Numerical model of particle size effect on planetary X-ray fluorescence experiments

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Irradiation of solar X-rays to a planetary surface excites X-ray fluorescence radiation whose spectrum represents the major elemental composition of its surface. Observation of this fluorescent X-rays is a useful method to map the major elements of the planetary surface. X-ray observation has already been carried out in various missions (e.g. Adler et al., 1972; Trombka et al., 2000; Okada et al., 2006; Grande et al., 2006). Since the method of X-ray fluorescence analysis was developed in laboratory experiments, it was usually assumed that the specimen was polished or pelleted to make the surface flat. However, the planetary surface is often covered with soil and breccias of tens to hundreds of micrometers called regolith. The effect of the surface roughness has to be taken into account for a detailed analysis. Previous studies showed that the rough surface generally decreases the intensity of fluorescent X-rays and this effect is called the particle size effect. X-ray fluorescence spectrometer is chosen as a payload for Japanese lunar orbiter SELENE, Kaguya and will be included in several future planetary missions such as Bepi Colombo. For a detailed analysis of the data from these missions, the particle size effect cannot be neglected and understanding its effect is essential. The effect of particle size on the planetary surface has been studied experimentally by the previous studies (Okada and Kuwada, 1997; Maruyama et al. 2007), but its theoretical investigation has not been carried out. This study focuses on understanding the physical process of the particle size effect and evaluates its influence by model calculations. Our goal is to establish a numerical method to interpret fluorescence X-ray data obtained from rough planetary surface.

The intensity of the fluorescent X-rays from planetary surface is determined by the surface composition, intensity of incident X-rays, and the ray path of the incident and fluorescence X-rays. In the case of rough surface, the length of the ray path will be increased by the surface roughness. The additional attenuation of this surface roughness is expected to be the dominant cause of the decrease of the fluorescent X-rays. To evaluate its effect, we calculated the length of ray path including the rough region at the surface. We applied a rectangular model for the surface roughness since Okada and Kuwada (1997) showed that to simulate the effect of the particle size, the surface roughness is best represented by rectangular waves. The emission angle was assumed to be 0 degrees to simulate the nadir observation by Kaguya. By using these assumptions we calculated the attenuation factor according to the energy of incident and fluorescent X-rays, and incident angle. The result implied that the rough surface with the particle of diameter of about 100 micrometers decreases the X-ray intensities by 20 to 30%. This calculation is consistent with the experimental result by Maruyama et al., (2007).

This model calculation enables us to evaluate the particle size effect for various energies and incident angles. The calculation result can be applied to the data of Kaguya.