

Mid Infrared Reflectance Spectra of Enstatite

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Abstract—We present experimental and calculated spectra of pure enstatite single crystals, indicating that viewing geometry and optical anisotropy influences the shape and positions of the Christiansen feature and adjacent Reststrahlen bands in remotely obtained mid infrared (MIR) data from planetary surfaces.

I. INTRODUCTION AND BACKGROUND

Crystalline silicates are very common on surfaces of all terrestrial planets, their moons, small solar system bodies and in circumstellar clouds. Their presence in general but also their variety can be studied from their characteristic infrared spectra and, for example, gives valuable information on the geochemical evolution of planetary bodies. It is apparent that laboratory spectroscopy performed on such minerals serves here as a ground proof for remotely obtained infrared spectra.

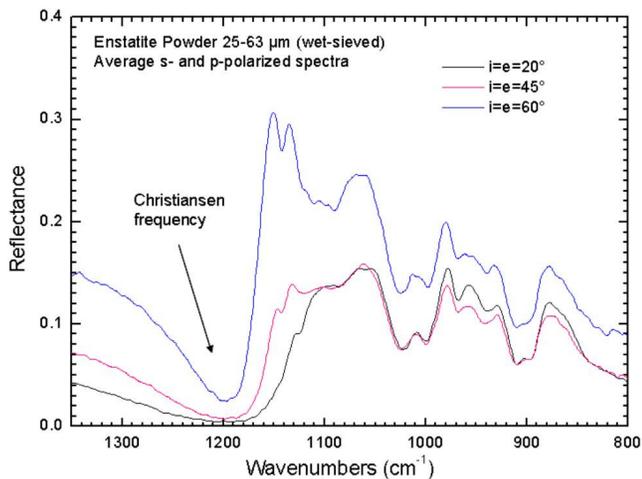


FIG. 1: Reflectance spectra of enstatite powder for different angles of incidence showing the change in the appearance of the Christiansen feature and the adjacent Reststrahlen bands.

Enstatite (Mg-rich low-Ca pyroxene) is one of the most abundant silicates in the solar system and usually appears in an orthorhombic crystal lattice. Like for other silicates, the Si-O stretching vibration of the lattice gives rise to a strong and characteristic absorption (Reststrahlen bands) in the mid infrared spectral range, often used to interpret remotely obtained spectra. One dominant frequency in the spectra associated with the Reststrahlen band is the so-called Christiansen feature¹ indicated by a minimum in reflectance or a maximum in the emissivity spectrum. This feature falls in the high-frequency spectral region of anomalous dispersion for a still small extinction coefficient of the mineral when the real part of the reflection coefficient reaches the value of the environment ($n = 1$ for vacuum). The position of the Christiansen feature in reflectance and emission spectra is highly diagnostic for chemical composition and mineralogy

but may be influenced by a number of experimental conditions which can affect the unambiguous identification of the silicate. For example, an increase of the ambient pressure can significantly shift the position of the Christiansen frequency in the emissivity spectrum caused by an increased absorption in a powdered sample². However, data on how the observation geometry and the crystal anisotropy influence the Christiansen feature and Reststrahlen bands in its vicinity are lacking. Nevertheless, several space missions are equipped with spectrometers operating in the MIR spectral range, where the fundamental Si-O vibrational modes are observed. For example, the TES spectrometer globally mapped Mars surface, and the MERTIS spectrometer will map Mercury. Pyroxenes are major rock-forming minerals of Martian crust and, based on the ground-based MIR observations, enstatite, together with feldspars may be a major surface component of Mercury.

II. RESULTS

We studied the reflectance properties of pure enstatite single crystals and powders. Prior to our analyses the crystals were characterized by chemical and petrographical methods. The orientation of the crystals was determined by x-ray diffraction and by optical goniometry and planes perpendicular to the a-, b-, and c-axis were saw-cut and subsequently polished. Absolute reflectance spectra for p- and s-polarization were obtained for each crystal plane for different angles of incidences. The complex optical constants for the three crystal axes were derived by the Kramers-Kronig formalism and used to calculate the specular reflectance using the Fresnel formula for anisotropic media. The calculated spectra fit well the measured data set. We show that the spectroscopic geometry and the anisotropy of the mineral can cause significant changes in the shape and position of the Christiansen feature and the Reststrahlen bands in its vicinity (e.g., Fig 1). Such influence should not be neglected when data from different laboratories or laboratory data with remote sensing spectra acquired at different viewing geometries are compared.

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REFERENCES

- [1] C. Christiansen, "Untersuchungen über die optischen Eigenschaften von fein vertheilten Körpern", *Annalen der Physik* **23** 298-306, 1884.
- [2] L.M. Logan, G.R. Hunt, J.W. Salisbury, and S.R. Balsamo, "Compositional implications of Christiansen frequency maximums for infrared remote sensing applications" *J. Geophys. Res.* **78** 4983-5003, 1973.