at 60–80 °C for 7 days. The samples were characterized by using Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), compressive tests, indentation hardness, thermogravimetric analysis (TGA), peel, and water absorption tests. This study anticipates perceiving the morphology and structural changes of natural fibers after chemical modification and pursuing the fiber loading effect on morphological, micro-mechanical, thermal, water absorption, and adhesion behaviors. Results showed that the treated fibers, as well as the source of fiber cellulose in composites, both in petro- and bio-, are found to be more compatible with the reduced water-holding capacity, improved thermo-mechanical and adhesion behaviours of composites than the neat fibers.

The fiber surface modification effects on composites are diverse in their morphological, micro-mechanical, thermal, adhesion, and water absorption behaviors. This is mainly because in treated fibers a large number of cellulose molecules are exposed towards the surface and hence the polar functional group bearing polymer matrix finds a large surface area for the interaction. Further, the use of compatibilizers is recommended for the homopolymer matrix composites. However, the water absorption effect is found to be reversed in biopolymer natural fiber composites as compared to the petro-based composites. The bio-based composite adhesives are useful for indoor applications, and many processing parameters and compositions have to be optimized for sustainable outdoor applications with high performance.

Keywords: Fiber modification, polymer composites, bio-composites, compatibilizers, polymer adhesives

Wine by-products as sustainable additives for biopolyesters – Feasibility, reliability, optimization & transferability

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Additives are often neglected when it comes to the investigation of sustainable materials. Especially the use of stabilizers requires closer examination, as conventional antioxidants have been criticized for being harmful to the environment and human health. A problem which can be solved using biogenic materials, containing natural functional substances like polyphenols. A biobased material with great potential to serve as a sustainable alternative to conventional additives is wine grape pomace (WP), a largely unused, low-value by-product of winemaking that is rich in natural antioxidants and available in large quantities worldwide.

This study provides detailed information on the general feasibility of using WP as a polymer antioxidant. It covers bio-additive preparation on an industrial scale and compounding using co-rotating twin-screw extrusion to incorporate WP into polybutylene succinate (PBS) at concentrations of up to 20 percent by weight (wt.-%). Thermogravimetric analysis (TGA) and dynamic oxidation induction temperature measurements (OIT) are used to analyze the thermal and thermo-oxidative stability of the resulting biocompounds. As WP is a natural material, reliability and quality assurance are addressed by examining WP from different varieties and vintages. Multiple bioanalytical methods are used to investigate annual variations of the biochemical properties. Based on OIT, a new method is developed to identify bioanalytical performance indicators, to enable the prediction of the bio-additive's efficiency. Finally, optimizing antioxidative effects through environmentally-friendly extraction is studied by comparing WP and its extracts with the conventional synthetic antioxidant Irganox® 1010 at concentrations of up to 5 wt.-%. In addition to PBS, polylactic acid (PLA) is used as a second matrix material to evaluate the transferability of the approach.

In summary, biogenic wine by-products represent promising alternatives to potentially toxic conventional stabilizers. A viable method to prepare bio-additives was found that preserves the functional character of WP. The thermo-oxidative stability of PBS was strongly increased and WP showed reliable stabilization effects independent of vintage and variety. Three bioanalytical performance indicators were identified, and the stabilizing efficiency was optimized by extraction, resulting in performance on par with the synthetic antioxidant. Furthermore, comparable results in PLA indicate good transferability. The results thus demonstrate an alternative bioeconomic approach based on the use of WP as a biogenic stabilizer, thereby contributing to the overall aim of a sustainable plastics industry.

Correlative fracture surface analysis of filled TPS/PBS blends using optical microscopy and micro-CT

Korrelative Bruchflächenanalyse von gefüllten TPS/PBS-Blends mittels Lichtmikroskopie und Micro-CT

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The growing demand for sustainable plastics has increased interest in bio-based and biodegradable materials. Starch is considered a particularly promising bio-based candidate, as it is regionally available, cost-effective and readily biodegradable. However, native starch cannot be thermally processed because its melting temperature exceeds its decomposition point. The addition of plasticizers, such as glycerin, reduces intermolecular interactions, lowers the glass transition temperature, and enables the production of thermoplastic starch (TPS). TPS can therefore be processed using conventional thermoplastic methods, such as compounding, extrusion or injection molding.

Despite these advantages, TPS has limited mechanical properties and poor dimensional stability, mainly due to its highly hydrophilic nature. To improve dimensional stability, TPS is often blended with polybutylene succinate (PBS) and reinforced with natural fillers such as hemp fibers. However, the fracture behavior of such reinforced TPS/PBS blends has hardly been investigated, especially regarding crack initiation, propagation and stable crack lengths (Δa).

Therefore, this work addresses this gap by using an instrumented notched-bar impact test (I-NBIT) with a stop block, which generates controlled, stable cracks. The fracture surfaces are analyzed using optical light microscopy, roughness profiling and X-ray micro computed tomography (µCT). Light microscopy enables rapid surface imaging and µCT allows non-destructive, three-dimensional reconstruction of the crack path. The correlation of these data sets allows quantitative characterization of the fracture surfaces and the derivation of a correction factor for accurate determination of the projected fracture surface.

Blends of waxy maize starch, plasticized with glycerin, combined with PBS and reinforced with 0, 10 and 15 wt.-% ground hemp fibers (HFm) are investigated. By combining the top-view optical assessment with roughness profiling, this work establishes a comprehensive methodology for the quantitative analysis of fracture surfaces in filled TPS/PBS blends and provides new insights into their fracture mechanics.

Sustainable polybutylene succinate production from organic waste

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The global annual production of fossil-based polyolefins such as polyethylene and polypropylene amounts to approximately 100 million tons and covers important applications in medical technology, the automotive sector, insulation materials, and packaging [1].

The project EcoPBS (Figure 1), funded by the BMFTR as part of the BioKreativ funding guideline, aims to create a fully bio-based and economically competitive alternative to these petrochemical plastics by producing polybutylene succinate (PBS) from organic waste streams. The project focuses on the development of a novel, cost- and energy-efficient fermentation process using the acetone–butanol–ethanol (ABE) and the succinic acid fermentation. The innovation of EcoPBS lies in an integrated fermentation and downstream processing strategy, including a purification technology that enables the production of 100 % bio-based PBS with an overall energy surplus while avoiding the common separation challenges associated with fermentation processes. Research efforts address process scalability, energy efficiency, and greenhouse gas reduction. First material prototypes are being prepared to demonstrate the great potential for application in areas such as medical products and technical components.

Figure 1: Circular approach for the production of 100 % bio-based PBS within EcoPBS

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Bio-based polybutylene succinate as a sustainable material alternative: From raw materials to textile applications

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The development of sustainable plastics requires a holistic view of the value chain, starting with the synthesis of monomeric precursors. Bio-based Polybutylene Succinate (PBS), a polyester composed of succinic acid and 1,4-butanediol, offers significant potential for defossilization. In current life cycle assessments, petrochemical-derived precursors represent a major environmental hotspot, as they significantly influence greenhouse gas emissions and the fossil resource consumption of the entire system. By utilizing innovative processes to obtain succinic acid from regional agricultural residues such as wheat straw, this footprint can be decisively corrected at the base. The life cycle assessment (LCA) demonstrates that substituting fossil-based components with bio-based alternatives significantly improves the environmental balance of PBS, positioning the material advantageously compared to established polymers.

In the Central Germany region, additional ecological synergies arise from the immediate proximity to raw material sources and synthesis plants, particularly through minimized transport distances. Although the production of the polymer is currently in a pilot phase and may show higher impacts in areas such as water consumption due to energy-intensive process steps like thermal drying and fermentation, prospective industrial scaling offers enormous efficiency gains. The investigation shows that with optimized process management and regional value creation, bio-based PBS provides an ecologically competitive answer to conventional, fossil-based thermoplastics.

The final stage of this analysis is the transfer to a specific end product in the form of a textile fabric. Compared to conventional fabrics made of polyethylene terephthalate (PET), the PBS fabric benefits from the sequestration of biogenic carbon and a significantly lower abiotic resource depletion. A key differentiating factor throughout the life cycle is also the excellent biodegradability of PBS. This reduces the risk of long-term pollutant accumulation in the environment, which is particularly relevant for textiles where fibers may be released unintentionally. Despite existing methodological challenges in quantitatively capturing biodegradability within standard life cycle assessments, the analysis underscores that PBS fabrics represent a sustainable alternative that combines mechanical recyclability with environmental safety, thus making an important contribution to the circular economy.

Protein fibers for thermoplastic bio-based insulation materials

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Naturally obtained protein fibers along with lignocellulosic fibers have a great potential to be used as perspective functional additives for development of sustainable biobased composites. Besides of high stiffness and strength, protein fibers own good moisture retention behavior as well as excellent heat insulation properties. Consequently, protein fibers have found large applicability in textile industry. However, large amount of protein fibers, such as meat sheep wool, are wasted because of unsuitability for qualitative textile production leading to wastage of valuable nature material.

This research report reveals potential of meat sheep wool waste (SWW) for sustainable use in production of novel bio-based composite materials. Main aim of the research is integration of SWW in the thermoplastic biopolymer composite developing sustainable insulation material, mainly for food or pharmaceutical industry. To achieve the aim commercially produced biobased polymers, such as polybutylene succinate (PBS) and polybutylene succinate-co-adipate copolymer (PBSA), have been used in combination with pure or modified SWW, nanostructured layered silicate filler and phase change materials obtaining hybrid composite materials with different SWW arrangement patterns, including bulk, layered and sandwich structures.

The obtained results confirm suitability of using SWW as reinforcing and insulative additive for development of a range of hybrid composites with nanoclay and different phase change materials.

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From residual biomass to high-performance PEF packaging: Scale-up pathways and food-contact demonstrators

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1 Introduction

Poly(ethylene furanoate) (PEF) is a bio-based, recyclable high-performance polyester with promising barrier and mechanical properties for food packaging. Owing to these characteristics, PEF offers considerable potential for material reduction and for the replacement of non-recyclable multilayer structures [1]. The work presented here addresses the transition from biomass-derived PEF towards scalable production and application-oriented packaging demonstrators, with the aim of increasing technology readiness and enabling piloting under industrially relevant conditions.

2 Integrated value-chain and demonstrator concept

The approach is based on an on-farm biorefinery concept in which heterogeneous residual and waste streams are converted into sugars and subsequently into 5-hydroxymethylfurfural (HMF). HMF is electrochemically oxidized to 2,5-furandicarboxylic acid (FDCA) and polymerized with bio-based monoethylene glycol to obtain PEF. The resulting polymer is processed into representative food-packaging demonstrators, including films, bags, injection-moulded cup prototypes and thermoformed cup structures based on extruded films. These demonstrators serve to assess functional performance, food packaging suitability and recyclability, while also supporting material selection, process optimization, and subsequent studies on barrier performance, application testing, and mechanical recycling. In parallel, the overall system is evaluated by life-cycle and techno-economic methods to identify hotspots and derive scale-up strategies.

3 Outlook

Taken together, the presented work contributes to the development of robust and scalable concepts for converting biomass-derived PEF into circular food-packaging solutions. The next steps will focus on transferring these findings into validated packaging demonstrators and on quantifying their sustainability and economic performance in comparison with fossil-based reference materials.

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Study of morphological and micromechanical deformation behavior of PBS/PLA blends reinforced with natural fibers

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Polybutylene succinate (PBS) and Polylactic acid (PLA) are biodegradable polymers with significant potential for sustainable applications. Reinforcing these blends with natural fibers can highly improve their mechanical performance. In this study, PBS/PLA blends were prepared with bamboo, Argeli, and hemp fibers utilizing microcompounding techniques. Structural features and blend morphologies were analyzed by Optical Microscopy (OM), Scanning Electron Microscopy (SEM), and Atomic Force Microscopy (AFM). The macroscopic and micro-mechanical properties were evaluated through tensile testing and hardness measurements. Compared to the neat PBS/PLA value, the natural fiber-reinforced blends demonstrated higher tensile strength, improved yield properties, and distinct failure modes. Among the different fibers utilized, Argeli-reinforced composites exhibited the best overall performance, showing superior strength and fracture resistance. Additionally, micromechanical deformation studies of the fracture surfaces revealed good insights into the fiber–matrix interfacial interactions. Overall, these results demonstrate clear processing–structure–property relationships and support the use of natural fiber-reinforced PBS/PLA blends in sustainable material design.

Keywords: Natural fibers, PBS/PLA blends, biocomposites, deformation behavior, micro-mechanical testing

Bio-based and natural fibre-reinforced plastics as sustainable lightweight sandwich structures for urban electric vehicles

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Increasing demands for climate protection, resource efficiency, and range are posing new challenges for urban electric mobility, which develops focus on lightweight design, sustainability and material efficiency. In lightweight vehicle construction, there is a growing need for materials that combine high mechanical performance with a significantly improved carbon food print. Therefore, transition to bio-based plastics and composites offers promising sustainable solutions for reducing greenhouse gas emissions and reliance on fossil resources. Bio-based plastics, derived from renewable biological sources such as plants, like polylactic acid (PLA), polybutylene succinate (PBS), bio-polypropylene (bioPP), bio-polyamide (bioPA) etc., align with sustainability targets and contribute to a circular economy. Bio-composites, which incorporate plant fibers or wood waste into conventional or bio-based polymer matrices, further enhance sustainability by utilizing abundant, renewable resources and reducing the environmental footprint of plastic products.

Figure 1: Natural fibre-reinforced thermoplastic foam demonstrator (IDberlin)

The lightweight construction of bio-based composites requires new manufacturing concepts that combine ecological requirements with industrial efficiency. Sandwich structures made of bio-based plastics and natural fibre-reinforced composites are becomes a promising solution, especially for structural applications in urban electric vehicles. In this aspect, the “Bio-Foam-NFK” research project is investigating novel manufacturing processes for sandwich

structures using foam injection molding process. For the first time, physical foaming combined with core-back technology is being tested for bioplastics and natural fibre-reinforced composites. The resulting fully automated production concept combines thermoplastic foam injection molding with the integration of functional elements directly into the component. This approach enables the production of complex structural components with a high degree of functional integration and significantly reduced weight.

However, the new materials and manufacturing processes always pose challenges, such as reproducibility, identifying influencing process parameters, control over the foaming percentage in relative to specific mechanical properties-to-weight ratio. These are examined using CAE tools before going into the design and development of the component, which reduces time and increases efficiency. With an added advantage of interoperability between processing simulation with Moldex-3D and structure simulation with LSDyna, the process data like local foam properties and local fibre orientation can mapped on to the part and considered for its structural performance under static and dynamic loading cases.

B. Strehmel, V. Strehmel
Light-mediated crosslinking of green monomers with photoinitiators of the next generation based on sustainable processing technologies

M. Moneke, K. Grünheide, E. Stuckert, H. Hofmann
Development of high-impact grass fiber polypropylene composite

B. Tillner, S. Wüstenhagen, I. Jahn, P. Hirsch, M. Feldmann
Processing and analysis of sustainable continuous fiber-reinforced thermoplastic composites based on polyethylene terephthalate and carbon fibers

M. Moreno
TiO_2 and ZnO atomic layer deposition as a biointerface foundry for antiseptic, regenerative, and immunomodulatory chitosan and polyamide scaffolds

Light-mediated crosslinking of green monomers with photoinitiators of the next generation based on sustainable processing technologies

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Light efficiently operates as a reagent and tool for crosslinking of epoxy and/or methacrylate-comprising monomers [1–5]. Recently, monomers derived from green sources have received remarkable attention. High-power LEDs emitting between 350–1050 nm or NIR lasers with a line-shaped focus have operated in distinct applications. The latter has opened a new technological field; that laser drying of coatings. These new photonic technologies have facilitated the replacement of old energy-wasting oven technologies with. Oven technologies use only 1–2 % of the introduced thermal energy for the chemical/physical process. In contrast, the technologies operating with light are much more efficient. Light operates where it is absorbed and needed, resulting in significant energy saving.

Systems that tolerate the inhibition of oxygen in radical polymerization have received additional attention, particularly in technologies that require a high throughput in distinct production lines. Society also demands to establish initiating systems with toxicological issues on the market. Systems based on heterogeneous habitus, namely carbon dots and new, homogeneous, multi-component photoinitiators represent promising alternatives. These new structural approaches improved mechanical properties of the material obtained as shown by DMA data. These new directions have opened new fields; that is sustainable photopolymerization and photothermal crosslinking. Examples of powder coatings using line-shaped focused lasers and LED drying of aqueous reactive dispersions demonstrate the practicality in various applications. These systems also have the potential to serve as PFAS alternatives in certain cases.

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Development of high-impact grass fiber polypropylene composites

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In a recent research project the goal was to develop a compound based on polypropylene and on regionally growing permanent grassland grass with increased strength, stiffness and especially impact strength. Permanent grassland grass (PGG) is the term for a variety of plants on meadows which are not plowed but mowed 1–3 times a year. So, while biodiversity is fostered by utilizing PGG the variety of plants poses a challenge for plastic compounds which shall have specified properties.

For compounding a feeding system for the fermented, washed, dried and cut PGG was developed [1]. The compounding process on a co-rotating twin-screw extruder was optimized including atmospheric and vacuum degassing. Compounds containing PGG with a mass content of 30 %, different coupling agents and impact modifiers with mass contents from 0 to 7 %, virgin and recycled polypropylene, and wax haven been investigated. The melt flow rate of the compounds has been measured after initial compounding and after up to 6 cycles of recycling. From the compounds samples have been injection molded. Tensile and impact tests have been performed on these samples and the morphology has been investigated by optical and electron microscopy. Furthermore, a test to characterize the flexibility of individual fibers has been developed [2, 3].

With the addition of the PGG fibers the tensile strength and the tensile modulus increase slightly. It can be shown that the coupling agents have the strongest influence on the impact strength which could be increased from 13 up to 19 kJ/mm², while the addition of impact modifiers alone does not change the impact strength significantly. Repeated recycling increases the melt flow index and the impact strength at the same time suggesting that polymer chains are shortened while the coupling of the PGG fibers to the matrix is still intact and that adhesion at the interface is the main reason for the increased impact strength [4, 5].

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Processing and analysis of sustainable continuous fiber-reinforced thermoplastic composites based on polyethylene terephthalate and carbon fibers

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Lightweight construction materials suitable for recycling are the basis of future-oriented application developments for many market sectors. Unidirectional continuous fiber-reinforced thermoplastic semi-finished products (UD tapes) can fulfil this demand. They combine recyclability with high mechanical property potential and the possibility of being functionalized for specific applications. Thus, innovative material combinations are investigated to make these high-performance materials accessible to a broader market [1, 2]. In addition to the possibility of using a wide variety of reinforcing fibers, the use of application-specific and recyclable matrix polymers is of essential importance for future market relevance. Especially by using renewable resources, the demand for ecological sustainability can be achieved.

In this study, the substitution of a continuously fiber-reinforced thermoset composite material for wind turbine rotor blades with a thermoplastic alternative based on polyethylene terephthalate (PET) and carbon fibers was investigated. The focus was on the process development of the continuous melt impregnation and the investigation of the resulting UD tape quality depending on the matrix polymer used. For this, different grades of virgin PET, recycled PET, and bio-based PET have been investigated. Comprehensive microstructural, rheological, and destructive mechanical investigations allowed a detailed correlation between process parameters and the resulting microstructure of the UD tapes as well as the associated mechanical properties. Accompanying process methods of inline diagnostics allowed the qualitative evaluation already during the ongoing process of manufacturing and served to directly optimize process parameters for tape widths of 50 and 100 mm. Additionally, the environmental impacts of the biological and fossil-based feedstocks were examined in various technically feasible recycling stages for the PET matrix in an exploratory life cycle assessment.

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TiO_2 and ZnO atomic layer deposition as a biointerface foundry for antiseptic, regenerative, and immunomodulatory chitosan and polyamide scaffolds

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Atomic Layer Deposition (ALD) has emerged as a powerful platform for rewriting the structure and function of polymers at the atomic scale. In this talk, I present ALD as a biointerface foundry capable of transforming chitosan and polyamide 6 (PA6) into multifunctional, metal oxide–hybrid scaffolds with programmable biological responses. By systematically comparing vapour phase metalation (VPM), multiple pulsed infiltration (MPI), and O_2 plasma enhanced ALD (PEALD), we uncover how each process dictates metal penetration depth, polymer restructuring, crystallinity, and interfacial energetics. Ti and Zn functionalized chitosan films exhibit tunable semiconductor behaviour, wettability, and antibacterial activity, while maintaining high C2C12 cell viability. In PA6, ALD drives deep hybridization (up to 180 nm in VPM), phase selective crystallite evolution, and controlled solid–liquid interfacial energies that modulate cell adhesion and bacterial inhibition. Across both polymers, PEALD enhances swelling and bioactivity, MPI amplifies nucleation driven antisepsis, and VPM promotes uniform hybrid interphases with superior biocompatibility. In vivo results reveal that ALD engineered ZnO–chitosan interfaces can actively modulate inflammation and angiogenesis, demonstrating the potential of atomic scale design to influence immune pathways. Together, these findings position ALD as a modular, chemistry agnostic strategy for activating antiseptic, regenerative, and immunomodulatory functions in polymeric biomaterials, opening a pathway toward the next generation of intelligent implants and sustainable biointerfaces.

Keywords: Atomic Layer Deposition (ALD), Chitosan, Polyamide 6 (PA6), TiO_2 and ZnO coatings, Biointerfaces, Antiseptic scaffolds, Regenerative biomaterials.

Biotechnological, Chemical and Material-related Recycling

C. Burgstaller
Recycling of short-fibre-reinforced thermoplastics

F. Morales, G. Campos, C. Ramirez, C. Rosales, A. Costantino, M. J. Galante, E. Agaliotis, V. Pettarin
Innovative engineering strategies to enhance polymer sustainability

D. Heymel, S. Schröter, T. Rothgänger, M. Seitz
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B. Gerets, K. Engelsing, R. Schlutter
Characterization of the environmental stress-cracking behavior of low-density polyethylene blends and recycled materials

C. Doerffel, M. Schreiter, M. Spieler, T. Swoboda, M. Richter
Ultrasonic separation for recycling of hybrid components

R. Berzins, R. Merijs Meri, J. Zicans
Development of recycled polypropylene composites with naturally occurring rapeseed waste modified with cardanol derivates

H. T. Nguyen, H. Schmidt, M. Gadara, S. Gramsall, P.-T. Miclea
Microplastic analysis in medical devices and biological samples using Raman spectroscopy and microscopy

M. Seitz, V. Cepus, L. Kuhle, M. Klätte
Potential and evaluation of solvolytic and solvent-based processes for recycling

A. Rawal, D. Singh, S. Pandey, S. Shukla, A. K. Maurya, H. Saraswat, V. Khatkar, A. Kukovecz, T. Sykes
Mechanistic insights of microplastic release through fibre fragmentation

C. Sandten, M. Kreyenschmidt
VOC analysis of polyether polyol polyurethane soft foams as a proxy for autoxidative degradation

Recycling of short-fibre-reinforced thermoplastics

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Materials recycling of thermoplastic polymers is a viable route to save CO_2 emissions and virgin raw materials, and it is applied to different products, from polyethylene terephthalate (PET) bottles to polyethylene (PE) films. While these materials show good behaviour in recycling, more complex mixtures, like multilayer materials, are also inherently more complex to recycle. In this work, we focus on another more complex material – specifically fibre-reinforced thermoplastics. While the thermoplastic matrix renders these materials inherently recyclable, the fibres pose some serious challenges in the recycling process. On the one hand, melt filtration tends to be more complicated or simply impossible, and on the other hand, fibre length reduction is directly linked to property degradation of the short-fibre composites.

Therefore, the aim of this work is to investigate the influencing factors of fibre length degradation in different processing steps, i.e. twin-screw extrusion and injection moulding, and their effects on the final composite properties. We show that recycling is possible by reprocessing, if the processing parameters are adjusted properly. Also, the use of additives and reinforcements can improve the composite properties, to prolong the possible recycling loops for such materials.

Innovative engineering strategies to enhance polymer sustainability

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The widespread use of polymeric materials has significantly improved modern technologies due to their versatility, durability, and low cost. However, their rapid expansion has also generated increasing environmental concerns, mainly due to inadequate waste management and limited recycling of post-consumer plastics. In this context, the transition toward a circular economy has emerged as a key strategy to improve polymer sustainability by reducing waste, recirculating materials within industrial systems, and promoting environmentally compatible alternatives. This work summarizes research carried out by our group aimed at advancing polymer circularity through three complementary strategies, all included in the butterfly diagram (Figure 1): the development of self-healing polymers to extend material lifetime, the recycling and upcycling of complex plastic waste streams, and the design of biodegradable polymer composites.

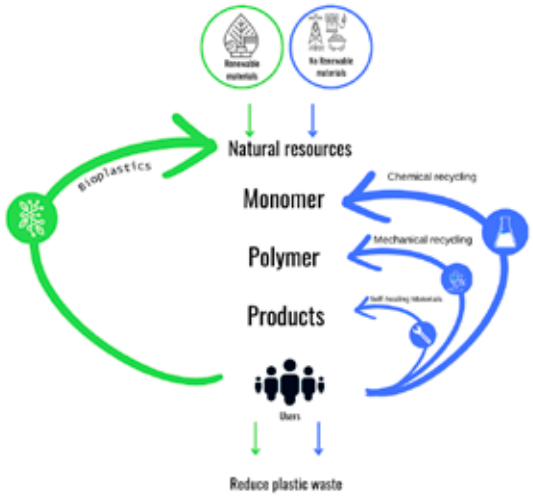

Figure 1: Adaptation of the butterfly diagram to polymer flow, see: https://www.ellenmacarthurfoundation.org/circular-economy-diagram

The first strategy focuses on photoresponsive self-healing polymers based on azobenzene-modified epoxy–amine networks. Azobenzene chromophores undergo reversible trans–cis photoisomerization under ultraviolet (UV) irradiation, enabling localized molecular mobility

that facilitates crack closure. Rheological and mechanical analyses reveal reversible photo-softening during irradiation, followed by recovery of the original properties once the stimulus is removed. Microscopy and nanoindentation confirm partial restoration of surface integrity after damage [1]. This concept has also been applied to protective coatings for metallic substrates, where light-activated healing improves durability and corrosion resistance [2].

A second research line addresses the recycling and valorization of complex plastic waste streams, particularly multilayer packaging and mixed polyolefin fractions. Mechanical upcycling strategies such as *in situ* microfibrillation of polyethylene/ethylene vinyl alcohol copolymer (PE/EVOH) blends [3], recycling of polypropylene/aluminum (PP/Al) multilayer packaging into functional particles [4], and the incorporation of ground tire rubber into linear low-density polyethylene/polypropylene (PE-LLD/PP) blends [5] significantly improve toughness and ductility.

The third strategy explores biodegradable composites based on polylactic acid reinforced with natural fibers. Even at low fiber contents, these materials show improved fracture toughness due to fiber pull-out and plastic deformation mechanisms, while fibers also act as nucleating agents affecting crystallinity and thermal behavior [6].

Overall, these approaches highlight the potential of combining advanced material design, innovative recycling strategies, and bio-based composites to support the transition toward a circular polymer economy.

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Catalytic cracking of plastic waste in a continuous scale

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The use of catalysts is an efficient method for improving the cracking of polyolefins in pyrolysis. One advantage of catalytic cracking is a high gas yield with high proportions of ethylene, propylene, butenes and aromatic compounds [1–3]. The gases produced during catalytic cracking can be easily purified using absorption techniques and fed directly into the steam cracker downstream. In contrast to the use of pyrolysis oils, this ideally eliminates the need for hydrogenation to remove heterocomponents and further steam cracking to produce monomers [3].

However, the recovery and regeneration of the powder catalysts is a major problem. For this reason, low-cost catalysts are used in small quantities, which then remain as waste in the solid residues [3, 4].

To use catalyst which can be separated from solid residues to be recycled, supported catalyst systems were formulated and tested in this work. The aim was to develop a catalyst system with low pore diffusion limitation that is similar in activity to the pure powder catalysts. The supported catalyst systems were tested in a rotary kiln in batch operation with pure PE and defined plastic waste fractions. Reference measurements with catalyst powder were carried out for comparison.

Suitable catalyst systems were then produced on a pilot scale and tested in a continuous reactor at temperatures between 450 and 600 °C. Various fractions from the sorting system were used as plastic-containing residues. These included fractions for refuse derived fuel (RDF), film sorting residues, and polyolefin flakes (MPO). The ratio between catalyst and reactant was between 1:5 and 1:50. The reactor throughput was between 0.25 and 1 kg/h. The products were analyzed using gas chromatography and elemental analysis.

A supported catalyst with no pore diffusion restriction and high activity was identified on a batch scale. The production of this supported catalyst on an industrial scale was successful. Yields of over 70 % of high-value chemicals (ethylene, propene, butene, volatile aromatic hydrocarbons (BTEX)) were achieved in a continuous cracking reactor. By-products such as saturated hydrocarbons can be used in a steam cracker. Tar and coke formation was less than 10 %, enabling yields of high-value chemicals of over 80 %.

The results show that efficient chemical recycling is possible through the use of catalysts. The authors would like to thank the BMFTR for its support as part of the KuRT research program (FKZ 033R388A).

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Recycling of bio-based polybutylene succinate – Current challenges and future prospects

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Bioplastics promise a more sustainable alternative to conventional plastics, but their recycling is often complex. Key challenges compared to conventional plastics include differences in waste infrastructure, sorting difficulties due to varying polymer and additive systems, degradation processes during use and recycling, contamination risks, and economic and environmental considerations along the value chain. In addition to technical aspects, political, regulatory, and standardized frameworks must also be considered, such as labeling requirements, recycling quotas, and life cycle assessments. Future prospects include optimized collection systems and sorting technologies, new recycling technologies, and combined upcycling strategies that preserve material value and functionality.

This study provides an overview of the current state of the recycling of bio-based polybutylene succinate (PBS). A case study on industrial sorting and material recycling is presented, success factors and obstacles are analyzed, and a roadmap for a more sustainable recycling landscape is outlined, including trans-disciplinary approaches from material development to disposal logistics.

Characterization of the environmental stress-cracking behavior of low-density polyethylene blends and recycled materials

Charakterisierung der umgebungsbedingten Spannungsrissbeständigkeit von Polyethylen-Mischungen und -Rezyklaten niedriger Dichte

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The transformation from a linear to a circular economy as well as a responsible use of resources constantly gains higher priority. Therefore, it is crucial to have reliable test methods for recycled materials which can be understood as material blends. In case of virgin polyethylene mono-materials several material or application focused test methods are established. But it is a question whether and how they can be used to characterize blends and recycled polyethylene materials.

Following an experimental approach, the applicability of the strain hardening test [1] and full-notch creep test [2] were thoroughly investigated. Hence, different low-density polyethylene materials were systematically blended with numerous mixing ratios to generate artificial recyclates. Testing parameters as well as evaluation procedures were checked and, if necessary, modified. A model to forecast the environmental stress-cracking behavior of poly-ethylene blends, respectively recycled materials, based on the properties of the incorporated components was developed. As a last step, recycled polyethylene material was mixed with a virgin grade and evaluated with regard to the stress-cracking resistance based on the former findings.

Overall, the possibilities and limitations of two test methods based on fundamentally different approaches (scale-shifting [1] vs. accelerated stress-cracking [2]) were evaluated in terms of stress-cracking resistance characterization of low-density polyethylene blends and recycled materials. Fracture surface analysis and dynamic scanning calorimetry were used for in-depth considerations. Finally, a model for stress-cracking resistance forecasting was derived.

Acknowledgement

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Ultrasonic separation for recycling of hybrid components

Ultraschalltrennverfahren zum Recycling von Hybridbauteilen

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Hybrid components of textiles and plastic parts offer a wide range of applications from knitting-needles to truck-battery-handles. The use of different plastic types or even different materials for the joined parts of the hybrid component (ref. Figure 1) is a challenge for the recycling of industrial and post commercial waste.

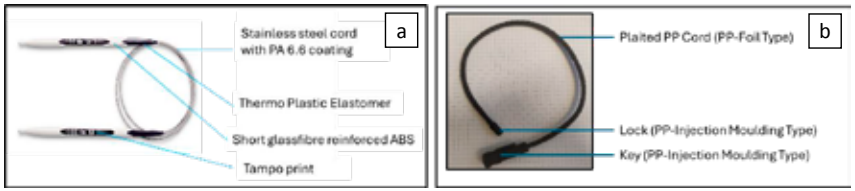

Figure 1: Examples of hybrid components with textile parts: a) multi-material knitting needles, b) truck-battery-handle of two PP-types

For an efficient mechanical recycling process, that avoids an unnecessary increasement of the entropy [1], it is necessary to separate the components before the recycling process to avoid mixing and polluting the plastics [2]. The complete separation of the parts firmly bonded in the production, should avoid thermo-oxidative damage of the material as much as possible [3]. Therefore, a local melting of the plastic based on inner friction instead of heat transfer by contact, convection or infrared-radiation is an innovative and efficient way to solve the firm bonding. Ultrasonic vibrations, as used for welding plastic parts, are a technology providing the opportunity to heat up the material at the interface of the parts.

The paper describes an experimental setup for to separate hybrid components with ultrasonic vibrations and mechanical tension. Truck-battery-handles made of injection-molded Polypropylene (PP) and a cord, plaited of PP foils, is used as reference object for the technology. In order to provide reliable data for the separation process the forces to pull out the cord have been measured and **O**xygen-**I**nduction-**T**ime analyses (OIT) [4] of all parts of the hybrid component where made.

Furthermore, the complete recycling chain from the waste part to the new part has been considered and depicted in lab-scale processes. Especially the treatment of the plastic after the separation process has been analyzed in order to characterize the influence of plastic processes on the material in comparison to the new separation process.

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Development of recycled polypropylene composites with naturally occurring rapeseed waste modified with cardanol derivates

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Nature and industry generate many potential resources, that could be used as raw materials for development of new polymers or composites. One of the natural resources that is not enough efficiently used is the residues of various plants after harvesting. In the current work we used residues after harvesting rapeseed as one of the most common crops in Latvia and all Europe, which is important because considerable material resources are required to make production efficient at industrial scale. During the work the focus was on the use of recycled and naturally renewable materials (recycled polypropylene, rapeseed straw and cardanol derivates).

The results obtained in the work show that the synthesized cardanol-modified rapeseed straw fillers which were integrated into the recycled polypropylene significantly affect mechanical properties, oxidative stability at elevated temperatures, and water absorption behaviour of the composites. The composite materials with the chemically modified fillers show 2,000 % higher tensile deformations, as well as 50 % higher impact strength values, the water absorption of the composite materials is reduced by 150 %, and the material also maintain its oxidative stability at the temperatures 20 °C higher, comparing to the composite materials in which chemically unmodified rapeseed fillers are used. The relevant improvements allow the obtained composite material to be used in various industries where ultraviolet stability and resistance to aqueous environments are required, such as outdoor coatings, panels, etc.

Microplastic analysis in medical devices and biological samples using Raman spectroscopy and microscopy

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Medical devices are widely manufactured from polymeric materials. Mechanical stress, sterilization procedures, and chemical exposure may lead to the release of microplastic particles from these materials. Understanding the occurrence, composition, and potential transfer of such particles is important for evaluating potential patient exposure.

Within this research, several sample series were investigated to assess microplastic release from polymer-based medical devices. These include contact lenses as examples of everyday medical products, pre-bypass filters from heart–lung machines representing clinical devices, and tracheal cannulas subjected to cleaning and sterilization procedures. Across all investigated systems, polymer particles were detected, indicating that microplastic release can occur in different types of medical environments. These systems were therefore examined as potential sources of polymer particle release associated with medical device use and processing.

Figure 1 presents the Raman analysis used to identify microplastic residues, with each mapping comprising 1,000–2,000 spectra. Microplastic particles originating from the tracheal cannula (Figure 1a) were analyzed and subsequently classified using a CNN-based spectral approach (Figure 1b). The results indicate that PU, PE, and PVC are the predominant polymers detected. This integrated method enables rapid and reliable polymer identification across large and complex datasets, making it particularly well suited for medical environments.

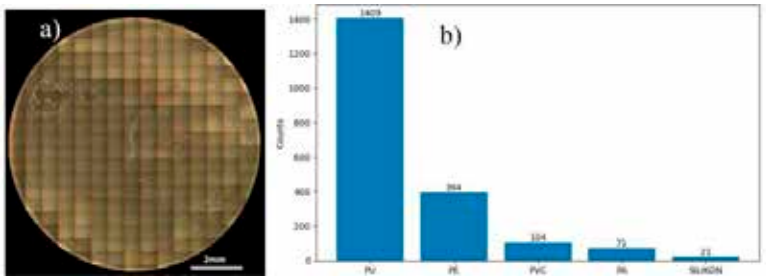

Figure 1: Raman analysis of microplastic from the tracheal cannula

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Potential and evaluation of solvolytic and solvent-based processes for recycling

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Plastics recycling is part of the European Action Plan for the Circular Economy and part of the European Green Deal, which aims to achieve net-zero emissions by 2050 and decouple economic growth from resource consumption. However, only a small fraction of the processed plastic waste is actually turned into recycled materials. In 2023, 12.85 mio. t/a plastics were processed in Germany, 5.58 mio. t/a of post-consumer plastic waste were collected, and only 1.95 mio. t/a of recycled materials are produced [1]. The share of recyclates used in production is 15.2 %. Solvent-based processes and chemical recycling technologies such as solvolysis are expected to increase the amount of recycled waste streams. A study was carried out for the German Federal Environment Agency to analyze the opportunities and limitations of these technologies.

The main reason for poor recycled materials today are heavily contaminated material streams, which can only be processed for mechanical recycling at great expense. However, the quality of the recycled materials is also a problem. Mixing with other plastics and additives often means that the quality of the primary materials is not fully achieved. When comparing these different processes the quality of the waste streams have to be taken into account. According to this, typical processes for specific applications were investigated and compared with regard to energy consumption and greenhouse gas (GHG) emissions. For Solvent-based processes polyethylene (PE) and polystyrene (PS) recycling and for solvolysis polyurethane (PU), polyamide 6 (PA6) and polyethylene terephthalate (PET) recycling processes were examined and compared with thermochemical processes [2] and mechanical recycling. The latter has the lowest energy consumption and GHG emissions. It is followed by processes such as the solvolysis of PU, which do not require the evaporation of solvents. The solvolysis of polyamide 6 with steam also has low energy consumption and GHG emissions because the solvent remains in the vapor phase, whereas in the solvolysis of PET, the separation of glycol/water (evaporation) increases energy consumption and GHG emissions. The energy consumption for liquefaction and pyrolysis is due to the cracking reaction and the complex pyrolysis oil treatment and use in the steam cracker. Liquefaction and pyrolysis thus had higher GHG emissions than the solvent-based and solvolytic processes. However, mixed, primarily polyolefin plastic waste can be used in thermochemical processes, whereas solvent-based processes and solvolysis require more defined or single-type waste with little foreign matter content for economic reasons.

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Mechanistic insights of microplastic release through fibre fragmentation

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Microplastic fibre release from textiles is increasingly recognised as a major source of environmental contamination [1]. However, predictive frameworks that link textile structure and mechanical degradation to fibre emission remain limited. Most existing studies rely on empirical measurements without establishing a mechanistic connection between use-phase loading conditions and the micromechanical processes governing fibre liberation.

In this study, a physically based model is developed to quantify microplastic release from woven fabrics by considering fatigue-driven fibre pull-out and fragmentation [2]. The framework captures progressive damage in constituent fibres subjected to repeated cyclic loading associated with laundering, abrasion and handling.

Figure 1 shows a comparison of number of microplastic fibre release per gram of fabric with and without abrasion, respectively.

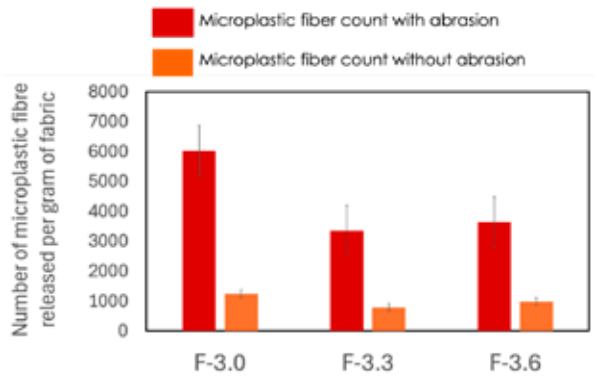

Figure 1: Number of microplastic fibre release per gram of fabric with and without abrasion

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VOC analysis of polyether polyol polyurethane soft foams as a proxy for autoxidative degradation

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Flexible polyurethane (PUR) foams contribute to volatile organic compound (VOC) emissions and odor, affecting product durability and indoor air quality. Conventional chamber tests provide only a snapshot of acute emissions, strongly influenced by cell structure, temperature, storage conditions, and surface-to-volume ratio. They cannot distinguish between pre-existing contaminants and VOCs formed by thermo-oxidative degradation and therefore offer limited guidance for targeted material development.

We applied a flow-through method in which PUR soft foam specimens are exposed to a controlled gas flow at defined temperatures (typically 65–155 °C). The gas stream is directed through the foam, ensuring convective transfer of volatiles from the entire material volume to the outlet. VOCs are sampled using Tenax thermodesorption tubes and dinitrophenylhydrazine (DNPH) cartridges and analyzed by thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS) and high-performance liquid chromatography (HPLC), respectively. By varying oxygen content and temperature, VOCs from initial load, hydroperoxide decomposition, and autoxidation are differentiated, allowing kinetic evaluation that is largely free from diffusion artefacts.

Polyether polyols used in the foams form hydroperoxides upon exposure to air. During foam production, these hydroperoxides decompose, generating additional VOCs, and are subsequently re-formed in the foam under oxidative conditions. The flow-through setup enables quantitative tracking of these processes by monitoring the temporal evolution of oxidation products. We identified polyether soft segment degradation as the dominant source of carboxylic acids, formates, acetates, α-hydroxy-ketones, (unsaturated) aldehydes, substituted dioxolanes and dioxanes, glycols, and allyl ethers, while hard segment degradation yields aromatic amines and benzoxazoles. Steady, nearly linear increases of peak areas with sampling time confirm that oxidatively formed analytes are continuously released and can be quantified reproducibly over a wide range of emission rates. By comparing formulations with different isocyanate index and polyol structure, we correlate foam composition with oxidation rate, activation energies of key marker compounds, and long-term emissions of critical VOCs such as formaldehyde, acetaldehyde, and acrolein. The method thereby bridges molecular degradation mechanisms with macroscopic emission behavior and toxicological relevance.

The presented flow-through approach provides a comprehensive, mechanism-based assessment of oxidation and VOC emissions from flexible PUR foams. In contrast to conventional chamber tests, it distinguishes between contaminants and degradation products, enables reliable total VOC quantification, and allows accessible kinetic studies under well-defined conditions. The method supports the evaluation of raw materials and stabilizers, the comparison of different polyether polyols, and the optimization of foam formulations for improved oxidative stability, reduced emissions, and enhanced product durability.

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Detecting variability in the flow behaviour of mineral fillers: A powder rheology-based approach to assess batch, handling, and environmental effects

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Influence of bulk density distribution in a hopper on the flow behavior of talc

Heterogeneous photopolymers for additive manufacturing

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Most photopolymers used in lithography-based additive manufacturing (AM) are typically brittle materials with thermoset characteristics which limits their use in engineering applications, despite the excellent surface quality and feature resolution. A promising approach for toughening such material is to use photopolymer induced phase separation (PhIPS) which yields heterogeneous microstructures with hard and soft domains. Such heterogeneous morphologies can prevent crack growth and initiate small- or large-scale yielding, respectively.

By additionally adding oligomers with high molecular weight and pronounced intermolecular forces (e.g. hydrogen bonds), fracture toughness and ductility can further be increased while glass transition temperatures of 100 °C and above can be maintained. Using AM approaches which allow processing of the resulting high-viscosity formulations (e.g. HotLithography), these materials can be 3D-printed with resulting excellent thermomechanical and geometric (precision, surface quality) properties. Using atomic force microscopy (AFM) and high-resolution scanning electron microscopy (SEM), the obtained microstructures can be characterized and related to the macroscopically measured values.

It doesn't always have to be micro: Mechanical and thermomechanical properties of 2 PP processed macroscopic specimens

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Two-Photon Polymerisation (2 PP) as a direct laser writing method becomes more and more popular in the field of micro fabrication due to its high resolution (feature size about 100 nm) and the feasibility to generate complex parts. A drawback of the 2 PP process was the long fabrication time which limited the application to the field of micro-sized parts. Therefore, also the characterisation of the mechanical properties of 2 PP structured specimens needed micro testing methods. Advances in the 2 PP technology, mainly in the machine hardware field, allow to produce parts in the size of several millimeters to centimeters and consequently the fabrication of meso- and macro-sized specimens which can be tested with common and/or standardized testing methods available in conventionally equipped polymer testing labs. This is one cornerstone for a prospective expansion of the 2 PP technology to a broader industrial application. Examples of the characterisation of mechanical, thermomechanical and fracture properties of 2 PP processed materials will be shown.

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Polymer blends compatibilization using block copolymers. Recent modifications and copolymer contents

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In a series of papers, we dealt with decreasing of the interfacial tension between polymer blends component using addition of a block copolymer with units identical or compatible with individual homopolymers in the blend [1]. Here, we would like to present the dependence of the results published in our paper [2] on copolymer contents in the blend.

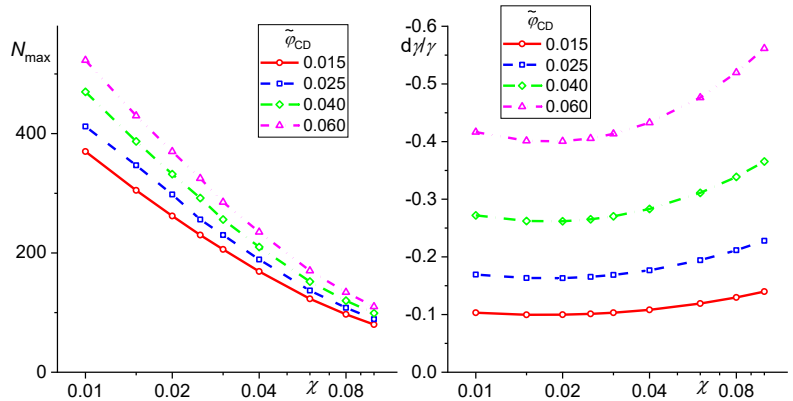

Figure 1: Maximal compatibilization effect (right) and copolymer length N_{max} where it occurs (left) as function of Flory-Huggins interaction parameter χ between blend components for 4 values of block copolymer reduced volume content in the blend $\tilde{\varphi}_{CD}$. Homopolymers consisted of 120 segments each, drops volume fraction in the blend 0.3.

With increasing interaction parameter χ, the maximal compatibilization efficiency occurs for shorter copolymers, and it is weakest for some χ value (0.02 for the presented system) that does not depend significantly on the copolymer content. Both dependences on χ are more pronounced for higher copolymer content.

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Advances in ultramicrotomy for the microscopical and electron-microscopical investigation of polymeric materials

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Microscopy is a relevant technique for the characterization of polymeric materials. For the precise preparation of different types of specimens ultramicrotomy is mandatory, which uses diamond knives for the manufacture of thin lamellae or smooth block-faces [1]. Several new developments are relevant for the investigation of special properties of materials.

The ultra-sonic oscillating diamond knife (Diatome, Switzerland) enables the production of ultrathin sections with exceptional precision. Fine structural features can be preserved during cutting specimens at room temperature, which typically require the use of cryo-ultramicrotomes.

The combination of ultramicrotomy and scanning electron microscopy (SEM) facilitates three-dimensional investigations of soft matter materials. A schematic of the integration of an ultramicrotome in an SEM (serial block-face scanning electron microscopy, SBF-SEM, or *in situ* ultramicrotomy) can be seen in Figure 1. An ultramicrotome is located below the electron column of an SEM, a specimen is cut slice by slice and of each new block-face an SEM image is stored. From the resulting stack of images three-dimensional reconstructions of materials can be obtained with the appropriate software tools [1]. Furthermore, these reconstructions can be the starting point of the simulation of different material properties.

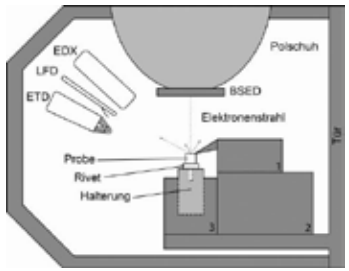

Figure 1: Schematic of an *in situ* ultramicrotome; ETD: Everhart Thornley detector (secondary electrons, SE); LFD: large field detector (SE); EDX: EDX detector (EDX: energy-dispersive X-ray spectroscopy); BSED: backscattered electron detector; 1: diamond knife holder; 2: ultramicrotome mechanics; 3: specimen stage [1, page 192]

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The use of online viscometer for the characterization of polymers: On the determination of molar mass, size and branching

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Intrinsic viscosity is a traditional parameter used in polymer science to characterize polymers. Conventionally it is determined by the Ubbelohde capillary viscometer from the concentration dependence of the reduced viscosity. An online viscometer coupled with size exclusion chromatography (SEC) measures the intrinsic viscosity at regular time intervals across the chromatogram. The key application of the online viscometer was the determination of true molar mass distribution using the idea of universal calibration. This application became markedly less frequent after the launch of light scattering detectors capable of measuring true molar mass directly without any column calibration. However, the universal calibration with a viscometer can become very efficient in the case of lignin and other fluorescent polymers for which the scattered light is distorted by the fluorescent light. Most importantly, coupling the online viscometer with a light scattering detector brings new possibilities in acquiring detailed information about molecular structure of polymers. The log–log relation between the intrinsic viscosity and molar mass, called Mark-Houwink plot, can provide detailed information about long-chain branching and conformation of polymer chains. In contrast to the relation between the root mean square (RMS) radius and molar mass obtained by the multi-angle light scattering (MALS) detector, the Mark-Houwink plot is more sensitive in revealing branching and can be used down to the molar mass of solely several thousand g/mol. The molar mass obtained by a light scattering detector and intrinsic viscosity from the viscometer can be used for the calculation of hydrodynamic radius which can be compared with the RMS radius. The comparison of the two radii brings information about the compactness of macromolecular chains. An interesting and almost unknown application of the viscometer is the determination of the number-average molar mass (M_n) without any other detector, just using universal calibration. This can become very valuable in the case of polymers which in a given mobile phase have the specific refractive index increment in proximity of zero and thus extremely low responses of light scattering and refractive index detectors. A theoretically interesting can be calculation of the RMS radius from the intrinsic viscosity and molar mass using Flory-Fox equation and comparison of the obtained values with those measured directly by MALS.

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About strategies to improve the quality of 3D-printed parts made from semi-crystalline polymers

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Fused Filament Fabrication (FFF) of polymers is one of the most popular 3D-printing methods and understood as key technology in changing the economic landscape. However, repeated heat introduction and shear forces during printing as well as low heat conductivity of polymers result in complicated heterogeneous temperature profiles during processing, influencing the homogeneity of the final component. We demonstrate how the structural features of FFF parts made from semi-crystalline poly (lactic acid) (PLA) and polyamide 12 (PA 12) are influenced by crystallization kinetics and flow behavior. This is studied by Fast Scanning Calorimetry (FSC), Wide-angle X-ray Diffraction (WAXD) as well as Dynamic Mechanical Analysis (DMA) [1]. PLA and PA 12 are well suited as model systems because they differ significantly in their crystallization kinetics in the processing relevant temperature window, show polymorphism and their viscosities can be tuned to be similar. Temperature-dependent WAXD scans on the unprocessed filaments reveal a single orthorhombic α phase for PLA while PA 12 shows a reversible solid–solid phase transition between the hexagonal γ phase at ambient temperature and the monoclinic α' phase above the Brill transition temperature T_B of about 140 °C. The influence of the print bed temperature T_b on crystallinity χ_c and semi-crystalline structure is investigated in height- and depth-dependent WAXD scans of FFF parts. These results are compared with single-layer prints, used as a reference. It is found that the heat transferred from subsequently printed layers has a strong influence on the polymorphic state of PA 12 parts where a mixture of γ and α phase is observed without significant changes in the crystallinity χ_c. PLA parts exhibit always a single α phase but T_b has a strong influence on the degree of crystallinity χ_c and thus the homogeneity of FFF parts. By comparing the obtained results from WAXD, DMA and FSC measurements with relevant printing times, guidelines for printing FFF parts with a homogeneous structure are derived and discussed.

Acknowledgement
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Development and characterization of EMI shielding and foamable electrostatic dissipative filaments for additive manufacturing

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This presentation outlines the results of subproject TP1 within the joint project AddiQ (VP1), focusing on the development of functional filament materials for additive manufacturing. The work at GMBU aims at developing electromagnetic interference (EMI) shielding filaments as well as foamable electrostatic dissipative filaments for use in technically demanding components.

For EMI shielding applications, a filament based on polyamide with conductive additives (carbon nanotubes) and reinforcing fibers was developed. Through systematic variation of material formulations and processing parameters, materials with high mechanical strength and reduced specific electrical resistance were achieved. The investigations show that additive manufacturing parameters, in particular nozzle and build chamber temperature, have a significant influence on the electrical and mechanical properties of the components.

In parallel, an electrically conductive, flexible, and foamable filament based on thermoplastic polyurethane was developed. By incorporating expansion agents and conductive fillers, materials with variable density, adjustable hardness, and defined electrical properties were realized. The degree of foaming and the resulting material properties can be specifically controlled via processing parameters in the additive manufacturing process.

The developed materials were successfully processed using additive manufacturing and characterized using test specimens with regard to their mechanical and electrical properties. The results demonstrate the potential of these filament materials for use in functional components, particularly in the field of electromagnetic shielding and electrostatic discharge applications.

Toolpath-driven finite element simulation with melt-pool-focused adaptive mesh refinement and thermal remapping for high-fidelity FDM modelling

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Finite element simulations are widely used to study the thermomechanical behaviour of fused deposition modelling (FDM) processes and to predict temperature fields, residual stresses, and deformation during fabrication. Many such numerical models still rely on simplified layer-based activation strategies and static meshes which cannot adequately resolve the localized thermal gradients that occur near the moving deposition zone. A critical review of such deposition processes points to the need for numerical approaches that include realistic deposition sequences and localized numerical resolution at a reasonable computational cost. Sudden heating and cooling during extrusion produce highly non-uniform temperature distributions that directly influence residual stress formation and warpage in printed parts.

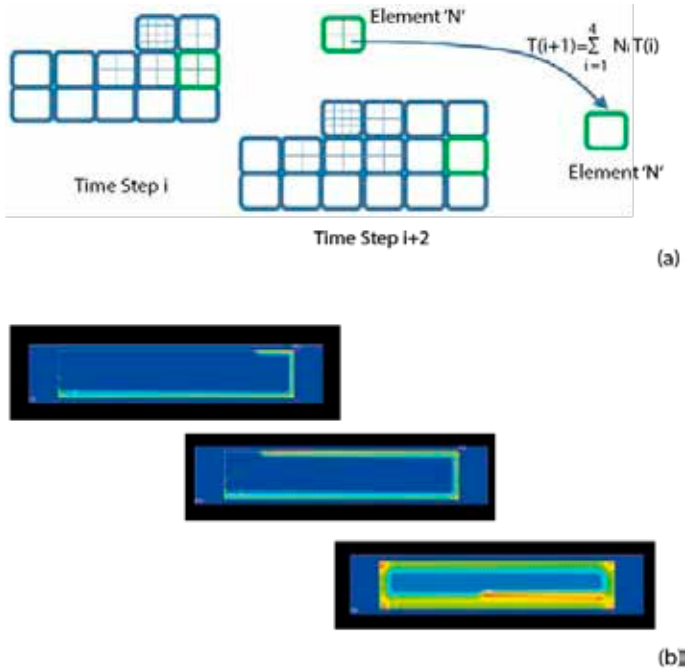

Figure 1: (a) Dynamic meshing strategy based on tool path (G-code). (b) Temperature profile from ANSYS FE simulation.

The present study examines a toolpath-driven finite element approach to simulate the FDM process in ANSYS. The simulation uses slicer-generated G-code to activate elements sequentially along the extrusion path. This approach lets the model show the order in which material is added over time. A moving heat source, representing the extrusion nozzle and melt pool, introduces thermal loading. The area around the deposition site experiences sharp temperature changes and strong thermal gradients. Higher spatial resolution is therefore required in this zone. An adaptive meshing strategy is used in which the mesh is refined locally around the melt pool while regions that have already cooled are represented with coarser elements. Concentrating refinement near the deposition front allows the simulation to resolve localized thermal behaviour without excessive computational cost.

The analysis proceeds in a transient stepwise manner following the toolpath progression (Figure 1). At each step, a short segment of the extrusion path is activated, and the thermal response is computed. After each solution step, the mesh is updated based on the current melt-pool position and gradient-based refinement indicators. Thermal fields from the previous mesh are transferred to the updated mesh via temperature remapping, preserving the thermal history of the process. Toolpath-based element activation, combined with mesh refinement around the melt pool and thermal remapping, helps capture local thermal behavior in the FDM process more efficiently. This approach shows how temperatures change over time and how stress develops during deposition. Further, this approach supports a more realistic numerical correlation of process-induced distortion in additively manufactured parts.

AI-guided predictive adaptive mesh for finite element simulation of fused deposition modelling

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Finite element simulations help analyze thermal behavior, stress, and deformation in fused deposition modelling (FDM). To accurately predict results, it is important to capture sharp temperature changes near the moving deposition front. Traditional adaptive meshing only refines the mesh after these changes are found, which raises computational costs for complex shapes or long toolpaths.

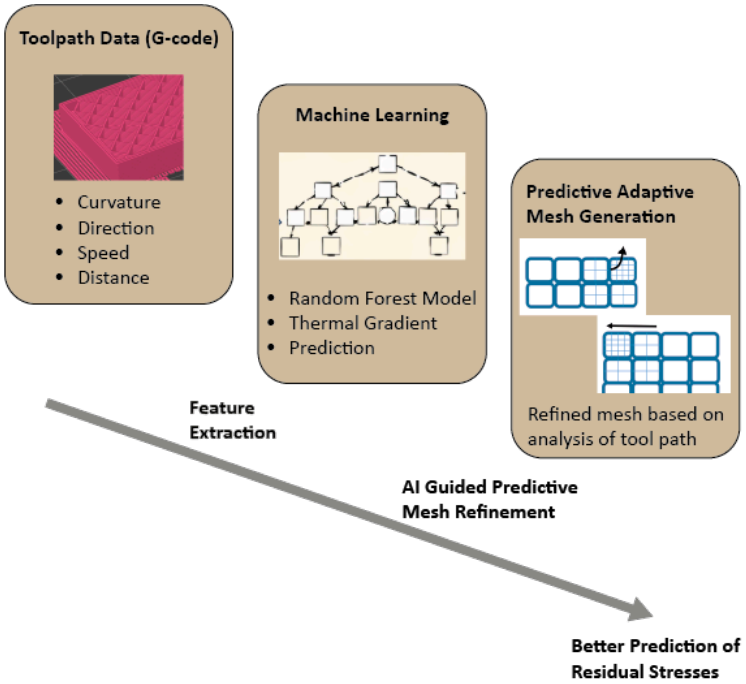

Figure 1: Illustration of AI guided approach for factoring geometrical and contour features in estimating stress concentration zones for simulating FDM processes with dynamic adaptive meshing

This study introduces a predictive mesh-refinement method based on machine learning regression. Toolpath data from slicer-generated G-code are processed in Python to calculate features for each segment, including deposition direction, path curvature, extrusion speed, segment length, and distance to previously deposited material or part boundaries. These

features are fed into a supervised Random Forest regression model, which is trained to predict where high thermal gradients are likely during deposition.

High-resolution thermomechanical simulations in ANSYS provide training data, linking toolpath features to measured temperature gradients and stresses. For new parts, the model reviews upcoming toolpath segments and predicts which areas need mesh refinement before the nozzle arrives. Segments with lower gradients are expected to use a coarser mesh, which saves computational resources. The predicted refinement map is used in a transient finite element simulation, where elements are activated one after another along the toolpath. Temperature continuity is maintained during mesh updates by thermal remapping, so the simulation accurately follows the changing thermal history of the part.

By combining toolpath feature analysis, supervised regression, and adaptive mesh refinement, this method offers a practical solution for high-quality FDM simulation. It adds detail where needed, keeps computations efficient, and allows accurate modelling of complex shapes and long toolpaths (Figure 1).

In-situ investigation of laser swelling in polymers

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Microlens arrays (MLA) are a versatile tool for plenoptical and wavefront sensors, collimating optics for emitters or fibers, homogenizers and vision correction in ophthalmic optics [1]. Fabrication techniques cover photolithography, printing, micro-embossing, micro-milling or swelling and have respective benefits. The laser swelling approach on polymers provides remarkable flexibility in design and spontaneity along with reasonable processing time. This qualifies it for prototyping or custom design, like ophthalmic optics where MLAs are applied to achieve complex correction in order to improve or restore visual acuity.

Working in a power regime below ablation threshold, irradiation is absorbed and causes heat accumulation and expansion of a spatially limited volume of the polymer. Time resolved observation of the optical characteristics shows a convex shaped refractive medium overlayed with a laser power induced thermal lensing effect of the volume. After the temperature decreases locally below the glass transition, the remaining hump appears as an implication of an irreversible local heating dynamic of the polymer [2].

The formation of an MLA by swelling proceeds sequentially, with each lens being formed one after the other. The evolution of the process influences the conditions under which subsequent lenses swell. To achieve control over the process dynamics, the dependencies between the relevant process parameters must be identified. In this work, we focus on water content, temperature, irradiance, scan trajectory, and heat dissipation. By accounting for these parameters, we aim to enable the deterministic fabrication of a desired optical design for an array of adjacent lenses.

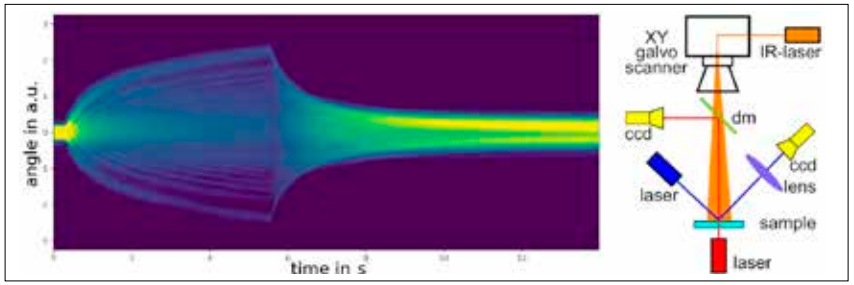

Figure 1: Time-resolved back focal plan imaging of collimated beam reflected on swelling spot (left); fabrication setup with IR-laser (swelling), extended with probe lasers, transmission (red) and reflection (blue) to monitor swelling dynamics (right)

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The use of sandwich samples to estimate the lifetime of PE-HD

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1 Introduction

One of the states that limits the service life of pipe materials high-density polyethylene (PE-HD) is slow crack growth (SCG) [1]. The evaluation of this condition is given by standards, among others, Pennsylvania edge notch tensile (PENT) test (ISO 16241) and full notch creep test (FNCT) (ISO 16770). Several tens of grams are needed for the preparation of laboratory tests (preparation from pellets) or sampling from the pipe. For various reasons (development, failure analysis, etc.) such a quantity is unavailable. A sandwich-type test specimen was proposed. This specimen contains the test material as the core of the sandwich; the arms are made of the material that is more widely available (Fig. 1).

Figure 1: Sandwich specimen, the mass of test material (white part) is 0.2 g

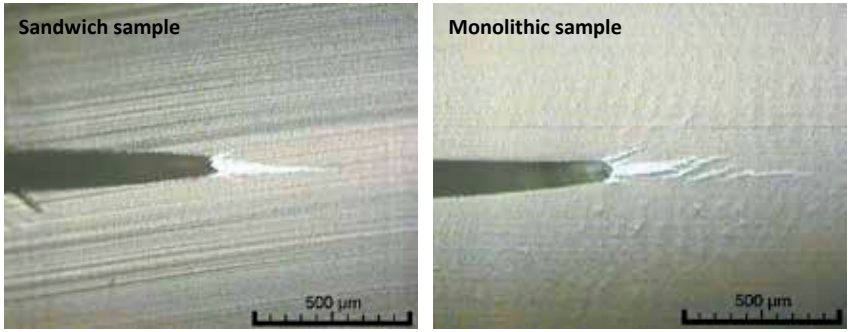

Figure 2: Side view of running crack

2 Experimental parts

The resulting sandwich contained a 15 mm thick plate that could be easily notched and the PENT test applied. For comparison, a monolithic sample was also tested and imaged using an

optical microscope (Nikon MM-60) in reflected light (Fig. 2). The fracture surface was imaged in a Philips XL30 scanning electron microscope (Fig. 3).

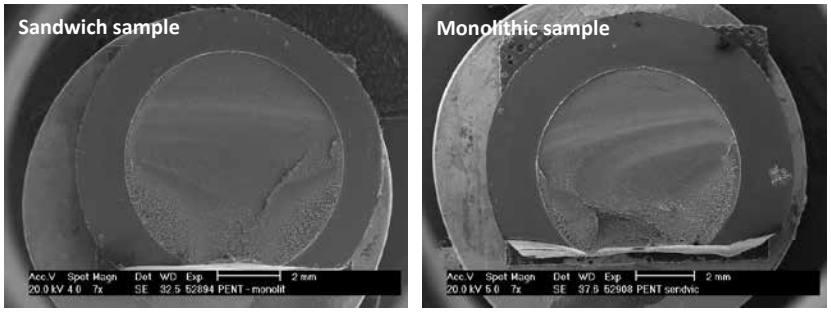

Figure 3: Fracture surface after PENT test. The PENT test condition are: 2.4 MPa, T = 80 °C, air. Time to rupture is 2,055 and 2,343 hours for the sandwich sample and monolithic sample, respectively.

3 Conclusions

The use of sandwich samples is useful primarily in the development of new materials or in understanding the influence of individual fractions on limiting states, specifically for PE-HD pipe applications. It can also be used to assess the residual service life of pipelines, where a small amount of material can be sampled from the pipe surface without limiting the operation of the pipeline system. The preparation of modified sandwich-type specimens enables the evaluation of relevant fracture-mechanical properties of materials that can be synthesized only in laboratory quantities. This technique enables the evaluation of macro-properties, which was previously not feasible due to the limited quantity of the prepared material.

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Quantitative non-destructive monitoring of water ingress into polymer laminates

Zerstörungsfreie quantitative Überwachung des Wassereintritts in polymeren Laminaten

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Water ingress poses significant reliability risks for a range of products containing polymeric materials, such as laminated safety glass, encapsulated microelectronic devices, and photovoltaic modules. Moisture penetration can lead to material degradation and delamination, thereby impairing product lifetime, safety, and ultimately sustainability and economic viability. Assessing the product degradation state without stopping its operation therefore requires non-invasive diagnostic tools capable of tracking water ingress.

This study presents a novel, non-destructive *in situ* method to quantify water ingress into polymeric samples using near-infrared absorption spectroscopy (NIRA), calibrated against absolute water content determined by Karl Fischer titration (KFT) (see Figure 1). A particular focus is placed on photovoltaic modules, where material selection (especially encapsulants and backsheets) strongly influences moisture ingress and thus long-term reliability and sustainability.

The method was validated through two laboratory studies and two real-world case studies. In the first laboratory study, moisture ingress in minimodules with PET- and PP-based backsheets was quantified, yielding diffusion coefficients consistent with values reported in the literature. The second laboratory study investigated multilayer polymer samples subjected to accelerated weathering. Backsheet cracking significantly increased water uptake, whereas encapsulant layers reduced moisture ingress.

In the first field case study, moisture distributions were mapped in rooftop modules after more than eight years of outdoor exposure, comparing modules with and without visible defects in the backsheet and solar cells. Modules exhibiting backsheet and cell cracking showed approximately 50 % higher water content, particularly near cell cracks (275 mg m^{-2} with defects vs. 181 mg m^{-2} without defects). The second case study examined insulation properties of field-retrieved modules after ten years of exposure in Germany using a wet-leakage test. Modules with cracked polyamide backsheets absorbed water almost immediately and exhibited water contents nearly an order of magnitude higher than modules with intact backsheets.

The presented approach provides a powerful tool for quality assurance and inspection for module manufacturers and solar developers. It enables improved moisture-resistant module design, timely mitigation measures, and more accurate durability predictions. Furthermore,

the methodology is transferable to other applications involving polymer-based barrier systems, such as laminated safety glass and encapsulated microelectronics.

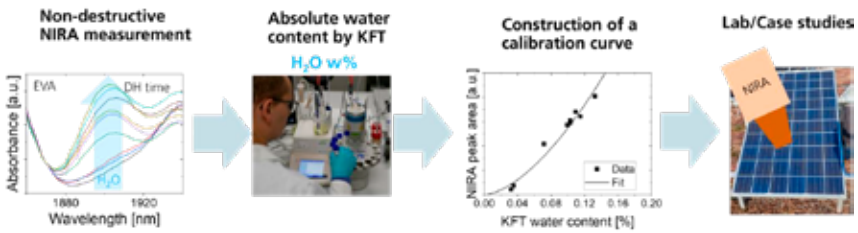

Figure 1: Concept for the non-destructive water content determination

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Pressure dependence of viscosity in SBR compounds

Druckabhängigkeit der Viskosität in SBR-Compounds

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To simulate the flow of a rubber compound during injection molding, the knowledge of viscosity is required [1]. While most rheological models describe viscosity solely as dependent on shear rate and temperature [2], the pressure also has a significant influence on viscosity, which is only since a few years widely considered. To better understand the pressure dependence, a combination of two viscosity models is used. The first is the Carreau-Yasuda-WLF model, considering temperature and shear rate and the second one is the Barus model, considering pressure [3].

Following the shift of Williams, Landel and Ferry (WLF) [4] and the work of Aho and Syrjälä [5], a time–temperature–pressure superposition was done using a pressure shift factor a_p. A parameter estimation derived from the model was based on measurements with a high pressure capillary viscosimeter with a counter pressure chamber. Three carbon black-filled SBR-based compounds were investigated, differing in styrene and vinyl content, leading to different chain mobility.

It was found that pressure dependence is generally more pronounced at lower shear rates, where also the strongest temperature dependence of viscosity can be seen. The compound with the lower weight fracture of side chains shows lower pressure dependence, as expected due to a larger free volume, associated to a lower glass transition regime. The compound with a higher weight fracture of side chains shows a higher pressure dependence. The third compound, which is based on a blend of the polymers shows the lowest pressure dependence.

This leads to the assumption that the pressure dependence of viscosity is connected not only to processing parameters, such as the shear rate, but also to the molecular structure and to interactions of polymers, highlighting the need for extended rheological models.

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Effect of PP impurities on the crystallization kinetics and tensile behavior of PE-HD

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The mechanical recycling of high-density polyethylene (PE-HD) represents a crucial step toward reach circular economy for polymer materials. However, recycled PE-HD often contains amounts of polypropylene (PP) impurities (< 10 %) due to the similar physical and chemical properties of both polymers, which complicate their separation during recycling processes. These impurities can alter the crystallization behavior of recycled PE-HD, which in turn may affect its mechanical performance. Nevertheless, the extent of this effect strongly depends on the processing and preparation conditions of the material.

To quantify the influence of PP impurities, the crystallization behavior of a selected PE-HD grade was systematically investigated under controlled conditions. PP was added to PE-HD at different impurity concentration levels to simulate contamination. The isothermal crystallization kinetics of the resulting blends was characterized using differential scanning calorimetry (DSC) and a rheological approach. The rheological measurements further enabled the correlation of crystallization behavior with macroscopic mechanical properties.

The results demonstrate that PP impurities significantly influence the dimensionality of the crystallization process, while the melting conditions have a pronounced impact. Despite these changes in crystallization characteristics, only a marginal influence of PP impurities on the mechanical performance of the material was observed. These findings suggest that the presence of PP impurities does only represent a minor obstacle for the mechanical recycling of PE-HD.

Service life of PE-HD pipe types: Accelerated tests vs. structural evaluation

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The service life of high-density polyethylene (PE-HD) piping systems used in gas and water distribution is primarily limited by slow crack growth (SCG), a quasi-brittle failure mechanism occurring under sustained stress at low load levels [1]. Standardized accelerated tests such as Pennsylvania edge notch test (PENT) and full notch creep test (FNCT), based on fracture mechanics principles, are currently used to evaluate the slow crack growth (SCG) resistance and expected lifetime of PE-HD pipe grades. However, for modern bimodal PE 100 and PE 100 RC grades, these tests require increasingly long durations, making faster alternative evaluation methods highly desirable. One such alternative is the “rapid” SIS/DSC method (Stepwise Isothermal Segregation / Differential Scanning Calorimetry), a structural characterization technique based on the original work of Gueugnaut and Rousselot [2]. The method monitors crystallization kinetics at three isothermal holds in the temperature range 20–170 °C under protective nitrogen atmosphere. The measured data are processed using the Avrami equation, yielding the crystallization time constant τ, which can reliably distinguish PE-HD materials of pressure class 80 and 100 and track changes in production technology. Previous studies, including EN 1555-1 [3] requirements and the authors’ earlier contribution at Polymertec 2024 [4], have demonstrated a good correlation between the τ parameter and the values obtained from standard fracture mechanics tests. However, it has been observed that the absolute magnitude of τ and, critically, the nature of its proportionality to fracture mechanics parameters (whether direct or inverse) depend on the mathematical model chosen to approximate the measured SIS/DSC curves. This paper investigates the sensitivity of the τ parameter to different curve approximation strategies. Using experimental data obtained on several commercial PE-HD pipe grades, we compare different mathematical fits of the isothermal crystallization curves and show how the choice of approximation model influences both the magnitude and the trend of τ relative to established fracture mechanics parameters. The practical consequences for material ranking and lifetime assessment of PE-HD pipes are discussed.

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New perspectives for functional materials: Axial-torsional dynamic mechanical analysis meets Raman spectroscopy

Neue Perspektiven für funktionale Materialien: Axial-torsionale dynamisch-mechanische Analyse trifft Raman-Spektroskopie

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Functional polymer materials exhibit precise and controlled responses to external influences, with changes occurring at the molecular level and reflected in macroscopic behavior. These advanced materials are increasingly shaping technological progress, particularly in polymer-based applications. Dynamic mechanical analysis (DMA) is an essential tool for monitoring the mechanical properties of these materials during the stimulation process. In this context, combined axial-torsional DMA – with rotation and axial stress – has significantly advanced the characterization of functional polymers in recent years [1–3].

This contribution shows how axial-torsional DMA can be used to characterize functional materials, including bio-based shape memory polymers (SMPs) and liquid crystal elastomers (LCEs). In addition, DMA can be coupled with Raman spectroscopy in a special setup to correlate changes in material morphology with corresponding changes in macroscopic mechanical properties. *In-situ* Raman measurements during DMA reveal morphological changes such as crystallization in SMPs such as polylactic acid (PLA), or the orientation of liquid crystal mesogens in LCEs. These morphological changes lead to anisotropic macroscopic structural changes that can be effectively quantified with axial-torsional DMA [2].

We show how a new macroscopic dynamic parameter, ζ, derived from the phase shift angles in torsion (δ_T) and extension (δ_E), can offer a new perspective for quantifying the viscoelasticity of anisotropic structures, such as those found in functional or "smart" materials.

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Detecting variability in the flow behaviour of mineral fillers: A powder rheology-based approach to assess batch, handling, and environmental effects

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Consistent flow behavior of mineral fillers is critical for reliable dosing and compounding in polymer processing. While batch-to-batch variability is commonly attributed to intrinsic material differences, practical experience indicates that deviations in flow behavior may also arise from environmental influences and prior handling or processing history. This contribution investigates the capability of powder rheology as a sensitive tool to distinguish between these sources of variability.

A systematic experimental approach was applied using mineral fillers, with a primary focus on talc-based materials. Powder rheological measurements were performed to characterize flow behavior under varying conditions, including controlled changes in humidity, storage conditions, and mechanical pre-treatment. In parallel, batch samples with known differences from industrial practice were analyzed to establish correlations between rheological metrics and observed process performance during dosing and compounding.

The results demonstrate that powder rheology can reliably detect not only intrinsic batch differences but also subtle variations induced by environmental exposure and process-related history. Furthermore, the study explores whether such influences lead to reversible or irreversible changes in flow behavior. Initial findings suggest that certain conditioning effects, particularly those related to moisture uptake and mechanical consolidation, can induce lasting alterations in flow properties. The work highlights the importance of considering state-dependent material behavior when interpreting rheological data and assessing raw material consistency. The findings provide a basis for improved quality control strategies and more robust process design in plastics compounding operations.

Influence of bulk density distribution in a hopper on the flow behavior of talc

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This study investigates the influence of local bulk density variations on the flow behavior and dosing performance of mineral fillers, with a focus on talc. A correlation between bulk density and flow energy was identified for multiple talc grades using powder rheometry. During dosing, bulk density variations arise due to factors such as drop height, consolidation time, and mechanical stresses during conveying. To quantify these effects, a methodology was developed to determine spatially resolved bulk density distributions along the dosing process. An industrial-scale modular test rig was designed to replicate conditions encountered in compounding operations. Measurements reveal that local bulk density variations lead to measurable fluctuations in flow behavior, which in turn affect dosing consistency. Regions of increased bulk density were found to correspond to altered rheological responses and higher flow energy values. Based on these findings, models linking state-dependent material properties to dosing performance are developed and experimentally validated. The results provide insight into the formation of localized density maxima in hoppers and their impact on process stability. The applicability of the developed approach to other mineral fillers, such as boehmites, is also evaluated.

Posters

C. Baumgart, I. I. Kleiber, T. Meins, M. Nase
Investigation of the influence of varying PIR recycling content on the thermal and molecular properties of PBT

A. Standke, A. Kohlsmann, M. Seitz, V. Cepus
Investigation of input and output compounds of the chemical recycling of EPS-based house insulations

P. Hirsch, T. Theumer, S. Henning
Numerical simulation and experimental validation of twin-screw compounding of polylactide and polybutylene succinate blends

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Comparative study of petro-and bio-based polymer composites: Solvent, crosslinkers and filler content effect on physicochemical and adhesion behaviours

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Microstructure-coupled predictive FEM simulation for FDM: Linking process, stress, and material properties

M. Haji, C. Sirch, M. Auerbach, R. Lach, B. Langer
Test device for analysing the mixed-mode crack propagation behaviour of polymer materials under quasi-static short-term and static long-term loading

Investigation of the influence of varying PIR recycling content on the thermal and molecular properties of PBT

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Currently the request for sustainability, CO_2 reduction and environmental protection is a highly significant issue. Besides the scarcity of fossil resources, greenhouse emissions and thus the combating of climate change play an important role. Therefore, many companies deal with the improvement and expansion of their production processes of polymer-based products. As stated earlier, the public demand for sustainable and environmentally friendly products rises to provide a positive input for climate change.

During the polymer processing (for example in the medical area), waste is generated. The waste (like polymer sprue, scrap or defective parts) could be used as the so called "post-industrial recyclate" (PIR). Typical polymers for the PIR are polybutylene-terephthalate (PBT), polyamide (PA) or polypropylene (PP). One major advantage of the PIR in comparison to post-consumer recyclate (PCR) is the purity and material homogeneity as well as the technical performance. But the use of PIR in every section, especially in the medical field due to the high standards (like material purity or biocompatibility) is challenging.

Thus, this poster deals with the PIR recycling content of PBT. The focus is thereby on the maximum content of the recycled material and the conditions to reintegrate this material without any significant loss of the required material and component properties in the injection molding process.

For the investigation of the influence of the PIR content (powered sprue) on the mechanical, thermal and molecular properties 10 wt.%, 30 wt.% and even 50 wt.% were examined. The virgin and PIR material were injection molded as dry blend and final compound. After thermal (via differential scanning calorimetry (DSC)), mechanical (tensile and Charpy impact testing), rheological (melt flow index (MFI) and shear rheology) and chemical (gel permeation chromatography (GPC)) analysis, the best mixture and process way could be identified. By using a dry blend, the material properties are better than with the compound, because extra processing step and so extra thermal stress could be prevented.

Investigation of input and output compounds of the chemical recycling of EPS-based house insulations

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Expanded polystyrene (EPS), widely used as packaging material and insulation, poses a particular challenge for recycling. The flame retardants contained in EPS, such as hexabromocyclododecane (HBCD), which was used until 2016 and is now banned, make recycling particularly difficult. HBCD has been used in EPS insulation materials since the 1960s to meet fire safety requirements. The chemical recycling of such EPS materials needs a careful characterization to reveal the fate of the brominated byproducts and the bromine-free styrene liberated by the depolymerization process. Thorough Characterisation of input and output compounds is conducted by combined methods of instrumental analytics.

In a Conversio market study [1], commissioned by the Industrieverband Hartschaum e. V. (Industrial Association for Rigid Foam), which represents EPS processors in Germany, it was found that 86.6 % of all EPS waste generated during renovation and demolition projects is sent for thermal recycling [1]. The study also shows that over 200,000 tons of EPS insulation were installed in Germany each year. So the chemical recycling of EPS materials seems to be environmentally and economically useful to increase the sustainability, since polystyrene-based polymers tend to depolymerise to styrene monomers with comparably high yields.

The aim is to create an industrial process for this route. For other routes as polyolefine-rich waste such depolymerization processes have been already investigated with respect to inputs and output compounds as well as calculation of energy and mass balances to be able to compare recycling processes [2].

In this project the combination of different techniques of instrumental analytics as Infrared (IR) spectroscopy, X-ray fluorescence, nuclear magnetic resonance (NMR) spectroscopy, ICP-MS (inductively coupled plasma-mass spectrometry), as well as chromatographic techniques as GC/MS (gas chromatograph-mass spectrometry) and IC (ion chromatography) will be employed to investigate and understand byproducts, the fate of brominated compounds and the quality of the liberated styrene monomer in order to ensure a safe and successful recycling process.

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Numerical simulation and experimental validation of twin-screw compounding of polylactide and polybutylene succinate blends

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The morphology of thermoplastic blends is a major factor in governing their mechanical properties. Thus, the morphology development of thermoplastic blends during twin-screw compounding is an area of prime interest in polymer industry. Therefore, the aim of the study was to correlate simulated process data of twin-screw compounding with experimentally found morphologies of blends from biobased Polylactide (PLA) and Polybutylene Succinate (PBS). Numerical simulation of the mixing process of a lab-scale twin-screw extruder was done with ANSYS Polyflow software for various blend compositions and screw speeds. As a result, a maximum local shear rate of 2041 1/s was found for the highest simulated screw speed of 400 1/min for the PLA/PBS-20/80 blend in the dispersive mixing section of the screw. Interestingly, no significant influence of the blend composition on maximum local shear rate but on maximum local shear stress was found. An increasing content of PBS led to an increase in maximum local shear stress with its peak at 212 MPa for the PLA/PBS-50/50 blend. Further increase in PBS content led to reduced maximum local shear stresses, indicating a co-continuous morphology at equal content of PLA and PBS in the blend. Subsequently, the resulting values of the maximum local shear stress for each blend were used to calculate the capillary number and to predict the droplet breakup according to the Grace model. The experimental validation of the numerical simulations was done by dead-stop compounding experiments and morphological analysis of blend samples along the screw by Scanning Electron Microscopy. In result, a good correlation of the predicted particle breakup by numerical simulations and the capillary number approach and the experimentally found particle diameters was found for all studied blend ratios and screw speeds. Thus, the studied workflow could help to reduce the needed numbers of experiments to adjust the morphology and properties of PLA/PBS blends.

Accelerated fatigue testing of a polyamide 6 material with 30 % glass fiber

Beschleunigte Zeitfestigkeitsbestimmung eines glasfasergefüllten Polyamid 6-Materials

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Material selection and component design are significant challenges regarding the fatigue strength of thermoplastic materials. Time-intensive and expensive material tests are a recurring issue. A new accelerated testing and analysis procedure was developed to characterize the fatigue strength of these materials.

The fatigue strength of materials is typically described by S–N curves, determined in high-cycle fatigue tests (Woehler). However, these tests are very time-consuming, since the range of interest for cycles to failure usually extends from 10^4 to 10^7. Several test specimens must undergo cyclic loading until failure at many different load levels, maintaining a constant frequency, load ratio and temperature. [1] A physically based lifetime prediction (PHYBAL) for metal materials was developed in the 2000 s at Kaiserslautern University [2–4]. This approach was modified to characterize the fatigue behavior of different thermoplastic materials. This method can estimate the S–N curve based solely on a single force-controlled cyclic load increase test and two brief force-controlled fatigue tests (Woehler). The research work presented here characterized the fatigue behavior of a polyamide 6 material with a 30 % glass fiber content. The results of these new accelerated fatigue tests using the modified PHYBAL approach were compared to classic high cycle fatigue tests. This also included the evaluation of fiber orientation induced anisotropy.

Acknowledgement

The financial support by the Federal Ministry for Economic Affairs and Climate, BMWK (now: Federal Ministry for Economic Affairs and Energy, BMWE), through German Federation of Industrial Research Associations (AiF) and DLR Projektträger (DLR) is gratefully acknowledged (IGF Research Project No. 01IF22552N).

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Comparative study of petro-and bio-based polymer composites: Solvent, crosslinkers and filler content effect on physicochemical and adhesion behaviours

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Growing environmental concerns associated with petroleum-derived adhesives have accelerated research on sustainable bio-based alternatives. This study presents a comparative analysis of petro- and bio-based polymer adhesive systems, focusing on the effects of solvent type, crosslinking agents, and filler content on their physicochemical, thermal, mechanical, and adhesion behaviours. Recycled and expanded polystyrene (EPS) blended with styrene–butadiene–styrene (SBS) rubber was used for the petro-based adhesives, and bio-based polymers (such as starch, proteins) derived from natural resources were employed as the matrix. Different solvents were used for the sample preparation by using calcium, silica and natural fibres as fillers in various contents with and without crosslinking agents.

Fourier transfer infrared (FTIR) analysis confirmed structural interactions between polymer chains and crosslinking agents in both systems. Morphological observations using optical and scanning electron micrographs showed that solvent selection influenced the dispersion of SBS in the EPS matrix, while chemical modification of bio-based adhesives improved the homogeneity of the films. Thermal analysis revealed that the incorporation of SBS reduced the glass transition temperature (T_g) of EPS from about 105 °C to 80–85 °C, whereas crosslinking slightly increased thermal stability and T_g. Bio-based adhesives exhibited lower transition temperatures; however, crosslinking and filler reinforcement enhanced their thermal stability. Adhesion performance improved in both systems with the addition of rubber, crosslinkers, and fillers. Petro-based adhesives showed higher peel strength (1.21–1.45 N) compared to bio-based adhesives (0.65–0.95 N), indicating superior mechanical stability. However, modified bio-based adhesives demonstrated considerable improvements in bonding performance and structural stability after crosslinking and filler incorporation.

In summary, the results highlight that solvent selection, crosslinking chemistry, and filler reinforcement play a critical role in controlling the physicochemical characteristics and adhesive behaviour of polymer composites. The petro-based systems exhibit higher mechanical and thermal stability, whereas bio-based adhesives offer environmental advantages and represent promising sustainable alternatives with further optimisation for construction, packaging, and furniture applications.

Keywords: Polymer adhesives, solvent effect, crosslinking, filler reinforcement, adhesion behaviours

Effects of epoxidized fatty acids from bio-based glycerin on the properties of polylactide, polyhydroxybutyrate and thermoplastic starch

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The use of plasticizers based on vegetable oils and alternative fillers is currently a focus of research and development. Chemical modifications can influence the compatibility with the polymer and the properties of the end products. Currently, epoxidized vegetable oils, such as epoxidized soybean oil (ESBO), which are produced by epoxidation with hydrogen peroxide, are already in use as non-toxic plasticizers and stabilizers. However, these plasticizers are not comparable to conventional phthalates in their properties; for example, they exhibit high migration behavior. Due to their lipophilic properties, they are easily extracted from fatty foods and are therefore only approved for indirect food contact in most countries. Promising bio-based and biodegradable thermoplastics for use in packaging applications, such as thermoplastic starch (TPS), polylactide (PLA) and polyhydroxybutyrate (PHB), exhibit high stiffness and brittleness and are therefore ideally suited for the use of bio-based plasticizers.

The aim of this study was to develop bio-based plasticizers that, compared to the state of the art, offer a completely renewable raw material source and improved migration behavior in thermoplastic biopolymers. Improved processability and long-term performance properties of these materials are also targeted. The new plasticizers to be developed consist of unsaturated fatty acids esterified with alcohols based on bio-based glycerol, with the double bonds subsequently epoxidized. By varying the alcohol used, the degree of saturation of the fatty acid composition, or by modifying the double bonds of the fatty acids, the polarity and migration behavior are to be specifically influenced.

Mixtures of bio-based thermoplastics (PLA, TPS, PHB) and newly developed plasticizers based on fatty acid-esterified glycerol ketals, which are subsequently epoxidized, as well as commercially available plasticizers for comparison, were produced on a laboratory scale and their properties determined. It was found that the bio-based plasticizers did not achieve an effect comparable to that of the commercial plasticizers. However, the flowability was improved more significantly with the fatty acid ketal plasticizers than with the commercial plasticizers, without noticeably affecting the mechanical properties. The feasibility of scaling up production using continuous melt mixing in a twin-screw extruder from laboratory scale to pilot plant scale was demonstrated. The manufactured sample materials were used to extrude films and injection molded parts.

Effect of bio-based impact modifiers on the properties of natural fiber-reinforced polyamide 11 composites

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The increasing demand for sustainable materials has become a key driving force in materials development across multiple industrial sectors. Growing environmental awareness, stricter regulations, and consumer expectations are pushing industries to reduce the carbon footprint of products without compromising performance. In this context, bio-based and partially bio-based polymers represent a promising pathway toward more sustainable material solutions, as they can reduce dependence on fossil resources while maintaining compatibility with established processing technologies. Among technical biopolymers, bio-based polyamides represent a particularly attractive class of materials for engineering applications. Compared to widely used biodegradable polymers such as polylactic acid (PLA) or polybutylene succinate (PBS), bio-based polyamides exhibit superior thermo-mechanical properties, higher service temperatures, and improved chemical resistance. These characteristics make them suitable for long-term applications where biodegradability is not the primary requirement. Importantly, bio-based polyamides can act as drop-in replacements for conventional petroleum-based polyamides, enabling their integration into existing industrial supply chains and processing routes. To further enhance the stiffness and strength of bio-based polyamides, natural fiber-reinforcement can be employed. The incorporation of natural fibers typically leads to a significant increase in elastic modulus and tensile strength, contributing to lightweight and mechanically efficient materials. However, this improvement is often accompanied by a reduction in impact resistance and fracture toughness. Thus, the motivation of this work was to investigate bio-based polyamide 11 (PA11) reinforced with natural fibers and modified with a bio-based impact modifier, aiming to achieve an optimized balance of mechanical properties suitable for technical applications. In addition to macroscopic mechanical performance, particular emphasis is placed on understanding the underlying structure–property relationships. The results demonstrate that it is possible to tailor stiffness, toughness and thermo-mechanical behaviour of natural fiber-reinforced PA11 composites within a relatively narrow processing window, while keeping the overall system largely bio-based and suitable for melt processing.

Production and evaluation of 3D-printing filaments from unidirectional fiber-reinforced semi-finished products

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Additive manufacturing by Fused Depostition Modeling (FDM) technology has advanced significantly, but pure polymer components exhibit insufficient stiffness and strength for certain applications. Additives, such as particles or short fibers, improve these properties, but even with these, the performance level of continuous fibers cannot be achieved. Continuous fibers in composite components bear the load better and relieve stress on the matrix. They are particularly suitable for lightweight yet robust components, for example in medical technology, aerospace, and automotive engineering.

The aim of the study was to develop a technological approach for the targeted, load-path-oriented reinforcement of additively manufactured components, on which continuously fiber-reinforced filaments with a thermoplastic matrix can be produced. The main challenges are fiber–matrix adhesion and complete fiber impregnation. The process was implemented in a multi-stage procedure. This involved a forming section, a coating unit, and a winding unit. In the forming section, a unidirectional (UD) tape with a rectangular cross-section was transformed into a filament with a round cross-section under the influence of heat. The filament was then coated with a polymer layer in the coating unit and subsequently wound onto a winding unit. UD tapes with glass or carbon fibers were initially used as semi-finished products. To determine the resulting fiber content and mechanical properties, the UD tape and the filament produced with the experimental setup were analyzed using thermogravimetric analysis (TGA) and tensile testing. The results showed that for filaments made from glass and carbon fiber-reinforced polyamide 6 the modulus of elasticity increased by 4.8 % for formed carbon fiber and by 1.2 % for glass fiber, respectively. The tensile strength decreased by 24.3 % for carbon fiber, while no clear difference was observed for glass fiber. Further investigations will focus on process and material optimization as well as the further processing of the filaments.

Effect of mechanical interlocking on interfacial strength in multi-material additive manufacturing of carbon fiber-reinforced polyamide 6, thermoplastic polyurethane and polyether block amide

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Adhesion at the interface between dissimilar polymers remains a critical limitation in multi-material additive manufacturing. However, additive manufacturing by Fused Deposition Modeling (FDM) enables the fabrication of complex interface geometries that are difficult or impossible to achieve using conventional manufacturing methods. Current work focuses on the design and testing of mechanically interlocked interface geometries intended to maximize both the cohesive strength of the individual materials and the effective adhesion at the polymer–polymer interface. These interlocked structures are expected to exhibit significantly improved mechanical integrity and durability compared to conventional planar interfaces. In this work, the potential of mechanical interlocking geometries to enhance interfacial strength in combinations of carbon fiber-reinforced polyamide (PA6/CF) and thermoplastic polyurethane (TPU) or polyether block amide (PEBA) have been studied. For this, a systematic investigation of the effects of interface design and processing parameters of the multi-material FDM process on the resulting interfacial strength was done. Evaluation of the adhesive strength was done with a specific compression shear test. The results showed a significant increase in the interfacial strength depending on the mechanical interlocking geometry. Based on the results, specific concepts for interface design in multi-material components from the FDM process can be derived.

Processing and analysis of continuous fiber-reinforced thermoplastic composites from bio-based polyamide 11 and carbon fibers

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Bio-based thermoplastic polymers may represent a sustainable future approach to developments in the field of fiber composite technology [1]. In addition to established petrochemical plastics like polypropylene (PP) and polyethylene (PE), bioplastics such as polylactic acid (PLA) and polyamide 11 (PA11) offer an interesting alternative made from renewable raw materials. Additionally, with its thermal and mechanical properties, PA11 enables the development of fiber-reinforced composites for technical lightweight components in industrial applications with higher service temperatures [2].

In this study, the use of bio-based PA11 and carbon fibers (CF) to produce continuous fiber-reinforced semi-finished products (UD tapes) was investigated. Using a continuous melt impregnation process, unidirectionally aligned carbon fibers were impregnated with thermoplastic PA11 melt and assembled into a UD tape. Thus, scale-up effects were also investigated from 50 mm to 100 mm tape width. Comparative evaluations focused on the microstructure formed in the UD tapes and the resulting mechanical and thermo-mechanical properties. Thereby the developed PA11/CF-Tapes show promising tensile properties in fiber orientation with tensile strength of 1030 MPa and tensile modulus of 63 GPa for a fiber volume content of 30 %. Additionally, the flammability of the semi-finished products was evaluated in accordance with the UL94 fire test standard [3].

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Engineering antiseptic PVA/PEG hybrids via TiO_2 MPI ALD: Toward multifunctional polymer interfaces

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Engineering polymer–oxide hybrid films at the atomic scale offers a powerful route to create multifunctional surfaces with built in biological activity. In this work, TiO_2 was incorporated into PVA/PEG blends using multiplied pulsed vapour phase infiltration (MPI) within an Atomic Layer Deposition (ALD) framework, enabling controlled inorganic penetration and hybrid network formation. X ray diffraction revealed the emergence of nanocrystalline TiO_2 domains, while ultraviolet (UV)–visible spectroscopy indicated band gap shifts associated with semiconductor activation. Raman and ATR FTIR microscopy (ATR – attenuated total reflection, FTIR –Fourier transform infrared) confirmed chemical hybridization through Ti–O–C and Ti–O–Ti linkages, accompanied by polymer matrix reorganization. Atomic force microscopic (AFM) measurements showed a transition toward a rougher, nucleation driven topology, and SEM–EDX mapping (SEM – scanning electron microscopic, EDX – energy dispersive X-ray spectroscopic) demonstrated uniform Ti distribution across the film surface. These structural and chemical transformations collectively enhanced the antiseptic performance of the TiO_2 MPI hybrids, highlighting the role of infiltration driven morphology and oxide–polymer interactions in antimicrobial activity. The resulting TiO_2 MPI ALD PVA/PEG films represent a promising platform for multifunctional polymer interfaces, with potential applications in biomedical coatings, packaging, and environmental materials where durability and antimicrobial function are essential.

Keywords: TiO_2 MPI ALD, PVA/PEG hybrids, multifunctional polymer interfaces, antiseptic coatings.

Vibrational spectroscopy and differential scanning calorimetry studies on recycled poly(ethylene furandicarboxylate)

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1 Introduction

Due to its thermal properties (a higher glass transition temperature (T_g) than poly(ethylene terephthalate) (PET), a lower melting temperature (T_m), and good stability), the biopolymer poly(ethylene furandicarboxylate) (PEF) is primarily used in packaging where barrier properties and sustainability are key considerations. This paper reports on the characterization of virgin and recycled PEF mixtures by vibrational spectroscopy techniques, which offer a quick and inexpensive means of quality control in an industrial context. Identifying the vibrational fingerprints that distinguish the amorphous and crystalline regions of PEF is the first step toward real-time monitoring of industrial processes using Fourier transform infrared (FTIR) and Raman spectroscopy. Differential scanning calorimetry (DSC) enables the quantitative characterization of thermal transitions, crystallization/melting, crystallinity, heat capacity, and stability of PEF-parameters crucial for material development, processing, and quality control.

2 Experimental

PEF was produced by polycondensation at the DITF (German Institute for Textile and Fiber Research, Denkendorf, Germany). The PEF was subjected to four recycling cycles through repeated processing into tensile test specimens (test bars). This paper investigates how adding 0 %, 33 %, or 66 % virgin material after each cycle affects the spectroscopic and thermal properties.

3 Outlook

In the next step, the test bars will undergo mechanical analysis via tensile testing, and the structure–property relationships generated by stretching will be determined.

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Development of process analytical tools for the monitoring of batch pyrolysis reaction of polyolefine-rich polymeric waste

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There is a high and global demand for robust recycling processes for complex plastic waste. The planned process is particularly suitable for regions without a functioning sorting infrastructure due to its low technical entry barrier and scalability. At the same time, it benefits from the increasing demand for recycled materials and non-fossil carbon. Using a batch process the plastic waste is kept at a high level in order to reduce CO_2 emissions and open up economically viable recycling options even for problematic fractions. For the robustness of the batch reaction close process analytical tools are needed to control the reaction and to monitor the output products in synergy with an AI-driven control unit of the process.

Processes for the chemical recycling of plastics have been under development for many years, but only a few processes have been implemented on an industrial scale and demonstrated in continuous operation. The plants built to date are generally continuous processes that recycle pure, contaminant-free plastic fractions. There are no established solutions for heterogeneous plastic-organic composite fractions, such as those addressed in this project.

Since chemical recycling plays an important role in achieving a sustainable, carbon-neutral future, previous developments have also been the subject of intensive scientific scrutiny. For instance the following study examines processes that can be used to assess the state of the art [1].

For the investigation of output characterization during the batch process robust process analytical tools have to be developed going beyond temperature, pressure, conductivity sensors and addressing the chemical composition of the depolymerized compounds using among others near-infrared (NIR), Raman, ultraviolet/visible (UV/VIS) sensors. For a deep and robust analysis of the output products, results of lab instrumentation for single substance analysis have to be compared and aligned with results from online sensors and the data matrix supported by AI-driven data handling tools.

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Effect of chemical modification on accelerated biological disintegration of polybutylene succinate films

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Biodegradable plastics are promoted as a solution to microplastic pollution. Various certifications regulate the biodegradability of bioplastics [1]. A distinction is made between industrially compostable and garden compostable plastics, as well as those biodegradable in soil. The primary criterion is the rate of degradation at different temperatures in the substrate. Petroleum-based plastics can also meet the requirements. A further obstacle to the use of biodegradable plastics is the long retention time in industrial composting facilities. For the industrially applicable use of biodegradable plastics, for example, for temporary soil stabilization, the adjustability of the degradation rate is of particular importance. The use of compounded additives is possible in this context, as these can accelerate degradation.

Different polybutylene succinate types (PBS) were compounded with two different peroxides and processed into films of three different thicknesses. These films were tested according to DIN EN 17033 [2] at 60 °C in a green waste compost for a qualitative assessment of decomposition in a slot frame test. This test allows a visual assessment of the disintegration of mulch films. Two films approximately 50 µm thick were not completely decomposed after 12 weeks under the tested conditions. No difference was detected between the two peroxides used. The influence of the peroxides becomes more pronounced with thinner films. With films approximately 25 µm thick, decomposition was not complete after 12 weeks for one chemical modification, while for the other modification, decomposition was significantly accelerated and completed in under 6 weeks. No recognizable fragments of the film were found in the sieve fraction. This effect was found to be even more significant for approximately 15 µm thin films, where decomposition is complete in under 4 weeks for one chemical modification, whereas the other modification requires up to 12 weeks. This demonstrates a reduction and adjustability in composting time by use of the different PBS types and peroxides.

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Design of g-C_3N_4-integrated polymeric thin films for flow-through photocatalytic removal of organic pollutants

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Thin-film photocatalysts have emerged as highly attractive materials for environmental remediation applications due to their facile recovery, reusability, and ability to sustain high photocatalytic activity while reducing the risk of secondary pollution [1, 2]. The integration of graphitic carbon nitride (CN) onto polymeric substrates such as polyvinylidene fluoride (PVDF) offers a promising strategy for the development of efficient thin-film-based photocatalytic removal systems [3, 4]. In this work, PVDF-incorporated with CN-based catalytic thin films were synthesized by performing phase inversion method. The catalytic films were evaluated in both aqueous and gas environment for visible light-driven degradation of tetracycline (TC) and ethanol (ET), respectively. Furthermore, particular emphasis was placed on elucidating their structural and morphological characteristics and correlating these features with photocatalytic performance. For that, a scanning electron microscopy (SEM), a Fourier transform infrared spectroscopy (FT-IR) and ultraviolet–visible (UV–Vis) diffuse reflectance spectroscopy (UV–Vis DRS) were performed. In case of antibiotic decomposition, the catalytic efficiency was attributed to 56.5 % TC removal in the presence of 1 × 2 mm thin film in 35 mL and 10 $mg \cdot L^{-1}$ TC solution. On the other side, the ethanol removal performance was calculated as 87.2 % under the optimum time (230.5 min), catalyst dosage (0.386 g) and oxygen percentage in total gas volume (21.8 %). Overall, the polymer-supported CN thin films demonstrated considerable photocatalytic efficiency, highlighting their potential applicability in industrial-scale photocatalytic treatment processes.

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Deposit formation in plastics processing: Thermal exposure of polycarbonate on steel surfaces

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Deposit formation and black specks caused by polymer degradation remain major challenges in plastics processing. In transparent plastics such as polycarbonate (PC), even small particles and discolorations can compromise the appearance of the final product. This problem is not only caused by polymer degradation, but may also involve metal–polymer interactions between the extruder screw and the molten polymer. Despite their industrial relevance, the underlying mechanisms are still not fully understood.

This work focuses on the fundamentals of deposit formation during PC processing. A custom sample holder was used to study the thermal degradation behavior of PC in an oven under applied pressure to ensure contact with the steel surface. The PC grade Makrolon 2408 was used on 1.2379 tool steel substrates. The samples were exposed to temperatures close to industrial PC processing conditions, using various time intervals to study the influence of exposure time on deposit formation. The samples were then characterized using microscopy techniques, infrared (IR) spectroscopy, and profilometry.

Initial observations indicate the formation of PC-derived deposits due to thermal exposure. After washing with dichloromethane, the unaltered PC dissolved, whereas some parts of altered material remained adherent to the steel surface. Microscopy and surface analysis are being used to assess morphological and topographical changes, while IR spectroscopy is applied to identify possible chemical modifications of the remaining material.

This study establishes a basis for generating reproducible PC-derived deposits under controlled conditions and enables systematic investigation of deposit growth over time, contributing to a better understanding of deposit and black speck formation mechanisms in PC processing.

Investigation of thermal and flammability behavior of DOPO functional thermoplastic polyurethanes

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Polyurethanes (PUs) are widely employed in coatings, adhesives, foams, and composite materials due to their high hardness, abrasion resistance, low thermal conductivity, and low water absorption; however, their inherent flammability and heat release under fire conditions limit broader applications [1]. In recent years, phosphorus-based flame retardants have attracted significant attention owing to their effectiveness in the condensed phase and their ability to reduce the formation of toxic gases. Covalent incorporation of such flame retardants into PU structures via post-modification offers improved flame-retardant performance and durability [2, 3]. In this study, a phosphorus-containing flame retardant based on 9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide (DOPO) was covalently introduced into a thermoplastic PU backbone using a thiol–ene "click" reaction. An alkene-functionalized linear aliphatic PU was first synthesized from an alkene-functionalized diol and hexamethylene diisocyanate. Subsequently, thiol-functionalized DOPO derivatives prepared via the Atherton–Todd reaction were grafted onto the PU backbone via post-modification. The thermal stability and flame-retardant properties of the resulting DOPO-functionalized PUs (DOPO-PU) were systematically investigated and compared with those of the alkene-functionalized PU. The results elucidate the contribution of DOPO moieties to the enhancement of the flame-retardant performance of thermoplastic PU materials (Figure 1).

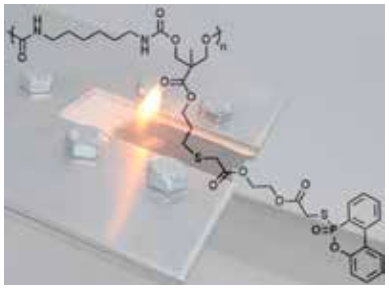

Figure 1: Photo of flammability test conducted on filter paper coated with DOPO-PU

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Design of polymer-coated composite systems for sustained curcumin release

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Cancer-related diseases are among the most extensively investigated areas in drug delivery research. One of the active compounds employed in cancer therapy is curcumin. Curcumin (CUR) is a naturally occurring polyphenolic plant pigment. It exhibits a broad spectrum of biological activities, including antioxidant, antibacterial, anti-inflammatory, analgesic, and wound-healing properties.

In this study, it was aimed to achieve controlled release of CUR and prolong its therapeutic effect while minimizing the effective dosage. Ethyl cellulose (EC) was selected as the carrier material in order to enhance the controlled release behavior and drug delivery performance of curcumin. Furthermore, to improve the efficiency of the drug release system, chitosan (Cht) was incorporated into the curcumin–ethyl cellulose (CUR:EC) structure, and a chitosan/curcumin:ethyl cellulose (Cht/CUR:EC) composite system was synthesized. The synthesized materials were comprehensively characterized, and in vitro release studies were conducted to evaluate their drug release performance. The release studies revealed that the 1:1 CUR:EC composite exhibited the longest release duration. At the end of the 102-hour in vitro experiments, the 1:1 CUR:EC formulation achieved cumulative release values of 3.78 % in simulated gastric medium and 26.32 % in simulated intestinal medium. The 1:1 CUR:EC composite was subsequently coated with chitosan (Cht) at different ratios, and among the coated formulations, the 10 % Cht/CUR:EC composite demonstrated the most prolonged release profile. Following 102 hours of release in the intestinal medium, the 10 % Cht-coated composite reached a cumulative release of 5.30 %. Kinetic analyses performed to elucidate the release mechanism indicated that the release system was best described by the zero-order kinetic model.

Microstructure-coupled predictive FEM simulation for FDM: Linking process, stress, and material properties

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Finite element (FE) simulations are widely used in fused deposition modelling (FDM) to study how temperature and residual stresses evolve. However, most contemporary FE simulations focus on thermo-mechanical behavior, while changes in the polymer's microstructure are often ignored to reduce the complexity of numerical models. These microstructural features are important because they affect the final strength, the bonding between printed layers, and the long-term durability of the parts. Adding microstructural prediction to process-scale simulations is an important step toward more reliable and property-focused modelling of 3D-printed components.

In this study, we use a finite element framework in ANSYS to explore how the deposition path and the material's thermal history affect its microstructure. The simulation starts with slicer-generated G-code to determine the deposition order. Elements are activated one after another along the toolpath to mimic how material is added during printing. A transient thermal analysis is performed, considering the nozzle as a moving heat source. In order to capture sharp temperature changes near the nozzle accurately, we use a finer mesh in that area and a coarser mesh in regions already printed. When the mesh changes during the simulation, we use thermal remapping to transfer temperature data from the old mesh to the new one, keeping the thermal history of each region intact.

We use the temperature and time data for each element to estimate how the microstructure changes, based on phase transformation kinetics. To track crystallinity, we apply well-known kinetic models like the Avrami equation, using local cooling rates and thermal exposure times from the FEM analysis to determine how fast crystallization happens. The material parameters for these models come from published data on similar polymers. We also look at porosity and how well the layers bond by using empirical formulas that link thermal gradients, cooling rates, and the time filaments are in contact during printing. These calculations are done for each element using external post-processing routines that use the temperature data from the FEM simulation.

This framework aims to predict influence of features like crystallinity, porosity, and inter- and intra-layer bonding quality in the printed part, along with standard results like temperature fields and residual stresses. By combining these predictions to the actual deposition process and thermal history, the method helps explain how printer settings and toolpath design affect the printed parts. In the long run, combining microstructural changes with process-scale simulation could lead to more accurate, property-focused models and future digital twin systems for additive manufacturing.

Test device for analysing the mixed-mode crack propagation behaviour of polymer materials under quasi-static short-term and static long-term loading

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Based on preliminary investigation into the mixed-mode crack propagation behaviour of polymeric materials under quasi-static loading conditions (short-term tests), a test device was developed and successfully tested to determine the fracture mechanics behaviour of investigations under static loading conditions (long-term tests) in Mode I (crack opening under tension), Mode II (crack opening under shear), and Mode I/II mixed mode, including at elevated temperatures.

Due to the available testing positions in the creep testing machine used, supplied by Coesfeld GmbH & Co KG, three test devices can be positioned in parallel, each accommodation one CTS specimen (compact tension shear). The loading angle can be varied from 0° (Mode I) to 90° (Mode II) in five intermediate steps (15°, 30°, 45°, 60°, and 75°), and it can be adjusted separately for each of the three specimens. Force and displacement data are recorded using the load cells and crosshead sensor system integrated into the creep testing machine.

After completion of the tests, the initial crack propagation angle was measured using a profilometer from Keyence. To verify the general applicability of the test device for evaluating the toughness of plastics, one semi-crystalline and two amorphous thermoplastic materials were selected: polyethylene (PE), polycarbonate (PC), and polymethyl methacrylate (PMMA). Due to the time required for static fracture mechanics investigations, the verification was initially carried out under quasi-static conditions at room temperature. However, creep fracture mechanics investigations are already being planned.

The result shows clear material-related differences in fracture toughness and in the initial crack propagation direction as a function of the loading angle. These investigations therefore provide important insights into the use of polymeric material in structurally relevant applications, particularly in cases where complex loading situations are expected.

Acknowledgement

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The **Bethge-Center for Micro-Characterization (BCMC)** is a central large-scale equipment center at Martin Luther University Halle-Wittenberg and offers state-of-the-art technologies for materials science analysis. Its equipment portfolio includes, among other things, a high-resolution X-ray microscope (XRM), an ESEM-FIB, several ESEM systems, various Raman microscopes, and an FTIR microscope. This equipment enables a broad spectrum of conventional as well as high-resolution and analytical micro-characterization.

The infrastructure is open to both internal university partners and external partners—including research institutions, companies, and startups. While the *XRadia 810 Ultra* X-ray microscope is operated exclusively by trained staff from the Chair of Microstructure-Based Material Design (Prof. Wehrspohn) and the BCMC, other instruments can be used independently after training, depending on their respective capacity.

In addition, the BCMC assists external users in selecting the optimal analytical methods for their specific research questions. We provide guidance on suitable procedures for different sample types and proper sample preparation.

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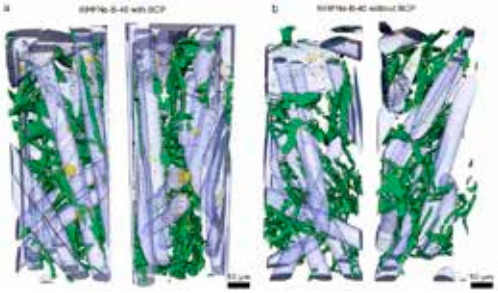
Scanning electron microscope Versa



XRM images of fibres for filtration

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der Hochschule Merseburg

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Der Gründungscampus HoMe bündelt vielfältige Angebote rund um Gründungskultur und Entrepreneurship an der Hochschule Merseburg.

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exist

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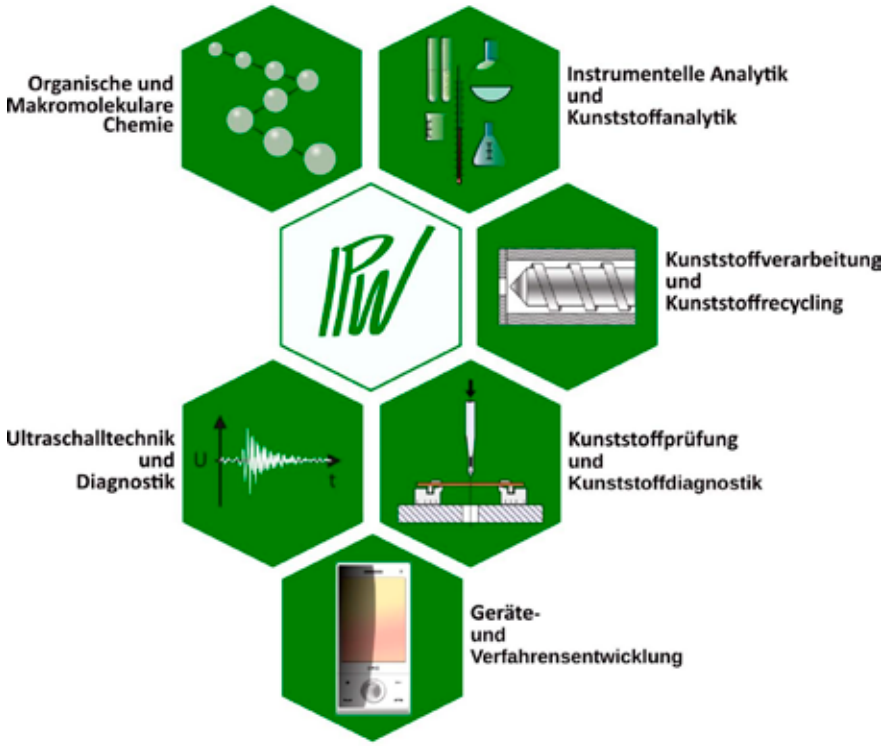
INSTITUT FÜR POLYMERWERKSTOFFE e.V.

Associated Institute at the Merseburg University of Applied Sciences

The Institut für Polymerwerkstoffe e.V. (IPW) was founded at 11 June 1992 as the first associated institute within the federal state Sachsen-Anhalt. The main activities of IPW are dealing with projects in research and development, assistance and support for the transfer of knowledge into the economy, and organisation and realisation of workshops, symposia and conferences.



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The **Akademie Mitteldeutsche Kunststoffinnovationen (AMK)** is a legally independent foundation based in Merseburg. Its mission is to promote science, research, and continuing professional education in the field of polymeric materials in the Central German region.
The foundation was established in December 2007 by professors and representatives of institutions that were affiliated with the former Kunststoff-Kompetenzzentrum Halle-Merseburg (KKZ Halle-Merseburg), including Polykum e.V., Institut für Polymerwerkstoffe e.V., and Polymer Service GmbH Merseburg.

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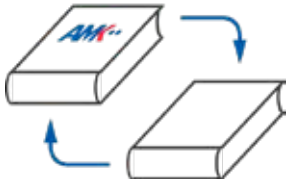

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