MODELING NUCLEATION AND GRAIN GROWTH IN THE SOLAR NEBULA: INITIAL PROGRESS REPORT.

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Introduction: The primitive solar nebula was a violent and chaotic environment where high energy collisions, lightning, shocks and magnetic re-connection events rapidly vaporized some fraction of nebular dust, melted larger particles while leaving the largest grains virtually undisturbed. At the same time, some tiny grains containing very easily disturbed noble gas signatures (e.g., small, pre-solar graphite or SiC particles) never experienced this violence, yet can be found directly adjacent to much larger meteoritic components (chondrules or CAIs) that did. Additional components in the matrix of the most primitive carbonaceous chondrites and in some chondritic porous interplanetary dust particles include tiny nebular condensates, aggregates of condensates and partially annealed aggregates. Grains formed in violent transient events in the solar nebula did not come to equilibrium with their surroundings. To understand the formation and textures of these materials as well as their nebular abundances we must rely on Nucleation Theory and kinetic models of grain growth, coagulation and annealing. Such models have been very uncertain in the past: we will discuss the steps we are taking to increase their reliability.

Astrophysical Models: Dying stars are the best natural laboratories for the study of the grain formation process, especially the formation of oxide/silicate grains. Mass outflows from oxygen-rich asymptotic giant branch (AGB) and red giant stars are roughly steady state, homogeneous, dynamic atmospheric escape processes (1,2) The stellar atmosphere initially contains only vapor at temperatures well in excess of 2000 K: gas expansion away from the stellar surface leads to smooth decreases in both the temperature and pressure of the gas. This cooling eventually leads to the nucleation of refractory grains. These grains then serve as condensation nuclei that rapidly deplete the gas of its remaining, less refractory, vapors. Nucleation and grain growth occur on rapid timescales and produce highly amorphous, chemically heterogeneous grains that become more ordered as they are annealed in the outflow (3-5). As an example, Fe- and Mg-silicates condense out as separate grain populations (6); iron silicates require much higher temperatures to anneal than do magnesium silicates. Therefore, for high mass outflow rates, where the condensation temperatures are higher due to higher concentrations of the condensable elements, some magnesium silicates can anneal to crystallinity while the iron silicates remain amorphous, explaining the observed 'pure' magnesium silicates and the absence of evidence for iron-bearing silicate minerals in these sources (5,7). Comparison of model results to these observations will be used to validate the parameters used in our models.

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