

Depth Profiles Studies using ChemCam. A. Cousin¹, S. Maurice¹, G. Berger¹, O. Forni¹, O. Gasnault¹, R. Wiens² and the ChemCam team, ¹Institut de Recherche en Astrophysique et Planétologie, Toulouse (agnes.cousin@cesr.fr), ²Los Alamos National Laboratory, New Mexico.

Introduction: ChemCam is part of the Mars Science Laboratory (MSL) rover payload, scheduled for launch in December 2011. This instrument uses the Laser Induced Breakdown Spectroscopy (LIBS) technique to investigate the chemistry of the Martian surface [1,2]. ChemCam is composed of the Body Unit (located in the body of the rover), including the spectrometers and their electronics, and of the Mast Unit including the laser, the Remote Micro Imager (RMI), the telescope and their electronics.

ChemCam will be the first instrument using the LIBS technique for planetary studies. The first innovation of this instrument is to perform LIBS analyses at remote distances, from 1 to 7 meters. This technique has several advantages: first, it allows large time savings, which is very important for space missions. Secondly, it provides the first analysis of rocks at long distances, which is useful to decide where to move the rover in order to perform some contact analyses by other instruments. Another advantage of ChemCam, as shown by MER APXS data [3], is that it is important to remove the alteration coating on rocks before their analysis since it is not representative of the whole composition of the rock.

The objectives of this work are (1) to study the depth of holes performed with ChemCam in a basalt, (2) to check the capability of ChemCam to remove the alteration coating, understanding the spectral behaviour while profiling the target, and (3) to simulate a cemented dust to understand the spectral evolution between the different layers. Some measurements were performed at LANL prior to delivery at JPL with the Flight Model (FM) Mast Unit and Body Unit, whereas others were performed using the Engineering and Qualification Model (EQM) at CESR for the Mast Unit and commercial spectrometers for the Body Unit.

Samples: The samples analysed with the FM are sawed rock slabs of Grapevine Spring black calcite vein and of basalt, both provided by D. Vaniman. The samples used for the depth profiles performed with the EQM consist in a basalt with a well known composition, and a multi-layer sample of qualitatively known composition done by G. Berger.

Experimental Setups: Data from the FM were collected with the FM setup, contained in a thermal vacuum chamber (TVAC, -45°C, laser at -10°C, 7 Torr). The samples were placed in terrestrial atmosphere but at 7 torr, at a distance of 3 meters. Data from the EQM were collected with both the instrument and the samples at ambient temperature. Note that for the FM, the laser was at its optimal temperature and achieved ~14

mJ energy per pulse, while the EQM laser energy at room temperature was degraded, and increasingly so during long duration depth profiling as the instrument warmed further. See [5] for more details about the experimental setup with the EQM.

Data analysis : Each active spectrum is corrected by subtracting non-laser background, removing noise, and is calibrated for channel to wavelength. To understand the evolution of spectra with depth, some preferred emission lines are chosen: Mg 279.63 nm, Mg 280.35 nm, Mg 285.29 nm, Mg 288.24 nm, Ca 315.97 nm, Ca 318.02 nm, Al 308.31 nm, Al 209.36 nm, Ca 393.47 nm, Ca 396.955 nm, Ca 422.52 nm, Ca 445.6 nm, Al 394.52 nm, Al 396.27 nm, Ca 612.39 nm, Ca 616.31 nm, K 766.71 nm, K770.11 nm, O 777.63 nm.

Most of these lines are well detected in each spectra (i.e., the standards basalt and calcite used with the FM, and the basalt used with the EQM). For each shot, the observed lines are fitted by a Lorentzian function to obtain their intensity and their Full Width at Half Maximum (FWHM) [5]. The total noise is calculated as the standard deviation of all the spectra, which allows to calculate the Signal to Noise Ratio (SNR). All of the data are normalized using the intensity of the Oxygen line at 777.63 nm.

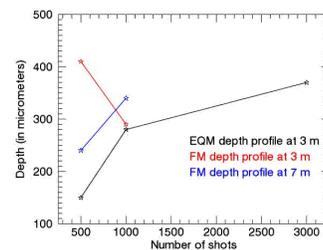


Figure 1 : Depth of holes versus number of shots.

Results : Depth penetration : The first objective was to measure the depth of holes performed by ChemCam in a basalt. This study was done using the two experimental setups. Using the FM, we shot first 500 times, and then 1000 times (after the target was moved), at 3 and 7 meters. Using the EQM, we shot only at 3 meters, first 500 times, then 1000 times, and then 3000 times, moving the target between each set of shots. Figure 1 shows the depth of these holes. With the EQM setup, the depth increases with the number of shots. Using the FM, at 3 m the hole made with 500 shots is deeper than the one done by 1000 shots. This can be explained by the fact that the basalt is not homogeneous, so it depends on where the 1000 shots were focused on the rock. A depth profile in calcite measured nearly 600µm in depth with the FM.

Alteration Coating : Because of the necessity to remove the alteration coating before analysis of pristine rock material, the second objective was to understand the evolution of the spectra with depth. In particular, it was necessary to check for peak broadening and weaker intensities due to self absorption, sometimes observed in passing through thick plasma characteristic of a deep hole. Using the FM, we performed 8 bursts of 125 shots at 3 Htz and 95 A. For each burst, the 5 first shots are ignored, and we use the mean of the 120 remaining shots. Targets were a basalt and a calcite. Using the EQM, we performed 83 bursts of 50 shots at 10 Htz and 95 A, on a basalt. Figure 2 shows the results from the FM. We can see that the FWHM (bottom) is constant, with a mean standard deviation of 0.001nm in UV, 0.002nm in VIS, 0.011nm in VNIR. The same results were obtained with the FM setup using a calcite standard. The results for EQM are similar, with a mean standard deviation of FWHM of 0.05nm in UV, 0.04nm in VIS, and 0.17nm in VNIR. Lines ratio were analysed for the FM data, and they are also constant, for the basalt and for the calcite. Mean standard deviation of the lines ratio is 0.036. The SNR (top) is relatively constant, and does not seem to be correlated with the laser energy (black dashed line). Contrary to these results with the FM setup, those from the EQM setup show that the SNR is strongly correlated to the laser energy, because of the temperature increasing during the tests.

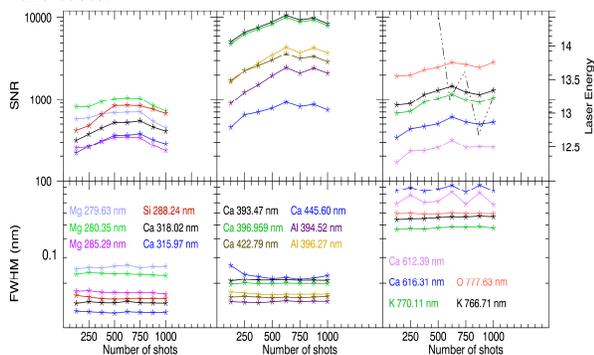


Figure 2 : Comparison of the SNR and FWHM of some lines, for study performed with the FM, on a basalt.

Cemented dust : Another objective was to analyse spectra from a cemented dust. To perform this, we created a multi-layer sample from cemented powders, by evaporation. Figure 3 shows the different three layers, which have a thickness slightly more than 1 mm. Using the EQM setup, 8 bursts of 10 shots at 1Htz and 100 A were performed for each spectrometer. We performed one more set of bursts in UV, using 5 shots at 1 Htz. The target was placed at 3 m, at ambient. We observed that the first two spectra are from the olivine layer. The

last two are from calcite, and the others spectra are from ilmenite.

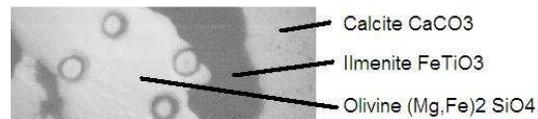


Figure 3: RMI (remote Micro Imager) image of the multi-layers sample at 3 m after shots. Holes diameter : ~3 mm

Figure 4 shows the spectra from the different layers. We can see that the olivine spectrum is Mg-rich (lines in blue), with almost no Fe and no Ca lines. The ilmenite spectrum shows a lot of Fe and Ti lines, as predicted by its composition. The calcite spectrum, the one from the deeper layer, is much more difficult to understand. Although all the lines from the ilmenite are still visible, those from the calcite (Ca lines) are much brighter (lines in red). This is due to contamination between the layers, either because of the intrasec multi-layer sample formation, or because of the interaction of material ablated with the surface, due to the poor density of this kind of target.

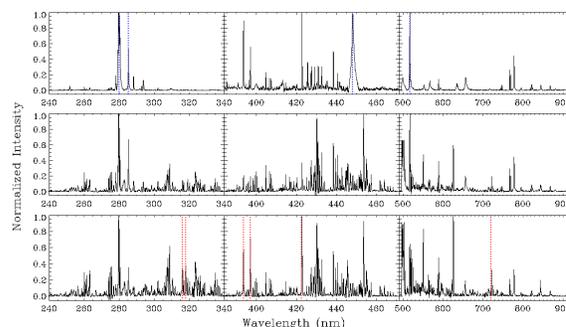


Figure 4 : Spectra from the multi-layer sample.

Test performed with the FM involving a thin dust layer of dolomite on a basalt show very well the transition of spectra from these two different layers. The FWHM for some lines observed in these two layers are constant for each layer, with a mean standard deviation of 0.003nm in UV, 0.003nm in VIS, and 0.005nm in VNIR.

Conclusions: Studies were performed to understand how LIBS spectra behave with depth. ChemCam, with its capability to ablate, will be able to analyse rocks after having removed the alteration coating. The SNR is not clearly dependent on the depth or laser energy. FWHM of lines are constant whatever the depth. Therefore, ChemCam will be able to analyze rock even after a long set of shots. ChemCam is also able to distinguish different layers of cemented dust.

References: [1] Wiens et al. (2005), *LPSC 36th*, #1580. [2] Maurice et al. (2005), *LPSC 36th*, #1735. [3] Rieder et al. (2004), *Science* 306, 1746-1749. [4] Wiens et al. (2010), *LPSC 41th*, #2205. [5] Cousin et al. (2010), *LPSC 41th*, #1983.