Morphology and elastic properties of swift heavy ion tracks in quartz

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Irradiation of a solid with swift heavy ions can induce structural modifications in a very narrow region around the ion trajectories, so called ion tracks. In quartz, swift heavy ion irradiation leads to a change in the refractive index and offers a means to impose an etch anisotropy in the material, paving the way for nano-fabrication and micromachining of optical devices. Ion tracks in quartz have been previously studied using different techniques including transmission electron microscopy (TEM) and Rutherford backscattering spectroscopy in channeling geometry (RBS/C), which revealed that the track interior is disordered and presumably amorphous [1]. By utilizing etching, the annealing kinetics of ion tracks in quartz was also investigated [2,3]; however, no annealing studies on the latent (un-etched) track structure have been reported up to date. In our experiments, we have combined synchrotron small angle x-ray scattering (SAXS) with *in situ annealing* in order to study morphology and annealing behavior of swift heavy ion induced tracks inside crystalline quartz. SAXS is a powerful tool for the measurement of ion track damage as it is a bulk technique which is sensitive to small density changes at the nanometer scale that often occur in the damaged regions. It can be used to determine changes in the track radii with sub-nanometer precision and is well suited for studying track annealing [4,5].

Ion tracks have been generated in crystalline quartz using ions with high energies ranging from 27 MeV to 2.2 GeV. Ion fluences between 5×10^{10} and 1×10^{12} ions/cm^2 were used which yield well separated ion tracks with negligible overlap. The change in track radii measured with SAXS as a function of the electronic energy loss (dE/dx) of the penetrating ion is compared with other techniques such as RBS/C and TEM. The measurement is consistent with an amorphous cylindrical track core presumably surrounded by a defective halo.

Elastic properties of ion tracks were studied by *in situ* annealing. The evolution of the track radius is well described by modeling the ion tracks as cylindrical elastic inclusions and using experimental values of the temperature dependent elastic properties of fused silica and quartz for the track and matrix material, respectively.

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