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Effects of alpha-irradiation on SiO_2 phases

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Aureoles surrounding radioactive inclusions – so called radiohaloes – are a common feature often observed in several rock-forming minerals. These alterations are caused by the action of alpha-particles (i.e. He^{2+} ions) emitted into the host mineral. While in some cases (e.g. biotite, cordierite) the most striking feature of radiohaloes is a strongly enhanced absorption of light, there are commonly no visible changes found in quartz. In this mineral, alpha irradiation leads to a marked change in the emission behaviour, which can be very well observed using cathodoluminescence (CL) imaging.

In the present study several micro- and nano-techniques [i.e., Raman spectroscopy, CL spectroscopy, and transmission electron microscopy (TEM)] were used to study the alteration in synthetic radiohaloes, produced by artificial alpha irradiation of various SiO_2 samples. Alpha-quartz of natural and synthetic origin as well as synthetic SiO_2 glass were implanted with different doses of 8.8 MeV He^{2+} ions (fluences in the range from 10^{13} to 10^{17} ions/cm^2). The initially dull bluish-violet CL color of the crystalline quartz samples was found to be transformed to bright yellow in irradiated areas. Monte Carlo simulations predicted that the observed depth of alteration is in very good agreement with the calculated range of alpha particles in quartz. Both, total intensity and radial intensity distribution of the CL emission change with the irradiation dose. Observations suggest a non-linear, approximately logarithmic increase of the CL intensity depending on the alpha dose. In contrast, no significant change in CL emission was observed in the case of He-irradiated amorphous SiO_2. The changed

emission behaviour of He-irradiated areas in alpha-quartz is accompanied by structural damage, caused by the impact of the alpha particles. Significant broadening of Raman bands is only observed near the far end of helium trajectories. This broadening is not only caused by the structural radiation damage but also by strain, inter alia due to (locally heterogeneous) volume expansion of irradiated micro-areas. Restricted to the end of the helium trajectories, there is a clearly defined, lense-shaped zone, characterised by changed optical and BSE behaviour. The structural state of this region, as investigated by TEM, will be discussed.