

## CRYSTAL FIELD SPECTRA OF LUNAR SILICATES

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The absorption spectra of single crystals of pyroxene and olivine minerals in rocks from the Apollo 11, 12 and 14 missions were measured in polarized light (360-2200 nm). In this preliminary study transmitted spectra were recorded for individual crystals (0.5-1.0 mm) occurring in petrographic thin sections and microprobe mounts, using polarizing microscopes equipped with a universal stage mounted in a Cary 17 spectrophotometer. As a result it was impossible to avoid working with compositionally zoned and exsolved phases, while crystal field spectral features could be detected only for the major transition metal cations  $\text{Fe}^{2+}$  and, occasionally,  $\text{Ti}^{3+}$ .

By analogy with terrestrial silicates, the spectra of lunar pyroxenes and olivines are polarization dependent in the near infrared (800-1200 nm) where spin-allowed transitions in  $\text{Fe}^{2+}$  ions occur. Absorption bands are most intense for light polarized along the b axis of pyroxenes and along a of olivines. Another very broad, spin-allowed  $\text{Fe}^{2+}$  band was sometimes measured between 1700-2200 nm and beyond in lunar pyroxenes. Numerous weak, sharp peaks occur in the visible region, the majority of which represent spin-forbidden transitions in  $\text{Fe}^{2+}$  ions. No evidence for  $\text{Fe}^{3+}$  ions was found; in particular, the  $\text{Fe}^{2+}$ - $\text{Fe}^{3+}$  charge transfer band around 700 nm was absent and metal-oxygen absorption edges were displaced well into the ultraviolet. Existence of  $\text{Ti}^{3+}$  ions in some pyroxenes was suggested by broad bands centered at 460-470 nm and 660-670 nm. No confirmation was obtained of the presence of  $\text{Cr}^{2+}$  ions in the olivines.

In pyroxenes from rocks 10045, 10047 and 10058 light polarized along the b axis gives broad absorption maxima between 980 and 1025 nm, the variation in position and intensity of which are related to compositional zoning and proportions of exsolved augite-pigeonite lamellae. This band is assigned to a spin-allowed transition in  $\text{Fe}^{2+}$  of the type  ${}^5\text{T}_{2g} \rightarrow {}^5\text{E}_g$ . In pyroxenes from rocks 12021 and 12052 separate spectra were obtained from core pigeonite and rim augite. The peak maxima reflect the observed exsolution and compositional zoning and range from 900-975 nm in pigeonite and 975-1025 in augite.

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These trends are similar to those found in terrestrial pigeonites and sub-calcic augites from the Mount Wellington diabase, Tasmania, in which additional features due to  $\text{Fe}^{3+}$  ions are found. The pyroxenes from Apollo 14 rocks 14053 and 14310 are similar to those from rocks 12021 and 12052, but the band maxima ranges 930-980 nm indicate a lower degree of compositional zoning.

Of the numerous weak peaks observed in lunar pyroxenes at 402, 425, 460-470, 505, 550, 585 and 660-670 nm, the broad bands centered at about 465 and 665 nm were attributed to spin-allowed transitions in  $\text{Ti}^{3+}$  ions originating from resolved levels of the  ${}^2\text{T}_{2g}$  ground-state to components of the split  ${}^2\text{E}_g$  excited state. The intensities of these  $\text{Ti}^{3+}$  bands relative to the spin-forbidden peaks in  $\text{Fe}^{2+}$  ions were most intense in pyroxenes from Apollo 11 rocks in which the Fe/Ti ratios may be as high as 0.1. However, the  $\text{Ti}^{3+}$  bands could not be resolved by the present experimental set-up in pyroxenes from the Apollo 12 and 14 rocks, in which the Ti/Fe ratios are lower. Nevertheless, the presence of  $\text{Ti}^{3+}$  ions in the Apollo 11 pyroxenes correlates with earlier evidence of low oxygen fugacities during the cooling history of the Moon, and indicates that the crystal chemistry of the lunar pyroxenes may have to be reinterpreted.