

**SULFIDE MINERALS STUDIED USING THERMAL EMISSION SPECTROSCOPY.** Melissa D. Lane<sup>1</sup>,<sup>1</sup>Planetary Science Institute, 1700 E. Fort Lowell Road, Suite 106, Tucson, AZ 85719 ([lane@psi.edu](mailto:lane@psi.edu)).

**Introduction:** Sulfide minerals are common in primitive Interplanetary Dust Particles [e.g., 1] and meteorites (and were detected in Comet Halley) [e.g., 2]. Sulfides likely occur throughout the solar system (e.g., Io, Europa, Ganymede [3], etc.), including being common in terrestrial volcanic terrains. Because Mars had extensive volcanic activity, sulfides ought to be present on Mars. Additionally, the bright ferric-sulfate bearing soils of Paso Robles may have originated from the oxidation of precursor volcanogenic sulfide deposits [e.g., 4, 5] as seen in terrestrial environments [e.g., 6]. Other sulfates on Mars, as well, may be derived from precursor sulfide minerals [e.g., 7]. This work will present preliminary analyses of a diverse suite of sulfide minerals using thermal emission spectroscopy in order to enhance the future analyses of Martian thermal spectroscopic data and possibly other midinfrared data sets of other bodies (from telescopic or spacecraft-borne instruments).

**Laboratory Technique:** Early midinfrared studies of sulfides and arsenates were limited because these minerals typically have spectral features longward of  $\sim 450\text{ cm}^{-1}$  and *reflectance* measurements are detector-limited to spectral regions shortward of  $\sim 667\text{ cm}^{-1}$ . Hence, the Arizona State University thermal *emission* spectrometer is ideal for spectral analyses of these minerals because the CsI beamsplitter and DTGS detector allow measurement to  $\sim 210\text{ cm}^{-1}$ , revealing the long-wave spectral structure. The samples included in this work are listed in Table 1 with their purported mineral name and idealized formula; however, note that no XRD work has been done as of the abstract submission date to confirm their mineralogy.

<b>Table 1.</b> Sulfide samples measured in thermal emission		
<b>Mineral</b>	<b>Ideal formula</b>	<b>Sample number</b>
Molybdenite	$\text{MoS}_2$	ML-I4
Sphalerite	$(\text{Zn,Fe})\text{S}$	ML-I1
Troilite	$\text{FeS}$	ML-I9
Stibnite	$\text{Sb}_2\text{S}_3$	ML-I10
Chalcopyrite	$\text{CuFeS}_2$	ML-I11
Chalcocite	$\text{Cu}_2\text{S}$	ML-I15
Arsenopyrite	$\text{FeAsS}$	ML-I28
Pyrite	$\text{FeS}_2$	ML-I29
Bornite	$\text{Cu}_5\text{FeS}_4$	ML-I3
Galena	$\text{PbS}$	ML-I5
Tetrahedrite	$(\text{Cu,Fe,Ag,Zn})_{12}\text{Sb}_4\text{S}_{13}$	ML-I25

The samples are all small hand samples that were heated in an oven to  $80^\circ\text{C}$  and measured over 160 scans at  $2\text{-cm}^{-1}$  sampling (i.e.,  $4\text{-cm}^{-1}$  resolution) at ambient

pressure. The spectrometer used is a modified Nicolet Nexus 670 FT-IR interferometer attached to an external glove box containing a temperature-stabilized sample chamber (maintained with circulating water behind the chamber wall). To reduce and maintain the amount of atmospheric water and  $\text{CO}_2$  vapor inside the spectrometer, external sample chamber, and glove box (and to reduce the degradation of the hydrophilic beam splitter) the entire system is continuously purged with air scrubbed of water and  $\text{CO}_2$ . Details regarding data calibration are presented elsewhere [8-10].

**Midinfrared Spectroscopic Results:** The majority of ore minerals are sulfides and they are typically opaque (with exceptions). The general formula for sulfide minerals is  $\text{M}_m\text{S}_n$ , where M is the metallic element, S is sulfur, and m and n are the numbers of atoms thereof. Similar minerals in this class (Strunz Class II—Sulfides and sulfosalts) include the arsenides and tellurides (plus the rarer selenides, antimonides, bismuthides, etc.), where the S is instead As or less commonly Te, respectively. Sulfide mineral structures range from simple (e.g., galena and sphalerite) to more complex (e.g., tetrahedrite) in which polyhedra are distorted [11].

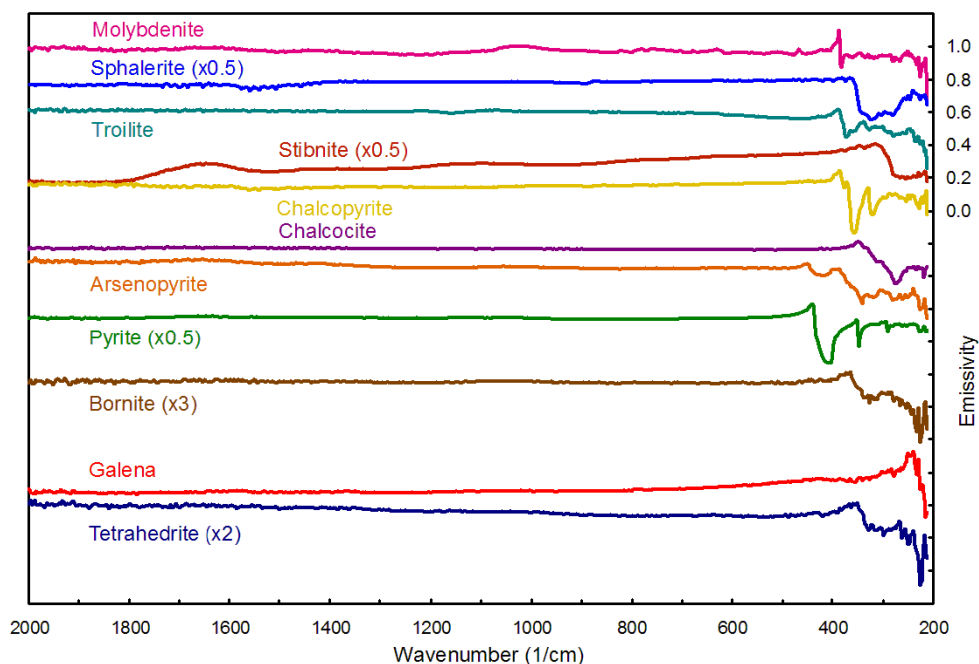
The spectra of 11 sulfides are shown in Figures 1 and 2 (next page). Figure 1 shows the entire spectral range acquired to show that the sulfides generally are spectrally flat (graybody) at the higher frequencies (higher wavenumbers) but exhibit spectral structure longward of  $\sim 450\text{ cm}^{-1}$ . Figure 2 shows the expanded view of the  $600\text{ to }200\text{-cm}^{-1}$  region where the sulfide features dominate the spectrum [12].

Further studies will include a wider range of sulfide (and arsenide) minerals as well as duplicate mineral samples from different localities. XRD data will also be acquired to address the true structure and chemistry of each sample and the effects of solid solution on the emissivity spectra. Band assignments for the vibrational modes (internal/lattice) of the minerals will be determined.

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**Figure 1.** Thermal emission spectra of sulfide minerals over the entire wavelength region studied. Spectra are offset for clarity.

**Figure 2.** Expanded view from Figure 1 of the thermal emission spectra of sulfide minerals over the 600 to 200  $\text{cm}^{-1}$  range. Spectra are offset for clarity.

