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Cathodoluminescence characterization of tridymite and cristobalite: Effects of electron irradiation and sample temperature

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Abstract

Cathodoluminescence (CL) spectra of tridymite and cristobalite have broad peaks around 430 and 400 nm, respectively, both of which can be assigned to the $[AlO_4/M^+]^0$ defect. The CL intensities of these spectral peaks in the blue region decrease with prolonged exposure to electron irradiation, similar to the short-lived luminescence observed in quartz, although quartz shows a lower decrease in CL intensity compared to these minerals. Cristobalite has a higher CL intensity reduction rate during irradiation than does tridymite. Irradiation of these minerals at low temperatures results in a more rapid decay of CL emission, whereas that of quartz shows no apparent change in the rate of CL emission at similar temperatures. Confocal micro-Raman spectroscopy of the electron irradiated surface of these minerals reveals the amorphization caused by the interaction of the electron beam with the surface layer to a depth of several micrometers. This suggests that such structural destruction diminishes the activity of CL emission centers related to the $[AlO_4/M^+]^0$ defects by migration of monovalent cations associated with exchanged Al in the tetrahedral sites. Both samples present a considerable reduction of their CL intensities at higher temperature, suggesting a temperature quenching phenomenon. The activation energy in the quenching process was evaluated by a least-squares fitting of the Arrhenius plots, assuming the Mott-Seitz model. The result implies that the energy of non-radiative transition in this process might be transferred to lattice vibrations as phonons in two different manners. This might be related to different irradiation responses of the CL with a change in sample temperature.

Keywords: Tridymite, cristobalite, cathodoluminescence, electron irradiation, temperature quenching, Raman spectroscopy