A Fluid Flow Model for Chondritic Parent Bodies

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Some carbonaceous chondrites (CC) preserve evidence of geologic activity in the life of their parent bodies (PBs), specifically aqueous alteration. The nature of alteration can constrain characteristics of both the porosity and permeability of the host rock, the composition of the fluid itself, initial ^{26}Al concentration, and the size of the PB. Oxygen isotopes may be a proxy for water-dominated or rock-dominated types of water-rock interactions[1][2][3].

Thermodynamic models have been used to predict thermal evolution, isotopic composition and abundance in chondritic PBs. Most of the models consider rock properties that are based on CV3 chondrite material, which include the presence of interstitial fluids. Assumptions about the rate of flow in these models are crucial to the analysis of geological processes that led to aqueously altered chondrite material. The "vapor piston model" is one such model that assumes that fluid from melting ice is flowing radially outward from the PB interior toward the vacuum of space, albeit slowly enough to engage in chemical reactions with would-be anhydrous minerals. An opposing hypothesis suggests a scenario in which the PB was in fact not permeable enough for fluid to flow at a rate that would cause phyllosilicates to form[4][5]. A third, less likely hypothesis posits that the fluid would be able to flow freely enough throughout the PB to convect beneath the surface, with high Al abundance providing plenty of internal heat. [5]

We present our initial results on the modeling of the evolution of oxygen isotopes in CC PBs under the assumptions of the "vapor piston model"[2][5]. We assess the robustness of this model's ability to produce isotopic compositions that are indeed found in aqueously altered meteorites, and the validity of the underlying assumptions that produce the scenarios stated above.

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Development of Cryogenic SIMS Technique for Isotopic Analysis of Individual Fluid Inclusions

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Introduction: Fluid inclusions found in halite crystals from meteorites can potentially provide direct information of extraterrestrial liquid water, and the cold-stage system equipped by SIMS realized in-situ isotope analysis of fluid inclusions[1, 2]. However, the fluid inclusions should be unexposed in previous system because there was no sample introducing system under low temperature. We are developing cryogenic apparatus for SIMS in order to overcome several difficulties for accurate analysis of fluid inclusions, such as targeting, long presputtering and charging.

Cryogenic SIMS: The major components of cryogenic SIMS technique are cryo-polisher, cryo-holder, cryo-coating, cryo-transfer vessel, cryo-loadlock chamber and cryo-stage.

Cryo-polisher is equipped with liquid nitrogen recirculating cooling system placed inside of glove-box purged with dry nitrogen gas. Temperature controller controls the influx of liquid nitrogen to achieve a temperature range (173K ~ 193K) of cryo-polisher. Frozen samples are polished by the polishing sheet on the stage of cryo-polisher to expose fluid inclusions. Polished samples are mounted into cryo-holder which is integrally molded to prevent deformation caused by temperature change. The cryo-holder containing polished sample is coated by gold to avoid charging caused by ion beam. We investigated gold-coating method under low temperature and found that the frost on sample surface prevented making a well-conductive gold-coating. When temperature of sample surface is higher than ~213K, we got good coating. The temperature is consistent with the dew point of the dry nitrogen gas. Coated cryo-holder is set into liquid nitrogen fulfilled cryo-transfer vessel by VAT-valve equipped cryo-loadlock chamber. This cryo-loadlock chamber can be attached to the storage chamber of SIMS directly. Cryo-stage can keep the cryo-holder at ~77K during analysis. All processes should be performed under low temperature enough to keep the fluid inclusions as solid state.

Fig. photo of exposed fluid inclusions in halite crystal

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