EFFECT OF ROUGHNESS ON VISIBLE REFLECTANCE SPECTRA OF PLANETARY SURFACE.

T. Sakai[1] and A. M. Nakamura[2], [1, 2]Graduate School of Science and Technology, Kobe University, 1-1 Rokkodai, Nada, Kobe, 657-8501, Japan, [1]tacchan@harbor.scitec.kobe-u.ac.jp, [2]amnakamu@kobe-u.ac.jp

Introduction: It is necessary to illuminate the effects of surface structures on reflectance spectra for a detailed study of planetary surfaces and the relevant works, e.g. asteroid-meteorite connection. It was shown in previous laboratory investigations that a surface prepared by "sifting" the sample powders has lower visible reflectance spectra than a "packed" surface[1], "porous" powdery surfaces are darker than compact surfaces[2], and macroscopic roughness of a surface due to a crater-shape depression reduces the reflectance[3].

For the purpose of a quantitative investigation on the relationship between surface structures and reflectance, powdery surfaces of three different conditions were prepared and their surface roughness was represented by the mean slope angle of the small facets on the surfaces [4]. The fluffy surface ("fluffy") was made by sieving the powders over a sample tray. The surface with intermediate porosity and roughness was made from the fluffy one by the tray being vertically knocked against a horizontal plane ("knocked"). The smoothest surface were made by the surface being compacted tightly ("compacted"). Bidirectional reflectance measurements of these surfaces at 633nm wavelength confirmed the previous tendency of roughness effect on the reflectance. Visible reflectance spectroscopy was performed for the "fluffy" and the "compacted" surfaces of olivine and meteorite powders[5]. Here we add our new results on intermediate ("knocked") surfaces of these materials and summarize the relationship between the reflectance and the surface roughness.

Measurements: The three types of surfaces of olivine, Allende [CV3], Gao-Guenie [H5], and NWA539 [LL3.5] powders were prepared. The diameter or the maximum length of the powder grains was below 45μm (Table 1). The typical falling velocity of the sieved powders on the surface was measured by a high-speed video camera and found to be about 20 ~ 40 cm/s. This is equivalent to the escape velocity of small bodies (a body with diameter ~500m and density ~2 g/cm^3 has an escape velocity of 52.8 cm/s).

The roughness was represented by the mean slope angle $<\theta>$ of 10μm sized lattices on the surface derived from elevation measurements (Table 1). The number of the lattice used to calculate $<\theta>$ was 10000. The slope angle of the each facet defined by the lattice was determined by the direction of the normal vector[6]. The surface roughness was in order of "fluffy", "knocked", and "compacted".

The sample surfaces were illuminated by a halogen lamp at 30 degree of incidence. The reflected light was detected at 0 degree of emission by a fiber spectrometer.

Table 1. Surface roughness of the samples. The standard deviation of the slope angle is shown in the column of $\Delta\theta$.

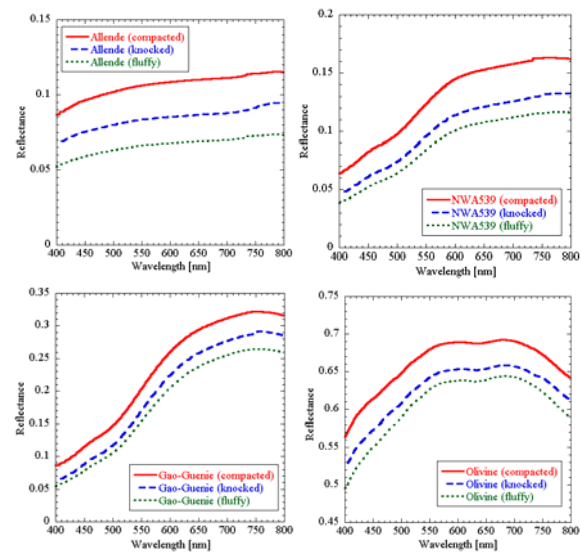|	Typical diameter	Surface condition	Roughness (deg.)	
			$<\theta>$	$\Delta\theta$
Allende	< 45μm	fluffy	40.7	18.5
		knocked	22.5	14.3
		compacted	4.0	3.8
NWA539	20~45μm	fluffy	33.5	18.9
		knocked	28.8	16.0
		compacted	6.3	5.2
Gao-Guenie	< 45μm	fluffy	34.9	15.8
		knocked	26.5	15.7
		compacted	5.6	5.7
Olivine	< 45μm	fluffy	34.3	19.5
		knocked	26.7	14.5
		compacted	6.0	5.1

Figure 1. Absolute reflectance of powdery surfaces.
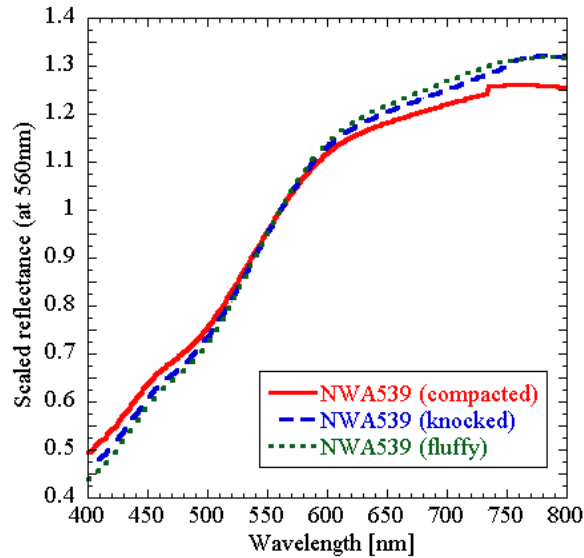
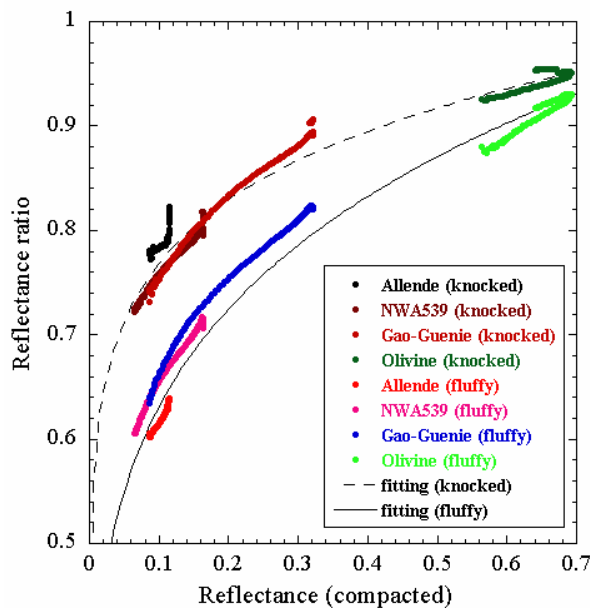*Figure 2.* Scaled reflectance of NWA539 surfaces.

Figure 3. Reflectance ratio of the "fluffy" and the "knocked" to the "compacted" one.

Results: Figure 1 shows the absolute visible reflectance of the powdery surfaces. For the all materials, the absolute reflectance was in order of "fluffy", "knocked", and "compacted". This is in agreement with the previous works[1-5]. Figure 2 shows the spectral reflectance of the surfaces of NWA539 powders scaled at 560nm. The spectra is reddened for the "fluffy" sample over the wavelength range of 400 ~ 800 nm. The "knocked" sample showed

intermediate result between the "fluffy" and the "compacted" surfaces. This result has some clues to understand the space weathering: it is inferred that the reddening phenomena observed on asteroids are caused not only by the alteration of materials but also by the physical structure of surface[7].

Figure 3 shows the ratios of the absolute reflectance of the "fluffy" versus the "compacted" and the "knocked" versus the "compacted". All the data points are aligned in the similar curves regardless of the sample materials, except for the slight discrepancies of those of Allende. The roughness θ are about 30 ~ 40 degrees for all the "fluffy" surfaces, about 20 ~ 30 degrees for all the "knocked", and about 4 ~ 6 degrees for all the "compacted". That is probably why we can recognize the degenerate correlation curves between the absolute reflectance for the surfaces with two different structures. If these correlations are described by power functions, we derive below,

$$R(\theta_{fluffy})/R(\theta_{compacted}) = 1.01 R(\theta_{compacted})^{0.20}$$

$$R(\theta_{knocked})/R(\theta_{compacted}) = 1.00 R(\theta_{compacted})^{0.11}$$

where R denotes the absolute reflectance, θ_{fluffy} ~ 35, $\theta_{knocked}$ ~ 25, and $\theta_{compacted}$ ~ 5 degrees. The values of the factor and the index in the above functions are probably characteristic of the pairs of θ. Further study with different pairs of θ is required to make a useful database.

References: [1] Adams J. B. and Filice A. L. (1967) *JGR*, *72(22)*, 5705-5715. [2] Capaccioni F. et al. (1983) *Icarus*, 83, 325-348. [3] Buratti B. J. and Veverka J. (1985) *Icarus*, *64*, 320-328. [4] Sakai T. et al. (2002) *LPS XXIII*, Abstract #1618. [5] Sakai T. and Nakamura A. M. (2003) *Proc. of 36th ISAS Lunar and Planet. Symp.* pp. 278-281. [6] Tomita N. et al. (2002) *Mem. Italian Astron. Soc.*, *73*, 739-742. [7] Clark B. E. et al. (2002) in *Asteroids III*, pp. 585-599.