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Raman spectroscopy of Fe-Ti-Cr-oxides, case study: Martian meteorite EETA79001

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Abstract

Raman spectral features of chromite, ulvöspinel, magnetite, ilmenite, hematite, and some of their solid solutions are presented. Although most Fe-Ti-Cr-oxides produce relatively weak Raman signals compared to oxyanionic minerals, sufficient information can be extracted from their spectra to identify the end-member mineral phases as well as some information about compositional variations in solid solutions. Correlations between Raman spectral features and mineral chemistry are used to interpret the Raman data of Fe-Ti-Cr oxides found during Raman point-count measurements on rock chips of Martian meteorite EETA79001, as an analog to Mars on-surface planetary investigations. In general, ulvöspinel, magnetite, and chromite end-members are readily distinguished by their Raman spectral patterns, as are ilmenite and hematite. In the low signal-to-noise (S/N) spectra generally obtained from the Raman point-count procedure, the position and shape of the strongest peak of Fe-Ti-Cr oxides in the region 660–680 cm^{-1} (A_{1g} mode) is the most useful for discriminating Fe^{3+}-Ti-Cr-Al substitutions in the magnetite-ulvöspinel, ulvöspinel-chromite, and chromite-spinel series, but minor peaks in the range 300–600 cm^{-1} also assist in discrimination. These spectral features are useful for investigating the variability among Fe-Ti-Cr-Al oxide solid solutions in natural samples. In EETA79001, a Martian basaltic meteorite, most of the oxide grains (as measured with the electron microprobe) are ulvöspinel, chromian ulvöspinel, and chromite, but ilmenite, titanian chromite, and titanomagnetite are also observed. The Fe-Ti-Cr-oxides identified by Raman point-count include end-member ilmenite, low-Al chromite-spinel solid solutions, ulvöspinel-magnetite solid solutions, and more complex chromite-spinel-ulvöspinel-magnetite solid solutions; the latter exhibit a wide range of main peak positions and broadened peak widths that may reflect structural disorder as well as specific cation contents. One Raman spectrum suggests end-member magnetite, and one spectrum from a different rock chip appears to be that of non-terrestrial hematite, reflecting local oxidizing alteration, which has not been observed previously in this meteorite. These results show that analyses done in an automated mode on the surface of an unprepared Martian rock sample can provide useful constraints on the Fe-Ti-Cr oxide mineralogy present and on compositional variations within those minerals, including an indication of oxygen fugacity.