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СИМПОЗИУМ
ПО ИССЛЕДОВАНИЯМ
СОЛНЕЧНОЙ СИСТЕМЫ

11 - 15 ОКТЯБРЯ 2021

ИНСТИТУТ
КОСМИЧЕСКИХ
ИССЛЕДОВАНИЙ
МОСКВА

THE TWELFTH
MOSCOW
SOLAR SYSTEM
SYMPOSIUM

11 - 15 OCTOBER 2021

SPACE RESEARCH
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ДВЕНАДЦАТЫЙ МОСКОВСКИЙ СИМПОЗИУМ ПО ИССЛЕДОВАНИЯМ СОЛНЕЧНОЙ СИСТЕМЫ 12M-S³

октябрь 11-15, 2021

**ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ
РОССИЙСКОЙ АКАДЕМИИ НАУК
МОСКВА, РОССИЯ**

THE TWELFTH MOSCOW SOLAR SYSTEM SYMPOSIUM 12M-S³

october 11-15, 2021

**SPACE RESEARCH INSTITUTE
OF RUSSIAN ACADEMY OF SCIENCES
MOSCOW, RUSSIA**

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- Институт космических исследований РАН
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2021

THE TWELFTH MOSCOW SOLAR SYSTEM SYMPOSIUM 12M-S³

**SPACE RESEARCH INSTITUTE
MOSCOW, RUSSIA
october 11-15, 2021**

Starting from 2010, the Space Research Institute holds annual international symposia on Solar system exploration. Main topics of these symposia include wide range of problems related to formation and evolution of Solar system, planetary systems of other stars; exploration of Solar system planets, their moons, small bodies; interplanetary environment, astrobiology problems. Experimental planetary studies, science instruments and preparation for space missions are also considered at these symposia.

The Twelfth Moscow international Solar System Symposium (12M-S³) will be held from October 11 till 15, 2021.

Subject matter of this symposium will cover many problems of the Solar system science with the central topic "Moon, Mars and Venus research". This topic relates to scientific problems of several missions: "Mars Express", "Venus Express", the missions under development in Russia: "Luna-Glob ", "Luna-Resource", "Venera-D", "ExoMars".

THE FOLLOWING SESSIONS WILL BE HELD DURING THE SYMPOSIUM:

OPENING SESSION

- Session. MARS
- Session. VENUS
- Session. MOON AND MERCURY
- Session. SMALL BODIES (INCLUDING COSMIC DUST)
- Session. GIANT PLANETS
- Session. EXTRASOLAR PLANETS
- Session. ASTROBIOLOGY

In light of COVID-19 travel restrictions the Symposium will be held both «face-to-face» and «virtual» formats.

For all «face-to-face» participants in Space Research Institute (IKI) the masks as well as social distancing will still be obligatory!

Space Research Institute holds this symposium with participation of the following organizations:

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- Brown University, USA
- Schmidt Institute of Physics of the Earth RAS, Russia
- Keldysh Institute of Applied Mathematics RAS, Russia
- Kotelnikov Institute of Radio-engineering and Electronics RAS, Russia
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TOWARDS MARTIAN MOONS EXPLORATION: MICRO-RAMAN AND VIS-MIR REFLECTION SPECTROSCOPY OF THE PHOBOS SURFACE SIMULANTS

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Phobos, MMX mission, Raman spectrometer, Surface Simulant.

INTRODUCTION:

The Japan Aerospace Exploration Agency (JAXA) Martian Moons eXploration (MMX) remote sensing, robotic and sample return mission [1], scheduled to be launched in 2024 and to return in 2029, will have a strong focus on studying Phobos, including close-up surface analysis and collecting samples for Earth return. A rover, provided by CNES and DLR, will be deployed to Phobos [2]. Its payload includes the Raman spectrometer (RAX) for in-situ characterization of the surface composition [3]. Characterization of payload instrumentation by measurements of planetary simulants is a crucial test for performance and prediction of scientific yield. Controversial conclusions on similarity of infrared reflection and imaging of Phobos to those of low-albedo asteroids imply that combined optical spectroscopy studies will prepare a set of possible clues shortly before the MMX mission. Different Phobos simulants were selected and have been used for Raman and broad range (visible-to-mid-infrared) reflection spectroscopy in order to provide critical parameters on detectivity of mineral phases in the sample matrix as well as to compare the close-up spectroscopy with the known remote sensing of Phobos surface by previous Earth-based observatories and planetary missions.

EXPERIMENTAL DETAILS

The Phobos surface simulants were of two main types, prepared assuming different scenarios governing the moon formation and surface weathering:

1) a “captured asteroid”, (CM1, C2 – 1 – TL) Phobos Simulants — mixes of Mg-rich phyllosilicates, olivine (Ol), magnetite, Fe-Ni sulfides and carbon-bearing

ing Fe – Ca – Mg and carbon (C) nm-particles [4], based on a composition similar to the Tagish lake meteorite (CI/CM2 carbonaceous chondrite), that exhibits similar featureless, near-infrared reflectance spectra as that of the Phobos surface (appearing as dark in visible spectral range);

- 2) a “giant impact” scenario simulants with the compositions similar to those developed in [5]: (PGI – 1*): a mix of pyroxene (Px), olivine, antigorite (Atg), magnetite representing CI-type of material; (PGI – 1**): the PGI – 1* with pyrite. A C-free PGI-1* simulant was aimed to distinguish between the contributions and interplay of organic and inorganic components i both Raman and reflectance spectra.

Raman spectra (100–4000 cm^{-1} in Stokes shift) were taken by the RAX breadboard spectrometer (532 nm excitation wavelength; spatial resolution on a sample of $\sim 50 \mu\text{m}$) and compared with the spectra of single mineral phases taken by a commercial Raman microscope (WiTEC alpha 300 : 532 nm; spatial resolution of $\sim 1.5 \mu\text{m}$). A Bruker Fourier Transform Vertex 80 v spectrometer was used for the broad visible to mid-infrared range (0.5–27 μm) bi-directional diffuse reflectance measurements (light spot on a sample $\sim 0.5\text{--}2 \text{ mm}$, ambient air pressure of $\sim 2 \text{ mbar}$). The grain size in the original powders was 25–63 μm , corresponding to the expected uppermost surface layer of the Phobos regolith [4].

RESULTS

Raman spectra of the Phobos simulants CM1 and PGI – 1* are generally accompanied with a strong luminescence (PL) signal, which is stronger for the C – bearing samples. After the PL correction, the main spectral features of Ol, Px, Atg phases are distinguishable in the RAX spectra for PGI-1* (Fig. 1a, b) together with the strongest bands specific for silicate minerals. Possible appearance of a serpentine phase (Chrysotile, Ctl, Fig. 1a, b) could point on natural alteration of Px phase at ambient laboratory conditions.

Visible to near-infrared diffuse reflectance spectra exhibit vanishing to absent features, similar to the analysis of the Phobos 2 ground-based observations [6] and as from the Compact-Reconnaissance-Imaging-Spectrometer-for-Mars (CRISM) onboard of the Mars Reconnaissance Orbiter mission [7]. Note that both, C-bearing and C – free Phobos simulants exhibit very similar, low-intense diffuse reflection in the entire VIS – MIR spectral range, obviously governed by the grain size, slowly decreasing towards mid-infrared and with increase of the incident or reflectance angle. Most of the characteristic bands, enabling determination of individual minerals, fall into the mid-infrared (2–30 μm), with prominent long-wavelength MIR features for sulfides (S); C – O vibration modes of C – bearing compounds and strong structural – OH (hydrated minerals) and Si – O (silicates) vibrational modes. For the PGI-1* simulant, the overall slope is governed by most abundant Px+Ol phases with the spectral features of Atg (Fig. 1c). Reflectance spectra of the CM – 1, C2 – 1 – TL simulants (Fig. 1d) are dominated by phyllosilicate (Atg) + C slope and broad bands with enhanced overlapping vibrational modes of carbon and silicon networks in the long-wavelength part of spectra (7–11 μm) and, apparently, a sulfide band (S) at $\sim 24 \mu\text{m}$. Iron oxide, having relatively weak Fe – O stretching and bending modes, spectrally overlapping with the stronger silicate’ bands, was not resolved in our diffuse reflectance measurements.

Generally, carbon-bearing components (in CM1, C2-1TL samples) conceal most of prominent mineral bands in both Raman scattering and infrared reflectance spectra. The RAX breadboard instrument demonstrated its capability to identify major characteristic bands of silicate minerals. Infrared reflectance spectra show gained capability of mineral differentiation by resolving distinguished characteristic bands in the long-wavelength mid-infrared range (7–26 μm), that could be a crucial step in development of future instrumentation for infrared sensing of surfaces of solar system bodies experiencing strong space weathering. Regardless the spatial resolution (μm for Raman and mm for IR spectroscopy) all main mineral phases can be identified by complementary Raman scattering and mid-infrared reflection spectroscopies.

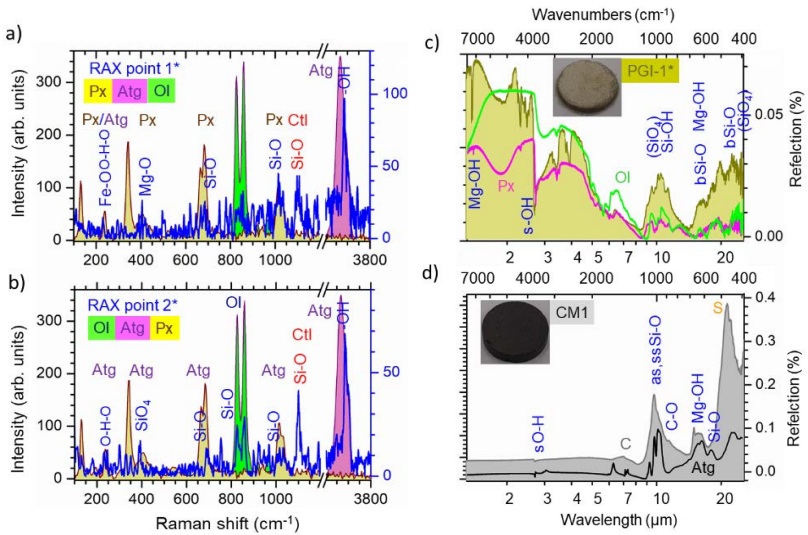


Fig. 1. Raman spectra (a, b) acquired by the RAX breadboard collected from the Phobos surface simulant PGI-1* at two different locations (blue) and compared with the single mineral phases (shown as filled areas) dominant in the simulant: Ol, Px, Atg, taken from polished rock surfaces by a commercial Raman microscope. Mid-infrared part of bi-directional (15° for both incident and collected reflected light) diffuse reflectance spectra (filled areas) of: c) PGI-1* and d) CM1 simulants (images in insets), parts of the characteristic single-mineral phase spectra, collected from the powdered Ol, Px, as well as from a bulk Atg, are shown as solid curves (not to scale with the simulant reflectance).

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