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Estimating the composition and the degree of space weathering of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa

Tokuhiro Nimura[1*], Masanao Abe[1], Takahiro Hiroi[2], Carle M. Pieters[2]

[1]ISAS/JAXA, [2]Brown University

Visible and near-infrared reflectance spectroscopy has been a useful method for remotely detecting mineralogy of planetary surface materials. However, there have been two problems in the analysis.

(1) On airless bodies such as asteroids, there exists a phenomenon called space weathering which is a process of alteration due to exposure to the harsh space environment including solar wind and micrometeorite bombardments. Their surface reflectance spectra show reddened continua, lowered albedos, and attenuated absorption features [Pieters et al., 1993], which makes it more difficult to analyze their spectra.

(2) In the reflectance spectra of solid planetary surfaces, we often find that each component mineral shows multiple broad bands which overlap with one another and with those of other minerals, making it very difficult to deconvolve them and assign the deconvolved bands into individual mineral components.

The purpose of this study is to solve these two problems.

First, this study made a progress toward solving the problem (1) by modeling the light-scattering property of a regolith particle having a vapor coating containing nanophase reduced iron ($npFe^0$) particles.

Next, the absorption spectra of silicates were studied. As a method of deconvolving the complex absorption spectra of silicates into individual absorption bands, the modified Gaussian model (MGM) is commonly used [Sunshine et al., 1990]. In this study, we investigated the relationships between the chemical composition and the absorption band parameters of major rock-froming minerals: olivine, low-Ca pyroxene, and high-Ca pyroxene, and also determined the band center, width, and relative strength of plagioclase. These relationships were utilized in MGM calculations. In this way, we solved the problem (2).

Utilizing the above two models and a mineral mixing model, we have constructed a unified model for estimating the mineral assemblage, chemical compositions of the component minerals, mineral grain size, and the degree of space weathering from the visible and near-infrared reflectance spectrum of a given airless celestial body.

This new model has been applied to the visible and near-infrared reflectance spectra of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa. The results indicate that their surface compositions correspond to those of H chondrites (6 Hebe) and LL chondrites (433 Eros and 25143 Itokawa) which are abundant in our meteorite collections. Although such results had been also given by past studies, this study has also determined their Mg numbers, mineral mixing ratios of four major minerals of olivine, low-Ca pyroxene, high-Ca pyroxene, and plagioclase, mineral grain sizes, and the degree of space weathering from their visible and near-infrared reflectance spectra only. These model calculations have demonstrated that there are differences in the thickness of vapor coating layer and the concentration of $npFe^0$ in the coating layer among the asteroids. The former indicates that airless celestial bodies having boulders and coarse regoliths may be more space-weathered than those having fine regoliths. The reason behind this may be that the surface of larger asteroids having stronger gravity are gardened and renewed more frequently. The latter is a new finding that the Fe concentration in the impact vapor varies among the three asteroids, which can be explained by the difference in the metallic iron abundance on these ordinary chondrite like asteroid surfaces. This is consistent with the fact that H chondrites contain significantly more metallic iron than LL chondrites, and the recognition that 433 Eros which is much larger than 25143 Itokawa should have a regolith which is fine enough to separate metallic iron particles from the remaining silicates in the LL chondrite mineral assemblage and the separated metallic iron may be concentrated on the top of the regolith, which may constitute the ponds on 433 Eros observed by NEAR spacecraft.

Keywords: spectroscopy, space weathering, asteroid, modified Gaussian model