Thermal Evolution of Amorphous Magnesium Silicate Smokes: Comparison to Circumstellar and Cometary Spectra

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Highly amorphous silicate grains which form in the outflows of mass losing stars or in the ISM must undergo some degree of thermal processing to form more ordered materials. Amorphous magnesium silicate smokes were prepared in the laboratory by vapor phase condensation and annealed in vacuum. The samples were monitored by IR spectroscopy as a function of annealing time and temperature (1000 - 1200 K), focusing on the development of the 10 micron silicate feature. The IR spectrum of the initial condensate displayed a broad band at 9.3 microns. As annealing proceeded, the maximum shifted to longer wavelengths and was eventually observed at 9.7 microns, the value typically reported for silicates in the interstellar medium and in circumstellar outflows of oxygen-rich stars.

Further thermal evolution of the amorphous magnesium silicate smokes led to the appearance of a dual maximum at 9.8 and 11 microns, indicative of “crystalline” olivine. The dual maxima 10 micron feature is a natural consequence of the thermal evolution of the amorphous condensate, rather than a mixture of amorphous and “crystalline” materials. There appears to be a natural pause in the spectral evolution of these samples, midway between the initially chaotic condensate and the more ordered glass. Thereafter, individual features sharpened as the sample became more ordered. The “olivine-rich” comets Halley, Bradfield, Levy, Mueller, and Hale-Bopp all display emission features with dual maxima at 9.8 and 11.2 microns which closely resemble the magnesium silicate smoke stall spectra.

Since grain temperatures range from 500 - 1000 K in typical stellar outflows, any magnesium silicate grain sufficiently annealed to exhibit the stall spectrum should remain at this stage of evolution for the remainder of its lifetime. The stall spectrum is therefore a practical endpoint in the spectral evolution of magnesium silicate condensates in natural systems. Currently, we are investigating how the appearance and duration of the dual maxima stall is effected by the magnesium concentration of the anhydrous silicate smokes.