LABORATORY MEASUREMENTS OF OPPOSITION SURGE FROM SIMULATED ASTEROID SURFACES T. Honda, A. M. Nakamura, T. Mukai, Graduate School of Science and Technology, Kobe University, 1-1 Rokkodai, Nada, Kobe, Japan, honchan@kobe-u.ac.jp

Introduction: Surfaces of small bodies such as asteroids and the Moon are covered with particles called regoliths. The light reflected from these bodies show a nonlinear increase in the intensity when observed at very small phase angle. This phenomenon of the nonlinear increase is called the opposition surge, and generally attributed to the existence of regolith on the surfaces. However, previous study of bare rock surfaces [1] down to the phase angle as small as 1° showed that the opposition surge could be observed not only from a particulate surface but also from a bare rock surface.

In this study, we performed measurements of the light scattered by simulated surfaces of asteroids at low phase angles. The samples prepared for the measurements were the cut surfaces of ordinary chondrite meteorite chips and the powders, and other materials. Focus was put on how the opposition surge depends on different factors of the surface, i.e., the albedo and surface conditions.

Samples: We used the similar samples from previous bi-directional reflectance studies conducted at visible wavelength. The samples were ordinary chondrite meteorites, NWA539 (LL3.5), TUXTUAC (LL5), and NWA542 (LL6) [2], and dunite from Horoman (Hokkaido, Japan) [3]. We also used ordinary condrite meteorites, NWA1794(LL5) and NWA543(LL4), and mortar (cement : sand : water = 1 : 1 : 0.47). All powder samples were dry sieved to size range of 5-20μm, 45-75μm, 180-500μm.

Powders were gently poured into a sample tray to form an optically thick layer with a depth of 6mm and the surface was leveled by moving the edge of a spatula to make it macroscopically smooth [3]. The chip samples were cut by a diamond cutter to make a macroscopically flat surface, and then were polished with sand papers of #120. We used the cut surface for the measurement.

Mesurements: The scattering intensity of the light from the different surfaces at different phase angles was measured using a newly developed multi-phase angle near infrared spectrometer at Kobe University. A beam through a diffuser from the light source, a YAG laser (λ =1064nm) illuminates the sample surface. The spot size on the surface is typically about 1mm. The beam, the sample, and the detector define the scattering plane. Of all observations, the scattering plane was fixed at right angle to the sample surface. The incidence angle to the sample surface was fixed at 2°, while the emission angle was varied from 2° to 27° (back), with 0.25° intervals. The phase angle coverage was from 0° to 25°, with the angular resolution of about 0.5° (FWHM). The light intensity was normalized to those of a Spectralon surface illuminated at 2° in incidence angle.

Comparison: To compare the shape of the phase curves and the opposition surge, we use four fitting parameters in a functional form of

$$I(g) = A - Bg + C\exp(-g/D),$$

where A, B, C, and D are the parameters of the reflectivity at g=0 (without the surge), the slope of the phase curve, the surge amplitude and the surge width, respectively. I is the relative intensity to the Spectralon and g is the phase angle in degree. The value of $A+C$ denotes the total relative intensity of the scattered light at g=0.

Results: Figure 1a shows the phase curves of an ordinary chondrite meteorite, NWA542 (LL6) samples. The opposition surge stands out at small phase angle less than 5° for the curves of all powdery samples and the chip sample. Figure 1b shows the phase curves normalized by the value at g=25°. The opposition surge stands out at small phase angle less than 5° for the curves of all the samples, that is, the reflected light from bulk surface also shows the opposition surge.

Figure 2 shows the dependence of the surge amplitude (C) on the relative intensity ($A+C$) at g=0. Present results are plotted with previous results of SiO_2 dust cakes [6]. Surge amplitude (C) increases as the relative zero phase reflectance of the surface (A+C) increases, but reaches a peak at a reflectance between 0.6 and 1. This trend is similar to the relationship between albedo and ratio of intensities *I(0.3deg)/I(5deg)* of asteroids[5].

Figure 3 shows the relationship of the surge width (D) and the micro porosity of the samples. Here we don't include the inter-grain pores, but only the intra-grain pores of mortar, dunite and meteorite chips and powders. The typical value of the grain porosity of the each meteorite types was taken from the literature [4]. The micro porosity of the dunite was also estimated from the specific density of the material in the literature and the bulk density of the dunite samples.

We adopt a value of specific density of the mortar determined by a gas pycnometer system. Dataset of phase curve and opposition surge taken from dust cakes [6] also plotted in Figure 3. We adopt the porosity due to the inter-grain pores as the micro porosity of the dust cakes. The upper bound of the opposition surge width (D) decreases with the micro porosity.

Summary: The opposition surge was detected for the meteorite chips as well as the powdery surfaces. The trend between the surge amplitude (C) and the relative reflectance of the surface ($A+C$) is similar to those found in the results of observation of asteroids. The upper bound of the opposition surge width (D) decreases with the micro porosity.

We will present the other data taken at different wavelength and will discuss on the possible comparison with the results obtained for Itokawa[7].

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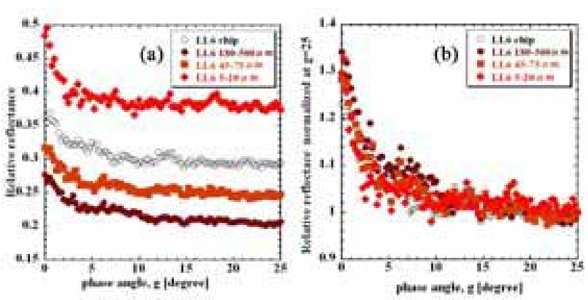

Figure1. Phase curve for LL6 (NWA542) samples. (a) Reflectance normalized by those of Spectralon. (b) Reflectance curves shown in (a) are normalized by the values at g=25°.

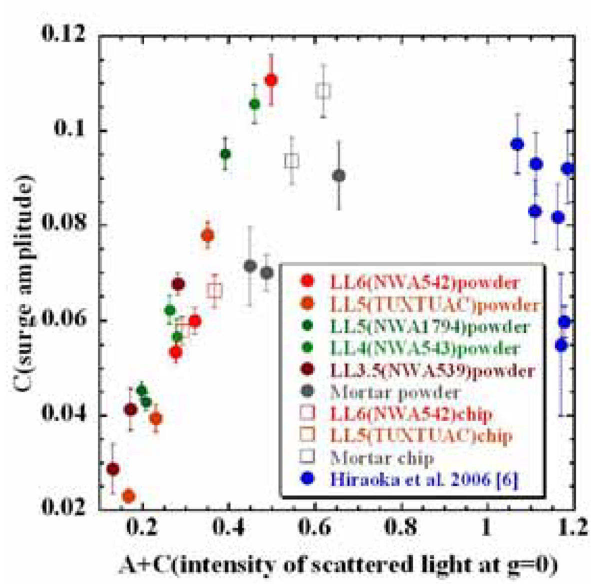

Figure2. A+C (the relative intensity of scattered light at g=0) vs C (surge amplitude).

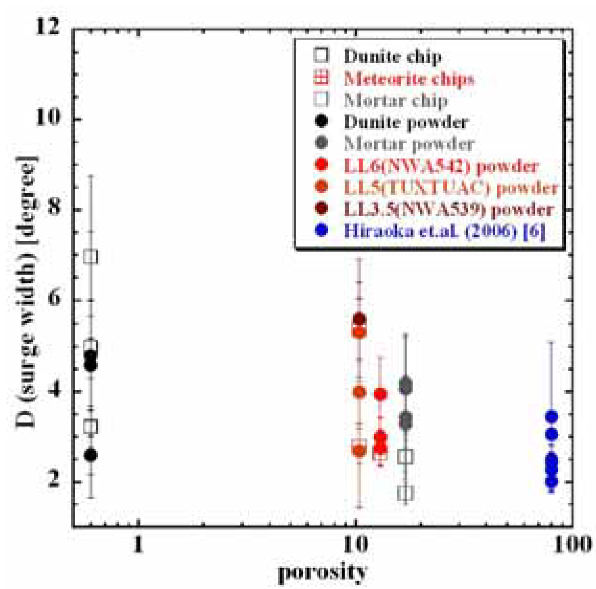

Figure3. D (surge width) vs micro porosity.