

Reproduction Experiments of Phobos Constituent Materials Using a Gas-jet Levitation System Based on the Giant Impact Hypothesis

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Regarding the origin of the Martian moons Phobos and Deimos, two hypotheses have been proposed: the capture hypothesis and the giant impact hypothesis. Both moons are small, irregularly shaped bodies exhibiting dark, featureless reflectance spectra in the visible to near-infrared range, similar to D- and T-type asteroids (Rivkin et al., 2002). While this similarity supports the capture hypothesis, it does not explain their nearly circular orbits in Mars' equatorial plane (Higuchi & Ida, 2017). In contrast, numerical simulations by Rosenblatt et al. (2016) suggest that the giant impact hypothesis can account for these orbital characteristics. Still, the detailed processes of the impact, as well as the spectral and chemical properties of the resulting materials, remain unclear.

In this study, we use a Gas-Jet Levitation System to simulate the giant impact process and evaluate its validity. By analyzing the reflectance spectra and chemical compositions of impact-generated materials, we aim to provide fundamental data for Martian moon exploration, particularly the Martian Moons eXploration (MMX) mission, where such data will help interpret observed spectra and returned samples. The starting material consists of a mixture of Martian mantle material and impactor chondritic material, with varying mixing ratios. Simulations by Hyodo et al. (2017) predict that a giant impact melts material at approximately 2000 K, forming a disk around Mars that subsequently cools and accretes into moons. To replicate this process, we employed a gas jet levitation system, allowing material to be melted and cooled without contact. Experiments were conducted at three different cooling rates (200–300 °C/s, 10 °C/s, and 1 °C/s), covering the range predicted by Hyodo et al. (2017). Since Pignatale et al. (2018) predicts that the chemical composition of dust and solids varies significantly depending on the type of impactor, we performed experiments under three atmospheric conditions with different oxygen partial pressures (ambient air, Ar gas, and Ar–H₂ gas) to investigate their effects on material properties. The synthesized samples were analyzed using FT-IR for reflectance spectra, FE-SEM/EDS for morphology and chemical composition, and STXM for Fe-XANES analysis. The results were compared with observational data of the Martian moons.

This study aims to: (1) verify reproducibility and establish the experimental methodology through repeated experiments under identical conditions, and (2) conduct experiments using the Martian mantle composition as an end-member, assuming that future studies will incorporate chondritic impactor material.

Analysis of the experimental samples revealed that cooling rate significantly affects crystallinity, while oxygen partial pressure strongly influences reflectance. Rapidly cooled samples tended to be amorphous, whereas slowly cooled samples crystallized into olivine and pyroxene. More oxidized samples exhibited lower reflectance, comparable to that of the Martian moons. However, a peak near 0.8 μm, which does not appear in observational data, was observed in the experimental spectra.

Currently, further experiments are being conducted by varying the chemical composition of the impactor material and its mixing ratio to better understand the material-science conditions that reproduce the reflectance spectra observed in the Martian moons.

Keywords: Martian moons, Giant Impact Hypothesis, Reflectance Spectra, Gas-jet Levitation System