Single Scattering Albedo (SSA) Analysis via Fiber-Induced Raman Signal (FIRS) of Jezero Crater from Perseverance

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Introduction: The SuperCam instrument on the Mars2020 Perseverance rover performs visible/near-infrared, LIBS, and Raman spectroscopies [1]. It contains a mast unit (MU) and body unit (BU), with the MU containing a 1064 nm LIBS laser and a 532 nm excitation laser for Raman, as well as a telescope as part of the collection optics. Connecting the two units is a 5.78 m fiber optic cable (FOC) constructed of UV-grade fused silica [1]. The transmission spectrometer (TS) which contains the Raman spectrometer is in the BU and analyzes the light after it has been collected with the telescope and traveled through the FOC. A consistent feature seen in all spectra ranges from ~ 200 – 500 cm⁻¹ as seen in Figure 1. Those Raman features match those of pristine fused silica glass and stem from the captured light interacting with the fused silica inside the FOC’s core as it travels the length of the cable. The collection angle of the laser and telescope was 180° which removes the effect of the phase angle in the signal which occurs due to alignment differences between the light source and collection optics [2]. This study is exploratory in nature due to the Raman being used in an unintended way but looks to analyze the single-scattering albedo (SSA) of the targets to make semi-quantitative determinations on the compositions of the target through comparison to the target grain sizes.

Experimental: To perform the SSA analysis Raman targets from Sol 0 to ~ 800 were used which had accumulation times of 0.9s. For these targets the band area from ~ 170 – 600 cm⁻¹ was integrated using GramsAI software. Grain sizes were determined via the use of the remote micro-imager (RMI) (effective resolution ~ 160 μm for targets at 2 m distance) located in the MU and confirmed by independent analyses from Perseverance rover studies [3, 4]. The reflectance (R) was estimated by determining the # of photons hitting the target within the field of view of the spectrometer (I₀), which was used to divide the # photons calculated from the FIRS band area (I). SSA was estimated via Hapke model that correlates R and SSA using python (pyhapke package from github) and MatLab code under the assumption we are working with reflectance factor [5, 6] Similarly, the VIS data was used to calculate the SSA at 430, 535, and 670 nm. The viewing geometry was extracted from the .fits files which correspond to each VIS measurement.

Figure 1: Averaged ICA Raman spectrum of the FOC feature from all Mars targets up to Sol 400 (top) and the Raman spectrum of a fiber identical to the one used on SuperCam acquired in the lab (bottom). Red rectangles highlight the main FIRS features.

Results & Discussion: Examination of integrated intensity of the band area with respect to the VIS reflectance values showed a correlation between the two types of measurements pointing to the FIRS intensity representing the reflectance of the target in question. As such retrieving the R values by computing I/I₀ represents the target reflectance and as explained previously, the 180° scattering angle removes the effect of the phase angle simplifying SSA calculations. These values can be used in tandem with grain sizes to determine whether variation in SSA stems from the grain size of target or the composition of the target. Additionally, these computed values can be used in tandem with VIS and LIBS data over the same range as
the feature (from ~532 – 549.5 nm) to help confirm the optical constants of the targets in question using the Kramer-König relation [7].

The FIRS SSA can be seen in Figure 2, above, plotted against the computed grain sizes. The points which fall outside the upper and lower bounds are attributed to being dependent on composition and not due to differences in grain size. These targets which fall outside these bounds originate mainly from Hogwallow Flats and Seithah followed by Maaz and Enchanted Lake. When compared to LIBS data the outliers with a higher SSA correspond with higher SiO2, FeO, and Na2O while also corresponding with lower CaO, K2O, and Al2O3. In terms of the Mg# Fe# and pyroxene (Px) Fe# Mg#, the higher the Fe# the higher the SSA. This points to the surfaces that contain higher Fe content having higher SSA, which matches with general trends seen in refractive indices for both olivine and pyroxene minerals.

When comparing SSA based on geological units/sections those from Seithah and Maaz exhibit the higher SSA to others followed by those of the Tenby (Curvilinear Unit). This is due to the difference in the mineralogy of the Maaz and Seithah being richer in low-Ca Px and olivine [8]. Tenby tends to follow Seithah in LIBS composition. This is compared to those of Hogwallow Flats and other delta/fan units which contain anhydrites, phyllosilicates, and carbonates, which are characterized by lower refractive indices. [9]

Conclusions: The FIRS band areas contain information on the albedo of the targets analyzed, which in conjunction with known laser power allow for reflectance measurements to be calculated. Using the Hapke model this reflectance has been converted to SSA which along with grain sizes allow for conclusions to be made on target compositions. After filtering for grain size, the data shows that higher SSAs correspond to higher FeO, SiO2, and Na2O values from LIBS data. These tend to match up with the difference in the mineralogy between the different geological units/sections and the expected ranges of refractive indices.