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Condensation experiments of Si-rich gas into the chondrule melt for rapid low-Ca pyroxene formation using a new furnace

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Introduction

Low-Ca pyroxenes (mainly enstatites) and the high-pressure polymorphs are the most major phases constituting rocks in the solar system. The formation mechanism of low-Ca pyroxenes in the solar nebula is problematic. It has been thermodynamically predicted that enstatite forms from forsterite by the reaction with Si-rich gas since enstatite and the preceding condensate Mg-silicate, forsterite, are in reaction relation (Grossman, 1972). However, the rate of the reaction is sluggish because of the solid diffusion-controlled in the enstatite layer, and the reaction is nearly treated as maximum fractional condensation (Imae et al., 1993). Also, the amount of enstatite condensed directly from the residual gas is very small. Tissandier et al. (2002) experimentally showed that pigeonite (CaO˜5-7 wt%) crystallized from chondrule melt by the interaction with Si-rich gas. In the present study, a new technique to simulate the solar nebula was developed and massive low-Ca pyroxenes (CaO˜1 wt%) were produced using the furnace.

Experiments

The total pressure was mainly controlled to be 100Pa under the hydrogen gas flow, using a butterfly valve indicated from the diaphragm-seal type pressure gauge. The maximum temperature for each run was 1200-1450^{o}C, in which pyroxene is in stable region and the cooling rate was mainly 100^{o}C/h. A tiny fragment of the Allende meteorite (˜30-50 mg for each run) was used as a starting material of the experiments. The staring material and silica powder were put avoiding the direct contact into the alumina cruicible with the 1 mm orifice. The experiments without silica powder were also carried out as reference experiments.

Result

Minor amount of low-Ca pyroxenes were found mainly with dominant olivines under the experiments without Si-rich gas source. While, a drastic change was observed from the experiments with Si-rich gas source: completely changed to low-Ca pyroxenes poikilitically enclosing rounded olivines were observed for the charges at 1450^{o}C, and low-Ca pyroxenes were observed mainly on the rim for the charges at 1350^{o}C and 1250^{o}C. The iron content increased on the decreasing temperatures.

Discussion

The collision frequency of the Si-rich gas on the melt of the Allende chondrite as a starting material is not so large to derive the crystallization of the massive low-Ca pyroxenes from the melt. Rather, the Si-rich gas helped the nucleation of low-Ca pyroxenes in the stability filed of low-Ca pyroxene. Massive crystallization of pyroxenes did not occur for the experiments without Si-rich gas source and here the forsterite continued to grow under metastable condition.

References

Grossman L. (1972) GCA 36, 597.
Imae N., et al. (1993) EPSL 118, 21.
Tissandier L., et al. (2002) MAPS 37, 1377.

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