

**NANOSTRUCTURES OF ALTERED LOW-CA PYROXENE IN THE ALLENDE CV3 CHONDRITE:  
AN INVESTIGATION BY ABERRATION CORRECTED SCANNING  
TRANSMISSION ELECTRON MICROSCOPY.**

I. Ohnishi<sup>1</sup>, M. Kadoi<sup>1</sup> and K. Tomeoka<sup>2</sup>, <sup>1</sup>JEOL Ltd., 3-1-2 Musashino, Akishima, Tokyo 196-8558, JAPAN  
([ionishi@jeol.co.jp](mailto:ionishi@jeol.co.jp)), <sup>2</sup>Faculty of Science, Kobe University.

**Introduction:** Low-Ca pyroxene is one of the major constituents of chondrules in chondritic meteorite. In oxidized CV3 chondrites, low-Ca pyroxene has been commonly altered by Fe-rich olivine to various extents [e.g., 1]. Although a number of studies have been conducted on alteration of low-Ca pyroxene in CV3 chondrites, much still remains to be known as to process and condition of the alteration. We here present the results of a mineralogical study of altered low-Ca pyroxene in a chondrule of the Allende CV3 chondrite using an aberration corrected scanning transmission electron microscope (STEM) with a highly sensitive energy dispersive X-ray spectrometer. Our purpose is to provide new insight into alteration of low-Ca pyroxene by observing its texture at atomic-level resolution.

**Material and Methods:** After ordinary petrographic observations of a polished thin section of Allende, ultrathin sections from the specific areas of the sample were made using a focused ion beam instrument (JEOL JIB-4501). The ultrathin sections were studied using an aberration corrected 300 kV STEM (JEOL JEM-ARM300F) equipped with a cold field emission electron gun and two windowless silicon drift detectors, whose sensor areas are 158 mm<sup>2</sup> and total X-ray collection solid angle is 2.21 sr [2].

**Results:** The low-Ca pyroxene studied here occurs as a phenocryst of a porphyritic olivine-pyroxene chondrule. The pyroxene phenocryst has been partially replaced by Fe-rich olivine and has many extremely thin (< 1 µm in thick) veins, whose thickness is less than the spatial resolution of conventional scanning electron microscopes. Our STEM observations reveal that the veins are filled with polycrystalline aggregates of small grains (< 50 - 300 nm in size) of Fe-rich olivine with minor amounts of magnetite and Fe-Ni sulfide. The aggregates also contain rectangular to irregular shaped voids (< 50 - 200 nm). Individual olivine grains in the aggregates contain even smaller grains (< 20 nm) of Fe-Ni sulfide and Al, Cr-rich phase, probably spinel and voids (< 20 - 50 nm). High-Ca pyroxene occurs as isolated grains (< 10 - 300 nm) near the veins and also as thin (< 3 nm thick) layers along the boundaries between veins and low-Ca pyroxene. The isolated high-Ca pyroxene grains have a specific relationship of crystal orientation with the low-Ca pyroxene; i.e., all crystallographic axes of both pyroxenes are almost completely parallel. In addition, the high-Ca pyroxene contains many planar defects and narrow double- and triple-chain lamellae oriented parallel to (010). Those multiple-chain lamellae terminate at the boundaries between high-Ca and low-Ca pyroxenes.

**Discussion:** Our study revealed the presence of high-Ca pyroxene grains inside a low-Ca pyroxene phenocryst in an Allende chondrule. The occurrence of high-Ca pyroxene is limited only in areas close to the veins filled with Fe-rich olivine. The high-Ca pyroxene is crystallographically closely related to the low-Ca pyroxene. These observations suggest that the high-Ca pyroxene formed by topotactic replacement of the low-Ca pyroxene in a process associated with the formation of veins. We also found that the high-Ca pyroxene contains multiple-chain lamellae parallel to (010). Those lamellae are very similar to the hydrous biopyribole found previously from low-Ca pyroxene in an Allende chondrules [3]. If we can assume that the multiple-chain lamellae are biopyriboles, then the presence of them in the chondrule studied here imply that the chondrule has experienced a hydration process. However, in the present study, the multiple-chain lamellae were found only in high-Ca pyroxene, not in low-Ca pyroxene. The results of both previous and present studies suggest that chondrules in Allende have experienced aqueous alteration, but the condition and process of alteration differed considerably among chondrules and the alteration reactions within individual chondrules were much more complicated than previous thought.

**References:** [1] Krot A.N. et al. (1995) *Meteoritics* **30**:748-775. [2] Ohnishi I. et al. (2018) *e-J. Surf. Sci. Nanotech* **16**:286-288. [3] Brearley A.J. (1997) *Science* **276**:1103-1105.