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Time-resolved X-ray diffraction measurement of dehydration of serpentine at high pressure and high temperature

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Introduction

Serpentine is the most abundant hydrous phase in subducted slab, and the descending slab transports water into the Earth's interior. Antigorite (Atg) is one of the polymorph of serpentine, and the dehydration of Atg at certain depth supplies free water, and the upward migration contributes to the generation of magma in the mantle wedge. To evaluate the ability of H_2O transportation into the deep Earth's mantle, it is important to know the dehydration rate of Atg at high P-T conditions. We have conducted the time-resolved dehydration experiments of Atg at high pressure and high temperature by in situ X-ray diffraction using MAX-80 (AR-NE5C) at PF-AR, Japan.

Experimental

Natural Atg was used as a starting material, and the sample was sealed by Au or Pt lids plus diamond sleeve, which enabled us to get high quality of diffraction because of high X-ray transparency of diamond [1]. Experiments were conducted between 3 and 9 GPa and temperature up to 700ºC. We gradually increased temperature to ~500ºC, and then the diffraction data were collected at every 50ºC with increasing temperature. In each temperature, the diffractions were collected in every 60 seconds for certain duration with checking the peak change.

Results

Atg dehydrated to forsterite (Fo) + enstatite (En) + fluid via small amount of "talc-like" phase (Tlc) formation with increasing temperature below ~6 GPa (Fig. 1). These results were almost consistent with Perrillat et al. (2005) [2], but the degree of "talc-like" phase formation was different. At 3 GPa, the rapid dehydration was occurred at 700ºC in 15 minutes, and at 5 GPa, that was occurred at 650ºC in 50 minutes (see Fig. 1). Comparing with the previous phase equilibrium studies of Atg [e.g. 3], our result shows that the dehydration of Atg quickly occurs when P-T path goes into the region of Fo +En + fluid. This shows that Atg in subducted slab should quickly dehydrate when the slab crosses the dehydration boundary of Atg. Thus metastable Atg can not exist in subducted slab at around 650-700ºC and 3-5 GPa.

To clarify the dehydration mechanism of Atg, we tried to fit the data by Avrami model [4]. The detailed analysis at 3-6 GPa and 650ºC, where was the dissociation condition of Atg, showed that the nucleation rate was quite high for enstatite, but low for forsterite (Fig. 1). This result also can be confirmed clearly from the observation that incubation periods exist for forsterite formation. And also the fitting of the dissociation of Atg showed that the slope (the n value of Avrami model) was changed with time; this indicates the nucleation rate is changed from high to low with increasing time. Thus, the dissociation mechanism of Atg is complicated because of the reaction with silicate-rich fluid.

Talc was formed above 6 GPa with dissociation of Atg, and the formation of phase A could not be confirmed in the present experiments. These results are inconsistent with the previous phase equilibrium reports [e.g. 3]. We are trying to conduct more experiments to clarify the above problems.

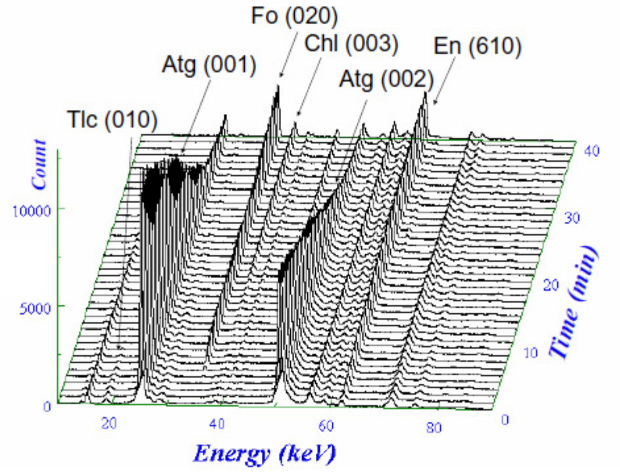

Fig. 1. An example of antigorite dehydration (AR068: 5.2 GPa, 650ºC). The reaction "antigorite(Atg) → forsterite(Fo) + enstatite(En) + Fluid" was occurred in this condition. Small amount of talc(Tlc) and chlorite(Chl) can be seen.

References

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