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ALL POLYOLEFIN COMPOSITES VIA NANOSTRUCTURE FORMATION DURING MELT PROCESSING

Rolf Mülhaupt Alexander Kurek, Markus Stürzel, Fan Zhong and **Timo Hees**
Freiburg Materials Research Center, FMF, Albert-Ludwigs University of Freiburg, Germany

Among polymeric materials, polyolefins are clear leaders with respect to both world production scale and sustainability. Produced in solvent-free and environmentally friendly processes, they combine high resource-, eco-, energy- and cost-efficiency with low weight and outstanding versatility in terms of properties, processing, applications, and recycling. However, to compete with metals they require reinforcement by alien materials which impair recycling and processing. Special processing technologies such as lamination of stretched tapes and fiber technology are required to produce "all polyolefin composites" in which both matrix and reinforcing phases consist of polyolefin. At the beginning of the 21st century, remarkable progress in multisite polymerization catalysis enables to produce reactor blends with tailored molar mass distribution which form extended-chain polyolefin during injection molding and extrusion, typical for commodity polyolefins. Robust chromium sites produce nanophase-separated ultrahigh molar mass polyethylene (UHMWPE) unaffected by other sites during ethylene polymerization on supported multisite catalysts. The site blend ratio governs ultrabroad PE molar mass distributions and nanostructures with unprecedented precision. Owing to significantly reduced UHMWPE entanglement, reactor blends with high UHMWPE content (>20 wt.-%) are melt processable by classical injection molding. HDPE wax serves as a processing aid which cocristallizes and does not cause emission and odor problems. This *in situ* formation of nanophase-separated fiber-like extended chain UHMWPE, with an average diameter of 80 nm, effectively reinforces the HDPE matrix as expressed by significantly improved strength/stiffness/toughness balance. In addition to tailoring two- and three-site catalysts systems and reactor blends, nanophase-separated UHMWPE embedded in HDPE wax represents a versatile new additive enabling fabrication of all-polyethylene composites by melt compounding without affecting ethylene polymerization of commodity polyethylenes. Hence, this versatile route to sustainable all-polyethylene composites holds great promise for converting commodity polyolefin materials into high performance engineering materials without impairing melt processing, sustainability and facile recycling. Unlike common polyolefin nanocomposites, neither handling of problematic nanofillers nor special composite processing is required.

Recent Publications

1. M. Stürzel; S. Mihan; R. Mülhaupt (2016) From Multisite Polymerization Catalysis to Sustainable Materials and All-Polyolefin Composites, Chem. Rev. 116, 1398.
2. F. Zhong; J. Schwabe; D. Hofmann; J. Meier; R. Thomann, M. Enders, R. Mülhaupt (2018) All-polyethylene composites reinforced via extended-chain UHMWPE nanostructure formation during melt processing, Polymer 140, 107.
3. M. Stürzel; T. Hees; M. Enders; Y. Thomann; H. Blattmann; R. Mülhaupt (2016), Nanostructured Polyethylene Reactor Blends with Tailored Trimodal Molar Mass Distributions as Melt-Processable All-Polymer Composites, Macromolecules 49, 8048.
4. M. Stuerzel; A. Kurek; T. Hees; Y. Thomann; H. Blattmann; R. Mülhaupt (2016) Multisite catalyst mediated polymer nanostructure formation and self-reinforced polyethylene reactor blends with improved toughness/stiffness balance, Polymer 102, 112.

Biography

Prof. Dr. Rolf Mülhaupt studied chemistry at University of Freiburg, Germany (1973-1978) and got his PhD (1981) at ETH Zürich, Switzerland. After industrial research at DuPont Central Research (1981-1985) in Wilmington, DE, USA, and at Ciba-Geigy AG (1985-1989) in Marly, Switzerland, since 1989 he is full professor for macromolecular chemistry and director of the Institute of Macromolecular Chemistry at the University of Freiburg, Germany. Since 1992 he is the managing director of the Freiburg Materials Research Center, FMF, at the University of Freiburg, Germany. His research focuses on polymer chemistry and engineering, sustainable materials, polymerization catalysis & polyolefins, functional polymer and tailoring polymer systems, reactive processing and 3D-printing. He has published 456 papers in refereed journals and is listed as coinventor of 106 patent applications. He was awarded the Silver Medal of ETH-Zürich (1981), Piero Pino Gold Medal of the Italian Chemical Society (2004), Hermann Staudinger Price of the German Chemical Society (2009) and the Hermann F. Mark Medal (2013).

rolfmuelhaupt@web.de