LASER micro Raman spectroscopy on returned particles from the Asteroid Itokawa (JAXA Hayabusa mission). V.H. Hoffmann[1,2]; M. Kaliwoda[3]; R. Hochleitner[3]; T. Mikouchi[4]; M. Komatsu[5]; K. Hagiya[6]; K. Ohsumi[7]; M. Zolensky[8]; J. Martinez[9]; Y. Terada[7]; N. Yagi[7]; M. Takata[7]; W. Satake[4]; Y. Aoyagi[4]; A. Takenouchi[4]; Y. Karouji[10]; M. Uesugi[10]; T. Yada[10]. [1]Fac. Geosciences, Dep. Geo- and Environm. Sciences, Univ. Muenchen; [2]Dep. Geosciences, Univ. Tuebingen. Email lavho@web.de; [3]Mineralogical State Collection, Muenchen, Germany; [4]Dep. Earth and Planetary Science, The University of Tokyo, Japan; [5]Waseda Inst. Advanced Study, Waseda Univ., Japan; [6]School of Science, Univ. Hyogo, Japan; [7]Japan Synchrotron Radiation Research Institute (JASRI), Japan; [8]Astromaterials Research and Exploration Science, NASA-JSC, USA; [9]ESCG Jacobs, USA; [10]Inst. Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA), Japan.

Introduction

JAXA Hayabusa mission successfully returned particles of the asteroid Itokawa in 2010. The recovered particles have been first studied by the preliminary examination (PE) team and the obtained results are providing significant and unique information about the formation and evolution of meteorite parent bodies [1, and publications in this issue]. The particles revealed that their mineral compositions and oxygen isotopes are close to those of equilibrated LL chondrites [1]. After the PE, the samples have been distributed by JAXA as international AO study and our team received 4 new and 3 PE particles. We have performed a detailed mineralogical and crystallographic study on these particles of which results have been published by [2]. Here we report detailed results of our investigations by Raman Spectroscopy on three selected Itokawa particles.

Samples and methods

The PE samples we received are: RA-QD02-0036, RA-QD02-0041 and RA-QD02-0049-2.

RA-QD02-0036 and RA-QD02-0041 are polished sections embedded in epoxy. RA-QD02-0049-2 is attached on the glass fiber. The additionally received new particles are RA-QD02-0100 (~29 µm), RA-QD02-0133-01 (~53 µm), RA-QD02-0138 (~49 µm), and RA-QD02-0179 (~50 µm). We made polished sections after we embedded them in epoxy (EPON812) at JAXA.

The polished sections were first observed by optical microscope, and then analyzed by FEG-SEM equipped with EBSD detectors (Hitachi S-4500 and Zeiss Supra 55VP Schottky), electron microprobe (JEOL JXA8900L). The polished sections and RA-QD02-0049-2 were also analyzed by synchrotron radiation (SR) XRD by using an energy scanning method (BL37XU, SPring-8) [details in 2]. We performed SR Fe-XANES on plagioclase in RA-QD02-100 and RA-QD02-133-1 to determine the presence of Fe^{3+} (BL-4A, PF, KEK).

The following three particles have been selected for investigations by Raman Spectroscopy (see fig. 1a,b,c):

(a) RA-QD02-0041
(b) RA-QD02-0036
(c) RA-QD02-0133-01

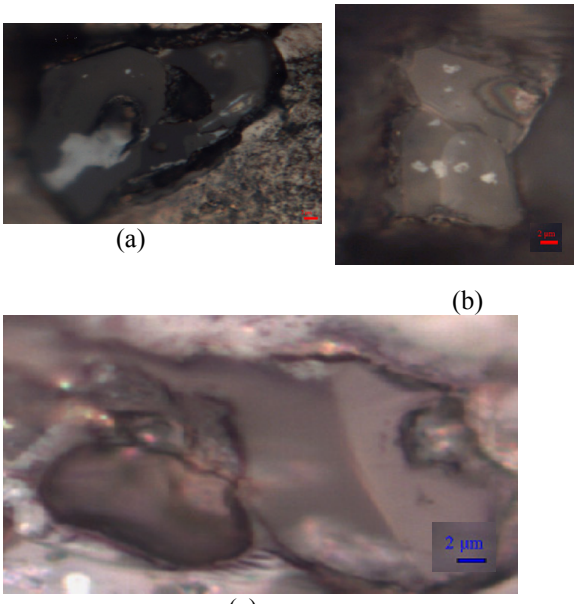


Fig. 1: The three Itokawa particles under investigation by Raman Spectroscopy.

A Horiba Xplora Integrated confocal LASER micro Raman system was used for our studies (mostly the 532/638 nm LASERs). Magnifications were between 100 and 1000x (LD) with acquisition times of 3-10 sec and accumulation numbers of 2-5. After a series of tests we decided to keep the maximum LASER energy on the sample surface at about 5 mW in order to reduce potential heating effects to a minimum.

The quality of the Raman spectra could be significantly enhanced after careful repolishing and removing the former sputtering layers (carbon?).

Results (see fig. 2)

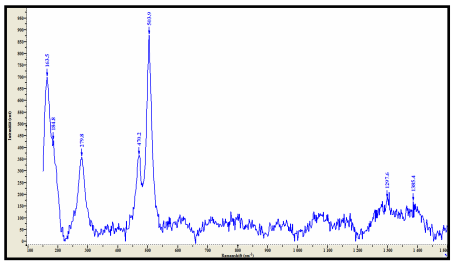
Particle RA-QD02-0036: olivine, plagioclase, troilite, chromite and a whitlockite-merrilite phase have been found by Raman spectroscopy. The sharp and well developed Raman pattern of the Plagioclase phase indicate a weak shock stage of S1-2.

Particle RA-QD02-0041: olivine and plagioclase have been found by the Raman experiments. This particle is generally characterized by a very high fluorescence background. Again, the features of the plagioclase Raman pattern indicate a quite low shock degree.

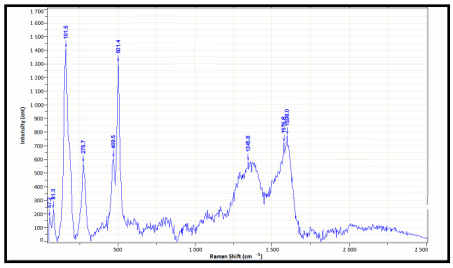
Particle RA-QD02-0133-01: this particle is dominated by olivine and plagioclase, we could not detect any other phase. Shock degree was estimated as similar to the other two particles from the Raman pattern.

On all particles we have performed very detailed mapping in (partly) less than 1µm steps in order to really catch all present phases (including micro particles). Slight variations in the LASER energy allowed us to map and interpret the Raman pattern depending on depth from the surface, and to detect phases below the surface (not directly accessible on top).

Summarizing our results which have been obtained by Raman spectroscopy, one can say that all obtained spectra are of high quality. These findings point to very fresh sample material from asteroid Itokawa without any significant weathering or alteration effects. For the first time we have fresh and non-altered material from the surface of an asteroid in our hands, best suited for scientific investigations towards a much better understanding of the origin and development of meteorite parent bodies in our solar system.



(a)



(b)

Fig. 2a, b: Particle RA-QD02-0133-01: typical plagioclase Raman pattern revealing very sharp features and therefore indicating only weak shock effects. In (b) a signal of carbon components is seen, most likely from the coating layer.

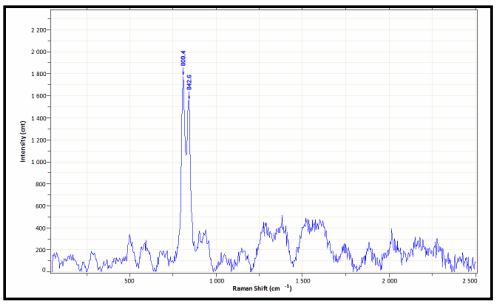


Fig. 2c: Particle RA-QD02-0036: typical Raman patterns of olivine.

Acknowledgements
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References

[1] Nakamura T. et al. (2011) *Science*, *333*, 1113–1116, and further Hayabusa-related publications in this Science Issue.
[2] Mikouchi T., and the Hayabusa Sample Project Consortium (2014). Mineralogy and crystallography of some Itokawa particles returned by the Hayabusa asteroidal sample return mission. Earth, Planets and Space, 66/82.