Polymer Synthesis and Fiber Technologies – from Atom to High Performance Fiber

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Abstract

The increasing demand for sustainable, functional, and high-performance fiber materials requires the development of tailored polymer systems combined with resource-efficient, scalable manufacturing technologies. Establishing defined structure-process-property relationships is essential for transferring novel material concepts into technically relevant fiber structures. Current research at ITM focuses on the integrated development of polymeric materials and melt- and solution-spinning processes from the laboratory to the pilot scale for the generation of high-performance fibers in combination with modelling of the involved fluid and fiber dynamics. Thus, e.g., percolation or crystallization during the spinning processes can be controlled. Melt-spinning approaches include mono- and multicomponent fiber systems based on conventional and high-performance polymers, as well as functionalized and bio-based materials with specifically designed application-specific properties. Adapted feeding and processing concepts enable the incorporation of thermally and mechanically sensitive additives as well as the realization of complex multicomponent fiber geometries.
Research on solution spinning focuses particularly on natural and sustainable polymers, including chitin, chitosan, lignin, and cellulose as well as polyacrylonitrile (PAN) as carbon fiber precursors, and electrically conductive polymer systems. Developing multifilament processes with up to 1,000 filaments and implementing alternative solvent systems provides a foundation for combining production scale up of novel materials with enhanced reproducibility and mechanical properties.
Further research addresses circular material concepts by recycling and upcycling of underutilized waste streams and implementing biodegradable raw materials for technical applications as well as the technical realization and scientific analyzation of noval reactive spinning processes to broaden the variety of spinnable polymeric materials and thus fiber-based technical applications. Targeted applications include carbon fibers for lightweight construction,

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architecture and batteries, conductive fibers, and soft robotics. Integrating *in-situ* analytical methods with material and process development enables the systematic investigation of material transformation, fiber formation, and resulting structural properties. This interdisciplinary approach provides the basis for knowledge-based process design and the development of scalable technologies for future high-performance fiber materials.

Keywords: Polymer synthesis, in, situ analytics, spinning process development, material development