Evaluation of radiation-damaged halo in quartz by cathodoluminescence

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The radiation-damaged halos in quartz have been investigated mainly with a CL microscope, which is applicable to color CL imaging, but not to spectral measurement and high-resoluted CL imaging. However, these CL halos have been almost not discussed quantitatively so far because micro meter size CL halo recorded in natural quartz might be caused complexly by a various kind of radiative elements. The purpose of this study is to evaluate the effect of alpha-particle radiation on the intensity of CL halos in quartz experimentally implanted with He^{+} ion by using high resolution CL imaging and CL spectroscopy.

A single crystal of colorless optical grade quartz from Minas Gerais, Brazil was employed for CL measurements. He^{+} ion implantation in the sample was performed on a 3M-tandem ion accelerator in the Takasaki Research Center of Japan Atomic Energy Research Institute. To maintain compatibility with the previous experiments for synthetic quartz [1], the acceleration energy of He^{+} was set at 4 MeV, corresponding roughly to the energy of alpha particles emitted from the decay of ^{238}U (4.18 MeV). The implantation was made under the four sets of conditions with different dose densities from 1.772×10^{-5} up to 3.544×10^{-4} C/cm^2. The sliced samples were cut vertically to the induced surfaces for cross-sectional observation of the CL halos.

CL imaging and spectral analyses were carried out on a SEM-CL system comprised of a SEM (JEOL JSM-5410LV) with a grating-type monochromator (Oxford Instruments MonoCL2) in wavelength range of 300 to 800 nm, where the operated condition was at 15 kV acceleration voltage and a beam current of 1.0 nA. Raman spectra and 2D Raman map were collected by a micro-Raman spectrometer (Thermoelectron Nicolet Almega). The measured laser power of the 532 nm excitation line (Nd-YAG laser) was 20 mW at the source with spot size 1 micrometer.

CL halos were observed in all samples after He^{+} ion implantation. The width of CL halos is consistent with theoretical range of alpha-particles from disintegration of ^{238}U in quartz [2] and agrees closely with that previously observed in synthetic quartz after He^{+} ion implantation under the same condition with a CL microscope [1]. The CL emission within the halo band gradually increased from the implantation surface to the inside up to about 14 micrometers. Regardless of He^{+} ion dose, this feature of CL halos was almost same in all samples, whereas the visual intensity of CL halo emission increased with increase of dose density. The distribution pattern of CL intensity obtained by CL line analysis looks similar with the Bragg's curve, which shows specific energy loss related to specific ionization along the track of a charged particle. CL spectra of halo are composed of two broad bands around at 390 and 650 nm, although blue emission at 390 nm is mainly correlated to dose density. Micro-Raman spectroscopy reveals the destruction of quartz lattice in CL halo. He^{+} ion implantation into quartz causes structural destruction, which results in defect centers responsible for blue emission in CL halo. CL line analysis shows that the dose density is related to integrated CL intensity obtained by subtracting the intensity of host material from intensity of CL halo area. The integrated CL intensity increases with dose density. Red component obtained by color CCD analysis of CL halo was enhanced by an increase in dose density [1]. The results conclude that the CL halos can be used for a geodosimeter of natural radiation recorded in minerals.

References:

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