Shock-induced vitrification affected on cathodoluminescence of quartz: possibility as a shock barometer and its potential application to natural impact samples

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Impact cratering is a ubiquitous process on terrestrial planets and asteroidal bodies in the solar system. Many researches focus on impact craters on the Earth to reveal details of planetary-scale shock metamorphism. In particular, quantification of shock pressure that minerals in meteorites and impactites have experienced leads to a clue to understanding a partition of the impact energy and cratering mechanism on Earth as well as terrestrial planet and asteroids. Quartz, which is one of the most abundant and widely distributed rock-forming minerals on the Earth’ s crust, has been widely used to evaluate shock pressure on the impactite. However, the conventional shock barometer based on the mineralogical features of quartz, such as observation of planer deformation features (PDFs), are no more than a qualitative approach. Hence, it is required for a more detailed and accurate evaluation of shock pressure to develop a new advanced method using quartz.

Recently, we clarified the drastic change of cathodoluminescence (CL) features of quartz due to shock metamorphism [1]. The blue CL emission intensity (450-460 nm) of quartz increases drastically with the experimentally shock-induced pressure and reaches up to 100 times as large as that of the starting materials. The mechanism for the increase in the blue CL intensity can be explained by a combination of Dauphine twin generation and shock-induced vitrification. Because of the monotonical response to shock pressure, the blue CL intensity of the shocked quartz could be used as a new shock barometer [1]. In this study, we measured natural samples of quartz in impactite from the Chicxulub Crater drill core (YAX-1) in order to verify its application as shock barometer using CL for the natural crater samples.

The two core samples named Unit 1 (ejecta from impact-produced tsunami deposit) and Unit 5 (impact melts) were extracted from the YAX-1 core and selected for CL analyses. The extracted quartz grains form these samples were measured by microphotography of the PDFs orientation and the qualitatively estimated shock pressures of the quartz grains are < 15 Gpa for Unit 1, and 25 - 40 GPa for Unit 5 [2].

Quartz samples from Chicxulub crater exhibit similar CL profile to shock experimental quartz samples. Both natural samples show two peaks; CL spectra of Unit 1 samples consist of a pronounced peak at ~440 nm and a broad peak at ~630 nm. On the other hand, Unit 5 samples have a weak peak at ~440 nm and the peak at ~630 nm with relatively high CL intensity. As Unit 5 samples originate from impact melt which have experienced a high-temperature effect, post-impact annealing could affect the original blue CL emission of the quartz samples. Unit 1 samples, ejecta from the tsunami deposit, would have experienced lower degree of post-impact annealing than Unit 5 samples. These facts suggest that blue CL emission could be used as a shock barometer for natural impact samples which were not strongly affected by post-shock annealing. The quantitative pressure estimation and applicable scope of CL to natural impact samples will be also discussed.

[1] Chang et al., (2016) JpGU Meeting, PSS11-P21.

[2] Chang et al., (2018) MAPS 53, 7, 1323-1340.

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