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Effects of powdering rock and mineral samples on optical observations and Raman analyses: consequences for ExoMars measurements

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Abstract

Most of the ExoMars 2018 instruments will make analyses on powdered drill samples. Apart from loss of context textural information, the crushing process also leads to changes in the physical properties of materials. These modifications could limit correct interpretation of the data. Here, we study the effect of the grain size distribution on the Raman analysis using a laboratory system and the ExoMars RLS instrument.

1. Introduction

The payload of the ExoMars mission (ESA/Roscosmos) will comprise a Raman spectrometer as part of its instrument suite. Analyses with this instrument will be made on crushed samples. The crushing process will cause the loss of context in the mineral grain distribution and position within the samples and could also change the physical properties of the studied materials resulting in partial misinterpretation of the data. We therefore investigated the influence of granulometry on the Raman spectrum of various minerals and rocks using laboratory equipment (WITec Alpha500 RA, CBM, Orléans) and the RLS Raman instrument being developed for the Pasteur payload of the ExoMars mission (Unidad Asociada UVA-CSIC, Centro de Astrobiología, Spain), both equipped with a 532 nm green laser. The aim was to determine what influence the crushing process could have on the correct identification of rocks and minerals and the detection of possible traces of life [1].

2. Chosen materials

Different materials were chosen: silicon, quartz, graphite, charcoal, cherts and basalt. In order to facilitate the observation of the change induced by the crushing process, we made Raman mappings of powders with various grain sizes deposited close to each other on a glass slide (see Figure 1).

Silicon was chosen as a model because of its simple Raman spectrum (only one peak at 520.6 cm^{-1}). Potential microfossils dating back to the Noachian on Mars (-4.5 to -3.5 Ga) may have been silicified by hydrothermal fluids and could thus be very similar to the oldest traces of life found on Earth in cherts from Australia and South Africa (3.5 Ga old) [2, 3]. These cherts were thus studied as well as quartz, the main constituent of chert. Graphite was used since the spectrum of disordered graphite can mimic that of kerogen associated with ancient microbial remains [4] and compared to charcoal. Finally, basalt was chosen as a reference rock since it is the most common rock on Mars [5]. Moreover, this basalt from Etna volcano can be considered as a good geochemical analogue of basalt analysed by Spirit in the Gusev crater on Mars [6, 7].

3. Results

The crushing process leads to a strong increase in the background level and to a decrease in the signal/noise ratio. Moreover, for certain minerals, the Raman spectra can be significantly modified: the peaks are shifted and broadened and new peaks can appear as shown in Fig.1 in the case of silica. Since mineral identification using Raman spectroscopy is made by comparison with database spectra, this kind of change could lead to misinterpretation of the spectra and thus must be taken into account during the in situ investigation. Most of these effects are explained by the temperature increase and by surface effect that are most important for the smallest grain size [1].

The same samples were then analysed with ExoMars instrument simulator (RLS). It is shown that the

previously observed effects are relatively limited and most of the time not observed with the RLS instrument. This good result is explained by the lower irradiance and the differences in the resolution characteristics with respect to the laboratory-WITec instrument.

The second part of the study focused on crushed rocks. The loss of texture associated with the crushing process complicates identification of rocks with subsequent consequences for the eventual detection and interpretation of past traces of life. But, on the other hand, the mixing of the components in the powder appears to facilitate the detection of minor phases using the RLS instrument. This capability implies that, besides the loss of texture due to the crushing process, the RLS data products are useful to obtain geologically relevant information, especially when in combination with complementary techniques of the ExoMars rover [8].

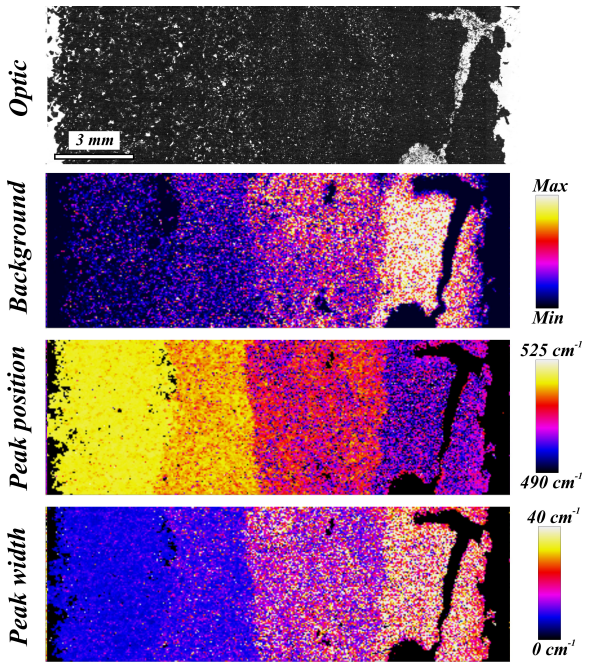

Figure 1: Silicon powders of decreasing grains size (from left to right). (a) Optical view and Raman mappings of 520 cm^{-1} peak width (b) and position (c) and (d) background level.

4. Summary and Conclusions

We have demonstrated that the crushing process induces several changes in the Raman measurement : an increase of the background level, a shift of the peaks and even changes in the crystallinity. However, the results obtained with the ExoMars instrument showed that, probably due to its irradiance and resolution characteristics, these effects are relatively limited with the RLS instrument and that the mixing of the components in the powder appears to facilitate the detection of minor phases.

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