

THERMOSPECTRAL EVALUATION OF FORSTERITE. M. L. Shusterman¹, B. R. Wing¹, N. R. Izenberg¹, C. A. Hibbitts¹, and P. R. Phelps^{2,3}, ¹John Hopkins Applied Physics Laboratory, Laurel, MD (Morgan.Shusterman@jhuapl.edu) ²The University of Tulsa, Tulsa, OK.

Introduction: Laboratory investigations and models have shown that the spectral behavior of silicate minerals varies with temperature [1,2,3]. Changes in band position and shape are the result of changed energy levels within crystal states with temperatures change [1]. To describe spectral variations relative to changing temperatures we evaluate a mineral's thermospectra; defined as the change in reflectance with respect to temperature as a function of wavelength. Thermospectral data can provide insight into spectral variations we see on bodies in the solar system that experience a wide range of temperatures. Using laboratory derived data, we can improve our understanding of how the spectral signatures of minerals change as a function of temperature to more accurately interpret surface mineralogy.

Here, we present thermospectra data for forsterite $Mg_2(SiO_4)$. Reflectance data in the visible to near-infrared was collected under high vacuum at temperatures ranging from 127 K to 500 K.

Methods: A powdered sample of forsterite was mounted behind a MgF_2 window into a copper sample well with an integrated thermocouple and UHV button heater. Under high vacuum conditions ($10^{-7} - 10^{-8}$ Torr), the sample was cooled to 127 K using a liquid nitrogen-fed cryostat and subsequently heated to 500 K using a button heater. Reflectance spectra in the Vis-NIR were collected in increments of ~ 10 K between 127 K and 500 K, across a wavelength range of 0.85 μm to 2.5 μm .

Thermospectrum calculation: To determine how the spectral reflectance of forsterite is dependent upon temperature, a thermospectrum analysis was completed. The thermospectrum was calculated by evaluating the reflectance dependence of a material on temperature as a function of wavelength.

Results: For forsterite, a significant change in reflectance is detected across the range of temperatures at absorption bands. Reflectance values for wavelengths further from the absorption band minimum change linearly as a function of temperature, a consistent finding with results from [2]. A spectrum for forsterite was plotted at each temperature increment in Fig. 1. There was little change in reflectance values at the bottom of the 1.06 μm absorption band and as longer wavelengths were evaluated, a wider variation in reflectance values was recorded. The increasing dependence of reflectance on temperature at each wavelength results in an absorption band that broadens at hotter temperatures.

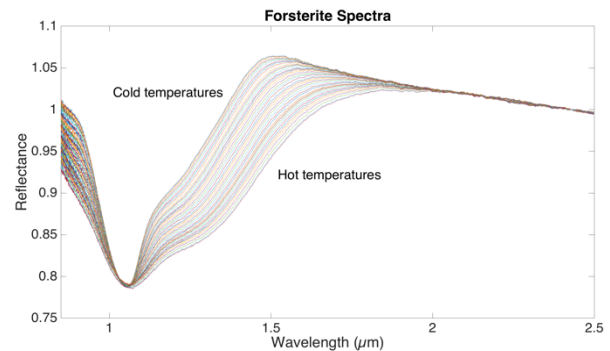


Figure 1. Reflectance spectra of forsterite in the Vis-NIR. Each spectrum represents a different temperature (cold temperatures at the top and warm at the bottom). The reflectance at the 1.06 μm absorption band does not change as temperatures change, but regions on either side change systematically as the band broadens or narrows with changing temperature.

The relationship between reflectance and temperature is approximately linear for all wavelengths. Seven wavelengths chosen from Fig. 1 and their reflectance data vs. temperature were plotted in Fig. 2a. A slope break appears to occur around 308 K (room temperature)(Fig. 2a,2b), which is the point at which we ended cooling data collection and began warming data collection. Because of this systematic difference, data and regression lines for cold and hot data were plotted separately. Flat slopes for wavelengths near the absorption minimum show that reflectance has little dependence on temperature near band minima. The wavelengths with negative slopes are further from the minimum and have an inverse correlation to temperature; they darkened as temperatures increased. Because the band depth was not affected by temperature changes, we expect to see a broadening of absorption features, which means reduced reflectance in the wings of the band, but no change in the reflectance at band minimum.

The cause of the slope break at 308 K is being investigated, but because the data is assumed to follow a linear progression, the effect may be explained by a systematic change in the experimental setup between cooling and heating experiments. The shift was found to occur across all wavelengths, indicating a systematic effect, which we currently attribute to mechanical shifting of the sample holder due to thermal expansion and

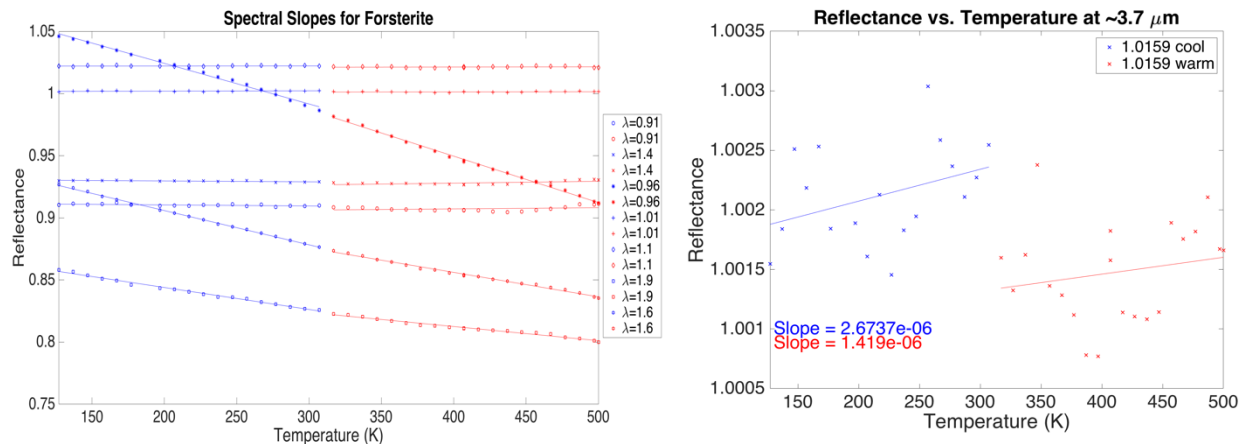


Figure 2a. The reflectance (normalized at 1.1 μm) at several wavelengths across the the temperature range shows that wavelengths close to the absorption band center and along the continuum are near zero, while the wavelengths selected in the wings of the band show a near-linear decrease in brightening as the temperature increases. **Figure 2b.** Plotted individually, the slope break around 308 K is more apparent than when scaled and plotted with other wavelengths as in 2a.

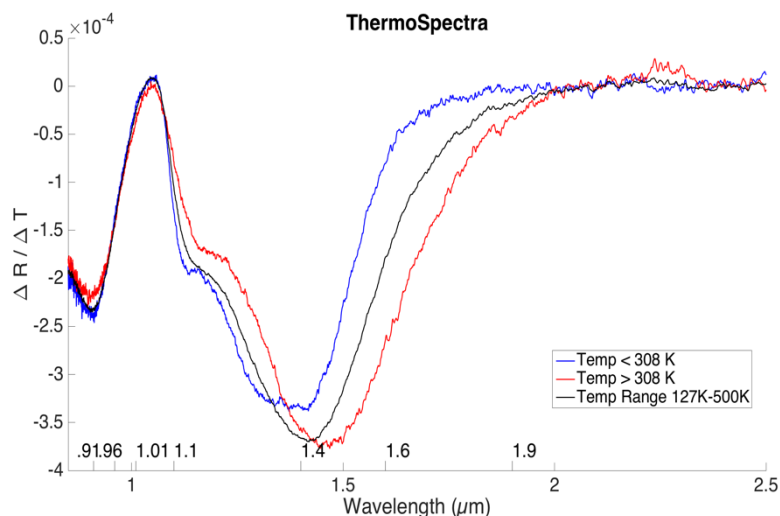


Figure 3. ThermoSpectra for forsterite is plotted with a slope derived similarly as those from Fig. 2a for each wavelength. The blue line represents the thermoSpectra calculated during the cooling experiment, using temperatures 127 K to 307 K. The red line represents the thermoSpectra calculated during the warming experiment, using temperatures 317 K to 500 K, and the black line represents the average of the two.

contraction. The difference between cool and warm thermoSpectra plotted in Fig. 3 shows that small variations in experimental setup can produce slightly different shaped thermoSpectra and indicates that the factor by which reflectance changes as a function of temperature is sensitive to experimental procedures.

Conclusions: Data collected of forsterite is largely consistent with previous experiemnts by other researchers but is conducted over a larger temperature range.

However, there is a small but significant systematic effect in the thermoSpectra. Our experimental setup continues to be improved and we will continue to make observations of various samples.

References: [1] Singer R. B. and Roush T. L. (1985) *JGR Solid Earth*, 90, No.B14, 12,434-12,444. [2] Hinrichs, J. L., and Lucey, P. G. (2002) *Icarus*, 155(1) 169-180. [3] Izenberg N. R. et al. EPSC, 10. EPSC2015-127.