

**RETRIEVING OPTICAL CONSTANTS OF GLASSES WITH VARIABLE IRON ABUNDANCE.** C. Carli<sup>1</sup>, T. Roush<sup>2</sup> and F. Capaccioni<sup>1</sup>, <sup>1</sup>IAPS-INAF (Via Fosso del Cavaliere, 100, 00133 Rome, Italy; christian.carli@iaps.inaf.it), <sup>2</sup>NASA Ames Research Center, Moffett Field, CA, USA 94035-1000.

**Introduction:** Visible and Near Infrared (VNIR, ~0.4-2.5  $\mu\text{m}$ ) spectroscopy is an important tool to explore the surface composition of objects in our Solar System. Using this technique different minerals have been recognized on the surfaces of solar system bodies. One of the principal products of extrusive volcanism and impact cratering is a glassy component, that can be abundant and thus significantly influence the spectral signature of the region investigated. Different types of glasses have been proposed and identified on the lunar surface and in star forming regions near young stellar objects [e.g. 1,2]. Moreover, previous research has shown that different FeO/TiO<sub>2</sub> ratio and/or change in oxygen fugacity can affect the spectral information of those glasses at VNIR wavelengths [3,4]. Here we report an initial effort of retrieving the optical constants of volcanic glasses formed in oxidizing terrestrial-like conditions. We also investigated how those calculation are affected by the grain size distribution.

**Analytical approach:**

*Sample preparation and compositions.* Four terrestrial igneous rocks have been considered: an anorthosite (sample A, FeO<sub>tot</sub>=1.82%), two different gabbro-norites (sample B, FeO<sub>tot</sub>=4.5%, sample C, FeO<sub>tot</sub>=7.1%), and an olivine basalt (sample D, FeO<sub>tot</sub>=11.3%). Their corresponding glasses were produced by melting at 1500°C for one hour in terrestrial oxidizing conditions. Different grain sizes were produced via grinding and sieving of the glasses to nine different sizes (20-50, 50-75, 75-100, 100-125, 125-150, 150-180, 180-200, 200-224, and 224-250  $\mu\text{m}$ ) all with ~25  $\mu\text{m}$  dispersion within the sieve fraction.

The reflectance spectra of all the grain sizes were measured in the VNIR (0.35-2.50  $\mu\text{m}$ ) with an incidence angle of 30°, and an emission angle of 0° with a ASD Fieldspec spectrophotometer at the Institute of Space Astrophysics and Planetology, INAF, under standard laboratory conditions. The real part of the refractive index was measured calculating the Brewster angles and assuming that the imaginary index is ~ five order of magnitude smaller in the VNIR.

Additionally, original bulk rock and glass compositions were characterized with XRF of major elements, and Fe oxidation state was investigated with Mossbauer spectroscopy. These data will be used to relate mineralogical and chemical information with the spectral parameters.

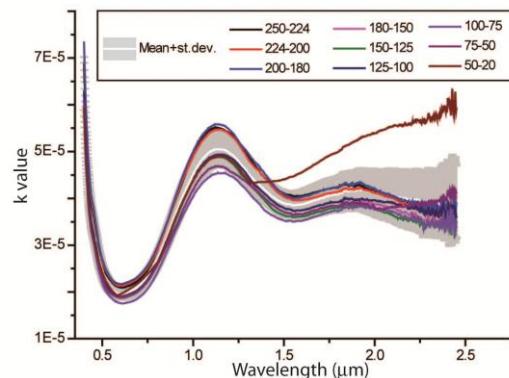
*Computational tools and assumptions.* The basic approach to retrieving the optical constants was to use multiple grain sizes of the same sample and assume all grain sizes compositionally equivalent. Unless inde-

pendently known as a function of wavelength, an additional assumption must be made regarding the real index of refraction, n. As described above, n is determined for the glasses and an initial assumption is that it is constant for all wavelengths.

The Hapke model [5,6] of the interaction of light with particulate surfaces was used to determine the imaginary index, k, at each wavelength by iteratively calculating the reflectance and comparing the result to the measured reflectance using a  $\chi^2$ -criterion. The interested reader is referred to [7] for more details regarding the exact equations and assumptions used in the Hapke model. The median grain size for each particle size separate was adopted for initially estimating k. Then, iterating the Hapke analysis results with a subtractive Kramers-Konig analysis we were able to determine the wavelength dependence of n [8,9].

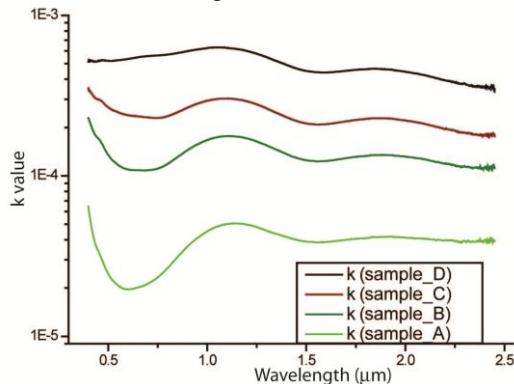
For each composition we used the k-values estimated for all the grain sizes to calculate a mean k-value representing that composition. These values were then used to fit the original spectra by only varying the grain sizes.

**Results and Discussion:** The calculated effective k's (e.g. Fig. 1) are quite uniform, all lying within one sigma of the mean with the exception the smallest grain size (20-50  $\mu\text{m}$ ). This variation is higher for the two extreme compositions. At longer wavelengths higher variability of k is seen for the iron-poor sample, whereas for the iron-rich sample k has a higher variability at wavelengths lower than 1  $\mu\text{m}$ . In all cases the highest deviation from the average is associated with the smallest grain size. Fig. 1 illustrates the results for the iron-poor glass. In this work we have considered two different average values, including (ave, shown in Fig. 2) and excluding (ave2, not shown) the 20-50  $\mu\text{m}$  grain size, and their standard deviations to illustrate how they can affect the recalculations of the spectra for the different grain sizes.



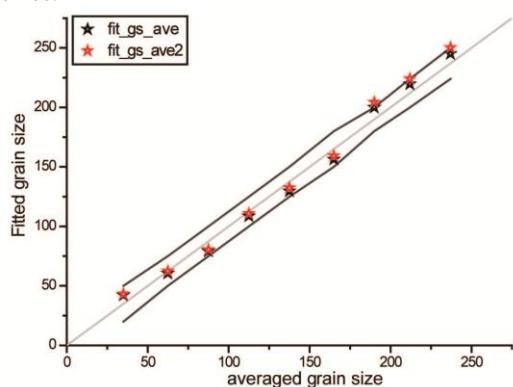
**Figure 1** - Imaginary index calculated for all the grain sizes produced for sample A. Also reported are the average k value (white line) and the standard deviation (grey area).

At this preliminary stage we decided to consider the average of all the grain size as the most representative for each sample. Fig. 2 shows the four average k-values for the different glasses.



**Figure 2** - Average k-values for all glass compositions (ave). All the grain sizes were used to calculate these mean values.

We used these k-values, and their standard deviations, and the measured n to calculate the best fit grain size for each measured spectra of the four samples. Fig. 3 shows that the results for the the iron-poor sample using both ave and ave2 are not significantly different. In general, a similar trend is seen for all the samples with a fit grain size within the sieve limits and an overestimation of the grain size with respect to the mean value for the larger and smaller grain sizes and an slight underestimation for the intermediate grain sizes.



**Figure 3** – Fitted grain sizes of sample A, using the two average k-values described in the text (description of fig.1) vs. the mean grain size value, based upon the sieve sizes. The black lines show the sieve size limits, and for comparison, the gray line illustrates a 1:1 correspondence.

**Preliminary conclusions and future work:** With some further refinements the optical constants of these

glasses will be available to model remote sensing observations of solar system surfaces. We found the mean k-values are quite close if calculated with or without the 20-50  $\mu\text{m}$  grain size for each composition. In contrast, the standard deviations are significantly higher when the smallest grain size is included, particularly for the extreme iron compositions.

We have evaluated how well the retrieved mean k-values can be used to estimate actual grain sizes by fitting the measured spectra. We have found that the fitted grain sizes are always very close to the nominal mean grain size values within the uncertainties of the sieving procedure. In the future we will consider mixtures of different grain sizes within the same compositional domain to improve our capability in considering the impact on the retrieving of optical constants for wider grain size ranges. Additionally, we will include similar glass compositions that are formed in less oxidizing conditions that may be more relevant to atmosphereless surfaces of Solar Sytem bodies.

#### References:

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