

**THERMAL-INFRARED SPECTRAL OBSERVATIONS OF MARTIAN CANDIDATE MATERIALS IN EMISSION; Philip R. Christensen and Sharon J. Luth, *Department of Geology, Arizona State University, Tempe, AZ 85287.***

Thermal-infrared spectroscopy provides a powerful tool for determining the composition of planetary surface materials. Virtually all silicates, carbonates, sulfates, phosphates, oxides, and hydroxides have thermal-infrared spectral features associated with the fundamental vibrational motions of the major ionic groups in the crystal structure. The vibrational frequency of these motions varies with both the ionic composition and crystal lattice structure, providing a direct means of identifying the composition of many geologic materials. Because rocks are composed of mixtures of mineral phases, this technique also permits the petrology of the rocks and soils exposed at the surface to be determined.

The purpose of our work was to investigate the properties of minerals and mineral mixtures as observed in the thermal-infrared. The primary focus was to study a series of candidate martian material, in order to support future observations to be acquired by the Thermal Emission Spectrometer (TES) instrument, currently being developed for use on the Mars Observer mission. The laboratory observations are intended to characterize the spectral properties of geologic materials in emission, and to study a variety of processes and surface modifications that may influence or alter the spectra of primary rock materials.

Pioneering studies of the thermal-infrared absorption characteristics of minerals were have been performed (Lyon, 1962, 1964; Farmer, 1974; Hunt and Salisbury, 1974, 1975, 1976). The vast majority of these studies have measured the spectral properties of materials in either transmission or reflection, whereas remote sensing observations of planetary surfaces measure the amount of energy emitted. In theory, reflectance measurements can be related to emission measurement assuming Kirchoff's law. However, this relationship is only strictly valid for measurements of the total hemispherical reflection and emission from a mat surface, rather than the reflection from a polished surface as is often measured (Hunt and Vincent, 1968).

In the studies reported here, we have acquired thermal-infrared spectra of materials in emission using the prototype TES brassboard spectrometer. This instrument is a Fourier transform interferometer, which covers the spectral range from 7 to 18  $\mu\text{m}$  at a spectral resolution of  $5.5 \text{ cm}^{-1}$  (0.055  $\mu\text{m}$  at 10  $\mu\text{m}$  wavelength). This resolution is approximately a factor of two better than will be achieved with the Mars Observer instrument, allowing the detailed spectral properties to be investigated and interpreted.

To acquire a spectra the sample is heated in a temperature-controlled oven for 4-6 hours to achieve a uniform temperature throughout the sample. At present, only solid rock samples and mixtures of moderate ( $>50 \mu\text{m}$ ) sized particles have been investigated, in order to minimize the effects of temperature gradients within the samples, which are known to cause uncertainties in the observed spectral properties (Logan and Hunt, 1970; Logan et al., 1975). Spectra are also acquired of a very accurately controlled blackbody reference surface, and of liquid nitrogen to determine the instrument response and background emission respectively. This suite of observations permits absolute determination of the emissivity of the sample, provided that the kinetic temperature of the sample is known. Because of the difficulty in measuring and interpreting the surface temperature of the sample, the temperature is determined by fitting a blackbody curve to the observed spectra. Tests using quartz crystals demonstrated that the derived temperatures agreed with the best measured temperatures to within 1 K. The Michelson mirror position is accurately

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determined using a visible light interferometer to count the fringe patterns of a neon light source. This standard technique permits an absolute wavelength determination to be made that is accurate and repeatable to approximately 0.01  $\mu\text{m}$  at 10  $\mu\text{m}$ . Double-side interferograms are acquired to permit phase offsets and non-linearities in the beamsplitter and interferometer to be removed. Using these technique the observed spectra were divided by the blackbody spectrum to determine the emissivity of each sample.

Emission spectra were obtained for a suite of samples taken within the Kelso dune field and the Cima volcanic region in the Mojave desert, California. These samples were acquired from surfaces within a region imaged by the Thermal Infrared Mapping Spectrometer (TIMS) airborne instrument (see Kahle and Goetz, 1983). The spectra were then compared to laboratory observations acquired in reflection (M.J. Bartholomew and A.B. Kahle, personal communication), and to field emission observations acquired using a field portable spectromter (Hoover and Kahle, 1986).

Comparison of these spectra confirm that thermal emission spectra contain the same absorption features as have been previously observed in transmission and reflection spectra, and demonstrate the successful utilization of the TES prototype instrument to obtain relevant spectra for analysis of rock and mineral composition. In addition, the laboratory observations indicate that clay and sand materials can be separately identified from intimate mixtures of different fractions of these components. Finally, these results indicate that surface coatings of desert varnish, up to approximately 50-75  $\mu\text{m}$  thickness, are sufficiently transparent to the emitted thermal energy to permit an identification of the underlying primary rock composition.

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