

Characterization of Fluorescence Signals in Synthetic Anorthite. E. Z. Tucker¹, M. N. Abedin¹, R. A. Wincheski¹, T. F. Refaat¹, D. L. Rickman², and S. A. Wilson³, ¹NASA Langley Research Center, Hampton, Virginia 23681, USA, E-mail: [E-mail: Eric.Z.Tucker@nasa.gov](mailto:Eric.Z.Tucker@nasa.gov), ²Jacobs, Jacobs Space Exploration Group/NASA Marshall Space Flight Center, Huntsville, AL, 35812, USA, ³U.S. Geological Survey (ret.).

Introduction: In-situ resource utilization (ISRU) is a key capability to enable a long-term presence on the Moon and other planetary bodies [1]. For example, efforts have been underway to develop processes to utilize the lunar regolith to produce building materials and extract useful resources [1]–[3]. In processes that utilize the regolith directly to produce construction materials, such as in various sintering methods, characterizing the composition of the regolith is important as the composition can affect the optimal process parameters [4]. In processes that involve extracting resources such as iron, oxygen, hydrogen, etc., identifying areas with higher abundance of a particular resource will be critical since different regions of the Moon exhibit differing regolith composition [3]. To this end, Raman spectroscopy is one technique that can rapidly characterize the mineralogy of rock samples. This technique has already been deployed on Mars to detect various minerals including olivine, carbonates, phosphates, etc. [5]–[9]. Besides characterizing the mineralogy, Raman spectra often contain fluorescence signals that can mask Raman peaks. In some cases, the fluorescence signals are narrow enough to aid in the identification of specific elements in soils [10]–[12]. In this work, we analyze a synthetic anorthite sample, one of the most abundant minerals on the Moon [3], which was found to exhibit distinctive fluorescence peaks. These fluorescence peaks, as well as similar distinctive fluorescence peaks attributed to rare earth elements and transition metals, could have important implications for lunar ISRU efforts and the mining of critical resources as has been previously described [13].

Experimental Methodology: A ruby and synthetic anorthite sample were measured with two different Raman systems using the same 532 nm excitation wavelength: (a) a confocal microscope-based commercial benchtop system, the RamanRxn1 microprobe from Kaiser Optical Systems Inc, using a continuous wave laser source and (b) the Standoff Ultracompact Micro-Raman (SUCR) sensor using a pulsed laser source. The SUCR instrument has been described in previous work [14].

Results and Discussion: First, shown in Figs. 1a and 1b are Raman/fluorescence spectra results for the ruby and synthetic anorthite samples collected at a single measurement location using the confocal microscope-based Raman system utilizing a 10x objective with spot size of approximately 50 μm in diameter. Both spectra are plotted in wavelength while insets in

both figures show the low frequency region from these spectra in wavenumbers.

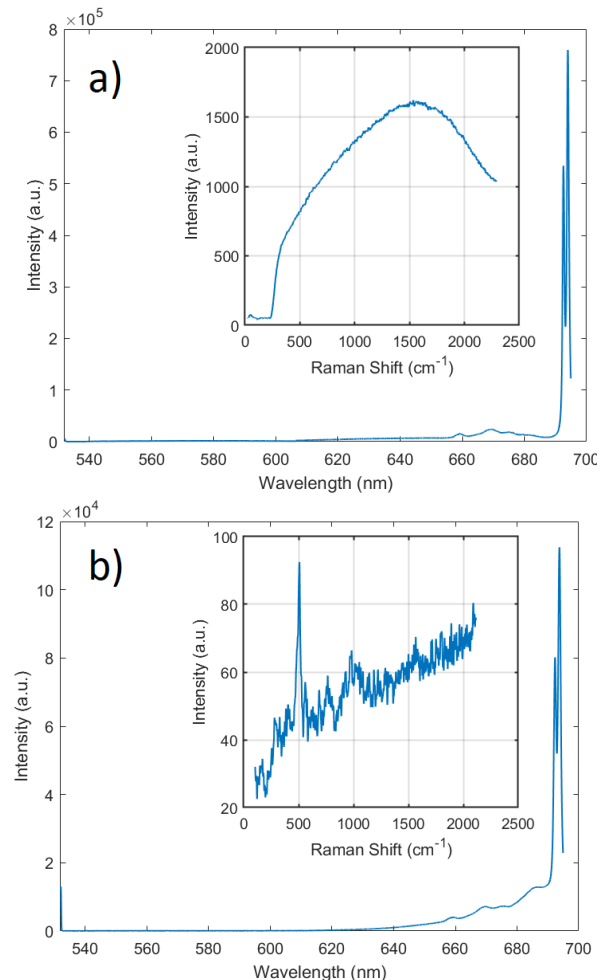


Fig. 1. Raman/fluorescence spectra of (a) ruby and (b) synthetic anorthite as a function of wavelength using a continuous wave 532 nm laser. Insets show the low frequency regions of both spectra as a function of Raman shift in wavenumbers.

The expected low frequency Raman peaks are not observable from the ruby sample due to long-range fluorescence background, as shown in the inset of Fig. 1a, but expected Raman peaks attributed to anorthite from the synthetic anorthite sample can be seen in the inset in Fig 1b. Meanwhile, doublet peaks are observed at the same wavelength positions between 690-700 nm in both spectra. The distinct fluorescence peaks between 690-700 nm for the ruby sample (Fig. 1a) are well known to be from chromium impurity as has been reported elsewhere [14]. Likewise, the doublet peaks shown in Fig. 1b observed from the synthet-

ic anorthite sample are in the same position and, thus, attributed to chromium too. Since chromium is not able to substitute into plagioclase feldspars, it is likely from the presence of another unintended mineral phase [12].

The inset of Fig. 2 shows an optical microscope image of an area of the synthetic anorthite sample, which was measured with the same confocal microscope-based system where annotations in the image show the different measurement locations. A 100x objective was employed, which projects an approximate 5 μm beam spot size onto the sample. Fig. 2 shows eight of those points measured as annotated in the image. The intensity variation of the fluorescence features point-by-point across the sample illustrates that the source of the fluorescence is not uniformly distributed and provides further evidence that the fluorescence is not from the synthetic anorthite, but an unintended mineral phase.

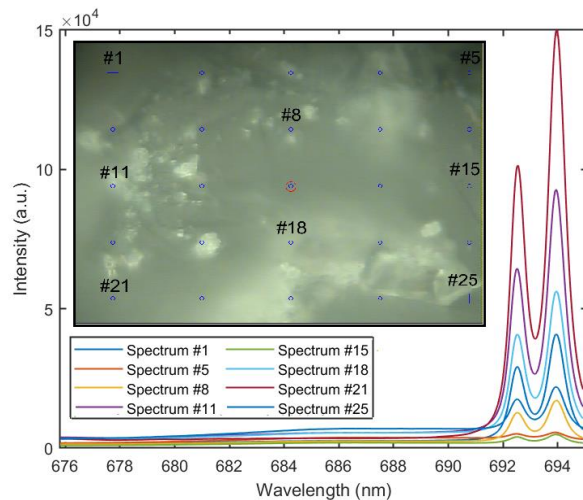


Fig. 2. Graph of Raman/fluorescence spectra from eight measurement locations on the synthetic anorthite sample using the confocal microscope-based benchtop system utilizing a 532 nm excitation source. Inset is an optical image of the sample showing the eight corresponding measurements locations among a total of 25 that were measured. Here, blue markers show positions of all the points measured.

Next, shown in Fig 3 is a series of spectra taken from one measurement location on the synthetic anorthite sample using the SUCR instrument. Each spectra is captured with the same gate delay of 500 μs , but with different gate widths. This result shows the sensitivity of the intensity of these features versus gate width. Here, the fluorescence intensity continues to increase up to a gate width of 450 ns, which is consistent with the lifetime of fluorescence from transition metals rather than organics or biogenic compounds that generally have much shorter fluorescence lifetimes [15].

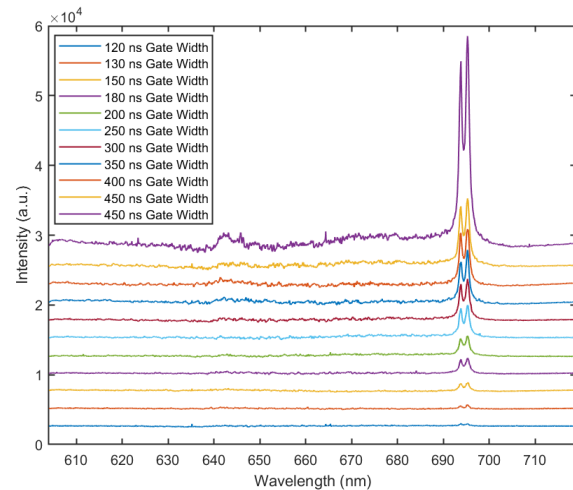


Fig. 3. Time gated Raman/fluorescence spectra of the synthetic anorthite sample collected using the SUCR sensor, which utilized a pulsed 532 nm laser at a sample distance of approximately 10 cm. A fixed gate delay of 500 μs was used, but different gate widths. Here, a long-range background subtraction method is applied and spectra were artificially offset from each other along the y-axis.

Conclusion: The steady-state and time-resolved Raman/fluorescence measurements of synthetic anorthite show fluorescence peaks, which we attribute to chromium impurity based on the similarity to fluorescence from a ruby sample. Chromium is not expected to be able to substitute into anorthite due to a lack of octahedral sites, so work is ongoing to identify the actual source of this fluorescence in the synthetic anorthite and will be presented [12].

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