

SHOCK WAVES AND TYPE II PO CHONDRULES

A. V. Fedkin¹, L. Grossman^{1,2}, and F. J. Ciesla¹. ¹Dept. of the Geophysical Sciences, University of Chicago. avf@uchicago.edu. ²Also Enrico Fermi Institute, Univ. of Chicago.

Introduction: Porphyritic olivine (PO) chondrules formed by heating solid precursors to subliquidus Ts [1]. To retard evaporation, dust enrichment is required [2] and, to stabilize the FeO content of Type II chondrules, water enrichment is necessary [3]. Nebular shock waves have been suggested as a heat source for chondrule formation, as they are calculated to produce peak Ts and cooling rates like those in experiments that yield chondrule textures. Shock wave thermal histories have been investigated as a function of initial total pressure, particle size, shock wave velocity, and dust enrichment at a spatial resolution of 200 km [4,5]. Here, we study effects of water enrichment on shock wave thermal histories, and model evaporation of Type II chondrule precursors at these conditions.

Results: Shock wave thermal histories in nebular settings are characterized by a near-linear heating rate, ending at what is referred to as a “pre-shock T”, followed by a sharp T spike to a “peak T”, followed by a sharp drop to a “post-shock T”, and then a near-linear cooling rate. At constant T and initial pressure, addition of water molecules increases the gas mass density. As a result, chondrule precursors moving through the gas immediately behind the shock front experience more energetic collisions, causing much higher peak Ts. Furthermore, at these elevated T conditions, capturing the full T increase requires modeling to be done at spatial resolutions as high as 2 km. Increasing water concentration also increases the gas heat content, requiring the system to radiate away more energy to cool, resulting in lower cooling rates, when all other factors are held constant. Shock wave thermal histories for water-rich systems obtained at high spatial resolution are hotter than previously published profiles, all other things being equal. A kinetic evaporation model was used to see the effects of such thermal histories on a droplet of reduced chondrule precursor material of radius 0.5 mm with liquidus T $1950 \pm 15\text{K}$ (depending on its composition when it reaches peak T), that undergoes melting, evaporation and oxidation in a closed system during the linear heating stage. For many combinations of parameters designed to keep peak Ts below but within $\sim 50\text{K}$ of the liquidus; namely, shock velocity from 6 to 10 km/sec, initial total pressure from 2.5×10^{-7} to 1.5×10^{-6} bar, and dust and water enrichments from 300 to 600 and 480 to 550, resp., relative to solar composition, all cases lead to total loss not only of alkalis but also of iron, both reduced and oxidized, before even the pre-shock T is reached, except for that residing in relict grains. Higher heating rates would prevent iron loss.

Conclusions: Our shock wave modeling does not include effects of 3-dimensional or line cooling, latent heat, finite shock size, or changing grain size. If the thermal histories are correct, however, chondrule precursor material subjected to shock waves under conditions favoring formation of textures and FeO contents of Type II PO chondrules passed through a stage when their compositions were entirely within the $\text{CaO} + \text{MgO} + \text{Al}_2\text{O}_3 + \text{SiO}_2$ system before recondensation, and must be modeled accordingly.

References: [1] Hewins R. H. et al. 2005. In *CPD*, 286. [2] Cuzzi J. N. & Alexander C. M. O'D. 2006. *Nature* 441:483. [3] Grossman L. et al. 2008. In *Oxygen in the Solar System*, 93. [4] Desch S. J. & Connolly H. C. Jr. 2002 *MAPS* 37:183. [5] Ciesla F. J. & Hood L. L. (2002) *Icarus* 158:281.