Ordering of Injection-molded TPU Under Mechanical load: Chain Orientation and Non-affine Deformation of the Nanostructure

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Thermoplastic polyurethane (TPU) material injection-molded from melts of 205°C, 215°C and 235°C is monitored by SAXS and WAXS during straining. Scattering experiments are carried out at HASYLAB, beamline A2. In an example of data-driven materials science many two-dimensional scattering patterns and macroscopic mechanical data are automatically evaluated to generate the results. Non-affine nanostructure deformation and related evolution mechanisms are found that cannot be resolved by the common peak analysis methods in reciprocal space.

DSC and optical microscopy are applied. DSC shows 2 melting endotherms. Only the material molded from the high temperature melt does not show spherulites. Results indicate that melts kept below the 2nd peak stay phase-separated. The orientation parameter \( f(\varepsilon) \) as a function of strain \( \varepsilon \) and its derivative \( df(\varepsilon)/d\varepsilon \) is related to chain orientation mechanisms. SAXS shows hard domains that are only correlated to a next neighbor ("sandwich"). Thick sandwiches lengthen more than thin ones. Thin-layer sandwiches feature a strain limit. During the straining test some thin-layer hard-domains fail and the corresponding sandwiches are converted into thick-layer sandwiches. The materials molded at 205°C, 215°C possess tough hard domains. Macroscopically these materials show a high elastic modulus and high toughness. The experiment is stopped when they slip from the clamps. Material made at 235°C contains weak hard domains that start to fail for \( \varepsilon > 0.75 \). Macroscopically the material is soft with a low elastic modulus. In the mechanical test it can be strained to high elongations without slipping from the clamps.

Reference