THERMAL-INFRARED SPECTRAL OBSERVATIONS OF COATED SURFACES
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Thermal infrared spectral observations of Mars will provide an important means of determining the composition of the martian surface. In the martian environment, however, it is expected that coatings of dust and weathering products will occur on rock surfaces, which will present problems to any spectral technique attempting to determine the composition of the underlying material. Prior to obtaining planetary observations, it is important to determine the effects of coatings on the spectral properties of rock and particulate materials. In addition, the study of coatings, in particular weathering products and varnishes, may be important in understanding the evolution of the martian surface. Interaction of volatiles between the surface and atmosphere appears to be a significant process in the development of crusts within the soil [1,2]. Similar interactions may act to produce weathering or depositional rinds on rocks and individual grains. It is therefore necessary to develop means for separating the rock and coating signatures in order to understand each separately.

Thermal infrared spectra have been obtained of a variety of terrestrial varnished materials to study the effect of compositional layering. While it is clear that the processes by which varnishes and weathering rinds may develop on Mars may be substantially different from those on the Earth, it is expected that the physics of emission, absorption, and scattering can be simulated using available, naturally varnished surfaces. Of particular interest is the effect of coating thickness on the spectral character and detectability of the underlying surface emission. The effect of the coating thickness will be controlled by the wavelength-dependent extinction within the layer, which is in turn controlled by the absorption coefficient of the coating and the scattering properties of the coating material. The latter will be dependent upon the wavelength-scale structure within the coating, including the presence of fine-grained particles within the coating matrix.

The spectra used for this investigation were acquired with a commercial Fourier Transform Interferometer at a spectral resolution of 4 cm\(^{-1}\). The data were acquired in emission in order to more completely simulate the radiative transfer characteristics of spectra acquired remotely from planetary surfaces. Samples were heated to 80 °C for 24 hours to achieve thermal equilibrium and minimize temperature gradients within the samples. Spectra were acquired within 60 seconds of removal from the oven, again to minimize temperature gradients. For solid rock materials at atmospheric pressure the thermal conductivity is \(-3.3\) W m\(^{-1}\) K\(^{-1}\). At room environments with the surface losing heat through radiation, conduction, and convection of the near-surface atmosphere, the conductivity is sufficient to maintain a temperature gradient of \(-0.1\) K/mm in the upper few millimeters where the emission originates.

On Mars solid rock surfaces will have very similar thermal conductivities and will therefore also have small temperature gradients in the upper millimeters. Granular surfaces will have conductivities that are lower and controlled by the conductivity of the pore gas [3]. Gas conductivity in the martian atmosphere will, despite its low density, provide sufficient conduction through the upper layers so that conductivity of particulates will only be a factor of 10-350 lower than for solid rocks. During the day this decreased conductivity will in part be offset by solar input, resulting in temperature gradients of less than \(-5\) °K/mm. This temperature variation will produce only a small effect on the spectral signature. Thus, the technique used does appear to provide an accurate simulation of the major environment parameters that will affect emission from the martian surface, and provides a reasonable means of studying the spectral properties of coated materials in planetary environments.
Selected results from preliminary investigation of a range of materials are shown in Figures 1 and 2. Surfaces studied were selected to provide a distinct spectral signature from the substrate, in order to study the masking effects of varnish materials. Again, these samples were selected to simulate the effect, rather than the exact process, expected for Mars. Detailed analysis of the thickness of the coatings has not been performed at the present time; estimates of relative thickness are based on visual inspection of the surface, including the degree of obscuration of the underlying surface and the completeness to which grains were mantled.

As seen in Figure 1, the relative thickness of the coating does affect the spectral signatures in certain wavelength regions. However, for moderate varnishes, in which the surface was visibly obscured and only the form of sub-varnish grains visible, the spectral properties of the underlying rock can be detected. In particular, quartz absorption features near 8.8 μm are readily detected. For the thickest varnish obtained, these features are obscured and the spectral feature due to the varnish at ~9.8 μm is readily apparent. However, even at this extreme varnish thickness absorption bands in the 18 to 25 μm region that were seen in the unvarnished rock are detectable. These observations suggest that in regions away from major absorption features within the varnish material, where the absorption coefficient is low, the varnish is relatively transparent to thicknesses approaching several hundred microns.

Figure 2 shows a similar effect for iron-oxide-coated sand grains. These grains have a distinct red color indicating a relatively complete coating. At thermal infrared wavelengths, however, the coating is nearly transparent, with the underlying quartz signature readily observed, including subtle features near 13 μm. This type of coating may be important for martian sand grains, and the results obtained indicate that coatings of this magnitude will not interfere significantly in the compositional analysis of these materials.

References