American Mineralogist, Volume 94, pages 883–898, 2009

Spectroscopic characteristics of synthetic olivine: An integrated multi-wavelength and multi-technique approach

M.D. Dyar,[1,*] E.C. Sklute,[1] O.N. Menzies,[2] P.A. Bland,[2] D. Lindsley,[3] T. Glotch,[3] M.D. Lane,[4] M.W. Schaefer,[5] B. Wopenka,[6] R. Klima,[7] J.L. Bishop,[8] T. Hiroi,[7] C. Pieters,[7] and J. Sunshine[9]

[1]Department of Astronomy, Mount Holyoke College, 50 College Street, South Hadley, Massachusetts 01075, U.S.A.
[2]Impacts and Astromaterials Research Centre, Department of Earth Science and Engineering, South Kensington Campus, Imperial College London, SW7 2AZ, U.K.
[3]Department of Geosciences, Stony Brook University, Stony Brook, New York 11794-2100, U.S.A.
[4]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, Arizona 85719, U.S.A.
[5]Department of Geology and Geophysics, E-235 Howe-Russell, Baton Rouge, Louisiana 70803, U.S.A.
[6]Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, Missouri 63130-4899, U.S.A.
[7]Department of Geological Sciences, Brown University, Providence, Rhode Island 02912, U.S.A.
[8]SETI Institute/NASA-Ames Research Center, Mountain View, California 94043, U.S.A.
[9]Department of Astronomy, University of Maryland, College Park, Maryland 20742, U.S.A.

Abstract

Spectroscopic measurements have been made of two suites of olivine minerals synthesized under slightly different conditions in 5–10 mol% increments across the solid solution from forsterite to fayalite. Here, we present Mössbauer results for the entire Fe-Mg olivine suite, as well as the results for only the fayalite end-member as an introduction to our team's other diverse spectral-analysis techniques and data that will be presented in forthcoming papers. Experimental methods used to synthesize both suites of samples are discussed here in detail, along with specifics of the analytical techniques used to study them. Electron microprobe data and Mössbauer spectra acquired at 293 K across the solid solution are presented first to characterize and address the presence of impurities in the broad suite of samples that may affect other spectroscopic methods. We then focus specifically on the fayalite end-member to illustrate its properties using multiple techniques. Fayalite is an especially important phase for different types of spectroscopy because, by definition, it contains an equal distribution of Fe^{2+} cations between the M1 and M2 octahedral sites. Thus, features associated with each of the two sites must represent equal numbers of Fe^{2+} cations, removing uncertainties associated with assumptions about order/disorder of Fe^{2+} and other cations. Mössbauer, Raman, thermal emission, attenuated total reflectance (ATR), specular reflectance, and visible to mid-infrared total reflectance studies are presented for fayalite. These include calculation of mid-infrared optical constants (n and k) and fundamental Mössbauer parameters: intrinsic isomer shift (δ_I), Mössbauer temperature (θ_M), and recoil-free fraction (f). Data from the different techniques are described and related, demonstrating the importance of multi-wavelength data to provide a complete characterization and understanding of the spectroscopic features in fayalite.

Keywords: Fayalite, olivine, Mössbauer, Raman, thermal emission, reflectance, visible region, infrared, optical constant, attenuated total reflectance