New Insights into the Formation of Radiohaloes: Effects of Artificial Alpha-Irradiation on Cordierite

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In a number of minerals, regions showing markedly altered light absorption behaviour can be found surrounding radioactive inclusions (Ramdohr, 1960). These so-called radiohaloes are caused by the action of injected alpha particles. Because very little is known about the exact processes of formation, a study on artificially produced analogues was conducted: Oriented cordierite crystals were implanted with 8.8 MeV He^{2+} ions, which corresponds to the highest alpha energy commonly encountered in nature. The irradiated areas are characterised by yellow colouration, which is strongly polarised parallel to the crystallographic *c* axis. Optical absorption spectra show that the colour is mainly caused by the low-wavelength slope of an intense absorption band in the ultraviolet region. Furthermore, the relative changes of metal–metal charge transfer and d–d band intensities as compared to the un-irradiated host indicate significant oxidation of the Fe^{2+} ions in the cordierite structure.

Monte Carlo simulations show that the observed alteration depth of ˜48 μm is in very good agreement with the calculated ranges of the injected particles. However, total intensity and radial intensity distribution of the radio-induced absorption change with increasing irradiation dose. The colouration intensity increases up to doses of 10^{14} He^{2+}/cm^2 but fades at higher doses, *i.e.* a radio-induced colouration reversal is observed.

The change in colour is accompanied by structural damage, caused by the impact of the He^{2+} ions: Raman spectra show increased broadening of vibrational bands when approaching the penetration depth of the injected particles, indicating a decrease of the short range order due to the accumulation of point defects. However, no indication of amorphisation was observed in cordierite irradiated with up to 10^{16} He^{2+}/cm^2. This seems to be in apparent contrast to He-irradiated -quartz where local amorphisation was detected after implantation with only 10^{15} He^{2+}/cm^2 (Krickl et al., 2008).

Furthermore, Raman and infrared spectroscopic investigations yield evidence for a radiochemical transformation of molecular species incorporated in the cordierite structure. Especially the transformation $CO_2 \rightarrow CO$, which was also found in natural radiohaloes, was reproduced artificially and experimentally confirmed. The presence of carbon monoxide in cordierite may therefore not only be caused by reducing conditions during formation (Khomenko & Langer, 2005) but also by the action of radioactivity.

References

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