WHAT DOES BULK COMPOSITION OF CHONDRULES TELL US? H. Nagahara[1], [1]Dept. Earth Planet. Sci., The Univ. Tokyo, 113-0033, Japan. hiroko@eps.s.u-tokyo.ac.jp

Introduction: Origin of chondrules has been one of the top issues of meteorite study and planetary science since 40 years ago. Various observations have given constraints on the mechanism of chondrules formation. Texture including relict minerals, bulk chemical composition, isotopic compositions specifically oxygen isotopic compositions, crystallization age estimated by the abundance of short lived radionuclide, relationship to matrices, and size distribution are the points extensively studied. Among them, bulk chemical compositions have played a key role to understand the formation temperature, precursor materials, and heating mechanism. The relationship among bulk composition, oxygen isotopic composition, and the formation age is crucial to evaluate the formation of chondrules in the evolution of the solar nebula.

Bulk composition of chondrules have been obtained by several techniques; INAA for fused chondrules, non-destructive INAA, broad-beam EPMA, or point counting by EPMA, all of which gave fairly consistent results that bulk composition of chondrules are fractionated relative to CI, refractory elements are homogeneously enriched or depleted, volatile elements are depleted significantly depleted as a function of the volatility of elements in the solar system in Type I FeO-free or poor chondrules but much less significantly in FeO-rich type II chondrules, type I and FeO-rich type II chondrules are contained in a single chondrite regardless of chemical type of chondrites [1-3].

Volatile elements: Interpretation on the volatile element distribution in chondrules is controversial. Hewins et al. [4] showed systematic volatile depletion with the increase of grain size of microporphyritic olivine in type I chondrules in Semarkona and discussed volatile loss during heating. On the other hand, volatile element or even a mildly volatile major element, Si, Mg, and Fe, enrichment in the periphery of individual chondrules have been found in many chondrules (e.g., [5-8]), which has been interpreted to represent condensation of elements during cooling and crystallization. These studies suggest open system behavior of major elements during chondrules formation.

Alexander et al. [9], however, discussed closed-system behavior of Na on the basis of distribution coefficient of Na2O between olivine phenocrysts and coexisting melt (mesostasis). They proposed chondrule formation in extremely dense region in the nebula, which may be related to planetesimal formation.

Oxygen isotopic composition: Oxygen isotopic composition of chondrules has been extensively studied mostly in order to relate the change of 16O abundance with special inference to the evolution of the solar nebula [10]. The variation of oxygen isotopic compositions so far found is mostly along the CCAM line since [11], as expected.

Recently, Kita et al. [12,13] found mass-dependent oxygen isotopic fractionation of oxygen isotopes in type I chondrules in Semarkona and least equilibrated H chondrite chondrules by about several permils, whereas almost no fractionation in type II chondrules. Although it has not yet be fully investigated whether the fractionation is equilibrium distribution between solid and gas or kinetic fractionation effect due to evaporation or condensation, the mass dependent isotopic fractionation could indicate open system behavior during chondrule formation. The possible open system behavior of type I chondrules is consistent with behavior of volatile element behavior.

Chronology: 26Al-26Mg chronology of chondrules have been also extensively studied since [14], which has thrown a fundamental question how chondrules were retained in the solar nebula through 2 m.y. and how it mixed with CAIs and matrix materials that contain interstellar materials to form chondrites. Kurahashi et al. [15] further showed a systematic difference in the formation age of type I and type II chondrules in ordinary and CO chondrites but with simultaneous formation of chondrules in different chemical groups of chondrites. The results suggest systematically different formation region of chondrules for chemical groups of chondrites, and thus there should have a certain mechanism to retain chondrules in the solar nebula for two m.y without large scale mixing. Assuming that oxygen isotopic composition is controlled by the composition of water ice [10], the chronological systematics would represent the formation and retention of chondrules in fairly limited region in the solar nebula.

Scenario: The bulk chemical compositional, oxygen isotopic and chronological information should be consistently satisfied in the evolution of the solar nebula. A possible scenario is that chondrules were formed in limited regions in the nebula, where the gas/dust ratio is variable. Due to the heterogeneity of gas/dust ratio, some experienced open system behavior, whereas, some closed system. This was possible if chondrule formation location is in highly dense region along the midplane near the snowline. This further suggest the formation of planetesimals almost simultaneously with chondrules formation.

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