EXPERIMENTAL STUDIES ON SIMULATED CIRCUMSTELLAR GRAINS

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ABSTRACT. Over the last few years a better understanding of the chemistry inherent in the refractory nucleation process has emerged from experimental studies performed in several laboratories. These studies shed light not only upon the factors which might control the onset of grain formation, but also on the spectral characteristics of freshly condensed grains.

The presence of several minor, broad, diagnostic features due to amorphous silicates over the spectral range from about 8 to 25 microns should be detectable in certain highly reddened circumstellar regions such as OH 26.5 + 0.6. We have studied the spectral changes induced in amorphous silicate smokes as a function of annealing in vacuo (Figure 1) and have measured the rate of these changes as a function of temperature (Nuth and Donn, 1984, J. Geophys. Res. (Red), 89, B657). As a consequence of these studies we can make predictions concerning the degree of crystallinity of grains ejected from circumstellar regions if the time-temperature history of the material can be estimated. We have also measured the rate at which the infrared spectrum of initially amorphous magnesium silicate grains changes as a function of hydrous alteration processes in liquid water (Nuth, Nelson and Donn, 1986, Proc. 17th Lun. Plan. Sci. Conf., J. Geophys Res. (Red), submitted). Such changes could be induced by the condensation of a water layer over or into the refractory amorphous core (cf. Jura and Morris, 1985, Ap. J., 292, 487) in the cooler regions of the outflow. Hydration produces several diagnostic changes which should be observable in moderately thick dust shells if such processing occurs (Nuth, Donn and Nelson, 1986, Ap. J. (Lett)., submitted). Our laboratory studies have indicated the need for higher resolution infrared observations taken in a "continuous mode" rather than "point-by-point" if we wish to learn details of the composition and degree of crystallinity of circumstellar grains. Laboratory synthesis of multicomponent silicate smokes which incorporate varying proportions of the elements Na, K, Mg, Ca, Fe, Si, Al, Ti, O, H and Cl

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is currently in progress. The structure and properties of these multicomponent systems will be determined as a function of the bulk compositon, thermal history and degree of hydrous alteration. In this way, data will be available to reliably model the physical properties of grains in a particular circumstellar environment based upon a knowledge of the gas composition and the likely temperature/pressure history of the average outflowing material.

Previous studies of the nucleation of SiO-H_2 (Nuth and Donn, 1982, J. Chem. Phys., 77, 2639) and Mg-SiO-H_2 (Nuth and Donn, 1983, J. Chem. Phys., 78, 1618) systems indicate that nucleation at temperatures in excess of 950K is controlled by the formation of pure $(SiO)_x$ clusters despite the fact that the Mg concentration is several orders of magnitude higher than that of SiO. (This is shown in Figure 2 where at high temperatures the Mg-SiO-H_2 system nucleates at the same SiO partial pressure as did the SiO-H_2 system.) A multi-element cluster beam apparatus is under construction which will allow us to measure the relative stabilities of various refractory, pre-condensation molecular clusters as a function of the temperature, pressure and composition of the ambient gas. This system will be used to determine the molecular pathway from refractory atoms and molecules to solid particles so that a realistic kinetic model for the formation of circumstellar grains can be formulated. We will also carry out a series of experiments aboard NASA's KC-135 Reduced Gravity Research Aircraft which are designed to measure the conditions under which a number of refractory materials nucleate from the vapor. These experiments will be free from the uncertainties associated with the possible presence of gravity driven convective instabilities which could have effected our previous measurements of the partial pressure of the refractory vapor at the time of nucleation. These experiments may also yield data from which we can derive the "sticking coefficient" for the coagulation of very small refractory grains colliding at very low relative velocities.

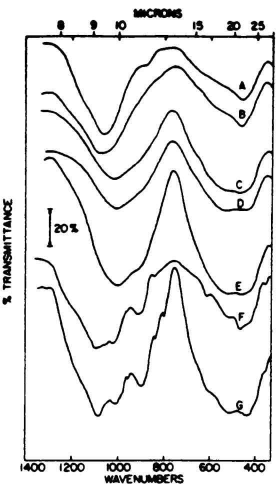

Fig.1 (left) Infrared spectra of MgSiO smoke annealed at 1000K in vacuo for 0,1,2,4,8, 16.5 and 30 hours.

Fig.2 (right) Plot of the temperature at which SiO would be in equilibrium at the observed pressure vs. the ambient temperature of the system for SiO-H_2 and Mg-SiO -H_2 nucleation expts.