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Mineralogy and Structure of Hayabusa Particles using Raman Micro-Spectroscopy

Böttger U. (1), Alwmark C. (2), Bajt S. (3), Busemann H. (4), Gilmour J.D. (4), Heitmann U. (5), Hübers H.-W. (1,6), Meier M.M.M. (2, 7), Pavlov S.G. (1), Schade U. (8), Spring N.H. (4), Weber I. (5)

(1) Inst. of Planet. Res., DLR Berlin, Germany, (2) Dept. of Geol., Univ. of Lund, Sweden, (3) Photon Sciences, DESY, Hamburg, Germany, (4) SEAES, Univ. of Manchester, UK, (5) Inst.f. Planet, WWU Münster, Germany, (6) Techn. Univ. Berlin, Germany, (7) CRPG CNRS Nancy, France , (8) Helmholtz-Zentrum Berlin (HZB), Germany

Abstract

Hayabusa is a recent sample return mission by JAXA that in 2010 returned samples from the S-type asteroid 25143 Itokawa. The first studies [1-6] indicated that Itokawa consists of mostly type LL5-6 material. Here we present the results and challenges connected with Raman micro-spectroscopy to derive mineralogy and structure of Hayabusa particles.

1. Introduction

In the scope of the 1st international Announcement of Opportunity we proposed a consortium study for the analysis of noble gases in Itokawa samples [7] combined with Raman spectroscopy, infrared spectroscopy (IR), and synchrotron radiation X-ray tomographic microscopy (SRXTM) [8], which was accepted by JAXA. The latter methods yield grain mineralogy, density, and structure necessary to estimate the gas concentrations of potentially present cosmogenic, solar, trapped and radiogenic noble gases. JAXA allocated? to the consortium amongst others three particles (RA-QD002-00158, -00187, -00197) delivered in inert N_2 gas with no previous contact to the terrestrial atmosphere. Here we present the mineralogy and structural results of particle RA-QD002-00197 (#197), derived from Raman micro-spectroscopy measurements.

2. Sample

The diameter of the Hayabusa particle #197 is about 59 µm. SEM-EDX analysis at the curation facility of JAXA identified olivine and plagioclase mineral phases (JAXA sample documentation).

3. Measurements

To allow Raman spectroscopy the original JAXA container was equipped in an inert N_2 atmosphere with a laser-transparent quartz window. The particle was investigated with a Witec Alpha 300 Raman spectrometer. The laser excitation wavelength was 532 nm, the spectral resolution was about 4 cm^{-1}. The spot size on the sample was approximately 1 µm. Single measurements took 120 s. The laser power on the sample was 200 µW.

4. Results and Summary

An orientation map of olivine crystals (Figure 1 top) was derived for the particle #197 by the interpretation of the relative peak intensities of the characteristic olivine Raman doublet (Figure 2) that are directly dependent on the orientation of the plane of polarization and thus to the crystallographic orientation of the olivine crystal [9]. Except for one area, minor or no changes in orientation were detected. This suggests that particle #197 consists of a single crystal instead of many small randomly oriented grains. The only area with a possibly varying orientation can be seen along a virtual line between the red (top) and black (bottom) part in the center of the particle which may be caused by surface topography. Indeed, SRXTM analysis confirmed dividing line as a ridge [8] and is, hence, consistent with the result derived from Raman measurements that this particle is a single crystal.

A mineralogy map (Figure 1 bottom) was derived from Raman measurements. Mg-rich olivine was identified comparing the Raman shifts of the Gauss-fitted olivine doublet peaks observed between 800 cm^{-1} and 900 cm^{-1} with the calibration curve from [10] using the dependency of the doublet peak positions with chemical composition. We determine that grain #197 consists mainly of forsterite (Fo_{60} – Fo_{70} ±10%). In addition, plagioclase has been identified in the grain using the peaks around 480 cm^{-1} and 510 cm^{-1} by comparison with literature [11]. Raman shifts around 667 cm^{-1} and 1013 cm^{-1} were used for pyroxene identification [12]. The results of the Raman measurements on grain #197 are consistent with an ordinary chondrite of the type LL5–6 and JAXA's mineralogical characterization.

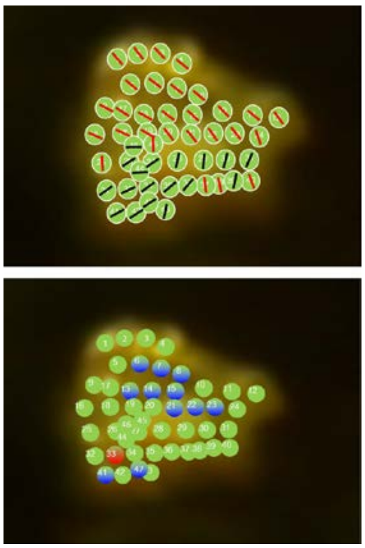

Figure 1: Top – orientation map of olivine; bottom – mineralogy map (green – olivine, blue – plagioclase, red – pyroxene).

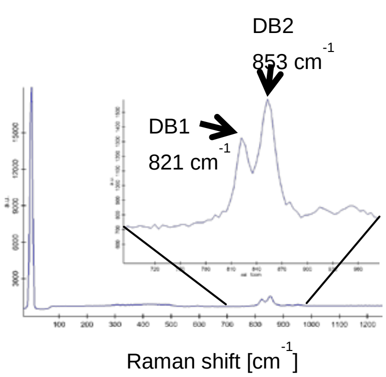

Figure 2: Raman peak position of the characteristic olivine doublet (DB1 and DB2).

Acknowledgements

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