Japan Geoscience Union Meeting 2011
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PPS024-P01 Room:Convention Hall Time:May 22 14:00-16:30

Structure and dynamics of the lunar exosphere

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The Moon has no global intrinsic magnetic field and only has a very thin atmosphere called surface-bounded exosphere. Some ground-based measurements have revealed the structure of the lunar exosphere since the discovery. The alkali components such as Na or K have especially been observed to understand the generation process and the transport mechanisms. The ground-based measurements and laboratory experiments have proposed that the alkali exospheric components are produced by ion-induced desorption (sputtering), photon-stimulated desorption, meteorite-induced vaporization and/or thermal desorption from the surface. One of the loss processes of the exospheric particles is photoionization and ion-pickup process. The ionized exospheric particles are transported by the surrounding electric field. By using the SELENE(KAGUYA) ion measurement data, we have studied the lunar exosphere as well as interactions between the solar wind and the planetary surface. MAP-PACE IMA has detected low-energy ions at 100-km altitude. The MAP-PACE measurements have elucidated that the ions originate from the lunar surface and exosphere and that the ions are at least composed of He+, C+, O+, Na+, K+ and Ar+. The measurements of ions from the Moon enable us to continuously monitor the lunar exosphere. The 1.5-year observation of SELENE(KAGUYA) shows that the ions from the Moon have been detected both when the Moon is exposed to the solar wind and when it is in the Earth's lobe region. The observation suggests that the solar wind is not the dominant source mechanism for the lunar exospheres. Moreover, the MAP-PACE observation shows the dependence on the solar zenith angle and the dawn-dusk asymmetry of the lunar exosphere. We report the features of the lunar exospheres obtained by the SELENE(KAGUYA) observation and discuss the source mechanism of the lunar exospheres.

Keywords: Moon, exosphere, mass analysis

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Study of lunar plasma environment using gyro-loss effect on electron velocity distributions

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The Moon possesses neither a global magnetic field nor a thick atmosphere. Therefore, the Moon and its surrounding plasma are ideal for investigating the interaction between charged particles and a solid body. Analysis of the data obtained by Kaguya (SELENE) revealed a partial loss in the electron velocity distribution function due to ”gyro-loss” effect, namely gyrating electrons being absorbed by the lunar surface. The empty regions in the observed electron distribution functions are consistent with the patterns of forbidden regions obtained by particle trace calculations, taking into account magnetic anomalies, lunar surface charging and electric fields around the Moon. In this study, lunar surface charging and electric fields around the Moon are studied by analyzing electron ”gyro-loss” events observed where there are weak or no magnetic anomalies.

Keywords: Moon, plasma, Kaguya

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Solar wind proton scattering at lunar surface

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Interaction between the solar wind and a solar system object varies largely according to the object's properties, such as the existence of a global intrinsic magnetic field and/or thick atmosphere. The Moon's case is characterized by the absence of both of them. Until recently, understanding of the lunar plasma environment has suffered from a lack of in situ measurements of low energy ions. The interaction between the solar wind and the lunar surface has not been understood well until Kaguya observed the plasma environment around of the Moon. Especially, the behavior of the solar wind ions after impacting the lunar surface has never been observationally clear.

MAP-PACE on Kaguya (SELENE) completed observation of the low energy charged particles around the Moon from low altitude (less than 100km) polar orbit. MAP-PACE consists of 4 sensors: two electron sensors (ESA-S1, ESA-S2) and two ion sensors (IMA, IEA). Since each sensor has a hemispherical field of view, two electron sensors and two ion sensors that are installed on the spacecraft panels opposite to each other can make full 3-dimensional measurements of low energy electrons and ions. IMA on Kaguya found scattering of the solar wind ions where the solar wind ions lose energy by the interaction with the lunar surface. Initial analysis found that most of the scattered ions was protons and 0.1% ~ 1% of solar wind protons were scattered at the lunar surface.

We have investigated the angular dependence of the scattering and energy spectra of the scattered protons by using high angular resolution IMA data that were obtained dividing the hemispherical field of view into 16x64 sectors. We have found that the scattered protons have two components : backscattering and specular reflection. Backscattered component distributes within +-40 deg. scattering cone whose axis is aligned with the direction opposite to the incident solar wind ion velocity. The energy loss of the backscattered component is largest along the scattering cone axis and it is smaller at the edge of the cone. We have also found that the energy loss of the specular reflection component is less than that of the back scattered component. We have succeeded in explaining the characteristics of the angular dependence of the backscattered component by making a simple numerical model.

Keywords: solar wind, lunar surface, scattering

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Theoretical study of the spectral formation of monochromatic whistler waves near the Moon detected by Kaguya

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We study the spectral formation mechanism of monochromatic whistler waves observed by the Lunar Magnetometer aboard the Kaguya spacecraft orbiting at 100 km altitude above the Moon. The waves are observed as narrowband magnetic fluctuations with frequencies close to 1 Hz and are mostly left-hand polarized in the spacecraft frame.

Assuming whistler-mode waves in the solar wind frame propagating in the sunward direction with the group velocity comparable to the solar wind velocity, we find that, in the spacecraft frame, the Doppler-shifted frequency spectra of the waves are considerably modified making a peak at a certain frequency. The similar discussions have been made on the characteristics of upstream whistler waves observed near planetary bow shocks [e.g., Russell, 2007]. We suggest that the characteristics of the spectra of monochromatic whistler waves are determined by the relation between the group velocity vector of the waves and the solar wind velocity vector. By using the dispersion relation of whistler-mode waves in a cold plasma, we show that the factors controlling the solution are the wave vector, the magnetic field directions, and the solar wind parameters. We investigate these parameter spaces and find that the wave vector angles with respect to the sunward and to the magnetic field directions change the solution considerably than the solar wind parameters do.

To confirm the theory described above, we compare the peak frequency distribution predicted by the theory with the observed wave distribution. The consistency between the theoretical and observed wave distributions indicates that the frequency shift of the waves is well explained by the theory and that the most important controlling factor is the angle between the group velocity and solar wind velocity vectors.

Keywords: whistler-mode, Moon, monochromatic, group velocity, upstream, bow shock

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Data analysis of the causes of electrostatic solitary waves near the moon

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Bi-polar pulses called ESW (Electrostatic Solitary Wave) were observed near the Earth's magnetosphere such as bow-shock and magnetopause by GEOTAIL, WIND and other satellites. However, it is reported for the first time that ESWs were observed in the region on which the Earth's magnetosphere made influence by the Kaguya satellite.

Kaguya is the satellite, which was launched on September 14, 2007 by JAXA to explore the moon. Various observation equipments were loaded on Kaguya. PACE(Particle Angle and Composition Experiment), WFC-L(WaveForm Capture-L) and LMAG(Lunar MAGnetomter) measured flux of charged particles, electric waveform and magnetic field respectively.

In this study, we transform data of plasma particles by PACE into reduced distribution functions and analyze them with electric waveform data and magnetic field data. In the presentation, we report the relation between charged particles and the causes of the ESWs in the vicinity of the moon.

Keywords: Kaguya, plasma, ESW

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PPS024-P06 Room:Convention Hall Time:May 22 14:00-16:30

Electric wave absorptions in Reiner Gamma by lunar radar sounder (LRS) on Kaguya orbiter

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Reiner Gamma is a sinuous higher reflectance features than the surrounding mare basalt area near the Oceanus Procellarum on the moon, and appears to associate with regions of significantly high crustal magnetic field. This association of crustal magnetic field with the high reflectance has been explained by several hypotheses: 1) less susceptibility to undergo optical maturation (e.g., space weathering) by magnetic field-induced deflection of solar wind (constant flow of charged particles coming from the Sun) (Hood and Schubert, 1980; Kurata et al. 2005), 2) electrostatic levitation of fine particles by magnetic field (Garrick-Bethell et al. in press). Therefore, it was suggested that the Reiner Gamma corresponds to magnetized materials in the crust or magnetic iron-rich ejecta materials, being able to deflect the solar wind and to deposit new fine particles. This would prevent surface materials to suffer space weathering, and so produce the higher reflectance.

Neish et al. (2010) have only focused on surface nature of Renner Gamma by Mini-RF (radio frequency) synthetic aperture radar. Here we show a first trial to determine surface electric properties on Reiner Gamma by Lunar Rader Sounder (LRS) on board Kaguya with numerical simulation of surface reflection echo. We found no subsurface echo underneath the Reiner Gamma, but found surface absorption characteristics of electric wave in Reiner Gamma. The surface reflection echo simulation inside and outside Reiner Gamma discriminated this absorption with the effect of surface reflection from topographic roughness, suggesting the presence of radar absorbent materials on the surface in Reiner Gamma.

Keywords: Kaguya(SELENE), Lunar Radar Sounder, Reiner Gamma

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PPS024-P07 Room:Convention Hall Time:May 22 14:00-16:30

Lunar space weathering dominantly induced by solar wind

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Space weathering causes the change in optical properties, such as darkening and reddening of the planetary surface. Two competing processes have been proposed so far as the main mechanism of such space weathering; hydrogen irradiation by solar wind and bombardment of micrometeorites. We use the new data set obtained by Spectral Profiler (SP) combined with Terrain Camera (TC) onboard SELENE/Kaguya which observed the Moon, and approach the actual process of space weathering. We investigated the optical characteristics of the so-called lunar swirls, which consist of bright/white parts and dark/black parts making enigmatic 'swirl' patterns. We found such albedo markings of lunar swirls correspond to the extent of weathering and not composition, which means some factors to induce space weathering is inhomogeneous connecting with the swirl patterns of the albedo contrast. We conclude space weathering on the Moon would be induced by hydrogen from solar winds dominantly and the effect of the bombardment of micrometeorites may be minor.

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An estimate of the shallow lunar electrical conductivity using SELENE magnetometer data

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The electrical conductivity of the moon can be determined by electromagnetic response. From the simultaneous Apollo and Explorer 35 magnetometer observation, the electrical conductivity structure of the lunar interior was estimated. However, it so far contains significant ambiguity larger than two orders of magnitude especially for the shallow part. The ambiguity principally comes from low sampling rate of Explorer 35, which is 6.14 sec. So we thought that it is possible to improve the estimate of the shallow lunar electrical conductivity by using SELENE magnetometer data, which is averaged every 1 sec.

Because we use only the magnetic field observation of SELENE as the output, we suppose that the external input is randomly oriented uniform field. Under the condition that the electrical conductivity is uniform inside the moon, we compute Pr/P, when Pr and P represent the power of the vertical component and sum of three components, respectively. Then, we obtain the apparent electrical conductivity by comparing $Pr/P|_{theory}$ with $Pr/P|_{obs}$.

At $6*10^{-3}$ Hz, the apparent electrical conductivity is $2*10^{-4}$ S/m (skin depth is 400 km), which is consistent with Hood et al.(1982). On the other hand, at high frequency data, it is no more than $3*10^{-6}$ S/m. This value is much smaller than that of the previous estimates. We could give constraints on the shallow lunar electrical conductivity to some extent.

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The Lunar Electrical Conductivity Structure using Magnetic Data Set of KAGUYA

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The lunar electrical conductivity structure is important to understand the origin and evolution of the Moon. However, the conductivity estimated from simultaneous Apollo 12 surface and Explorer 35 orbital magnetometer records contains the uncertainty up to two orders of magnitude at shallow and deep parts of the Moon (Dyal et al., 1976; Hood et al., 1982). The object of this study is to remove this uncertainty to some extent and to improve the precision of the lunar conductivity estimation.

The external magnetic field fluctuations induce the electrical eddy currents in the Moon. The amplitude of the magnetic field resulting from these currents depends on the lunar electrical conductivity structure. Thus, the lunar electrical conductivity estimation can be achieved by analyzing the electromagnetic response of the Moon. But it is difficult to separate inducing magnetic field and induced magnetic field from data set observed by the magnetometer onboard KAGUYA, LMAG, because simultaneous magnetic observation at different point was not done. We analyze the time variation of the magnetic field when the Moon is in the geomagnetic tail lobe and goes into/out it, and then decide the lunar electrical conductivity.

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Modeling of lunar magnetic anomaly and paleomagnetic pole: Lunar dynamo in the past?

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Since findings in the Apollo era, the origin of magnetic anomaly is one of the biggest problems of the Moon. Whether or not the anomalies are records of an ancient magnetic field of lunar core origin puts strong constraints on the thermal evolution, internal structure and origin of the Moon. Magnetic field observations around the Moon by lunar-orbiting spacecrafts such as Lunar Prospector and Kaguya provide us with data to examine if the Moon once had a dynamo-generated magnetic field. For this purpose, we have conducted a study of modeling the lunar magnetic anomaly. A small-scale, relatively isolated anomaly can be modeled using point dipole sources, while more thorough modeling efforts are required for magnetic anomalies with complex structure. In this study, we have modeled lunar magnetic anomalies, taking effects of magnetization source with finite spatial scale into account. A rectangular prism is distributed in a bin of variable size as a magnetization source body. Depth of the bottom plane of the prism is fixed, while height of the prism can vary. Thus, for each prism, the magnetization vector and the height of prism are unknowns to be solved. Here, we report a preliminary modeling result using vector magnetic field data by Kaguya and Lunar Prospector low altitude observation. This technique will be applied to somewhat complicated anomalies, which are difficult to be modeled using a dipole source, such as Crisium-Antipode, Hartwig, Keeler-Heaviside, Kolorev, Krasovsky, Mendel-Rydberg, Moscoviense and Rima-Sirsalis anomalies. After modeling them, the obtained magnetization directions are mapped into distribution of paleomagnetic poles to discuss the ancient lunar dynamo hypothesis.

Keywords: Moon, magnetic anomaly, dynamo, paleomagnetic pole

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Geology of Th and K enriched Aristillus on the moon

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Global Th and K abundance map of the moon derived by the Lunar Prospector and SELENE gamma-ray spectrometer indicate that there are several highly enriched spots (hot spots) in these elements within the Procellarum KREEP Terrane. To understand the origin and distribution of the KREEP material, information of geologic characteristics and occurrence of these hot spots is important.

In this study we selected Aristillus crater among the hot spot and investigated geologic structure of this area by using SELENE Multiband Imager data.

Results indicate that relatively Fe-poor ejecta are observed in the northern area of the crater which is apparently corresponding to the Th rich material as previously suggested by [1] although reflectance spectra of this Fe-poor and surrounded relatively Fe-rich ejecta suggest basically similar mineralogy of these ejecta. Central peak of the crater has distinctively different Fe content compare to the Fe-poor ejecta and this may suggest the crater excavated Th rich material.

[1] Gillis et al. (1999) in Workshop on New Views of the Moon II, LPI.

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Estimation of the lunar surface permittivity based on Kaguya radar sounder and imager observations

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For the discussions on the lunar volcanic history, it is important to understand the composition, age, spatial extent, and the amounts of accumulation of the lava flow. Previous studies based on the spectral observation and the crater chronology suggested that the basalt of the lunar mare surface was formed by the deposition of the lava erupted several times (Heather et al., 2002; Hiesinger et al., 2003). Lunar Radar Sounder (LRS) aboard the Kaguya spacecraft succeeded in identifying echoes reflected from the paleoregolith which is at the interface of lava layers (Ono et al., 2009). By assuming the depth of subsurface layers as the thickness of the basalt at the lunar surface, we can obtain the amount of the accumulated basalt in the wide spatial region covered by the LRS observations. However, for the purpose of the estimation of the thickness of basalt from LRS observations, we need to know the electric permittivity of the basalt. In the previous studies, the typical permittivity was estimated to be in the range from 4 to 11 based on lunar rock samples [e.g., Olhoeft 1975]. Although this assumption is acceptable for the rough estimation, we need the accurate value of the permittivity of the basalt in each area on the lunar surface for the accurate estimation of the thickness of the basalt.

In this study, we estimated the accurate permittivity of upper basalt from observations of LRS, Multi-band Imager (MI; Ohtake et al., 2008), and Terrain Camera (TC; Haruyama et al., 2006). We focused on the craters (Bessel A, Bessel D) in Mare Serenitatis. We defined the permittivity of basalt around the crater as eps_1. The analysis method was as follows. First, we identified the boundary of the layers exposed on the inside wall of the crater based on the spectral images observed by MI. Next, we obtained the thickness T of the basalt exposed on the inner crater wall from the depth of the identified boundary by using the digital elevation model (DEM) based on TC. Finally, we calculated the permittivity eps_1 from the identified thickness T, the apparent depth D measured by LRS, and the permittivity of vacuum eps_0. However, we need to use assumptions of the crater formation model to calculate the thickness T. Because craters were created by the impact of meteors on the lunar surface, it should be considered that the boundaries between the subsurface layers were not simply exposed on the crater wall and are deformed by the shock wave generated when the meteor impacts. In this study, we assume some deformation models of the layers in order to estimate the permittivity eps_1 of the upper basalt layers.

We also compared the estimated dielectric constant with that of the rock samples collected by Apollo.

Acknowledgements: This study is based on TC / MI data provided by the Kaguya/LISM team through the SELENE Data Archive. We would like to express our deepest gratitude to the Kaguya/LISM team.

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Diverse crystallization trends in NWA 773 basalts

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At least three distinct crystallization trends in mafic rocks from the Moon can be extracted based on textural distinctions and pyroxene analyses from the Northwest Africa 773 (NWA 773) clan of lunar meteorites. The NWA 773 clan consists of brecciated and unbrecciated meteorites with a characteristic olivine gabbro cumulate lithology and other mafic rocks [1-5]. This study focuses on zoning trends in pyroxene within the olivine cumulate, in more evolved co-magmatic rocks that occur as breccia clasts, and a distinct mafic lithology characterized by fine-grained pyroxene+feldspar-rich groundmass [6,7]. Electron microprobe analyses for this study are from NWA 773 and NWA 2727.
Three trends can be distinguished based on Ti# (Ti/[Ti+Cr]) and Fe# (Fe/[Fe+Mg]) in pyroxene. (1) The main olivine gabbro cumulate clast (OGC) of NWA 773 [see 6,7]; smaller clasts of OGC in the breccia; co-magmatic, later-stage, coarse-grained, zoned pyroxene+feldspar-rich clasts, symplectite and extremely ferroan clasts with fayalitic olivine and silica and/or feldspathic glass form common trend with Ti# and Fe# both increasing in pyroxene. We refer to this as the ”main trend” of NWA 773 breccia. The large clast of OGC in NWA 773 was originally considered the most magnesian (most primitive) endmember of the main trend [6,7], but we have identified a slightly more magnesian clast with abundanct Cr-rich spinel.
(2) Within the olivine cumulate, pyroxene shows a wide range of Ti# but little variation in Fe# [6]. In this study, we collected pyroxene analyses along transects toward intercumulate K,Ba-feldspar-bearing pockets. These pockets are rich in incompatible elements and are considered products of residual liquids trapped between cumulate crystals (see Fig. 2B of [6]). We analyzed pyroxene adjacent to five pockets in NWA 773. In 7 of 9 transects in pyroxene, Ti# increases with minimal change in Fe# (”pocket trend”). Plagioclase feldspar adjacent to four of the five pockets showed a decrease in An-content (increase in Ab) approaching the pocket. These results are consistent with the interpretation of the pockets as residual liquids trapped in the cumulate.
(3) One group of texturally distinct clasts in the breccias of NWA 773 and NWA 2727 has a groundmass of fine, elongate, parallel crystals of feldpsar and pyroxene (straw-texture, see Fig. 6D of [6]). Pyroxene phenocrysts in the straw-textured clasts show complex zoning patterns. Fe-rich groundmass pyroxene analyses are similar to the main trend, but several analyses from the pyroxene phenocrysts have higher Ti# at a given Fe# than the main trend (straw-textured trend).
We infer that: (1) the main trend formed from fractional crystallization in the main body of NWA773 liquid; (2) the pocket trend formed from fractional crystallization as pyroxene grew toward trapped liquids in the cumulate; (3) the straw-textured trend formed from a separate mafic liquid with higher Ti#.
References: [1] Bunch et al., 2006, LPSC 37, #1375; [2] Jolliff et al., 2007, LPSC 38, #1489; [3] Zeigler et al., 2007, LPSC 38, #2109; [4] Zhang et al., 2010, MaPS 45, p. 1929-1947; [5] Nagaoka et al., 2011, LPSC 42, #1864; [6] Fagan et al., 2003, MaPS 38, p. 529-554; [7] Jolliff et al., 2003, GCA 67, p. 4857-4879.

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Geological structure of lunar SPA basin

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SPA is one of the biggest basins (2500 km in diameter) on the lunar far side. Previous studies have suggested that most of the crustal material of this basin was excavated and that the mantle materials have been exposed [1]. Therefore, most of the anorthosite composing the crust may have been excavated and ejected from the basin. However, the basin formation process and consequent mineralogy of this basin are still unclear because of the degradation after the supposedly ancient SPA basin-generated impact. For example, Pieters et al. (2001) and Ohtake et al. (2009) reported that the central part of the SPA basin contains anorthosite which is crustal material[2][3]. Additionally, Ishihara et al. (2009) estimated the anorthositic crust in the SPA basin to be 20 to 30 km thick based on data derived from the SELENE Relay satellite, its Main Orbiter transponder, and the Laser Altimeter [4]. These observations are apparently inconsistent with the theory of previous studies. In this study, we estimated the cause of this disagreement by investigating the distribution of anorthosite within the SPA basin and compared the results with topographic data. And we speculated the geological structure of this large impact basin.

We used the SELENE Multiband Imager (MI) to estimate the lunar mineralogy of SPA basin. MI is a high-resolution spectral imager with both visible and near infrared coverages at spectral bands of 415, 750, 900, 950, 1000, 1050, 1250 and 1550 nm. In all MI images, spatial resolution is adjusted to 20 m x 20 m per pixel. Mineral phases have diagnostic absorption features depending on the minerals. Plagioclase has an absorption band at around 1250 nm; olivine, at around 1050 nm; and pyroxene, at around 1000 nm. These minerals are the three commonest minerals on the Moon. We detected a peak shoulder at around 1250 nm compared to the line between 1050 nm to 1550 nm to select anorthosite spectra. Locations without this peak shoulder are categorized as other rocks.

We made a color-composite image in which red is assigned to a continuum-removed absorption depth at 950 nm; green, to that at 1050 nm; and blue, to that at 1250 nm to display the distribution of these minerals. We also used topographic data derived from the SELENE Laser Altimeter (LALT) to compare the mineralogy with topography. Its spatial resolution is finer than 0.5 degrees. We identified rings within the SPA basin based on the topographic features.

In the result of this study, we found anorthosite in 20 locations within the SPA basin. Particularly, 16 locations of them located near the fringe region within the SPA basin. Other four locations located near the center of this basin and recognized in the northwest area of this region.

The second topographic ring counted from the outside was matched the boundary of the anorthosite distribution derived from mineralogical data. In other words, few anorthosites present inside of the second topographic ring. This result suggests that the crustal material is excavated within the SPA basin, and that the second ring corresponds to a transient cavity of this basin.

[1] D.Spudis et al.,(1994)Science,266,1848-1851
[2] C.M.Pieters et al.,(2001)Journal of Geophysical Research,vol.106,No.E11
[3] Ohtake et al., (2009)Nature461(7261):236-40
[4] Ishihara et al., (2009)GRLvol.36,L19202

Keywords: Moon, South Pole-Aitken basin, Multiband Imager, Anorthosite

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Development of the Deferential Image Motion Monitor (DIMM) for Lunar Laser Ranging station

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We propose the Lunar Laser Ranging (LLR) experiment for SELENE-2 moon landing mission. We will upgrade the current SLR station (Koganei) for the first step and aim to find ranges from the LLR ground station to retroreflectors on the lunar surface. Because the influence of the atmosphere fluctuation is significant in LLR, it is necessary to improve the reliability of observed data by measuring the seeing during the observation. The seeing observation is generally conducted by using Deferential Image Motion Monitor (DIMM). We report the status of the DIMM to be developed newly for the LLR ground station.

Keywords: LLR, SELENE-2, DIMM

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Ground station for Lunar Laser Raging : condition and upgrade using present SLR station

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The paper presents a study of the ground station for the LLR (Lunar Laser Ranging) experiment in Selene2. The science goal of the LLR is to get better understanding of inner structure of the Moon and other principal physics through lunar orbit, lunar solid tides, and lunar rotation.

The current SLR (Satellite Laser Ranging) network on the Earth has about 30 operational stations and they track regularly about 30 earth orbiting satellite in which the most distant target is up to geosynchronous satellite(GEO) or about 40,000 km. A few stations can track retro-reflector arrays on the Moon which has distance of 380,000 km from the Earth. The signal strength from moon is as -40 dB weak as one from GEO because of space loss if all other conditions including the target cross section are same.

We plan to range the Moon from a Japanese ground station in two major steps. The first step is to acquire returned photons from the lunar retro-reflectors by upgrade of the existing SLR station to assess technology used and figure out necessary requirement for each subsystem and software. In the second step, full-scale development and installation in an ideal location will be planned. As the first demonstration site, the SLR station in Koganei is selected which has 1.5 m diameter telescope but does not have good atmospheric seeing.

The pointing stability of the telescope and the atmospheric seeing are the most important factors for LLR. We will monitor the seeing during ranging, and the adaptive optics approach will be taken for basic development by using tip-tilt mirrors, wavefront sensors and control software.

A tracking laser for long-distance target is to be introduced in a transmitting pass, which has 532nm wavelength, nominal repetition rate of 2 kHz, energy per pulse of 5 mJ and pulse width of about 20 nanoseconds. The kHz ranging engine (KRE), composed of a range gate generator and epoch timer (A033-ET) with newly developed control software, is capable of 2 kHz operation to control the tracking laser and data I/O. It can also control the present 20 Hz picoseconds laser by triggering using 1/100 divider. The requirements of LLR stations are investigated in terms of technology and site condition, and the upgrade of the present SLR station will be discussed.

Keywords: LLR, SLR

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Development of a Telescope for In-situ Lunar Orientation Measurements (ILOM) in the next Lunar Exploration - Evaluation

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We are proposing a selenodetic observations by using an optical telescope on the Moon to study lunar rotational dynamics in post-SELENE mission. Main targets are direct observations of the lunar physical libration and the free librations of the Moon. A small telescope like PZT set near the lunar surface determines the orientation of the axis of rotation of the Moon by positioning of several tens of stars in the field of view at every moment for longer than one year [1]. An accuracy better than 1 mas is necessary in order to put a strong constraint upon the structure and property of the lunar deep interior, such as the existence of liquid core, since libration parameters related to property of the lunar core have amplitude of at most a few mas [2].

We have already developed a BBM (Bread Board Model) of the telescope and made some experiments in order to know the performance of the optical system and the driving mechanism under similar condition to lunar environment showing high vacuum, large temperature change and dusty condition.

The important problem which can affect the accuracy is effects of temperature change. We evaluated the effects of temperature change upon shifts of star images by simulations using a ray tracing method. The patterns of the shifts due to uniform temperature change are similar to divergent flows from the origin, and we can correct for the pattern of the shifts by using linear functions with the accuracy better than 1 mas. The other kind of effect such as horizontal or vertical temperature gradient causes shifts of star images in one direction as well as radial shifts, and we need more complicated model for correction.

After the performance test of the motor under the vacuum of 3 Pa for 8 to 29 hours, we found that the temperature near the motor increased. We need to establish the condition concerning the operation of the motor in order not to cause any damage in the driving mechanism.

[1] Hanada, H., Heki, H., Araki, H. et al., Application of PZT telescope to In-situ Lunar Orientation Measurement (ILOM), International Association of Geodesy Symposia, 2004, 128, 163-168.
[2] Williams, J. G., Boggs, D. H., Yoder, C. F. et al., Lunar rotational dissipation in solid body and molten core. 2001, J. Geophys. Res., 106, 27933-27968.

Keywords: lunar rotation, telescope, PZT, physical libration, lunar exploration

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Development of thermal control unit for scientific instruments on lunar surface

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We are developing the temperature control unit for long-term survival of scientific instruments. In the SELENE-2 mission, several geophysical instruments are being considered to deploy on the lunar ground surface, including a seismometer, a magnetometer, a heat flow meter, and a VLBI radio source. These types of instruments require a long-term observation term beyond the lunar nights to obtain statistically sufficient amount of data. The lunar survival module was designed for temperature control of the instruments in the severe temperature environment (variable in -200 to 100 degC) on the lunar surface.

Conceptual examinations were conducted by numerical thermal modeling and thermal vacuum tests with a bread board model. Results of both thermal calculations and thermal vacuum tests showed a sufficient potential of the long-term survival on the Moon without high power consumption by heaters. Several devices for the module were actively considered in the recent progress.

Keywords: thermal control, lunar exploration, SELENE-2

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Development status and scientific objective of ALIS/LMUCS/LUMI for the SELENE-2 mission

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Conceptional design of SELENE-2 is on going. In this presentation, development status and science objective of ALIS/LMUCS/LUMI are discussed.

Keywords: Moon, SELENE-2, Geological survey, Spectroscopy, Crater