

Damage structure in the ionic crystal LiF irradiated with swift heavy ions

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In many insulators, swift heavy ions in the MeV to GeV energy regime create latent tracks characterized by irreversible structural and chemical changes. Based on a large data set, the present report will give a detailed description of the damage structure and defect morphology of ion tracks in lithium fluoride. The results were obtained by different complementary techniques including optical absorption spectroscopy, small-angle X-ray scattering (SAXS), chemical etching, scanning force microscopy, and surface profilometry. In a large cylindrical halo of several tens of nanometers around the ion trajectory, single defects such as F- and F₂-centers are evidenced by optical absorption spectroscopy, similar to the damage known from conventional irradiations. Above a critical electronic stopping power of the ions of around 10 keV/nm, new effects occur, namely the formation of more complex defects in a very small core region with a radius of 1-2 nm. The damage in this zone is responsible for a characteristic anisotropic X-ray scattering and for chemical etching. Several observations indicate that this core consists of a quasi-cylindrical discontinuous array of complex defect aggregates (presumably small Li colloids, molecular fluorine and vacancy clusters). Profilometer measurements reveal substantial ion-induced volume expansion. This swelling can be assigned to a track radius of about 5-10 nm, an intermediate zone between the track core and the halo, and appears at a much lower threshold of around 4 keV/nm. Track data (radii and threshold) linked to the core and to swelling can be described within the frame of the thermal spike model assuming two different criteria, namely quenching of a vapor and a melt phase, respectively created along the ion path.