Cathodoluminescence and micro-Raman spectroscopic measurements of shocked quartz

Tasuku Okumura[1]; Hirotsugu Nishido[1]; Kiyotaka Ninagawa[2]

[1] Res. Inst. Nat. Sci., Okayama Univ. Sci.; [2] Applied Phys. Okayama Univ. of Science

Cathodoluminescence (CL) spectroscopy provides us with useful information on an existence of trace elements in materials as well as lattice defects. micro-Raman spectroscopy is a technique that provides vibrational information on crystal structure for microscopic area. In this study we discuss an effect of shock-metamorphism on quartz by means of CL and micro-Raman spectrometry.

Samples used for this study were shocked quartz from the Ries Crater, Germany (WEN-03/1) and from Arizona Crater, USA (CO2-01). The samples were prepared as polished thin sections using nonluminescent epoxy resin and coated with 20 nm thickness carbon. Multiple sets of PDFs (planar deformation features) were observed in quartz grains of WEN-03/1 under a petrographic microscope. Powder X-ray diffraction analysis shows the presence of coesite and stishovite in CO2-01, while there is no evidence of PDFs in it.

Raman spectra were obtained with an Almega: confocal micro-Raman spectrometer with a 20 mW at 532 nm with Nd:YAG laser excitation system. CL spectral measurements were carried out using a JSM-5410LV SEM combined with a MonoCL2 grating monochromator (Oxford Instruments) in wavelength range of 300 to 800 nm, where operated condition was at 15 kV acceleration voltage and 0.05 nA beam current. The sample temperature was controlled in the range from -192 to 25 deg. C using a cryostage. CL observations were performed with a CL imaging system (Gatan MiniCL) attached to SEM.

Raman spectra of WEN-03/1 exhibit a pronounced peak at around 474 cm-1, which can be assigned to Si-O stretching vibration, whereas typical low-quartz has a sharp and intense peak at 464 cm-1. This frequency shift might be related to a distortion of structural configuration caused by shock-metamorphism. 3D micro-Raman imaging analysis using this Raman peak reveals a striped image comprised of crystalline band and amorphous band. This 3D Raman image corresponds to the optical image of PDFs (planar deformation features) characteristic of shocked quartz.

MiniCL imaging of WEN-03/1 gives no apparent features related to PDFs, which can be clearly observed under polarized microscope. Boggs et al. (2001) revealed striped CL images in shocked quartz from the Ries Crater. The sample analyzed here shows typical decorated PDFs with welded texture in a matrix. This fact suggests that temperature rising produced by a impact shock reduced CL signals in the quartz.

CL spectra of shocked quartz exhibit a doublet peak in the range from 450 to 500 nm. Upon heating the CL intensity rapidly decreased. The decay of CL intensity in low-quartz is well known as a temperature quenching effect.

The temperature quenching of the luminescence arises at high temperature because of the increased probability of non-radiative transition from the excited state to ground state. We quantitatively evaluated activation energy of this process by assuming Mott-Seitz model. As a result of modified Arrhenius plot, activation energy (E) were obtained in the range from -180 to -30 deg. C. They are 0.085 eV for WEN-03/1 and 0.091 eV for CO2-01. According to Okumura et al. (2004; 2005), typical low-quartz exhibit two temperature quenching processes, where the E is approximately 0.03 eV up to -110 deg. C and 0.235 eV above -110 deg. C. Therefore, the effect of shocked-metamorphism might affect to electronic transition process in defect centers correlated to CL emission.

A combination of CL and micro-Raman spectroscopy is a powerful technique for appreciating an effect of impact shock upon minerals.

1) Boggs, Jr., S., Krinsley, D.H., Goles, G.G., Setedolali, A., and Dypvik, H. (2001) Meteoritics & Planetary Science, 36, 783.
2) Okumura, T., Nishido, H., and Ninagawa, K. (2004) 32nd IGC, Abstract 114-24.
3) Okumura, T., Nishido, H., and Ninagawa, K. (2005) 15th Goldschmidt Conference, Abstract 192.