X-RAY FLUORESCENCE EXPERIMENTS OF ASTEROID ITOKAWA BY THE XRS ONBOARD HAYABUSA. T. Okada[1,2], K. Shirai[1], Y. Yamamoto[1], T. Arai[1,3], K. Ogawa[1,4], K. Hosono[1,2], and M. Kato[1,2,4], [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan. okada@planeta.sci.isas.jaxa.jp, [2]University of Tokyo, Hongo, Tokyo 113-0033, Japan., [3]Graduate University for Advanced Studies, Sagamihara, Kanagawa 229-8510, Japan, [4] Tokyo Institute of Technology, Ookayama, Tokyo 152-8550, Japan.

X-ray fluorescence spectrometry of the near-Earth asteroid 25143 Itokawa has been performed by the CCD-based X-ray spectrometer, XRS, onboard Hayabusa to determine major elemental composition of the asteroid during the rendezvous phase. We present here the first results of the XRS observation, which indicates that the surface of Itokawa has chondritic composition and that LL- or L-chondrites are most likely but H-chondrites or primitive achondrites cannot be rejected so far[1].

Introduction: The Hayabusa mission is a Japanese engineering explorer to demonstrate the new technologies for sample return from asteroids[2], but it still has a high scientific significance including the remote observations and characterizations of the asteroid during the rendezvous phase as well as the sample return of surface material of the asteroid[3].

The target asteroid is a near-earth asteroid 25143 Itokawa, which has been characterized by ground based observations as an S(VI) class[4], 550m x 250m in shape[5], and the rotation period of 12.1 hours[6]. The key scientific objectives of Hayabusa are to understand what the asteroid is made of and what is its origin.

Hayabusa was launched by the 5th M-V launch vehicle from the Kagoshima Space Center on May 9, 2003 and renamed from the MUSES-C. After the 2.5 years' cruise, it has arrived at the proximity of asteroid 25143 Itokawa in September, 2005. The rendezvous phase was originally planned to last three months. During the first two months, the remote instruments conducted the remote observations of Itokawa for shape modeling, characterization of the geologic features, mapping the surface composition, and estimation of the density. The last month has been used for trial of sample collections: rehearsal descents and two touchdowns to the surface of Itokawa. In this periods, the close-up imagery and the local area mapping have been performed by the remote instruments.

XRS: The XRS is one of the remote instruments onboard Hayabusa for major elemental analysis of Itokawa by measuring X-rays off the surface of the asteroid[7]. Remote X-ray fluorescence or XRF technique is an application of a well established XRF method in the laboratory but the excitation source is solar X-rays. It has been proven by the Apollo missions to determine major elemental composition of the surface of atmosphere-free planets such as the Moon, the Mercury, and the asteroids[8].

The XRS[7] is an advanced X-ray fluorescence spectrometer based on charge-coupled device (CCD), whose energy resolution (160eV@5.9KeV) is much higher when cooled than that of the conventional proportional counters used by the Apollo 15 & 16 and the NEAR Shoemaker missions[9]. In addition, it has a standard sample plate aboard to concurrently calibrate X-rays excited by the Sun. Since the intensities and spectral profiles of the solar X-rays drastically changes time to time, this compared analysis by using the standard sample has much improved the accuracy of elemental compositions.

The observed data from CCD are processed by using the programmable gate-arrays and the onboard computer of the XRS electronics. X-rays are effectively extracted as X-ray events, judged for its grades, and analyzed into histogram with pulse height for each CCD chip[10].

The performance of the XRS has been examined during the cruising phase to observe X-rays off the standard sample, X-rays from some X-ray bodies such as Kepler Super Nova Remnant. Just before the Earth swing-by, the XRS has observed the far side of the Moon for the first time[10,11].

Remote XRF Spectrometry of Itokawa: During the rendezvous phase, the XRS remotely performed XRF spectrometry of the surface of asteroid Itokawa. In this study, we used the data obtained during the decent for the first touchdown on November 19, 2005.

Since the intensities of X-rays excited from the asteroid highly depend on solar activity, X-rays simultaneously observed from the standard sample and from the asteroid were selected and analyzed for some sites.

An example of the set of X-ray spectra is shown in Fig.1a-b. Fig.1a shows the spectrum of X-rays off the standard sample, in which K-α line spectra of Mg, Al, and Si are clearly detected. The observed spectrum has been fitted with Gaussian functions for each line along with the continuum dominated by the scattered solar X-rays. Fig.1b shows the spectrum of X-rays off the surface of Itokawa as well as the background space, and fitted in the same way as Fig.1a. Since the field of view of the XRS is relatively large (3.5 x 3.5 degrees) and the attitude control of the spacecraft is almost 1

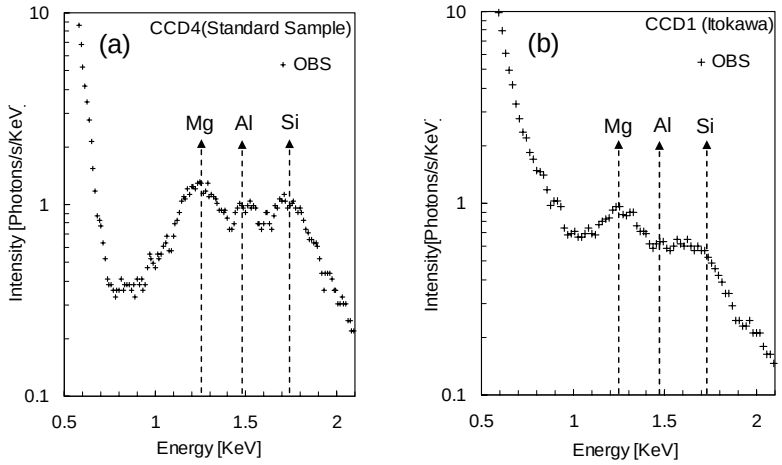

Fig.1 X-ray spectra ranging from 0.5 to 2.1 KeV were simultaneously observed by the XRS at 9:27 UTC on November 19, 2005. The integration time was five minutes. The observed spectra (OBS) have K-α lines of major elements (Mg, Al, and Si) and continuum spectrum for scattered solar X-rays and irradiation of cosmic rays or charged particles. X-rays off the onboard standard sample plate has clear K-α lines of Mg, Al, and Si (a), while relatively higher Mg/Si and lower Al/Si are shown for the X-rays off the surface of Itokawa (b).

degree so that the background space other than the surface of Itokawa might have been included in the FOV of the XRS during the integration time of 5 minutes. However, K-α lines of Mg and Si have been clearly detected in Fig.1b as well as the enhancement of Al-Kα should be required to account for the observe spectrum.

The results show that the X-rays off the surface of asteroid have relatively higher Mg/Si and lower Al/Si than that of the standard sample. This fact indicates that composition of the surface of Itokawa is more chondritic compared with that of the standard sample that has intermediate composition between chondrites and basalts.

In addition, similar results have been obtained for other sites analyzed in this study. The normalized XRF ratios of Mg/Si and Al/Si by those of the standard sample are within 5 to 10 %, indicating the relatively homogenous composition all around Itokawa.

Elemental composition of Itokawa: The surface composition of Itokawa has been analyzed by compared method between the X-rays off the asteroid and the standard sample. Under the assumption that the composition is nearly chondritic and the solar X-rays has steeply decreasing spectrum with energy, which were supported by the XRS observation, the quantitative analysis is possible within 5 % errors[12].

We have calculated the surface elemental ratios of Mg/Si and Al/Si for each site. Furthermore, under the assumption that the continuum component of X-rays at Si-Kα is dominantly by the solar scattered X-rays, the absolute abundance of the Si (and correspondingly Mg from Mg/Si) can be derived. There are relatively small regional variations in composition and regional average of Mg/Si=0.78±0.09 and Al/Si=0.07±0.03, indicating that LL- or L- chondrites are most likely but the H-chondrites or primitive achondrites cannot be rejected[1]. Since the preliminary results have relatively large uncertainties for those composition, it should be carefully treated and further analysis should be needed, especially for heavier elements other than Mg, Al, and Si.

Acknowledgments: The Hayabusa mission has been organized by the Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency. The XRS was manufactured by Meisei Electric Co. The scientific discussions have been lead by the joint science team of Japan and US members.

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