Cathodoluminescence imaging and X-ray diffraction analysis of shocked eucrites

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Introduction

Shock metamorphism is one of the most important geologic processes on asteroids. The characterization of shock metamorphism is important for a better understanding of the crust evolution. The petrologic evidence of shock metamorphism in meteorites remained as breccia textures, shock melt veins, and high-pressure minerals. Eucrites are meteorites from the surface crust of the differentiated protoplanet (probably asteroid 4 Vesta [1]). Petrologic evidence indicates that they suffered from complex shock metamorphism on Vesta [e.g., 2]. Bischoff and Stöffler [2] defined shock stages of achondrites. Their shock stage classification is mainly based on the observations of the textures of pyroxene and plagioclase in naturally and experimentally shocked samples. However, their classification is not applicable to eucrites in some cases because of different mineral compositions. We have been developing a detailed shock classification for eucrites [3]. In this presentation, we focused on CL property of plagioclase and maskelynite in eucrites with relation to the results from optical and scanning microscopy and X-ray diffraction (XRD).

Samples and methods

We examined polished thin and thick sections of 16 eucrites using a luminoscope (ELM-3) at the Okayama University of Science and an X-ray diffractometer, SmartLab (RIGAKU) an optical microscope, a field emission scanning electron microscope (FE-SEM: JEOL JSM-7100) with an energy dispersive spectrometer (EDS) (Oxford AZtec Energy) and a cathodoluminescence system (GATAN Chroma CL), an electron probe microanalyzer (EPMA: JEOL JXA-8200), and a Raman spectrometer (JASCO NRS-1000), at the National Institute of Polar Research (NIPR).

Results and Discussion

The color CL image provides the two-dimensional distribution of maskelynite and plagioclase in eucrites. We found maskelynites in A-881747, Y-790266, Y 980433, Cachari, and A-87272. These color CL images show the heterogeneity of the CL emission color in the plagioclase grain indicated by the yellow and purple portions (Fig. 1). The difference in CL color is also represented by the CL spectrum (Fig. 2). The yellow portion contains mainly cracks in the grain, but the purple portion is uncracked and smooth under the optical and electron microscopes. The Raman spectra of the yellow portion show the sharp peaks around 280, 480, 510, and 560 cm^{-1}, corresponding to those of plagioclase (Fig. 3). On the other hand, Raman spectra of the purple portion show broad peaks of around 510 and 570 cm^{-1}, corresponding to those of maskelynite. Thus, the yellow and purple CL color emissions represent the plagioclase and maskelynite, respectively. We obtained relative abundances of plagioclase and maskelynite using the CL property.

We proposed the shock degrees of eucrites, on the basis of petrographic observations and X-ray diffraction (XRD) data from A to D (unshocked to highly-shocked eucrites) [3]. Eucrites with shock degree B contain plagioclase with wavy extinctions. Eucrites with shock degrees C and D are characterized by the presence of maskelynite. In this study, we divided the eucrites into shock degree C and D on the basis of the relative abundance of plagioclase and maskelynite at ~70 vol% (the modal abundances of maskelynite divided by those of plagioclase plus maskelynite. A-881747, Y-790266, Y 980433, and Cachari were classified as shock degree C. A-87272 was classified as shock degree D.

The macroscopic XRD features have correlations for the shock degrees from the petrographic observations. The number of peaks in the XRD pattern shows a negative correlation for the increase of shock degrees. Unshocked eucrites, Agoult (A), EET 90020 (A), and Moama (A), display the total number of the peak as 163, 159, 148, respectively. Shocked eucrites, A-87272 (D), Cachari (C), and Y 980433 (C), display the total number of the peak at 35, 70, 64, respectively. The XRD peaks become weaker and broader by increasing the shock degrees. We found that the shock degrees are divided by the averaged full width at half maximum (FWHM) values of the peaks. The higher value of the averaged FWHM of shock degree D than those of C indicates that the shock pressure of shock degree D is higher than shock degree C. The results of XRD analyses and the CL observation is generally consistent.

In summary, we showed that the color CL image provides the two-dimensional distribution of maskelynite and plagioclase in eucrites. Our detailed observation using color CL images show two distinct occurrences of maskelynite in eucrites between shock degree C and D. The results are generally consistent with the XRD data. The higher averaged FWHM value of shock degree D than C also suggests that the shock degree D suffered high shock pressure than shock degree C. We are making more detailed comparison with the CL and XRD data.

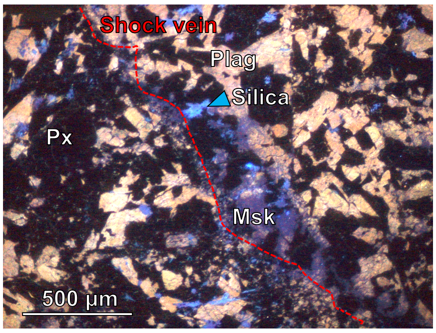

Fig. 1. Color CL image of Y-790266. The color of CL emissions represents yellow to brown, purple, and aqua-blue are corresponding to plagioclase, maskelynite, and silica minerals, respectively.

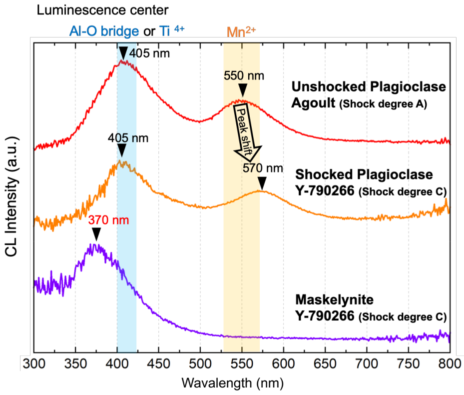

Fig. 2. CL spectra of plagioclase and maskelynite. The unshocked plagioclase in Agoult has double peaks at 405 and 550 nm. The shocked plagioclase in Y-790266 has similar spectrum some as Agoult, but Mn^{2+} peak is shifted to at 570 nm.

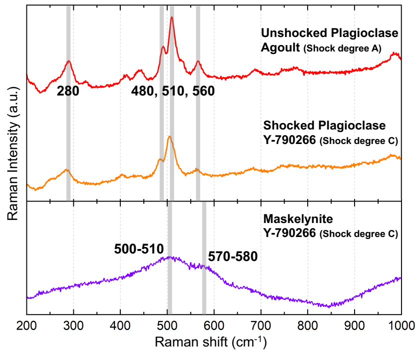

Fig. 3. Raman spectra of plagioclase and maskelynite in eucrites. The unshocked plagioclase has peaks at 280, 480, 510, and 560 cm^{-1}.

References

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