FORMATION CONDITIONS OF TYPE I CHONDRULES: COMPARISON OF EXPERIMENTALLY DETERMINED COOLING RATES WITH THE SHOCK WAVE MODEL FOR CHONDRULE FORMATION

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Introduction: FeO-poor porphyritic olivine and pyroxene (type I) chondrules are ubiquitous in all chondrite groups. Understanding thermal histories of these chondrules provides important constraints for chondrule formation models. Previous experimental studies have reproduced textures of type IAB chondrules at cooling rates of 100 to 1000°C/hr [1]. We conducted a set of one-atmosphere experiments for type IAB chondrules to test whether slower cooling rates, comparable to those predicted by the shock wave model [2], are also plausible.

Results: Our experiments were cooled at linear cooling rates of 5 to 25°C/hr from peak temperatures of 1500 and 1600°C to quench temperatures of 650 to 1000˚C. In order to approximate a non-linear cooling path that is more likely to apply to natural chondrules, several experiments had multiple stages of successively slower cooling rates. Our starting material was an oxide powder mixture of type IAB chondrule bulk composition [3]. All experiments produced textures that match very closely to natural type I chondrules, including olivine grains poikilitically enclosed in low-Ca pyroxene grains and Ca-rich pyroxene overgrowths on low-Ca pyroxene. Olivine in experiments with a peak temperature of 1500˚C was much finer grained than olivine in experiments with a peak temperature of 1600˚C. Mesostasis was either glassy or contained quench crystals. Compositions of all phases are very close to compositions of minerals and mesostasis in type I chondrules in CO and LL chondrites.

Discussion: Close similarities between our experiments and natural chondrules show that the peak temperatures and cooling rates used are plausible conditions for the formation of type I chondrules, therefore the range of cooling rates should be extended to include rates of 5 to 25°C/hr. These slower cooling rates agree with [4]. Our experiments very closely reproduce chondrule thermal histories predicted by the shock wave model of [2], which is updated from [5] with treatment of the radiation field, opacity of solids, and molecular line cooling. Model input parameters are the same as in [5], apart from a shock velocity of 8 km/s, and a solids-to-gas ratio (chondrule concentration) of 10 x solar. The model predicts a peak temperature of 1727°C, which is experienced by the chondrules for less than 30 sec, after which the chondrules cool more slowly from ~1570˚C. The model predicts cooling rates of 45 to 15°C/hr between 1427 and 1127°C, the temperature interval when most of the olivine and pyroxene observed in chondrules crystallizes. Faster cooling rates are predicted by the model as solid densities increase, i.e. in regions of higher chondrule concentrations. Overall, slow cooling rates for type I chondrule formation are supported by both the shock wave model and by experimental constraints.

References: [1] Radomsky P.M. & Hewins R.H. 1990. *Geochim. Cosmochim. Acta* 54:3475-3490 [2] Morris M. & Desch S.J. (2010) *Astrophys. J.*, in revision [3] Wick M.J. & Jones R.H. 2010. Abstract #1925. 41st Lunar and Planetary Science Conference [4] Dehart J.M. & Lofgren G.E. 1996. *Geochim.Cosmochim. Acta* 60: 2233-2242 [5] Desch S.J. & Connolly H.C.Jr. 2002. *Meteorit. Planet. Sci.* 37: 183-207.