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Radiation damage in zircon

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ABSTRACT

A single, zoned, Sri Lankan zircon exhibits a range of microstructures from crystalline to nearly amorphous that are the result of radiation damage over a dose range of $2.1–10.1 \cdot 10^{15}$ α-decay events/mg (0.16–0.47 dpa). The zones in the crystal were examined at a variety of length scales using optical microscopy, micro-Raman spectroscopy, electron microprobe analysis, and transmission electron microscopy. Birefringence varies linearly with dose: *birefringence* $= –4.71 \cdot 10^{–18}/\text{g} \cdot D_\alpha + 4.86 \cdot 10^{–2}$. Full width at half maximum (FWHM) measurements of the $B_{1g}(\nu_3)$ peak, as determined by micro-Raman spectroscopy, were used to estimate the extent of radiation damage in each zone. The radiation dose (calculated on the basis of U and Th concentrations and sample age) vs. damage (from the FWHM measurements of the $B_{1g}(\nu_3)$ peak) relationship among zones was consistent with results for a suite of Sri Lankan single crystals, suggesting that all of these zircon crystals have undergone a similar thermal history. Based on a comparison with zircon crystals that are considered to have undergone minimal annealing (e.g., lunar zircon), the Sri Lankan zircon crystals have accumulated less damage than is expected based on their calculated dose, consistent with previous evidence for annealing. To estimate the extent of annealing in Sri Lankan samples, an equivalent damage dose (i.e., the dose required to produce the same amount of damage in an unannealed sample) was calculated for a given U and Th concentration by determining the time of damage accumulation required to create an equivalent amount of damage in an unannealed zircon. The dose vs. damage relationship in Sri Lankan zircon crystals (560 Ma) is equivalent to that of a ~375 Ma unannealed zircon, suggesting that approximately one-third of the damage has been lost due to annealing. The dose vs. damage relationship is consistent with the direct impact model of damage accumulation. Transmission electron microscopy revealed zoning on a scale finer than could be identified optically (<0.5 μm) and the presence of abundant ZrO_2 nano-particles at zone boundaries.