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Spectral and Thermophysical characterization of a Phobos regolith simulant for MMX mission

A. Maturilli (1), H. Miyamoto (2), T. Niihara (2), M. Grott (1), J. Knollenberg (1), J. Helbert (1), N. Sakatani (3), K. Ogawa (4)

(1) Institute of Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, 12489 Berlin, Germany – alessandro.maturilli@dlr.de

(2) Dept. Systems Innovation, University of Tokyo, Tokyo 113-8656, Japan

(3) Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, 252-5210, Japan

(4) Department of Planetology, Kobe University, 1-1 Rokkodaicho, Nada, Kobe, 657-8501 Hyogo, Japan

Abstract

The two natural satellites of Mars, Phobos and Deimos are both important targets for scientific investigation. The JAXA mission Martian Moons eXplorer (MMX) is designed to explore Phobos and Deimos, with a launch date scheduled for 2024. The MMX spacecraft will observe both Martian moons and will land on one of them (Phobos, most likely), to collect a sample and bring it back to Earth.

The designs of both the landing and sampling devices depend largely on the surface properties of the target body and on how its surface is reacting to an external action in the low gravity conditions of the target. The Landing Operation Working Team (LOWT) of MMX started analyzing previous observations and theoretical/experimental considerations to better understand the nature of Phobos surface material, developing a Phobos regolith simulant material for the MMX mission [1].

At the Institute for Planetary Research of the German aerospace Center (DLR) in Berlin we performed a spectral and thermophysical characterization of the Phobos regolith simulant.

1. Composition of Phobos regolith

The composition of Phobos regolith still remains controversial despite decades of telescopic and remote based observations. Reflectance spectrum of Phobos is generally featureless and very dark, with at least two major spectral units identified (a red and a blue unit). Visible to near infrared spectroscopy study show that the moons' surfaces resemble D- or T-type asteroids or carbonaceous chondrite [2]. The origin of the two Mars moons is still debated: current hypotheses are that Phobos and Deimos formed in situ in Mars orbit or by capture of asteroidal bodies originating outside the Mars system [2]. A recent study [1] showed that the spectral characteristics of both the blue and red units are not that different from each other, and their reflectance spectra are mostly similar to those of Tagish lake and CM2 chondrites.

2. Structure of Phobos regolith

Mechanical properties of the surface soil (bearing capacity, bulk frictional coefficient, and other parameters) are crucial parameters for designing a lander/sample collector, and also for a good scientific understanding of surface processes active on Phobos. The mechanical properties of Phobos regolith are poorly constrained because of the difficulty in estimating the particle sizes, particle size-distributions, the packing density of the regolith and other frictional parameters. Thermal inertia values indicate that the average particle diameter is expected to be <2mm in most regions. Earth-based radar observations of Phobos, as well as previous studies on the Moon and Itokawa particles, help better modelling of the Phobos surface properties. Accounting for these considerations, we assume that the regolith structure of Phobos has at least three layers; (1) a thin uppermost layer (<3cm in depth) of micron-scale dusts accumulated at extremely low density, (2) a 10cm- to 3m-depth regolith layer with particles accumulated at relatively higher porosity, and (3) a >10m-depth regolith layer with lower porosity.

3. Univ. of Tokyo (UT) Phobos simulant

A Tagish Lake-based simulant (UTPS-TB) was produced by crushing and Mg-rich phyllosilicates (asbestos-free serpentine), Mg-rich olivine, Magnetite, Fe-Ca-Mg carbonates, Fe-Ni sulfides into very fine particles, and then mixed with carbon nanoparticles and polymer organic materials. The mixing happened as first under wet condition; the mixture was then successively completely dried to adapt the compressible strength to that of Tagish Lake.

4. Spectroscopic measurements at PSL of DLR in Berlin

The Planetary Spectroscopy Laboratory (PSL) of DLR in Berlin is a spectroscopic facility providing bi-directional and hemispherical reflection, transmission and emission spectroscopy of target materials. Bi-directional reflectance of samples is measured with variable incidence and emission angles between 13° and 85°, for sample temperature 170K to room temperature, under vacuum conditions, covering the 0.2 to above 200 µm spectral ranges. Two integrating spheres allow measuring hemispherical reflectance of samples under purging in the entire PSL spectral range. An external emissivity chamber (working under vacuum) features high efficiency induction system heating the samples to temperatures from 320K up to 900K [3].

At PSL we measured the Phobos simulant material sieved in 3 different grain size ranges: 400-500 µm, 1.6-2 cm, 3.55-4 cm. For each size separate, emissivity was measured in vacuum for sample temperature 320K (50°C). Bi-directional reflectance was measured under several phase angles conditions for sample temperatures between 170K (-100°C) and room temperature in the whole UV to FIR spectral range [4]. Hemispherical reflectance was measured under purging conditions on the sample at room temperature in the whole UV to FIR spectral range.

5. Thermophysical properties of Phobos regolith simulant

Regolith thermophysical properties play a major role in explaining the exchange of radiative energy between the asteroid and its environment. The knowledge of these parameters is needed to calculate several parameters related to the surface and subsurface temperatures. We are going to measure some thermophysical properties of the Phobos regolith simulant in at least the 3 already cited grain size ranges. We use a Transient Hot Strip to measure the thermal conductivity while minimizing the contact resistance and sensor heat capacity during the measurements. The measurements taken following this method are calibrated against standard materials. The sample container is placed inside a thermal vacuum chamber; measurements can be performed at temperatures of -150°C to +50°C. Soil mechanical properties for the difference grain size fractions will be studied too, trying to get information on the cumulative (mass) size distributions of each fraction, sphericity, angularity, and grain porosity if possible. Compressive/crushing strength measurements of the porous materials could also be possible.

5. Conclusion

Spectral and thermophysical properties of a Phobos regolith simulant soil (developed from the University of Tokyo) will be measured. This study non only will increase the knowledge needed for landing and sampling on Phobos surface (MMX) but will be useful for the JAXA Hayabusa2 mission to asteroid Ryugu, being the MMX soil simulant material now part of a suite of Ryugu simulant materials, whose spectral and thermophysical properties are going to be measured.

References

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