Micro-XANES Ddetermination on the Oxidation States of V and Fe in Olivine-Hosted Glass Inclusion and Groundmass Glass of Yamato 980459

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Introduction: The redox condition, or oxygen fugacity (fO_2), of a magma controls the stability and composition of crystallizing and volatite phases in a magma, and provides information on the genesis, differentiation, and a source region of the mantle. A knowledge on the evolution of the Martian interior has been acquired by the analysis of the Martian meteorites. Mineralogical oxybarometers such as Fe-Ti oxides have been conventionally used to estimate the fO_2 of Martian magmas (e.g., [1]–[5]). Partitioning of redox sensitive elements has been more recently used to evaluate the fO_2, combined with laboratory experiments (e.g., [6]–[10]). These previous studies, however, did not pay much attention to olivine-hosted glass inclusion and groundmass glass that generally crystallized at the earliest and the latest stages of the formation of basaltic roks, respectively; investigation of these contrasting phases will provide the information on the transition of fO_2 condition during the basalt magmatism. Therefore, this study performed micro X-ray absorption near edge stducture (μ-XANES) analysis on V and Fe in both inclusion and groundmass glasses of a Martian meteorite (Y98: Yamato 980459) to estimate the fO_2 condition of Martian magma.

Sample: Y98 is an olivine-phyric shergottite, displaying a porphyritic texture with olivine megacrysts. Since Y98 represents a primary melt composition that evoloved in a close-system ([11], [12]), Y98 is an ideal meteorite sample to compare the valence states of V and Fe in the inclusions and groundmass glass.

Analysis: A polished thin section of Y98 (#51-2) was used in this study. The V K-edge (5465 eV) μ-XANES analyses were performed using the bending-magnet beamline 10.3.2 at the Advanced Light Source (ALS), Lawrence Berkeley National Laboratory, California. The X-ray beam was focused using a K-B mirror to a final spot size of 3.3 (vertical) × 2.8 (horizontal) μm^2. The Fe K-edge (7111 eV) μ-XANES spectra were measured at the BL-4A of Photon Factory (PF; Tsukuba, Japan), where the X-ray beam was focused using a K-B mirror to a final spot size of 4.5 (V) × 4.0 (H) μm^2. Prior to the μ-XANES measurements, X-ray fluorescence (XRF) mapping which was scanned in 5 μm step were obtained to determine the analytical spot with referring to the backscattered electron images [12]. The oxidation state analyses on V and Fe were performed by analyzing the pre-edge features ([13], [14]).

Result and Discussion: The mean V valence varied from 3.11 to 3.34 for the olivine-hosted glass inclusions, whereas 3.28 to 3.65 for those of the groundmass glasses. The oxidation state of Fe is strongly correlated with that of V, and varied from 1.85 to 2.01 for the inclusions and 1.90 to 2.36 for the groundmass glasses. The mean fO_2 values relative to the iron-wüstite (IW) buffer for the inclusion glass was IW–0.1, whereas that of groundmass glass was IW+0.8. Previous studies reported similar redox conditions. The oxygen fugacity during the spinel crystallization of Y98 was estimated to be IW+0.9 [15]. The partitioning of V between olivine and melt suggested that the fO_2 of Y98 was IW+0.9 [7]. Chemical composition of olivine megacryst suggested ~IW+1 [12]. The partitioning of V and Cr between pyroxene and melt was IW±0 to IW+1 [8]. The current study based on direct V and Fe μ-XANES analyses on glass inclusion and groundmass glass showed consistent fO_2 values with previous studies. In addition, it should be noted that the current study successfully indicated the redox evolution during igneous process occurred in Mars.

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