INFRARED REFLECTANCE SPECTRA OF PLAGIOCLASE FELDSPARS

Douglas B. Nash, San Juan Institute, San Juan Capistrano, CA 92675
John W. Salisbury, Johns Hopkins University, Baltimore, MD 21218

This study addresses mid-infrared reflectance properties of plagioclase feldspars in powdered form for both crystalline and glass phases. It covers the solid-solution series from sodium end-member albite to calcium end-member anorthite. Spectra were measured in the laboratory using the diffuse (biconical) reflectance mode. The study goal is to understand and decipher emission spectra of silicate rocks and their fragmental regolith or soil equivalents in the thermal IR range (generally 5 to 15 μm). The intended application is to identify and map rock and soil composition on surfaces of terrestrial planetary bodies such as the Moon, Mars, and asteroids.

Spectra presented here were obtained using an interferometer (FTIR) spectrometer covering the mid-IR (2.5-25 μm) at a resolution of 4 cm^{-1} [1]. Spectra are obtained by ratioing the sample reflectance to that of a reference standard, gold-coated sandpaper [1]. Samples of plagioclase (Table 1) were prepared by crushing to a particle size <50 μm. The powdered material was very lightly packed in 3-mm-deep sample cups and their top surface placed at the focal plane of the spectrometer. Aliquots of powdered crystalline plagioclase were quick-fused (1 min.) in a resistance strip furnace using a molybdenum-foil crucible in a nitrogen gas atmosphere [2]. Beads of the air-quenched glass were likewise powdered and their spectra determined with the FTIR.

Figure 1 shows the biconical reflectance spectra for the series of plagioclase crystalline samples (top panel) and glass samples (bottom panel). The baseline of each spectrum except the bottom one in each panel is offset 5% vertically for clarity. The spectra are characterized by the following features in the 5 to 15 μm range:

1. Steep fall off in reflectance from 5 to 7.5-8.0 μm due to gradually increasing resonant absorption owing to many molecular vibration (stretch) modes of the Si-0 and A1-0 bonds in silicate materials.

2. Distinct minimum in reflectance near 7.7 to 8.1 μm; the wavelength of this minimum is clearly related to plagioclase composition, shifting systematically from 7.69 μm for albite to 8.03 μm for anorthite. This reflectance minimum (emission maximum) is identified as the Christiansen Frequency (CF), which in spectra of silicate powders has been shown to have important diagnostic implications for remote sensing identification purposes [3], [4], [5], [6]. The results presented here document that the wavelength position of the CF in reflectance is compositionally dependent and can be used to identify plagioclase in terms of its Na or Ca concentration, as suggested by the pioneering work of Conel [3], [4], with transmission spectra of silicate powder films.

3. Structure consisting of a broad reflectance plateau from 8.3 to 12.0 μm; this includes a persistent band gap at 9.2 μm separating stretching vibration bands (reflectance peaks) at 8.7, 9.1, 9.7, and 10 μm in the albite spectrum; the intensity and contrast in these features are clearly related to plagioclase composition and are much more pronounced for the crystalline than for the glass phase. This structure seems to be related to a systematic variation in the relative strength of Restrahlen bands and the so-called transparency peak, which result from variation in strength of several fundamental molecular vibrations (asymmetric stretch modes involving Si-0 and A1-0 bonds) in the silicate lattice [6].

The band structure in the 8.3-12 μm plateau region, shown here most clearly in the case of albite, has been the subject of much research going back many years, and the changes in band position and intensity with Si-Al ordering and Na/Ca ratio are well documented; e.g., Lyon [7] showed from transmission spectra that the double peak in albite at 9.7-10 μm becomes a single peak and shifts to near 10.6 μm in going to anorthite. However, we now know that a highly porous and finely particulate regolith like that on the Moon minimizes the diagnostic importance of these band features and it is for this reason that the Christiansen Frequency has been studied as an alternative key to composition.

IR REFLECTANCE SPECTRA OF PLAGIOCLASE: Nash, D.B. and Salisbury, J.W.

In conclusion, these lab results show for the first time in reflectance spectra of powdered plagioclase feldspars that (1) the wavelength position of the Christiansen Frequency migrates systematically with composition ranging from albite to anorthite, and (2) there is no loss of compositional information in the Christiansen Frequency by a change in phase from crystalline to glass, which might be the expected result of hypervelocity impact. Thus, the composition of regoliths with a variety of developmental histories can be examined using mid-IR spectroscopy.

References: [1] Nash, D.B. Appl. Optics 25, 2427-2433, 1986. [2] Nash, D.B. In Advances in X-ray Analysis 7, edited by W. Mueller, Plenum press, 1964. [3] Conel, J.E. J. Geophys. Res. 74, 1614-1634, 1969. [4] Conel, J.E. JPL Space Program Summary 37-63, Vol. III, 7-9, 1970. [5] Logan, L., G. Hunt, J. Salisbury, and S. Balsano. J. Geophys. Res. 78, 4983-5003, 1973. [6] Salisbury, J. and L. Walter. J. Geophys. Res. 94, 9192-9202, 1989. [7] Lyon, R.J.P. Stanford Research Institute Report, Project No. PSU-3942, 139 pp., September, 1962.
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Table 1. Sample characterization:

		(1)	SiO_2 (2)	Reflect. min.(3) cm^{-1}	μm
Albite	Amelia County, Virginia	An 2.5	68.6	1301	7.69
Oligoclase	Bancroft, Ontario	An 12.5	62.0	1298	7.70
Oligoclase	Mitchell County, N.C.	An 24.5	59.5	1289	7.76
Labradorite	San Gabriel Mts., Calif.	An 52.4	54.2	1272	7.86
Labradorite	Nain, Labrador	An 64.5	51.2	1266	7.90
Bytownite	Crystal Bay, Minn.	An 80.5	47.3	1258	7.95
Anorthite	Grass Valley, Calif.	An 98.5	42.3	1245	8.03

(1) Molecular % anorthite; from glass-bead refractive index determination technique.
(2) Weight % SiO_2; from wet chemical analysis by A.G. Loomis.
(3) Wavelength of reflectance minimum (emission max) for powder in air at 25 °C.

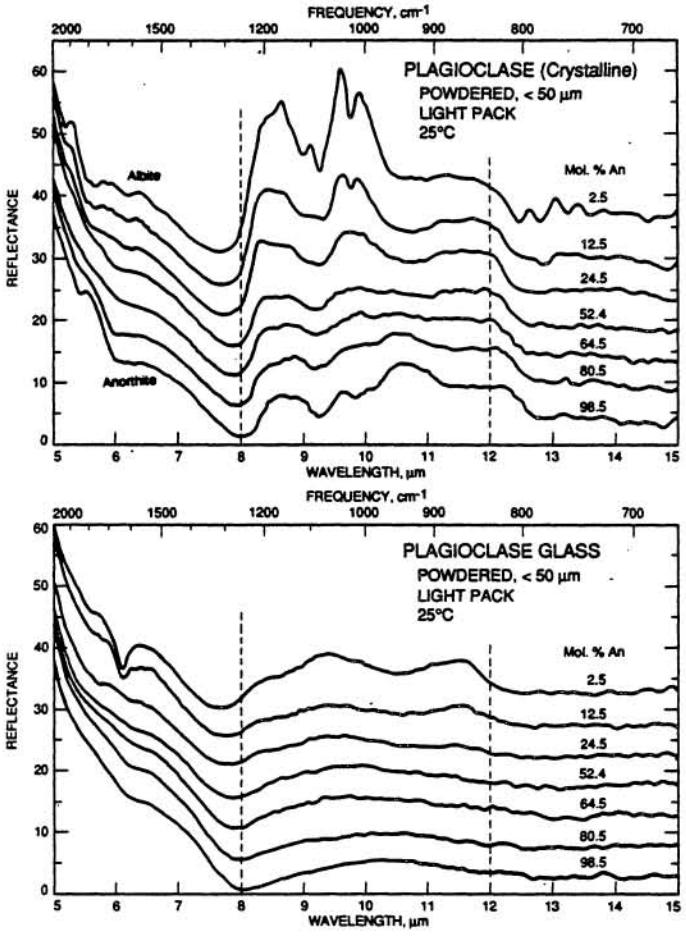

Figure 1. Reflectance spectra of powdered plagioclase (crystalline in top panel, glass in bottom panel), relative to gold-coated sandpaper. Except for bottom spectrum in each panel, baseline for each spectrum is offset vertically 5 % from its neighbor for clarity. Vertical dashed lines are for arbitrary reference only.