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Mid-IR emissivity of hyperfine small bodies analogues

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Introduction

Small bodies of the Solar System are residues of the epoch of formation of the planetary system. The most primitive of these bodies are likely comets, that should provide the best recording of the chemical composition and mineralogy of the protoplanetary disk. P- and D-type asteroids present featureless reddish spectra similar to the comets nuclei ([10]; [8]) and are believed to be somehow related to comets. Mid-infrared spectroscopic observations have led to the suggestion that these objects are covered by a porous layer constituted of submicrometer-sized (hyperfine) grains ([2]; [11]).

Radiative transfer models have been used to retrieve composition from cometary dust emission as well as asteroid mid-IR spectra ([3]; [4]), but laboratory simulations on specific analogues that could also give indication regarding their compositionand their surface texture (porosity, roughness) are currently lacking. This study aims to explore the emission spectral features of hyperfine and hyperporous powders with decreasing grain size in order to compare laboratory simulations to observational data of the comet C/1995 Hale-Bopp and the D-type Trojan asteroid (624) Hektor.

Methods

Using a specific grinding and sieving protocol [9] we were able to produce large quantities of powder of different composition (olivine and smectite) at decreasing grain size. Grain size has been quantified using SEM imaging. The finest powders obtained have average grain size below one micron.

In order to explore the effect of porosity on emission spectra, we produced hyperporous surfaces (with a porosity larger than *99 %*) by sublimating under vacuum mixtures of water ice particles containing the mineral powders, following the protocol described in [7]. We also simulated porosity in our samples by mixing the mineral powders (*1 vol%*) with potassium bromide (KBr, *99 vol%*), which is non-absorbing in the Vis-IR.

The powders were brought to the DLR in Berlin to perform emissivity measurements at the PSL [5]. During the measurements, samples are heated from the bottom of the sample holder. Measurements at several temperatures were obtained. Emission spectra in the mid-infrared region were measured on the different samples.☐ Reflectance was measured after direct emissivity measurements to observe chemical/mineralogical changes during the heating process.

Results

Figure 1 presents normalized emissivity spectra between *8* and *13 µm* of the hyperfine powder of olivine, the hyperporous and hyperfine smectite powder, the KBr-diluted olivine powder, and observations of D-type asteroid Hektor and comet Hale-Bopp ([2]; [1]).

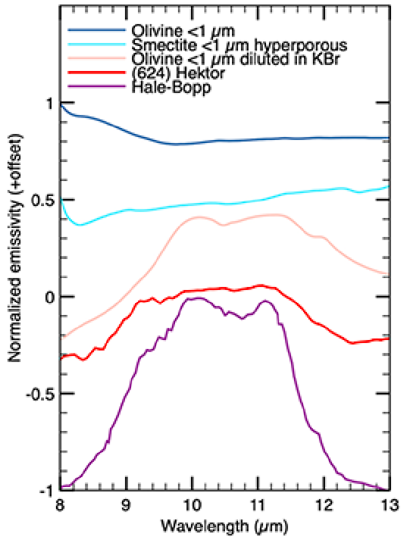

Figure 1: Normalized emissivity of hyperfine olivine grains, hyperfine and hyperporous smectite grains, KBr-diluted hyperfine olivine grains and observations of (624) Hektor and Hale-Bopp (*Emery et al. (2006)*; *Crovisier et al. (1997)*). The hyperfine olivine and the hyperfine and hyperporous smectite do not exhibit any feature in the region *9-12 µm*, but the KBr-diluted sample does present an emission peak similar to what has been observed on the two small bodies.

Both observations of Hektor and comet Hale-Bopp exhibit a notable emission feature in the region *9-12 µm*.□ Powder of submicroscopic olivine does not show the silicates emission features around *10 µm* as well as the hyperporous smectite sample. These two spectra are very flat on the whole spectral range studied here.□ The spectrum of the KBr-diluted powder however shows a strong feature around *10 µm*.

Discussion

Emissivity of D-type objects resembles to features observed for cometary dust tails ([2]; [10]). This may seem surprising at first since cometary dust tail may not be optical thick, while the surface of an asteroid is. The presence of such an emissivity feature has been interpreted by the presence of high-porosity, based on reflectance measurement of mixture of silicates with KBr.

In the present work, we produced a hyperporous and hyperfine grained sample to simulate the presence of porosity without using KBr, which showed that such sample is featureless and has an emissivity close to *1* (whether emissivity is directly measured or estimated by Kirchoff's law). This means that porosity solely cannot explain the presence of emissivity features of silicates on small bodies. Emissivity of samples with porosity simulated using KBr and with real porosity are therefore very different in our results. This could be explained by the fact that, while KBr is non-absorbing, its real optical index is higher than *1*. Using KBr will increase reflectance outside of where the silicate absorbs and therefore decrease emissivity, thereby producing the observed emission contrast. So alternative processes have to be proposed to explain the presence of emission feature.

A first one is that, somehow similar to KBr, a brightening constituent is present in the material of D-type asteroids. Potential candidates are salts, responsible for the *3.2 µm* signature on comet 67P/Churyumov-Gerasimenko and possibly on some asteroids including Trojans [6]. Another possibility that needs to be investigated is the presence of a temperature gradient. In our experiment the temperature at the top of the sample is lower than at the bottom, and there is no emissivity feature in the measured spectra. However, when observing the illuminated side of an object, the temperature gradient is in the other direction (the top surface is warmer). If only a few layers of hot surface grains are producing the emission signature, they may emit like an optically thin layer, similarly to cometary dust tails. The two possiblities will be investigated further.

Acknowledgements

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