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Micro-Raman of mineral phases in the strongly shocked Taiban ordinary chondrite: ringwoodite coloration

T. E. Acosta (1,2), E. R. D. Scott (2), S. K. Sharma (2), and A. K. Misra(2)
(1) Department of Geology & Geophysics, University of Hawaii, Honolulu, HI 96822, USA, (2) Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822, USA.
(tayro@hawaii.edu)

1. Introduction

High pressure polymorphs of major minerals are commonly found in shocked meteorites. During the formation evolution of the Solar System asteroids have collided with each other and with larger bodies triggering shock waves. The produced Meteorites show different shock effects depending on the peak pressures and temperatures, and duration of the collision events [5]. Taiban is a very strongly shocked, shock stage S6 ordinary L6 chondrite. It shows multiple veins of opaque shock melt forming a network of complex branches surrounding pockets of highly shock altered, mosaicized, relict or recrystalized silicates, and their high pressure polymorphs [4,5]. Micro-Raman spectroscopy has been used to provide univocal identification of minerals and glassy phases in meteorites as well as a tool to obtain additional information on structural and compositional variations inside mineral grains [7]. We studied the polished thin section UNM297 of Taiban meteorite with micro-Raman spectroscopy and Raman mapping to identify and characterize major and minor phases. Ringwoodite γ-$(Fe,Mg)_2Si0_4$ is the high-pressure polymorph of olivine with the spinel structure.

2. Experimental

Spectra were acquired with a micro-Raman instrument (Kaiser Optical Inc.) using 785 nm laser excitation, 10 mW laser power and 150 s exposure time. The spatial resolution was 3 µm with 100x objective, and the stage spatial resolution was 1 µm. Additional spectra were acquired with a Renishaw inVia micro-Raman instrument which operates with excitation wavelengths 244, 514.5, and 830 nm.

3. Results and discussion

The thin section is intersected by a 4 mm wide melt vein in which the shock silicate pockets are dominated by blue and white ringwoodite crystals.The white matrix is composed mainly of pyroxene and plagioclase converted to its shock induced glass form, maskelynite [4].
Raman spectra measured in the inner part of the crystal show the Raman fingerprints bands of ringwoodite located at 799, and 844 cm^{-1}. These Raman fingerprints have also been observed in natural ringwoodite [1]. The intensity of the 877 cm^{-1} line is very spatial dependent, and presents a remarkably accurate spatial correlation with the color of ringwoodite observed by optical microscopy. The intensity of 877 cm^{-1} peak is higher when the ringwoodite is deep blue, intermediate in clear blue areas, and absent when the ringwoodite is colorless. The same peak was observed by other researchers [3]. Signature spectra of relict olivine are found in grains within the ringwoodite and between ringwoodite grains. The composition of the olivine is 88% forsterite within the ringwoodite and 94% in the crack, according to a Raman compositional calibration of olivines [2]. Pyroxene assemblages and the melt vein are in direct contact with the ringwoodite around the rest of the perimeter. White grains show high-Ca pyroxene Raman fingerprints along with majorite and jadeite assemblages. Majorite is the cubic garnet polymorph of pyroxene and is often found in other shocked meteorites, forming mainly from low-Ca pyroxenes. Jadeite is a pyroxene, polymorph of the original plagioclase.
The cause of the blue ringwoodite color has been discussed in the past but it still remains mostly unknown. Figure 1 shows the strong dependence of the 877 cm^{-1} peak with the excitation wavelength. We

attribute this intensity dependence to near-resonance Raman enhancement in the blue ringwoodite.

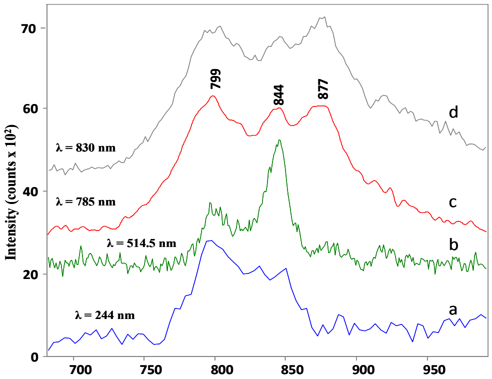

Figure 1: Variation in relative intensity of the peaks 799, 844 and 877 cm-1 in blue ringwoodite far from grain boundaries with various laser excitation wavelengths due to resonance Raman effect. The excitation wavelength, laser power and acquisition time are (a) 244 nm, 0.5 mW and 1800 s (b) 514.5 nm, 1 mW, and 600 s (c) 785 nm, 10 mW, and 150 s, and (d) 830 nm, 5 mW, and 300 s, respectively.

Absorption spectra from blue and dark blue natural ringwoodite from other meteorites present a strong absorption line centered at 793 nm. This absorption band follows the same color correlation as we observe in the 877 cm^{-1} Raman peak and explains why the Raman enhancement is only observed in colored ringwoodite [6]. The color correlation of the absorption spectra and the Raman spectra suggest that the cause of the color lies in the crystal structure of the ringwoodite. Therefore the 877 cm^{-1} peak is probably due to cation redistribution inside the spinel structure. Taran et al. [6] suggested an inverse spinel structure for the clear varieties of ringwoodite, based in the apparent different nature of the absorption spectra of blue and colorless varieties. However, the observed Raman shifts of the 799 and 844 cm^{-1} ringwoodite in colorless and blue ringwoodite, suggest that most of Si is in four-fold coordination. This is consistent with nuclear magnetic resonance and X-ray diffraction observations. On the other hand, the observed increase in the line widths of 799 and 844 cm^{-1} indicate some degree of structural disorder in blue ringwoodite. Therefore, our data is consistent with the explanation that the gradation in color of the ringwoodite is due to a spinel structure ranging from normal to marginally inverse. Assuming such cation disorder and that the band at 844 cm^{-1} comes from Si-O bonds stretching in tetrahedral sites [8], we tentatively assign the 877 cm^{-1} Raman band to symmetric Fe-O stretching of a small amount of iron in four-fold coordination. Because of the Raman enhancement effect, we believe that we are able to detect low trace amounts of Fe^{+2} in tetrahedral sites.

Acknowledgements

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