

Cathodoluminescence of alkali feldspars and radiation effects on the luminescent properties

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ABSTRACT

Cathodoluminescence (CL) spectroscopy provides useful information about the existence of radiation-induced defect centers with a few micrometer resolutions and therefore has great potential to estimate the accumulated dose of natural radiation in micrometer-ordered mineral grains from radioactive decay. Although great scientific interest exists concerning the CL of various types of minerals, very few investigations have been conducted on the luminescence properties of radiation-induced alkali feldspars. This study, therefore, has sought a clarification of radiation effects on emission centers detected by CL analysis of alkali feldspar implanted with He⁺ ions at 4.0 MeV, which corresponds to the energy of an α particle derived from radioactive decay of ²³⁸U and ²³²Th.

Panchromatic CL images of cross sections of sanidine, orthoclase, and microcline show a dark line with ~ 1 μm width on the bright luminescent background at 12–15 μm beneath the implanted surface, of which behavior may be corresponding to the electronic energy loss process of 4.0 MeV He⁺ ion. CL and Raman spectroscopy revealed that He⁺ ion implantation may lead to a partial destruction of the feldspar framework and Na⁺ migration, resulting in a quenching of CL emission from alkali feldspar, proportional to the radiation dose. CL spectra of unimplanted and He⁺-ion-implanted sanidine, orthoclase and microcline have emission bands at ~ 400 –410 nm and at ~ 730 nm. Deconvolution of the CL spectra can successfully separate these emission bands into emission components at 3.05, 2.81, 2.09, 1.73, and 1.68 eV. These components are assigned to the Ti⁴⁺ impurity, Al-O-Al/Ti defect, a radiation-induced defect center, and Fe³⁺ impurities on the T1 and T2 sites, respectively. The intensity at 3.05 eV negatively correlates with radiation dose owing to decreases in the luminescence efficiency. A slight Na⁺ diffusion and breaking of the linkage between Ti⁴⁺ and oxygen as a ligand might reduce the activation energy, which decreases the availability of radiative energy in the luminescence process of Ti⁴⁺ impurity centers. Furthermore, He⁺ ion implantation causes electron holes to be trapped at and released from Löwenstein bridges as a consequence of Na⁺ migration and leads to a partial destruction of Al-O bonds, which might be responsible for an increase and decrease in the intensity of emission component at 2.81 eV. With an enhanced radiation dose, there is a decrease in intensity at 1.73 eV and an increase in intensity at 1.68 eV. Deconvoluted CL spectra of the alkali feldspars reveal a positive correlation between intensity at 2.09 eV and the radiation dose, which may be due to the formation of a radiation-induced defect center. These correlations can be fitted by an exponential curve, where the gradients differ between the alkali feldspars studied, and are largest for the microcline, followed by the orthoclase and then the sanidine. The intensity at 2.09 eV has the potential to be used in geosimetry and geochronometry.

Keywords: Cathodoluminescence, alkali feldspar, quenching, radiation-induced defect center, He⁺ ion implantation