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Spectroscopic analysis of allophane and imogolite samples with variable Fe abundance for characterizing the poorly crystalline components on Mars

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Abstract

Nanophase materials including silicates, aluminosilicates, and iron oxides are widespread on Mars. These minerals are important because they likely represent a solid-phase record of ancient climatic conditions on the martian surface. Identification and characterization of nanophase compounds is technically challenging due to the small size and poorly ordered nature of these materials, particularly because their chemical compositions can vary widely.

This study presents spectra of several synthetic allophane and imogolite samples with a range of chemical compositions that are typical of the natural variability of allophanic materials. These samples were formed under controlled conditions and have been thoroughly characterized in terms of chemical composition and short-range structure.

Analyses confirmed that the synthetic materials were allophane and imogolite and were structurally similar to previously studied natural and synthetic examples of these phases. NMR and XAFS data indicated that high-Al proto-imogolite allophanes were similar in structure to imogolite but were less well ordered, and supported the proposed nanoball structures based on rolled octahedral Al sheets. Increasing Si content in allophane produced increasing tetrahedral Al substitution as well as polymerized Si chain structures at Al-Si mole ratios of 1:1, and sheets and possible framework structures at Al-Si mole ratios of 1:2. Fe in allophanes and imogolites substituted exclusively for octahedral Al.

Reflectance spectra of the synthetic allophanes and imogolites were comparable to previously analyzed samples. Variations in Fe content of allophane and imogolite resulted in some observable changes in visible/near-infrared (VNIR) reflectance spectra, but these changes were not detectable in emission spectra. Emission spectra of the samples suggest that variations in Al-Si ratio of allophanes should be detectable using remotely sensed data. Because allophanes with different Al-Si ratios typically form in very different environments, this could be significant for interpretation of formation conditions on Mars, with high-Al compositions suggesting possible tephra weathering and high-Si compositions indicating possible formation from thermal waters.

Keywords: Mars, spectroscopy, nanophase, allophane, imogolite