Formation of Compound Chondrules from Supercooled Melts. S. Arakawa[1] and T. Nakamoto[1], [1]*Department of Earth & Planetary Sciences, Tokyo Institute of Technology, Meguro, Tokyo, 152-8551, Japan.*

Introduction: Chondrules are sub-millimeter sized igneous grains which were melted in the protoplanetary disk. About 4% of chondrules are compound chondrules (hereafter, CC): two (or more) separate chondrules adhere together [1]. It is commonly believed that CCs were formed when molten precursors collided.

Textural types of chondrules are related to the thermal history. Non-porphyritic chondrules (e.g. barred olivine) underwent complete melting. About 16% of chondrules are non-porphyritic [1], and 92% of CCs are non-porphyritic CCs (we here define a non-porphyritic CC as a CC of which secondary is non-porphyritic) [2]. Then, 3.7% of all the chondrules are non-porphyritic CCs.

	Compound	Single	Total
Non-porphyritic	(a) 3.7%	12.3%	(c) 16%
Porphyritic	0.3%	83.7%	84%
Total	(b) 4%	96%	100%

Table 1. Ratios of four types of chondrules. We define a non-porphyritic compound chondrule as a compound chondrule of which secondary is non-porphyritic.

We note two observed features. First, almost all ((a) / (b) = 92%) the CCs are non-porphyritic while most of single chondrules are porphyritic (feature A). This feature strongly suggests that the CC formation and the non-porphyritic chondrule formation are related to each other. Second, the ratio of compound in non-porphyritic (= (a) / (c) = 23%) is much higher than that in all the chondrules (feature B).

In previous works, the CC ratio among all the chondrules, which is 4%, was focused. To reproduce the ratio, models using the number density of precursor particles, collisional cross-section, the relative velocity, and the plastic time, were discussed. But the observed ratio has been hardly reproduced [2]. The biggest problem is that plastic duration time is extremely short [3–4].

On the other hand, experimental studies have shown that floating completely molten dust particles may become supercooled, and non-porphyritic chondrules may be made from supercooled droplets [5–6]. Supercooling is the key of the CC formation because almost all CCs are non-porphyritic CCs (feature A). If the supercooling occurs, melting duration of precursor can be long.

We propose a new scenario for the CC formation: a CC is formed by a collision and a coagulation of supercooled molten droplet. In this study, we examine whether the observed frequency of CCs in non-porphyritic (feature B) is reproduced.

Model: We make some assumptions for the mechanism of heating and the source of dust relative velocity, to construct an analytical model. In order to do some quantitative estimates, we use the planetesimal bow shock chondrule formation models [7–8]. Behind the shock front, relative velocity among dust particles is produced by turbulence. We suppose that the relative velocity is 1 m s^{-1} [9]. It is supposed that CCs are formed by low speed (< 4 m s^{-1}) collisions between supercooled melts and solid particles [10] (Fig. 1).

We assume that the gas density is that of the minimum mass solar nebula, and the dust-to-gas mass ratio is 1:1. And we employ a simplified size distribution for precursor particles: precursors have only two radii of 0.1 mm and 0.4 mm. We use the number density ratio of small and large precursors, 14:1 [11].

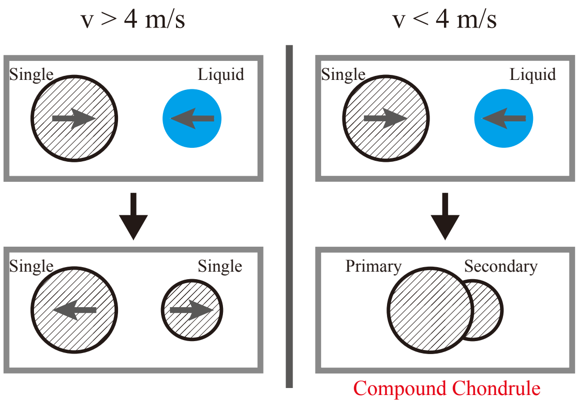

Fig. 1. A conceptual diagram of compound chondrule formation. Compound chondrules are formed by slow collisions (right), not by high-speed collisions (left).

Results: Solving differential equations about precursors' number densities, it is found that the frequency of CCs in non-porphyritic (23%) can be achieved if supercooling duration time is longer than 8.6×10^3 s (about two hours).

The new model of CC formation is based on the observed feature that almost all ingredients of CCs are experienced in melting (feature A), and this model can explain the abundance ratio in non-porphyritic (feature B).

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