X-ray fluorescence from rough rocky surfaces of asteroids

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X-ray fluorescence (XRF) from orbit is a frequently-used technique to determine the elemental composition of atmosphereless planetary bodies. So far, XRF observations have been conducted for asteroids by the Near-Earth Asteroid Rendezvous Shoemaker mission at (433) Eros [1] and the Hayabusa mission at (25143) Itokawa [2]. There has been difficulties to interpret the XRF data to derive the composition quantitatively. One of the reasons is the surface-roughness effect.

We have investigated the XRF intensity influenced by a powdery surface as an analogue to fine regolith [3,4]. However, the surfaces of asteroids explored by the spacecraft at, e.g., (25143) Itokawa or (433) Eros, were not always covered with fine regolith but with pebbles or boulders. Thus, we have performed laboratory experiments to study the roughness effect for rocky surfaces to interpret the XRF observations of those asteroids and the observations of future missions.

For the powdery surface, we have obtained the following results: 1) the XRF with lower energy is more effective for the same roughness; 2) the XRF intensity decreases for rougher surfaces but converges to a constant value almost 50–60 % of that of a flat surface; and 3) the XRF intensity decreases for larger phase angles, but does not change so for a varying incident angle when when the phase angle remains fixed.

We started the experiments for rocky surfaces to investigate the elemental composition of natural unprepared rocks as well as ground rocks for past and future planetary missions. We prepared the basaltic rock samples with different surface roughness. The roughness of the rock surface is measured with a laser microscope to obtain the three-dimensional surface features and characterize the roughness in <10, 30, 60, 100-micron scales by a rectangular function as in our previous studies.

We used the X-ray generator (RIGAKU RINT-2000) using an X-ray tube of Cr-target (V-filter) at 20 kV and 10mA, and detected with the Si-PIN diode (AMPTEK XR-100CR). The sample is in the He-filled atmosphere. X-ray spectrum is measured from 1 to 10 keV. We analyze the XRF spectrum to obtain the major elemental ratios as customary, but this time we just compare the intensity ratios of each XRF line peak characteristic of the element.

Our preliminary experiments for the rocky samples show the roughness effects similar to those of powdery surfaces, but the effects are slightly weaker (almost by one half or less). This is probably due to the smaller depth-width ratio and less porous structure of the rocks relative to that of powders. Further information will be given in the presentation.

References: [1] J.I. Trombka et al., The elemental composition of asteroid 433 Eros: Results of the NEAR-Shoemaker Xray Spectrometer, Science, 289, 2101–2105, 2000. [2] T. Okada et al., X-ray fluorescence spectrometry of Asteroid Itokawa by Hayabusa, Science, 312, 1338–1341, 2006. [3] T. Okada, Particle size effect in X-ray fluorescence at a large phase angle: importance on elemental analysis of asteroid Eros (433), Lunar Planet. Sci., 35, 1927, 2004. [4] Y. Maruyama, K. Ogawa, T. Okada, M. Kato: Laboratory experiments of particle size effect in X-ray fluorescence and implications to remote X-ray spectrometry of lunar regolith surface, Earth Planets Space, 60, 293-297, 2008.