

Temperature dependent formation of ion tracks in quartz studied using small angle x-ray scattering *

D. Schauries¹, M. Lang², S. Botis², B. Afra¹, M. D. Rodriguez¹, M. Toulemonde³, O. H. Pakarinen⁴, K. Nordlund⁴, R. Ewing², M. Bender⁵, D. Severin⁵, C. Trautmann^{5,6}, N. Kirby⁷, and P. Kluth^{1,#}

¹The Australian National University, Canberra, Australia; ²University of Michigan, Ann Arbor, USA; ³CIMAP, Caen, France; ⁴University of Helsinki, Finland; ⁵GSI Helmholtzzentrum, Darmstadt, Germany; ⁶Technische Universität Darmstadt, Germany; ⁷Australian Synchrotron, Clayton, Australia.

Ion tracks are narrow cylindrical defects of displaced atoms, a few nanometres in diameter and up to tens of micrometres in length. They result from the interaction of high-energy heavy ions with the electrons of a target material. We have performed a systematic investigation of the effects of the temperature during track formation in natural quartz samples, using synchrotron-based small angle x-ray scattering (SAXS). SAXS is a powerful and non-destructive technique well suited to measure ion track radii with high precision [1].

Natural quartz samples were irradiated at the UNILAC accelerator with 2.2-GeV Au ions and a fluence of 5×10^{10} ions/cm². This leads to the formation of ion tracks of ~ 95 μm length, as estimated by SRIM2008 [2]. The irradiation was carried out at room-temperature (RT) as well as at elevated temperatures. The quartz was cut parallel to the c-axis, thus leading to a track alignment perpendicular to the crystal's c-axis. Reference samples, irradiated at RT, underwent the same heat cycles as the samples irradiated at elevated temperatures. For characterization of the track radii, SAXS measurements were carried out at the SAXS/WAXS beamline at the Australian Synchrotron and analysed using our existing protocols [1].

Figure 1 shows the SAXS spectra of Au-ion tracks in quartz together with the corresponding fits and plots of track radii as a function of temperature for both reference and high temperature irradiated samples. The error bars display the standard deviation of the respective fits; they are below visibility for most SAXS radii. The track radius increases as a function of irradiation temperature with 0.1 nm/100K. The reference samples also exhibit an increase in track radii, although about one order of magnitude lower than samples irradiated at high temperature. This small increase is possibly a result of heat-induced stress relaxation and will be discussed elsewhere. We can thus attribute the increase in track radii for the high temperature irradiated samples predominately to the conditions during track formation. For verification, thermal spike model calculations [3] as well as molecular dynamics simulations were carried out yielding a similar track size increase of 0.08 and 0.10 nm/100K, respectively. We conclude that at elevated temperatures the energy required for melting of the quartz is lowered and thus the melting

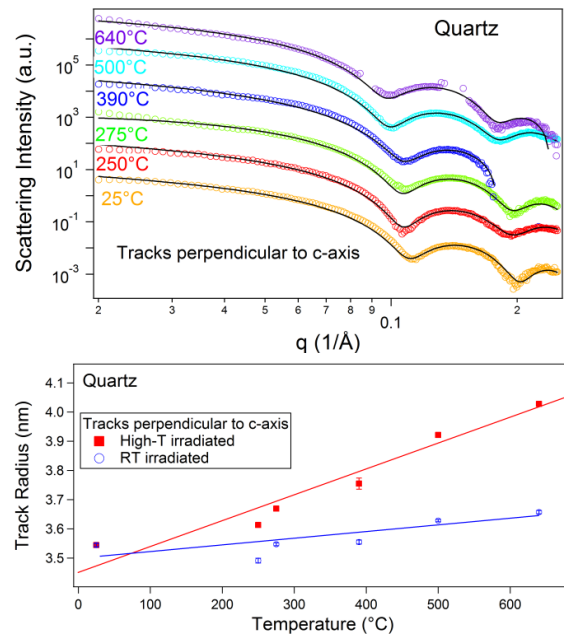


Figure 1: (top) SAXS intensities and corresponding fits of ion tracks in quartz, irradiated at different temperatures; (bottom) radii deduced from SAXS data of samples irradiated at RT (blue circles) and at high temperatures (red squares).

radius or equivalently the ion track radius is increased. We note that the small changes observed in the track radii are challenging to resolve with conventional analytical techniques such as transmission electron microscopy. Thus SAXS becomes an important tool in studying high temperature effects on ion track formation.

References

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#patrick.kluth@anu.edu.au