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Infrared Microspectroscopy of Interstellar Grain Analogs: Annealed Amorphous Mg-Silicates

L.P. Keller (NASA/JSC) and G.J. Flynn (SUNY, Plattsburgh)

Beamline(s): U10B

Introduction: Infrared (IR) spectroscopy has proven to be the primary means of remote mineralogical analysis of materials outside our solar system. The nature and properties of interstellar grains are inferred from spectral comparisons between astronomical observations and data from natural and synthetic materials. In this study, we compare the infrared spectral properties of annealed amorphous silicate analogs to the astronomical amorphous silicates that are the common grain type in the interstellar medium and in some circumstellar environments.

Methods and Materials: Starting materials were prepared by heating serpentine [$Mg_3Si_2O_5(OH)_4$] to 550°C where it dehydrates and becomes a poorly-ordered amorphous solid. We performed a series of annealing experiments on aliquots of the starting material that were heated in 50°C steps for 1 hour starting at 577°C up to 777°C in order to investigate the transition of the amorphous material to a fully crystalline material. The end product of the annealing experiments is an equimolar mixture of forsterite (Mg_2SiO_4) and enstatite ($MgSiO_3$).

Results: Fourier transform infrared (FTIR) measurements of the annealed samples were obtained using the Continuum FTIR instrument (Beamline U10B) at the National Synchrotron Light Source at Brookhaven National Lab. We focused on the Si-O stretch and Si-O-Si bending mode vibrations that occur at ~10 and ~18 μm, respectively. FTIR spectra of the sample annealed at 627°C shows the development of fine structure due to the nucleation and growth of forsterite crystals. The forsterite features become more prominent with subsequent heating steps. Enstatite was not detected in the spectra until the sample had been annealed to 727°C.

Conclusions: These results suggest that a kinetic barrier exists in the nucleation behavior of enstatite relative to forsterite. If our hypothesis is correct, then the annealing properties of the amorphous silicates may explain why forsterite is more commonly observed than enstatite in astronomical spectra.

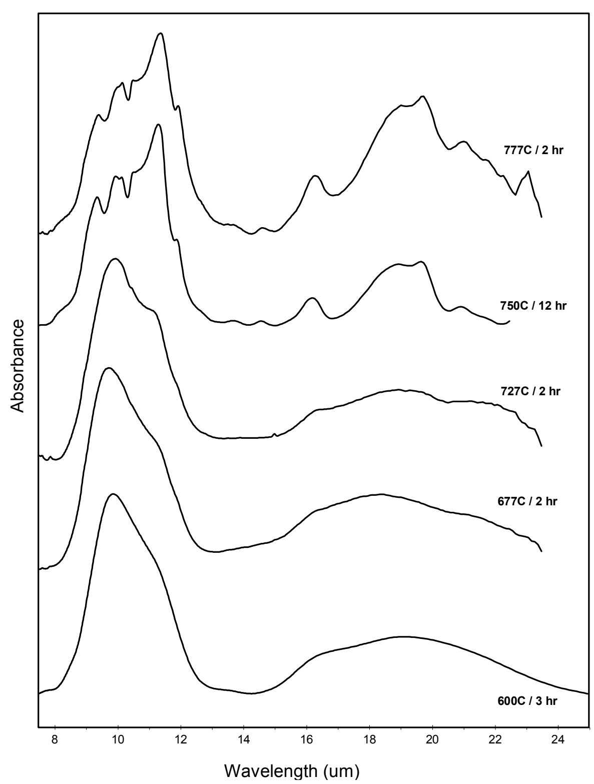

Figure 1. FTIR spectra of annealed interstellar silicate analog material which range from largely amorphous (bottom) to fully crystalline (top). Spectra are labeled with the temperature and duration of annealing.