A model for estimating mineral and chemical compositions and the degree of space weathering through VIS-NIR spectroscopy

Tokuhiro Nimura[1]; Takahiro Hiroi[2]; Carle M. Pieters[2]

[1] Earth and Planetary Sci., Tokyo Univ; [2] Geological Sci., Brown Univ

Visible and near-infrared reflectance spectroscopy has been a useful method for remotely detecting mineralogy of planetary surface materials. However, there are two problems which exist in this analysis: (1) In the case of airless bodies, space weathering effects may be so strong that their surface reflectance spectra show reddened continua, lowered albedos, and attenuated absorption features (*e.g.*, Pieters *et al.*, 1993). Thus, it is more difficult to use important diagnostic features for detecting component minerals and chemical compositions. (2) In the surface reflectance spectra of planets, we often find composite absorption bands arising from multiple component silicates. Moreover, each mineral species usually has multiple bands which overlap with one another and those of other minerals, making it difficult to assign the deconvolved bands into individual mineral components. The purpose of this study is to solve these two problems.

First, we introduce a space weathering model. One form of space weathering products is a vapor coating containing nanophase reduced iron ($npFe^0$) particles on each regolith particle. Transmission electron microscope (TEM) images of lunar soil grains show the details of layering of $npFe^0$ particles along the rims (*e.g.*, Keller and McKay, 1993, 1997; Wentworth *et al.*, 1999). Simulations of micrometeorite bombardment successfully formed vapor-deposited layers containing $npFe^0$ particles (*e.g.*, Sasaki *et al.*, 2001). Hapke (2001) modeled the optical effect of $npFe^0$ particles in a semi-transparent matrix. We have adopted an improved version of this Hapke's model and successfully accounted for its effect on the boundary reflectivity of regolith particles. This model can provide reasonable estimates of the total amount of $npFe^0$ particles formed in the coating layer, as well as the absorption coefficient spectrum of the host material fit for analyzing its composition.

Next, we introduce the modified Gaussian model (MGM) (Sunshine *et al.*, 1990) and a mineral mixing model that considers mineral bands to assign the deconvolved bands into individual mineral components. As a method of deconvolving a spectrum having complex absorption bands into individual bands, MGM is used almost as the standard method. However, because each mineral species usually has multiple bands which overlap with one another and with those of other minerals, it is difficult to assign the deconvolved bands into individual mineral components. Because the relationship between the chemical composition and absorption band characteristics of some minerals are known to a certain extent, it is expected that the above problem can be solved by utilizing such knowledge. These relationships are utilized in our MGM calculation. For example, in the case of olivine, there are three bands, making the number of parameters 9. We model the relationship between the Fa value and the band parameters (center, width, and relative strength) using linear functions, wherein the number of parameters decreased to only 2 (Fa value and one absolute strength). Reflectance spectra were taken from Sunshine *et al.* (1998), Klima *et al.* (2007), the RELAB database (Pieters 1983). We accounted for mixing ratio of minerals in the model (Hapke 1993; Hiroi and Pieters 1994).

The integration of the Hapke's space weathering model, Hapke's photometric model, the modified Gaussian model, and the mineral mixing model opens up a possibility to estimate the degree of space weathering, mineral and chemical composition, and mixing ratio of minerals on planetary surfaces. Future improvements are expected to increase its usefulness and help interpreting data from telescopic observations and spacecraft missions equipped with appropriate spectrometers such as the Spectral Profiler (SP) onboard SELENE/KAGUYA and the Moon Mineralogy Mapper (M^3) onboard Chandrayaan-1.