

THIN FILM ABSORBANCE SPECTRA OF FORSTERITE AND FAYALITE DUST GRAINS K. M. Pitman¹ and A. M. Hofmeister¹, ¹Dept. of Earth and Planetary Sciences, Washington University, Campus Box 1169, St. Louis, MO 63130-4862 <kpitman@levee.wustl.edu>.

Introduction: Forsteritic (Mg_2SiO_4 , Fo) and fayalitic (Fe_2SiO_4 , Fa) olivines exist as micron-sized dust grains in a variety of astrophysical and planetary environments. While an estimated ~ 95% of the silicate material that dominates the interstellar medium by mass is assumed to be amorphous [1], crystalline silicate dust particles are known to be present in dust disks around main-sequence stars, some solar-system comets, and outflows from evolved stars (c.f., [1-3]). Forsterite and fayalite are also important constituents in differentiated meteorites and occur in a range of (Mg, Fe) compositions, e.g., Fo₁₀₋₂₀ for eucrites and pallasites ranging to Fa₉₋₂₁ for some angrites [4]. Further evidence from comets, meteorites, interplanetary dust particles, and asteroids suggests that the occurrence of forsterite or fayalite may correspond to primordial conditions or to the presence of (aqueous) alteration on planetesimal surfaces, respectively. The spectral detection of Fe-rich olivine dust particles around a remote astronomical object (e.g., a Vega-like star [5]) could imply the existence of a surrounding asteroid belt or a series of planetesimals.

Given the presence of micron-sized crystalline silicate dust grains in so many environments and the fact that dust particles of a given size, temperature, crystal structure, and composition may be differentiated by their distinct spectral signatures over infrared (IR) wavelengths (~ 200-2.5 μm , or ~ 50-4000 cm^{-1}), obtaining detailed spectroscopic information on intermediate and end member forsterite and fayalite compositions over a broad range of infrared wavelengths is critical for proper analysis of astrophysical and planetary dust grains. In this work, we present mid- and far-IR laboratory diamond anvil cell (DAC) thin film absorbance spectra and peak position wavenumbers for approximately 20 different olivine compositions along the Fo/Fa binary.

Experimental Samples and Methods: Natural forsterite and fayalite samples (Fo₉₃, Fo₉₁, Fo₈₂, Fo₆₈, Fo₆₃, Fo₅₄, Fo₄₆, Fo₄₁, Fo₄₀, Fo₃₈Te₆, Fo₃₁Te₁, Fo₁₄Te₂, Fo₇Te₂, Fo₆Te₂, Fo₀Te₅) supplied by R. M. Hazen, S. A. Morse, H. S. Yoder, and the Harvard collection were selected for spectral measurement. Of the ~ 20 olivine samples measured, one sample was meteoritic: Fo₈₂, Alice Springs Meteorite. Additional synthetic olivines were provided by C. Koike (Fo₁₀₀), H. K. Mao (Fo₁₀₀), R. M. Hazen (Fo₈₀, Fo₇₅, Fo₆₇), C.

B. Finch (Fo₀), B. Fegley and R. G. Burns (Fo₅₀), and Alfa Aesar supply company (Fo₁₀₀). Chemical compositions for all samples were either previously published in the literature [6-9] or measured directly via electron microprobe at Washington University by D. Kremser (Table 1). Only a few samples studied were found to have high Mn content (3-4.5 wt. %). Because Mn₂SiO₄ spectra closely resemble Fe₂SiO₄ spectra (c.f., [10]), these low Mn amounts should not affect our results.

Table 1. Chemical Compositions of Selected Olivines

	Forsterite San Carlos, AZ	Hortonolite Rustenberg, Transvaal, South Africa
SiO ₂	40.98	33.86
TiO ₂	0.02	0.02
Al ₂ O ₃	0.00	-
Cr ₂ O ₃	-	-
Fe ₂ O ₃	-	-
FeO	9.04	46.83
MnO	0.12	0.72
MgO	49.48	18.25
CaO	0.07	0.06
Na ₂ O	-	-
K ₂ O	-	-
H ₂ O ⁺	-	-
H ₂ O ⁻	-	-
Impurity	0.39% NiO	0.05% NiO
Sum	100.10	99.79
Formula	Fo ₉₁	Fo ₄₁

Analyses by EMP performed by D. Kremser, Wash. U.

For each sample, the bulk sample (initially in pellet, chip, or powder form) was first mechanically crushed into micron-sized particulates. Optically thin films (thickness ~ 0.4 to 2 μm) were created by mounding the micron-sized sample particulates onto one of the diamond tips in a DAC sample mount and compressing to minimize cracks and granularity. Mid- and far-IR absorbance spectra were collected as described in references [11] and [12] (Fig. 1). Mid-IR spectra were acquired over the wavenumber region ~ 1800-400 cm^{-1} (λ ~ 5.5-25 μm) at 1 and 2 cm^{-1} resolution using a liquid-nitrogen-cooled HgCdTe detector, a KBr beamsplitter, and an evacuated Bomem DA 3.02 Fourier transform spectrometer (Bomem Inc., Quebec, Canada). A Si bolometer and a coated, broadband mylar

beamsplitter were used for the far-IR range from 50–650 cm⁻¹ (~ 200–15 μm) at 1 cm⁻¹ resolution. The accuracy of the instrument is ~ 0.01 cm⁻¹. An absorbance spectrum of the empty DAC served as the reference spectrum.

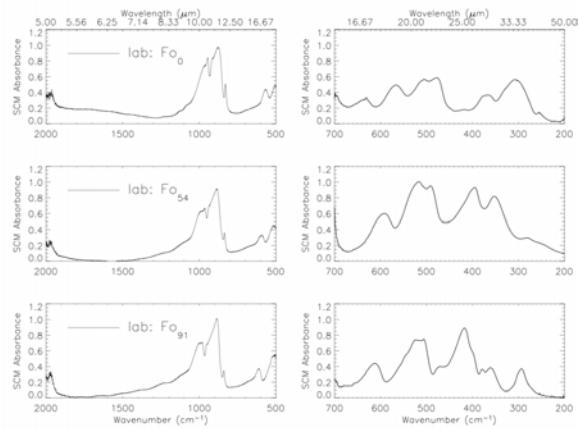


Fig. 1. Mid- and far-IR common log absorbance as a function of wavenumber for 3 representative olivine compositions: Fe-rich fayalite (Fo₀), intermediate Fo/Fa (Fo₅₄), and Mg-rich forsterite (Fo₉₁). Mid-IR modes change little across the binary whereas the far-IR modes are greatly affected due to changing mass.

Discussion: Dispersion spectra of samples with essentially binary compositions varying from forsterite to fayalite were measured by [13] and [14]. Our selection contains a larger number of samples, with more compositions near the middle of the binary (Fo₃₀ to Fo₅₀) than measured in either of these previous studies. Peak positions reported here are similar to both studies, but intensities differ; we attribute the latter effect to light being received from areas of the dispersion that lack sample. Our data do not agree with the relative intensities from either [13] or [14] regarding the two peaks at ~500 and ~520 cm⁻¹, and a shoulder near 550 cm⁻¹. The shoulder is much more intense in the dispersion method, which in turn increases the apparent intensity of the ~520 cm⁻¹ peak. For samples near the middle of the binary, our data indicate that the cluster near 400 cm⁻¹ is too intense relative to the pair of peaks from ~490 to 550 cm⁻¹ for some, but not all of the samples studied in [13]. Overall, better agreement regarding relative intensities is obtained between our results and those of [14]; we note, however, that spectra in [14] show some artifacts at high frequencies (LO modes). The thin film method should give correct relative intensities, whereas a dispersion with clumps of sample, or too large a particulate will not. It is possible that some of the irregularities in trends of peak positions with composition from the dispersions

noted by [13] and [14] are due to these types of sampling problems.

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