



19<sup>th</sup> International Conference on Advanced  
Computational Engineering and Experimenting  
29 JUNE – 3 JULY 2026 | RHODES, GREECE

## ABSTRACT:

### Bridging the Gap to Injection Molding: in situ USAXS/WAXS Insights into Structure Formation in Semi-Crystalline Polymers under Process-Near Conditions

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Understanding structure formation in semi-crystalline thermoplastics under processing-relevant conditions is essential for establishing reliable process-structure-property-relationships. In extrusion and injection molding, crystallization is governed by a complex interplay of temperature history, local cooling rates and pressures, and flow-induced polymer chain orientation. While in situ synchrotron scattering provides unique access to the evolution of crystalline and supermolecular structures, reproducing processing-near conditions in a controlled experimental environment remains challenging. To address this challenge, we developed the FlowCell [1], an experimental setup combining in situ USAXS/WAXS with a microfocused X-ray beam at the P03 beamline of PETRA III (DESY) [2]. A process-Raman probe provides complementary access to structure formation during polymer solidification. Recent improvements enable stable thermal control and defined linear cooling profiles for systematic studies of cooling-rate-dependent structure formation. Using measurements at two cooling rates, we demonstrate that the FlowCell provides direct insight into supermolecular structure evolution in the USAXS range under controlled, process-near conditions. These results show that the FlowCell has matured into a robust platform for in situ studies of polymer crystallization. Direct comparison with ex situ line scans of injection-molded samples reveals persistent structural differences between morphologies generated in the FlowCell and those formed under the more extreme conditions of injection molding. The combined in situ/ex situ approach highlights the capabilities and the current limitations of the setup and helps assess how far process-near model experiments represent industrial processing conditions.

[1] Sambale, A.K., Euchler, E., Henn, E., Uhlig, K., Boldt, R., Schwartzkopf, M., Stommel, M.: “Experimental setup for in situ investigation of structure formation during solidification of polymer melts

in process-near conditions via synchrotron SWAXS“, Invited talk at 17. ACEX Conference 2024, 03.07.2024, Barcelona, Spain.

[2] Buffet A, Rothkirch A, Döhrmann R, Körstgens V, Abul Kashem MM, Perlich J, Herzog G, Schwartzkopf M, Gehrke R, Müller-Buschbaum P, Roth SV. “ P03, the microfocus and nanofocus X-ray scattering (MiNaXS) beamline of the PETRA III storage ring: the microfocus endstation.“ J Synchrotron Radiat. 2012 Jul;19(Pt 4):647-53. doi: 10.1107/S0909049512016895.