ESTIMATING THE COMPOSITION AND THE DEGREE OF SPACE WEATHERING OF ASTEROIDS 6 HEBE, 433 EROS, AND 25143 ITOKAWA BY REFLECTANCE SPECTROSCOPY USING A NEW MODELING APPROACH. T. Nimura[1], M. Abe[1], T. Hiroi[2] and C. M. Pieters[2], [1]JAXA Inst. of Space & Aeronautical Sci., 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan. (nimura@ planeta.sci.isas.jaxa.jp), [2]Dept. of Geological Sci., Brown Univ., Providence, RI 02912, USA.

Introduction: It is believed that because most asteroids were destroyed in the process of evolution and remained small, they did not experience as strong erosion, thermal metamorphism, or remelting as the Earth, Mars, or Moon did. By examining asteroidal mineralogy and the degrees of secondary processes such as aqueous alteration, thermal metamorphism, and space weathering, the initial distribution of materials in the Solar System and the environment (temperature, pressure, etc.) they experienced can be understood, and constraints can be given to the Solar System formation model calculations.

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 [1], 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. And we analyzed visible and near-infrared reflectance spectra of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa.

A model for estimating the composition and degree of space weathering of asteroidal surfaces by reflectance spectroscopy: 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, including not only the effect on absorption coefficient as in Hapke (2001)[2] but also the change in boundary reflectivities[3]. This model can provide reasonable estimates of the volume concentration of $npFe^0$ particles and thickness of the coating layer from the visible and near-infrared reflectance spectra even in cases such as lunar regoliths wherein their reflectance spectra change drastically just by the difference in the degree of space weathering even if their compositions are similar to one another.

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 [4]. In this study, we investigated the relationships between the chemical composition (Fe, Mg, and Ca content) and the absorption band parameters (band center, width, and relative strength) 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)[5].

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[5].

Analysis of visible and near-infrared reflectance spectra on asteroidal surface: This new model has been applied to the visible and near-infrared reflectance spectra of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa (Fig. 1). 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. This model has also determined the thickness of vapor coating layer made by space weathering and the volume concentration of $npFe^0$ particles in the layer separately for each asteroid regolith particles. The former result shows that airless celestial body that has doulder and coarse grain have more space weathering effect than that has fine grain. This suggests that the surface had gardening and renewal on surface more strong gravity body. The later result shows that a new finding has been obtained that there are differences in the volume concentration of $npFe^0$ among the three asteroids, which can be explained by the difference in the metallic iron abundance on their 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.

Conclusion: We have estimated the mineral assemblage, chemical compositions of the component minerals, grain size, and degree of space weathering of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa from their visible and near-infrared reflectance spectra. We got new knowledge about space weathering effect. This study is a new, ambitious attempt to determine the composition of an unknown mixture of minerals from its reflectance spectrum by significantly reducing the number of unknown variables through restricting the visible and near-infrared absorption coefficient spectra of the end-member minerals utilizing Gaussians with the characteristics of mineral absorption bands built-in and by simultaneously applying a mineral mixing model and a space weathering model. This is the first attempt in the world and is a method having a potential of continuing to develop in the future.

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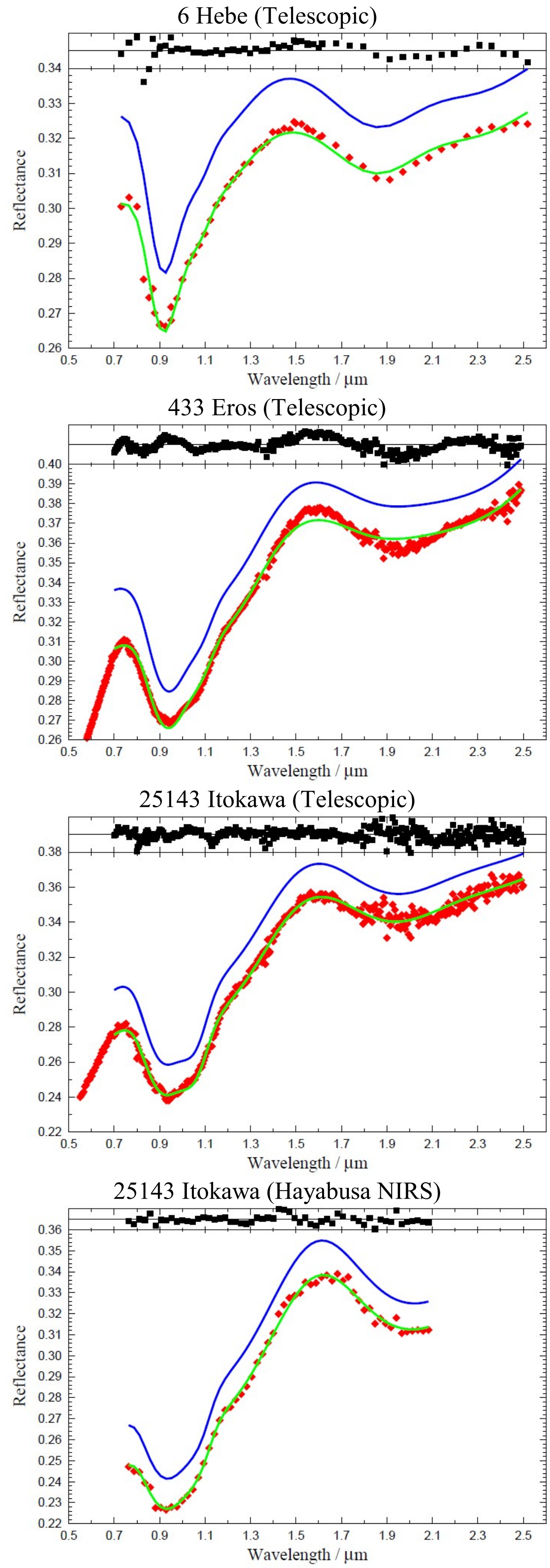

Fig. 1. A model fit of the reflectance spectrum of asteroid 6 Hebe [6,7], 433 Eros [8]. 25143 Itokawa [9,10,11]. Observed and model spectra are shown in red diamond and a green line, respectively. The blue line shows the model spectrum with space weathering effect removed. The top black squares represent the residual error spectrum.