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Mechanical properties of natural radiation-damaged titanite and temperature-induced structural reorganization: A nanoindentation and Raman spectroscopic study

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Abstract

This study provides new insights into the relation between thermally induced structural reorganization and the macroscopic mechanical properties of radiation-damaged titanite. The natural sample contains ca. 30% amorphous fraction. Low-temperature annealing affects only slightly the sample stiffness and leads to a softening resulting from the defect annihilation in crystalline regions. In the high-temperature annealing regime, amorphous domains recrystallize and this leads to further recovery of defects, reduction of interfaces, grain growth, and, in general, an increase in the long-range order. The thermally induced recrystallization is accompanied by massive dehydration leading to considerable stiffening and hardening. This interpretation of the recrystallization process in titanite based on the correlation of new results from nanoindentation and Raman-spectroscopic measurements complementing previous investigations using thermogravimetric and gas analyses by Hawthorne et al. (1991) and infrared spectroscopy by Zhang et al. (2001). The new data combined with previous work leads to a detailed description of the annealing behavior of a radiation-damaged titanite, which is a complicated process that includes dehydration and atomic-scale structural reorganization. To minimize the influence of surface phenomena on the hardness measurements, the so-called "true" hardness was used instead of the standard hardness calculation (Oliver and Pharr 1992). A comparison shows that the Oliver and Pharr method clearly underestimates the hardness.

Keywords: Titanite, radiation damage, α-decay, metamict, partially amorphous, dehydration, nanoindentation, Raman spectroscopy, true hardness, elastic modulus, recrystallization