Emissivity spectra of anorthite-forsterite Mixtures in a Simulated Lunar Environment
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Introduction: We have taken laboratory emissivity spectra of fine-grained powder mixtures of anorthite and forsterite in varying weight percentages, to constrain changes in the Christiansen feature (CF) position with mixture composition. Emission spectra were measured in a chamber that approximates the thermal environment of the lunar surface produced by vacuum conditions [1]. Previously, simulated lunar environment (SLE) spectra had been acquired for pure end-members and compositions along solid solutions. However, the lunar regolith is composed of an intimate mixture of fine-grained materials. These measurements address two questions: 1) How does the CF position as estimated from Diviner data respond to mineral mixtures? 2) In regions where olivine has been detected with VNIR instruments [2,3,4], why olivine is less apparent some areas (Fig 1) than others (Fig 2) in the MIR?

The Christiansen feature and composition: The Diviner Lunar Radiometer Experiment (Diviner) has three narrow band “8µm” channels located at 7.80 µm (Ch 3), 8.25 µm (Ch 4), and 8.55 µm (Ch 5). These were chosen to distinguish the Christiansen feature (CF) of silicate minerals [5]. The CF is a mid-IR emissivity maximum that moves to shorter wavelengths with increasing SiO₂ polymerization [6]. As a consequence, felsic minerals will have CF positions at shorter wavelengths than mafic minerals as shown in Fig 3. The arrows in Fig 3 point to this maximum, while Diviner channels 3, 4, 5 are indicated by red markers. Fig 4 shows the Ch 3,4,5 emissivities are fit to a parabola to estimate the CF position.

Samples and Methods: The olivine used for this study consisted of mm-sized forsteritic grains determined by electron microscope to have an ~Fo₉₅ composition. Anorthite samples were ~1cm single crystals and originated from Miyake Isla, Japan. Based on the measured CF, the anorthite is ~An 80-90. The pure minerals were ground and sieved to less than 6µm, then seven samples were prepared with compositions ranging from 100 wt. % anorthite to 100 wt. % olivine, according to the percentages given in Fig 4.

Measurements and Results: The SLE emissivity spectra for all mixtures is shown in Fig 5. It is apparent that the mixture spectra are not linear combinations of the pure mineral spectra, especially between 700-1200 cm⁻¹. The spectral contrast of the mixtures are smaller for the end-members. This is consistent with the subdued spectral contrast we see in the Diviner data.

Conclusions: The difference in mixing behavior between ambient and SLE conditions shows SLE emissivity data is important for constraining the behavior of the CF for mixtures. Linear mixing is a reasonable assumption if the area is forsterite-rich. For the CF position of an anorthite-forsterite mixture to be elevated above average mare (~8.3) [8], there must be greater than about 90 weight percent forsterite in the mixture. This information can constrain olivine abundance in regions where it has been detected with VNIR instruments. In the future we would like to collect lunar environment data for a range of olivine compositions, as fayalite has a longer-wavelength CF, and hence a smaller amount would be needed for detection by Diviner.

Comparison to linear mixing model: Full resolution lab spectra were convolved to Diviner spectral resolution (Fig 8). Then, the CF position was estimated as it would be from Diviner data. The estimated Diviner CF for each mixture under both ambient and SLE conditions is given in Fig 7. Not only are both mixing trends non-linear, but the deviation is different in each case. So, while ambient spectra the CF is depressed faster than expected, in a SLE linear mixing is a pretty good assumption down to about 50 wt% forsterite.