Shock induced vitrification, defect generation, and change in cathodoluminescence of quartz: possibility as a new shock barometer

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Impact cratering is a ubiquitous process on both terrestrial planets and small bodies in the solar system. Researches for impact craters on the Earth provide a valuable opportunity to constrain planetary-scale impact event. In particular, reconstruction of shock pressure recorded in the shock-metamorphosed minerals leads to a clue to understand a partition of the impact energy and cratering mechanism on Earth.

Quartz, which is one of the most abundant and widely distributed rock-forming mineral on the Earth’s crust, has been widely used to evaluate shock pressure on the impactite. However, the conventional shock estimations based on the mineralogical features of quartz, such as PDFs, are no more than a qualitative approach, hence it is required for more detailed evaluation of shock pressure to develop new advanced method using quartz.

Recently, we found the drastic change in cathodoluminescence (CL) features of quartz due to shock metamorphism [1]. The blue emission intensity (450-460 nm) of shocked quartz increases drastically with the experimentally induced pressure and reaches up to 100 times as large as that of the starting materials. On the other hand, CL intensity around 630 nm changes less than 3 times in spite of the pressure increase. Therefore, the relationship between shock pressure and blue CL intensity could be used as a new shock barometer. The mechanism for the increase in the blue CL intensity, however, still remains unclear because of a lack of information on structural defect in shocked quartz. In this study, Raman spectroscopy and EBSD analysis were conducted for the experimentally shock-induced quartz to clarify the structural change and generation of misorientations with the pressure. Consequently, we elucidated the CL mechanism of shocked quartz by comparison with the obtained Raman and EBSD data.

Raman spectra of the shocked quartz show a weakening of the main peak at ~464 cm^{-1} with pressure increase. At 30 GPa, the new peak at ~495 cm^{-1} appears, indicating the generation of shock-densified silica glass [2]. EBSD mapping revealed that shocked quartz undergo high pressure (~20 GPa) has high-density domains with boundary misorientation dominated by 60°, suggesting the development of Dauphiné twinning. However, for the quartz undergo pressure over 30 GPa, EBSD diffraction pattern was unrecognized because of low crystallinity. Therefore, the blue CL emission is closely related to Dauphiné twin, but this phenomenon is limited to the pressure lower than 30 GPa. On the other hand, the destruction of crystal structure and generation of high-density silica glass are consistent with the continuous increase in CL intensity of blue emission with pressure increase. These facts indicate a spectral change depending on the extent of vitrification. The relationship between CL intensity and the possibility as a new shock barometer will be also discussed.

[1] Chang et al., (2015) JpGU Meeting, PPS22-19.

[2] Okuno et al., (1999) PCM, 26, 304-311.

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