SUSTAINABILITY CENTER FREIBURG

LIGNIN-BASED MOLDABLE PLASTICS: A WASTE PRODUCT FROM THE WOOD INDUSTRY REPLACES FOSSILE RESOURCES

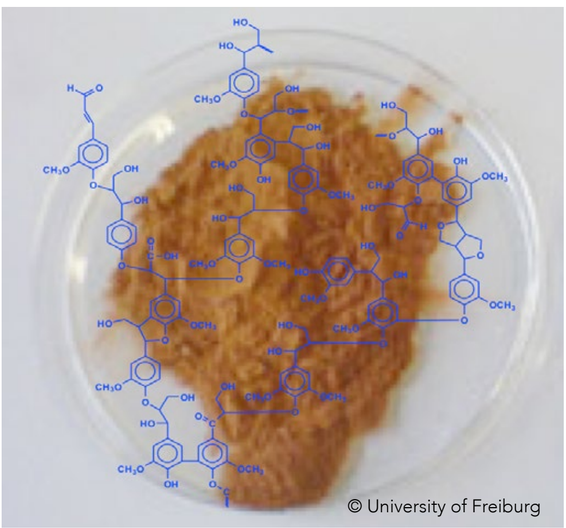

Figure 1: Thanks to its chemical functional groups, lignin can in principle be used as a bio-based plastic and replace fossil fuels. However, only 2 percent of the currently produced lignin mass are transferred into a chain which adds economic value. The remaining 98 percent are burnt in an effort to obtain energy.

Lignin is a major constituent of wood. It occurs in enormous quantities as a waste product during the manufacturing process of paper. However, lignin could be a valuable resource due to its chemical structure (c.f. Fig. 1). Its many phenolic functional groups make it in principle an attractive candidate for a biologically based renewable plastic. However, some technological difficulties exist which currently prevent the industry from processing lignin to actually usable plastic products which could reduce the consumption of fossile resources. Instead, lignin is burnt directly to provide energy for paper processing plants. Thus, every year, 50 million tons of a potentially usable, high-value green resource are wasted solely for the generation of heat.

This research project aims at creating a technology that transforms raw lignin into a plastic which can be processed using conventional techniques such as injection molding or extrusion. Currently, lignin cannot be processed with these conventional techniques because its viscosity is too high. If lignin is heated in an attempt to reduce its viscosity, it will decompose before a sufficiently low viscosity is reached. Thus, the challenge at hand is to reduce the viscosity of lignin in a cost-effective and eco-friendly manner. To this end, the rheology is altered and improved by mixing lignin with a second constituent, typically a derivative of cellulose, such that a microphase separation with liquid-crystalline properties is obtained (c.f. Fig. 2). In this new mixture, a liquid aqueous phase contains highly ordered cellulose molecules. This phase interpenetrates and separates microscopic entities of lignin, similar to an emulsion but not quite: the individual phases remain topologically connected similar to interleaving combs. The low viscosity of the aqueous microphase provides gliding planes which dramatically lower the total viscosity of the whole mixture. This results in a product which – in contrast with raw lignin – is suitable for processing with injection molding techniques.

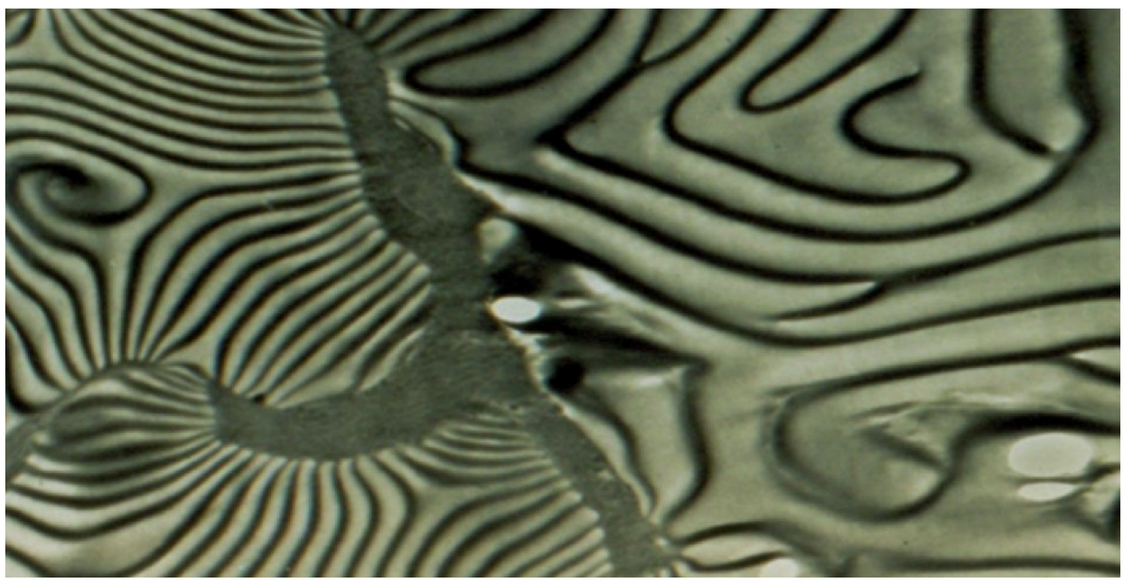

Figure 2: A mixture of a cellulose derivate and lignin form a stable microphase-separated structure. (Davé, Glasser, and Wilkes. 1992. "Evidence for Cholesteric Morphology in Films of Cellulose Acetate Butyrate by Transmission Electron Microscopy." Polymer Bulletin 29 (5): 565–70).

This research endeavor features a number of unknown parameters. For example, it is yet unknown how the precise chemical structure of the cellulose derivative interacts with the effect of microphase separation, which is the basis for lowering the effective viscosity. These questions are addressed with computer simulation techniques. Additionally, an extrusion process is modeled on a laboratory scale. To this end, a 3D printer is used which extrudes the hot lignin mixture from a small nozzle. This way, complex structures can be additively manufactured. We will use this technology to directly print test specimens for characterizing the mechanical properties of this new biologically based plastic. As a result, we have a complete evaluation loop for optimizing the process of converting raw lignin into a usable plastic which can lower our consumption of fossil fuels.

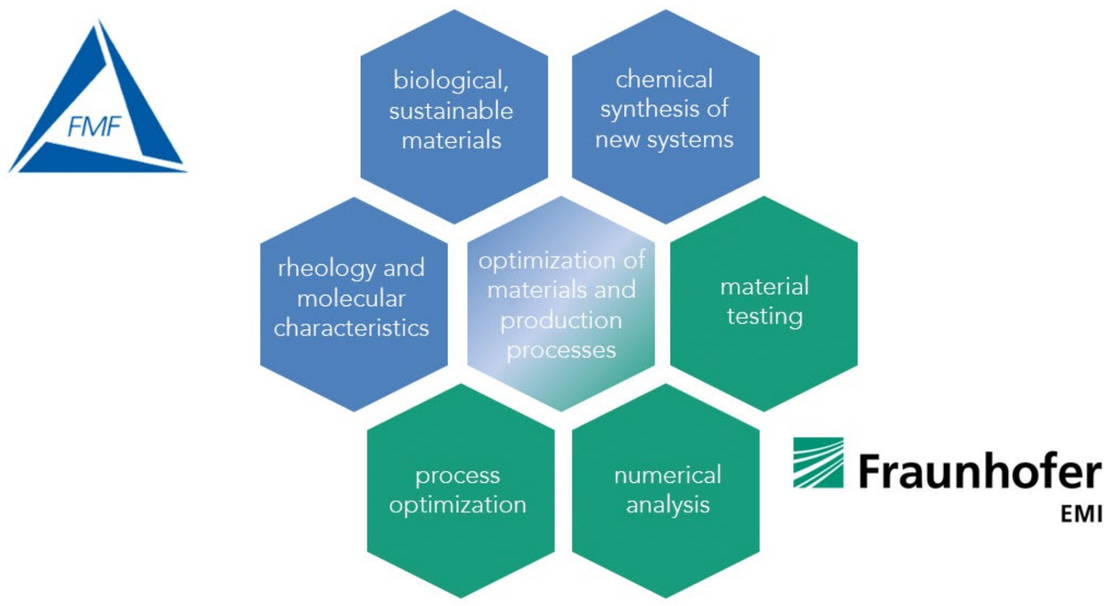

Figure 3: A chart of the project partners´ competences and the synergetic effects within the Sustainability Center.

Contact

Dr. Georg Ganzenmüller
Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI
georg.ganzenmueller@emi.fraunhofer.de

Prof. Dr. Marie-Pierre Laborie
University of Freiburg
Forest Biomaterials, Materials Research Center
marie-pierre.laborie@biomat.uni-freiburg.de

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