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SAXS and SANS characterization of ion irradiation in polymers

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Organic polymers display some of the most prevalent applications in ion track technology. With the high susceptibility of ion tracks to chemical etching, track-etched polymers are commonly utilized for the production of nano-porous track-membranes and filters, embedding microelectronic devices such as micro-capacitors, diodes and nanowires as well as for in-vivo storage vessels and a large range of sensor applications.

We present our results on the investigation of un-etched ion tracks in polymers, such as polycarbonate and polyimide. The ion tracks were created by swift heavy ion irradiation at the Universal Linear Accelerator at GSI. We have previously demonstrated that synchrotron-based small angle x-ray scattering (SAXS) allows the detailed characterization of ion tracks in a number of materials [1]. Here, SAXS reveals a diameter of 5 nm for tracks in polycarbonate films. Complementary small angle neutron scattering (SANS) measurements reveal a similar value, yet the combination of both techniques allows an element-specific investigation in the change in density as a consequence of the ion irradiation. A significant hydrogen deficiency in the irradiation polymer areas is revealed that is independently confirmed by infrared spectroscopy (FTIR) on the same specimens.

Furthermore, the effect of energy deposition and irradiation fluence was studied systematically, both displaying a significant influence on the resulting track size. The stability of tracks was investigated by thermal annealing: For temperatures up to 200°C, the damage region was observed to recover gradually and a decreases in the difference in density to the undamaged region was measured. However, this process is accompanied by an increase in the track diameter, contrary to our previous results on tracks in inorganic materials, where the diameter displays a shrinkage. This suggests a fundamental different recovery mechanism for this class of materials.

[1] P. Kluth et al., Phys. Rev. Lett. 101 (2011) 175503.

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