MICROMECHANICAL TESTING AT HIGH STRAIN RATES AND VARYING TEMPERATURES OF 3D-PRINTED POLYMER STRUCTURES

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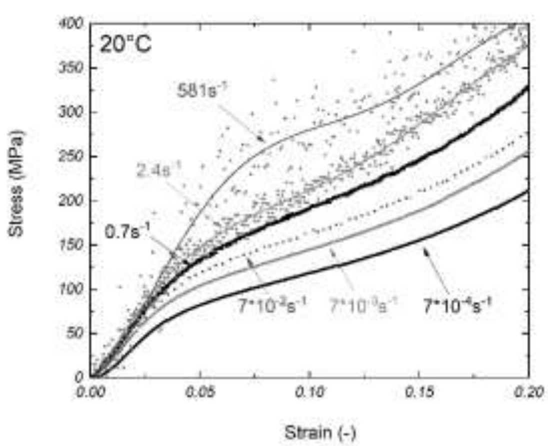
Following recent developments, in-situ nanoindenter systems can now perform tests at much faster speeds, enabling us to accomplish micro-compression experiments using strain rates in the range of 10^3 s^{-1} for micron-sized specimens. Thus, it has become possible to study deformation processes occurring in the very small scales of all types of materials. Here, we focus on the effect that dynamic testing speeds have on the mechanical behaviour of 3D-printed micron-sized polymer structures. We look at the influence of temperature and compare results obtained from compression and tensile tests.

All structures were fabricated with a Two-Photon Lithography system using the commercially available photoresist IP-Dip (both by Nanoscribe GmbH). Pillars were printed with a diameter of 6 µm, whereas tensile test specimens had a gauge cross-section of 25 μm^2. The structures were printed onto silica substrates and no further post-processing was done. Micro-compression and tensile tests were conducted using an in-situ nanoindenter from Alemnis GmbH (Thun Switzerland) allowing dynamic and high temperature testing. This way we could apply strain rates spanning seven orders of magnitudes overall with the maximum strain rate accomplished just below 600 s^{-1}.



True stress strain curves determined during micropillar compression tests of polymers using varying strain rates

The stress strain curves obtained in the micro-compression tests at room temperature are given in the figure to the left. The strain rate sensitivity is significant and for a strain rate of 581 s^{-1} yielding only occurred well above 200 MPa, which was roughly 4 times as a high compared to the slowest quasistatic tests. In addition, there was some variation seen in the elastic modulus as well (2.5 to 3.5 GPa), but the increase with strain rate was significantly less pronounced compared to yielding ().

In the experiments conducted here the temperature was increased up to 80°C during testing, which lead to a significant decrease of yield stress and elastic modulus in the quasistatic regime. For higher strain rates, however, the drop in the yield stress was much less pronounced. When comparing the yield extracted from tensile tests to the micro compression results the same strain rate dependency is determined. The values are slightly lower for the yield in the tensile tests, which is likely due to the lack of a hydrostatic pressure component.

To our knowledge this is the first time that small-scale dynamic testing has been performed on polymer micropillars and the development of this experimental technique will be of interest also to the wider micromechanical research community.