

Temperature dependence of cathodoluminescence in quartz

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Cathodoluminescence (CL) of quartz has been extensively investigated by many researchers. Its applications have been advanced as an optical CL observation for mineral identification, growth and fabric analyses as well as provenance studies. A quantitative evaluation of quartz CL, however, has not been clearly shown by the reason of complicating features of diverse defect and impurity centers, or weak CL intensity at room temperature [1, 2].

Commonly, impurities in crystals, defect structures and sample temperature influence on CL emission [3, 4], where sample temperature shows an appreciable effect on CL of quartz. Luminescence efficiency significantly decreases with increasing temperature [4, 5, 6]. Its phenomenon is known as temperature quenching. In this study we measure the temperature dependence of the CL below room temperature and clarify a mechanism of peculiar temperature quenching effect on the CL of quartz.

Samples were selected from different origin; hydrothermal quartz [Hy-quartz], pseudomorphous crystal [Ht-quartz] of high quartz (Beta-quartz), and quartz [Hp-quartz] in high pressure metamorphic rocks (Jd+Qtz and eclogite). All measurements were made with a scanning electron microscopy-cathodoluminescence (SEM-CL), which comprises a SEM combined with an integral monochromator, in the scanning mode of accelerating voltage of 15 kV, current 0.05 to 1.0 nA and wavelength region of 300 to 800 nm. The sample stage can be controlled at various temperatures using liquid nitrogen and embedded heater.

In CL measurements under low temperature, CL spectra in the blue region with doublet peak at 450 and 500 nm were obtained below 223 K, but almost no obvious CL emission was observed above 223 K. Under highly dense irradiation at 1.0 nA, CL spectra were shown at 450 and 630 nm in Ht-quartz at room temperature. In Hy-quartz and Hp-quartz, CL spectra were shown at around 630 nm. However, difference of CL spectra of quartz from different origin was not seen by reason that CL intensity was weak at room temperature. The blue CL at 450 to 500 nm might be assigned to STE (self-trapped excitons) or E' center caused by oxygen deficient defect in framework lattice. Luminescence efficiency (A) adopted integrated intensities obtained from a Gaussian peak fitting of the CL spectra converted to energy space (eV) after the sensitivity correction of the spectrometer. The efficiency at 3.1 eV significantly increased with decreasing sample temperature, where the efficiency at 81 K was between 60 to 80 times than at 298 K. A salient feature of such temperature effect on CL emission is peculiar to quartz.

The CL efficiency of Hy-quartz rapidly decreases beyond 163 K, and moderate decrease beyond 143 K for Hp-quartz, but gradual decrease over wide temperature range up to 263 K for Ht-quartz. The results of modified Arrhenius plot of $\ln[(1/A)-1]$ against $1/T$ (T : absolute temperature) reveal activation energies of thermal quenching process; 0.245 eV from 163 to 263 K for Hy-quartz, 0.153 eV from 143 to 223 K for Hp-quartz, and 0.075 eV from 81 to 263 K for Ht-quartz. Consequently it leads to the difference in the nature of defect centers of quartz from different origin. The result implies the possibility of an application of temperature quenching behavior of CL for the genetic and provenance studies of quartz minerals.

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