

**FTIR AND RAMAN SPECTROSCOPY OF THE LUNAR PICRITIC GLASSES.** D. T. Wetzel<sup>1</sup>, S. D. Jacobson<sup>2</sup>, S.-M. Thomas<sup>3</sup>, E. H. Hauri<sup>4</sup>, M. J. Rutherford<sup>1</sup>, and A. E. Saal<sup>1</sup>, <sup>1</sup>Dept. of Geological Sciences, Brown University, Providence RI 02912 (Diane\_Wetzel@brown.edu), <sup>2</sup>Dept. of Earth and Planetary Sciences, Northwestern University, Evanston, IL 60208 (steven@earth.northwestern.edu), <sup>3</sup>Dept. of Geoscience, University of Nevada Las Vegas, Las Vegas, NV 89154 (sylvia-monique.thomas@unlv.edu), <sup>4</sup>DTM Carnegie Institute of Washington, DC 20015 (hauri@DTM.ciw.edu).

**Introduction:** The Moon had long been considered dry, until recently, when Saal et al. [1] used SIMS to measure water dissolved in the lunar picritic glasses. Before this discovery, carbon was considered the primary volatile dissolved in the picritic magmas. The formation of a CO-rich gas phase was thought to drive fire fountain eruptions on the Moon producing the lunar glass beads [2]. Fogel and Rutherford [3] used FTIR to study natural lunar glasses in order to test this theory, but they were unable to detect any dissolved carbon. A more recent study [4] used synthetic orange lunar glasses, but they were also unable to detect dissolved carbon using Raman and FTIR spectroscopy. The SIMS measurements [1] suggest that hydrogen is dissolved in large enough quantities (up to ~40 ppm) to be detectable by FTIR spectroscopy. We used Raman and FTIR spectroscopy to study the speciation of hydrogen in the natural orange, yellow, and green lunar glasses. We also report linear absorption coefficients,  $\epsilon$ , for each glass composition based on experimental samples. The synthetic sample spectra were also used as a guide to baseline correct and locate the weak O-H stretching peak in the natural samples.

**Experimental and analytical methods:** We used two A17 orange (sample 74220), two A15 yellow-brown (sample 15427), and two A15 green (sample 15427) glass beads in our FTIR, Raman, and SIMS analyses. These beads were doubly polished in order to collect FTIR and Raman spectra at Northwestern University. Prior to FTIR, the samples were washed with acetone and methanol and dried in a vacuum oven at 100°C for four hours. The samples were then mounted in indium and measured for water content using the NanoSIMS at DTM. A series of experiments were conducted following the methods of Wetzel et al. [5] in order to synthesize orange, yellow, and green picritic glasses to compare with the natural samples. We measured these experimental glasses for major elements and volatiles using SIMS, EMP, FTIR, and Raman.

**Results and Discussion:** FTIR and Raman spectra of the natural and synthetic lunar samples are compared in Figs. 1 and 2. Each glass type has unique FTIR and Raman spectra due to compositional differences, mainly seen in the 1000 cm<sup>-1</sup> region for the Si-O vibrations (Fig. 2). The similarity between spectra of

synthetic and natural glasses demonstrates that our synthetic samples can be used as a guide to interpret analyses of the natural ones.

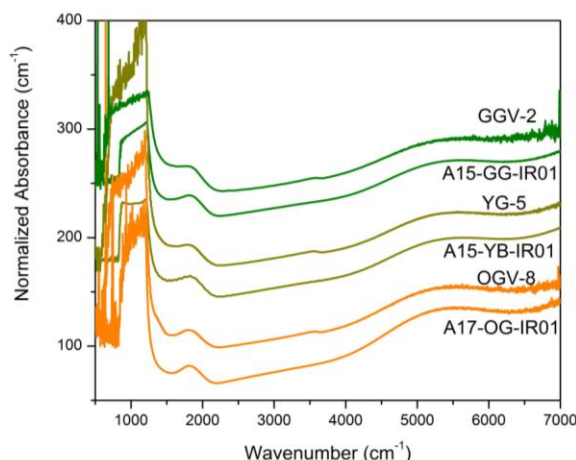


Fig. 1. Unpolarized FTIR spectra of natural and synthetic lunar glass compositions. The natural sample spectra (A17-OG-IR01, A15-YB-IR01, and A15-GG-IR01) are compared with the synthetic orange, yellow, and green compositions (OGV-8, YG-5, and GGV-2, respectively). The spectra are the same except the synthetic samples have higher water contents, which can be seen in the different peak intensity at 3550 cm<sup>-1</sup>.

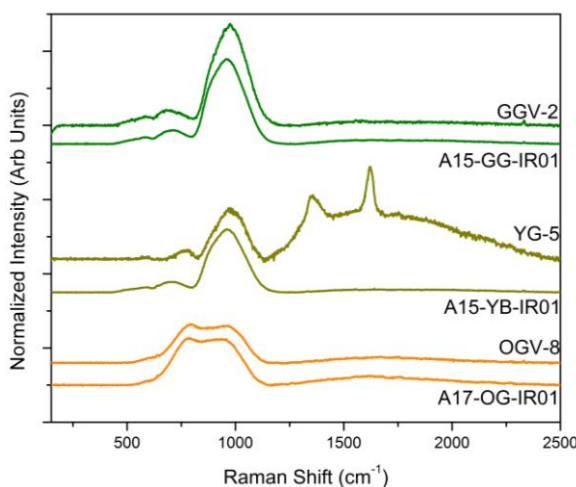


Fig. 2. Raman spectra of natural and synthetic lunar glass compositions. The natural sample spectra (A17-OG-IR01, A15-YB-IR01, and A15-GG-IR01)

are compared with synthetic orange, yellow, and green compositions shown in Fig. 1. The spectra are similar except the synthetic YG-5 sample has disordered carbon peaks at 1300 and 1600  $\text{cm}^{-1}$  due to undissolved carbon in the synthetic glass.

With the three synthetic compositions, we can use glasses with variable water and carbon contents measured by SIMS and the corrected FTIR peak heights to determine linear absorption coefficients for each lunar glass composition. The total water peak has a  $\epsilon_{3550}$  of 50  $\text{L/mol}\cdot\text{cm}$  for the green glass composition. The carbonate peaks have a  $\epsilon_{1430}$  of 234  $\text{L/mol}\cdot\text{cm}$  and a  $\epsilon_{1520}$  of 243  $\text{L/mol}\cdot\text{cm}$  for the green glass composition. As a comparison, terrestrial tholeiitic basalts have a  $\epsilon_{3550}$  of 63  $\text{L/mol}\cdot\text{cm}$  and a  $\epsilon_{1430}$  and  $\epsilon_{1520}$  of 375  $\text{L/mol}\cdot\text{cm}$  [6]. The absorption coefficients for the orange and yellow glasses will be determined as well and presented at LPSC.

Using these absorption coefficients and the synthetic glass water peaks as a guide for baseline corrections, we are able to resolve a 3550  $\text{cm}^{-1}$  total water peak (dissolved OH and molecular  $\text{H}_2\text{O}$ ) for the natural samples (Fig. 3) and compare the water content determined by FTIR and SIMS. We used the same baseline and wavenumber region as for the synthetic glasses to correct the natural sample spectra in order to quantify the 3550  $\text{cm}^{-1}$  peak height and calculate the amount of dissolved water. Using this method we are able to compare this water content with the SIMS measurements to see if they are within error of each other. We also noted that the asymmetric total water peak occurs at  $\sim 3550 \text{ cm}^{-1}$  for the synthetic samples containing hundreds of ppm water, whereas the peak is shifted to a lower wavenumber in the natural samples (Fig. 3).

**Conclusions:** This is the first time full FTIR and Raman spectra are reported for the three natural lunar glass compositions on the same samples that were also analyzed by SIMS. With these spectra, we demonstrated the 3550  $\text{cm}^{-1}$  peak is measurable. We can also calculate the amount of dissolved water using FTIR with the absorption coefficients determined from experiments.

**References:** [1] Saal A.E. et al. (2008) *Nature*, 454, p.192-95. [2] Sato M. (1976) *PLSC 7th*, p.1323-25. Fogel R.F. and Rutherford M.J. (1995) *GCA*, 59, 201-15. [4] Nicholis M.G. and Rutherford M.J. (2009) *GCA*, 73, 5905-17. [5] Wetzel D.T. et al. (2012) *LPSC XLIII*, Abstract #1535. [6] Dixon et al. (1995) *J. Petrol.*, 36, 1607-1631.

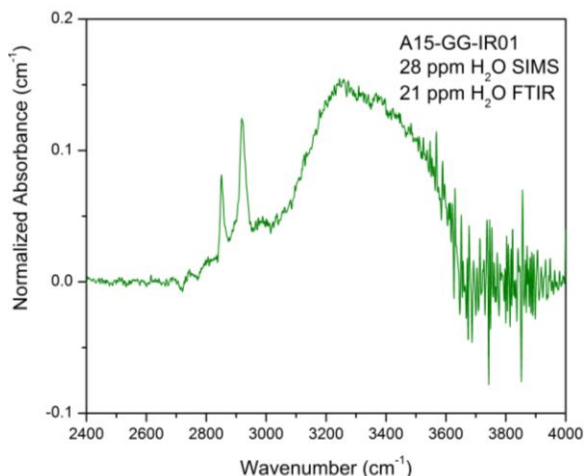


Fig. 3. Unpolarized FTIR spectrum of the natural green glass sample (A15-GG-IR01) showing the total water peak at  $\sim 3550 \text{ cm}^{-1}$ . After using a linear baseline and correcting from 2700 to 3700  $\text{cm}^{-1}$ , a water peak is detectable from the background. Using the absorption coefficients from the experiments,  $\text{H}_2\text{O}$  contents are calculated and compared to SIMS measurements. Peaks at 2850 and 2920  $\text{cm}^{-1}$  are due to C-H surface contamination.