Ion track morphology in fluoropolymers

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The interaction of energetic heavy ions with materials can cause various structural and property changes. For example, when energetic heavy ions pass through polymer materials, they can create elongated damage regions of a few nanometres in width and up to tens of micrometres long called "ion tracks". The study of such ion tracks in polymer materials is a reseach field of current significant activity because of both its beneficial and detrimental aspects on materials modfication. Using the generally high susceptibility of the damaged material in the tracks to chemical etching, they have found various applications such as the production of nano-porous track-membranes for filters, micro-capacitors, diodes and nanowires for microelectronic devices and a large range of sensor applications. On the other hand, radiation damage may lead to unwanted degradation of their physical properties, e.g. in space applications or large scale particle accelerators.

Fluoropolymers are high performance polymers and show a very high resistance to solvents, acids and alkalis. A combination of interesting chemical and physical properties such as high mechanical and electrical resistance, thermal stability and low friction coefficient make them suitable for many hi-tech and biological applications e.g., as engineering plastics for aero-space industries, in optical and electronic devices and also as films or membranes [1, 2]. Several groups carried out experiments on chemical modifications of fluoro polymers exposed to protons, electrons, and ions. However, a detailed understanding of ion tracks morphology in fluoropolymers is still lacking.

Here, we investigate ion tracks in fluoropolymers e.g. polyvinylidene fluoride (PVDF), ethylene-tetrafluoroethylene (ETFE), tetrafluoroethylen-perfluoromethoxyethylen (PFA), and tetrafluoroethy-len-hexafluoropropylene (FEP). The tracks were created by irradiation with Xe ions of 1.1 GeV at the GSI UNILAC in Darmstadt, Germany, and Au ions of 185 MeV at the ANU Heavy Ion Accelerator Facility in Canberra, Australia at ion fluences between 2×10^8 ions/cm^{2}and 5×10^{10} ions/cm^2. The track morphology was characterised using small-angle x-ray scattering (SAXS) performed at the Austraian Synchrotron and structural changes were measured using Fourier-Transform Infrared Spectroscopy (FT-IR).

The average track radii and their dependence on the irradiation fluence and ion energy are compared and related to the individual polymer structure. The results show that the ion energy influences the size of the ion tracks. For samples irradiated with 185 MeV ions, the track size was significantly greater than for those irradiated with 1.1 GeV ions. However, track radii vary for different polymers showing the largest track radius (14.2 nm) for ETFE and the smallest track radius (4.5 nm) for FEP for identical irradiation conditions.

References

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