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Clues on the composition of bright regions of Mars from TIR spectroscopy

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Abstract. Mars shows a strong surface dichotomy and its two hemispheres are dominated by different albedo surfaces: dark and bright regions. Dark regions are better characterized than bright ones, with a typical composition which varies from basaltic to andesitic. More recently high quality infrared spectra of bright regions were retrieved and analyzed and, using fine grained materials, was found out that its main mineral component belongs to the plagioclases class.
In this work we tried to reproduce in laboratory the infrared signature of Martian high albedo surfaces, by using analogue materials of the Martian surface. Our result are in agreement with previous results, although the retrieved abundance of carbonate seems to be sensibly smaller.

Key words. Bright regions – mineralogic composition – carbonates – plagioclases - IR spectroscopy

1. Introduction

Rocky and dusty materials on Mars form different surface types, which could be typically divided in two classes, depending on the albedo properties: bright and dark regions. A value of 0.2 for the bond albedo is usually chosen as the edge between these two families. Moreover, Dark regions (DRs) show a wide compositional variability and are again subdivided in two distinct spectral classes, called Type 1 and Type 2 (Bandfield et al. 2000).
Bright regions (BRs) exhibit, on average, a lower thermal inertia than dark ones and this seems to be related to the different size of the grains composing the two regolith types. BRs could actually be made up of fine particles (less than 10 μm in size), whereas DRs should be composed of particles larger than 100 μm.
Analysis of Thermal Infrared (TIR) spectra returned by the Thermal Emission Spectometer (TES) onboard the Mars Global Surveyor (MGS) (Christensen et al. 1992) showed that the dark Type 1 terrains are composed by basaltic material, while for the Type 2 regions a debate is still open. Formerly an andesitic composition were invoked (Bandfield et al. 2000), whereas an alternative analysis brought to the explanation of a water-weathered basalt (McSween et al. 2003; Wyatt & McSween

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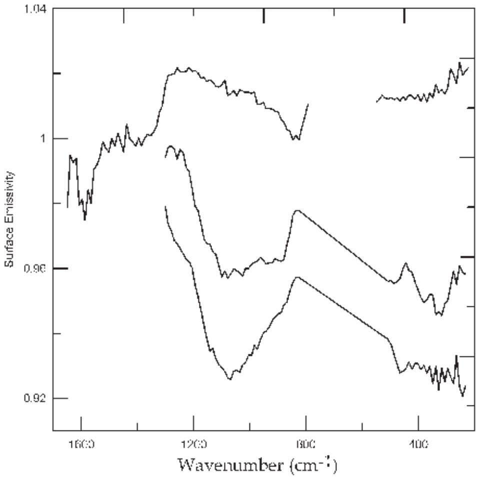

Fig. 1. Spectra of (from top to bottom): Martian high albedo surface, Type 1 (Cimmeria) and Type 2 (Acidalia) (all the spectra are shifted from each other in emissivity for simplicity).

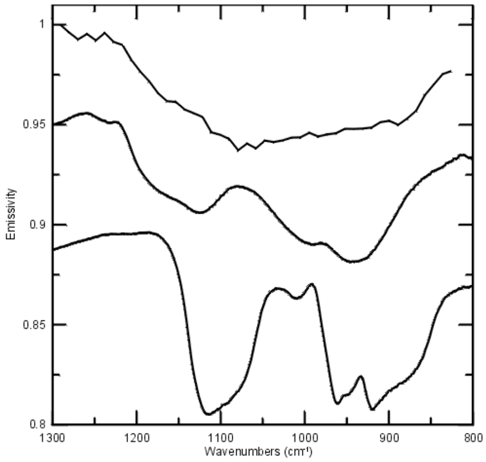

Fig. 2. TIR spectra of (from top to bottom): Martian high albedo surface, labradorite and augite ≥100 μm (all the spectra are shifted from each other in emissivity for simplicity).

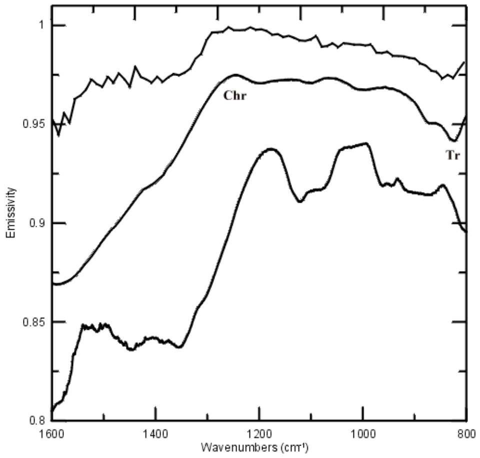

Fig. 3. TIR spectra of (from top to bottom): Martian high albedo surface, labradorite and augite 0-20 μm. "Chr" and "Tr" respectively indicate the labradorite Christiansen and transparency features (all the spectra are shifted from each other in emissivity for simplicity).

2002).

Due to the low S/N ratio of BRs signatures in the TIR is was impossible to extract compositional information by means of the deconvolution analysis as obtained, conversely, for the DRs (Ramsey & Christensen 1992).

A recent study of BRs, observed in particular geometrical conditions, produced an average spectrum with high S/N ratio. Although a mineral abundance analysis is still practically not possible, a qualitative study of the materials present on the regolith can be performed. At a first attempt the main mineral component of the BRs was found to be a plagioclase mineral (Bandfield & Smith 2003), but a minor presence of carbonates was necessary to explain the observed spectrum (Bandfield et al. 2003). In this work we try to reproduce in laboratory the TIR behaviour of Martian BR spectrum, by using mixtures of Martian analogues materials.

2. Bright vs dark Martian materials

In Fig. 1 we report the spectra of bright and dark regions (both type 1 and type 2) (Bandfield et al. 2003). A different spectral shape is clearly evident, especially between dark and bright regions. The formers present a strong band centred at 1000 cm^{-1} with a different U-shaped or V-shaped structure, for the type 1 and 2, respectively. This feature is absent in the bright spectrum, which exhibit instead a band around 825 cm^{-1}. Another clear

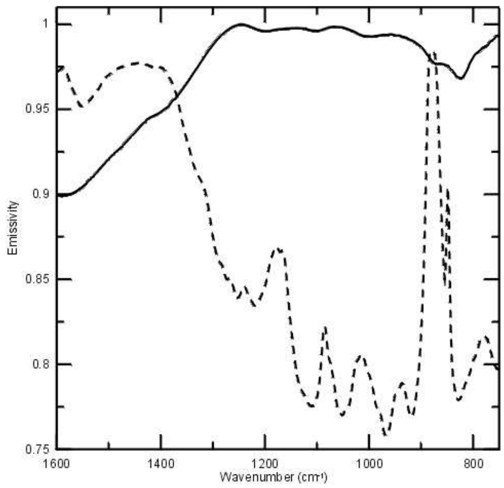

Fig. 4. TIR spectra of labradorite 0-20 μm and calcite 0-20 μm (dashed line).

In Fig. 2 and 3 we show how it is possible to infer compositional and morphological information of Martian BR spectrum, in Fig.2 we compare the $\geq$100 μm-size labradorite and augite with the DR Type 1 and Type 2 spectra. Their spectral behaviour is very similar with a very strong band at 1000 cm^{-1}, due to the Si-O vibration. Conversely Fig. 3 shows the absence of this band. It is evident a similarity between the spectral shape of BR and smallest size labradorite spectra, while augite seems to be not present, at least in large amounts. In fact transparency and Christiansen features and overall shape of labradorite alone mimic well the BR spectrum. Giving that the main mineral component is a fine grained feldspar, we would like to study the small departure of the high albedo spectrum from the labradorite one.

difference is in the 1200-1650 cm^{-1} spectral region, in which high albedo spectrum presents other three features located around 1200, 1500 and 1650 cm^{-1}. The first feature corresponds to the maximum value of emisivity and, together with the band at 825 cm^{-1}, it suggests a strong presence of plagioclases, because they have both Christiansen and transparency features at those wavelenghts. The peak placed beyond 1600 cm^{-1} is probably due to the presence of water in weathered silicates, such as sheet silicates, while the broad emittance band centred around 1500 cm^{-1} was explained as due to the presence of a little amount of carbonates (Bandfield et al. 2003). Since the deconvolution technique is focused onto the 1000 cm^{-1} band, where the BR spectrum have no clear bands, its application seems to be inadequate for a quantitative analysis.

3. Laboratory approach

We prepared Martian regolith analogues by crushing and grinding samples of a feldspar (labradorite), a pyroxene (augite) and a carbonate (calcite), followed by a sieving process which allowed us to produce size calibrated samples (0-20, 20-50 and 50-100 μm). The TIR spectra were acquired by means of a Bruker Equinox 55 Fourier Spectrometer.

In fact, as it is clearly seen in Fig. 3, labradorite (as all the plagioclases and pyroxenes do) has no bands in the region under study, whereas calcite (and tipically all the carbonates) shows strong emissivity value band in the range from 1400 to 1600 cm^{-1} (see Fig. 4) In order to investigate this we prepared mixtures of labradorite with calcite at different abundances (1, 2 and 5 % by areal fraction).
In Fig. 5 we show a comparison between the BR and the labradorite mixtures spectra.

3.1. Labradorite-calcite mixtures

In all of the mixtures it is evident that the hydration band at 1600 cm^{-1} seems to be absent, but this could be explained with the lacking of hydrated minerals, such as sheet silicates, in our laboratory mixtures.
The 5% mixture spectrum clearly shows that the band at 1500 cm^{-1} is sensibly much stronger than in the BR spectrum, suggesting an overabundance of calcite respect to the real situation on Mars.
Decresing the content of calcite in the mixture (the 2% case) the contrast of the feature at 1500 cm^{-1} decreases too, but it is still stronger than in the BR spectrum.
The mixture containing the lowest amount (1%) of calcite seems to be the best fit. While

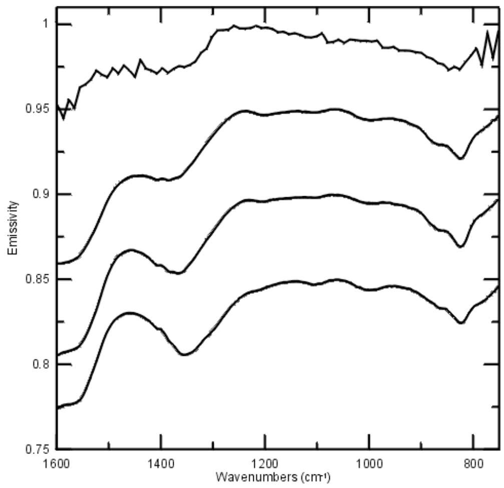

Fig. 5. TIR spectra of (from top to bottom): Martian high albedo surface, laboratory mixture with 1% of calcite, laboratory mixture with 2% of calcite, laboratory mixture with 5% of calcite (all the spectra are shifted from each other in emissivity for simplicity).

the region from 1200 to 800 cm^{-1} is well reproduced by all the different mixtures, the weak feature lasting from 1400 to 1550 cm^{-1} is well fitted only by this mixture. This indicate a very small abundance of carbonates in the Martian high albedo regions, not larger than 1% by areal fraction.

4. Conclusions

A quick comparison between the Martian BR laboratory spectra shows that the main mineral has to be labradorite (pertaining to plagioclase family) and that grains in these terrains should be of very small size (less than 20 μm).

Furthermore, by comparing mixtures of carbonates and labradorite, we found out that the abundance of carbonates that best fit the BR spectrum seems to be close to 1 %. A value lower than the one obtained by Bandfield (Bandfield et al. 2003).

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