Report for the Joint Use/Research of the Institute for Planetary Materials, Okayama University for FY2024

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Category: ☑International Joint Research ☐General Joint Research ☐Joint Use of Facility ☐Workshop

Name of the research project: Fluorine host in subduction zones

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Research report:

Research Purpose:

The purpose of this study is to explore the role of fluorine as a volatile component in subduction zone processes, with a particular focus on its incorporation into deep mantle minerals. Fluorine, as a halogen element, can significantly influence the stability, structure, and physical properties of mantle minerals. In this research, we aimed to synthesize fluorine-bearing enstatite ($MgSiO_3$) under conditions relevant to the Earth's upper mantle and transition zone, in order to investigate how different fluorine concentrations affect phase stability. This study contributes to our understanding of how fluorine may be transported and stored in the deep Earth, particularly through the subduction of altered oceanic lithosphere.

Actually Conducted Research:

The experimental work was conducted using a large-volume multi-anvil apparatus to simulate high-pressure and high-temperature conditions, specifically around 20 GPa, which corresponds to depths of the mantle exceeding 500 km. A series of synthesis experiments were carried out using starting materials with varying fluorine contents to produce enstatite-based phases.

After the synthesis, all recovered samples were carefully examined using several analytical techniques. First, micro-area X-ray diffraction (XRD) was used to identify the crystalline phases present in each sample and determine their structural characteristics. Scanning electron microscopy

(SEM) provided information on the textures and morphology of the synthesized phases. Then, quantitative chemical analyses were performed using electron probe microanalysis (EPMA), allowing precise determination of elemental compositions, especially the distribution and concentration of fluorine in the mineral structures.
Based on these analyses, the stability fields of various fluorine-bearing enstatite phases were mapped as a function of pressure and temperature. A pressure-temperature (P–T) phase diagram was constructed to visualize how the incorporation of fluorine affects phase boundaries and stability ranges. These results were further compared with previous experimental data and thermodynamic models to evaluate consistency and implications.

Research Outcomes:

The main outcomes of this research include:

- Successful synthesis of multiple F-bearing phases under high-pressure conditions.
- Clear evidence that increasing fluorine content expands or shifts the stability fields of certain silicate phases.
- Detailed mineralogical and chemical characterization of the synthesized samples using XRD, SEM, and EPMA.
- A P–T phase diagram that shows the influence of fluorine on the phase relations of Mg-Si minerals at mantle depths.

These findings provide valuable constraints on the behavior of fluorine in the deep Earth and suggest that F-bearing minerals may play a role in transporting volatiles into the lower mantle. The figures and tables attached to this report summarize the experimental results, analytical data, and interpretations.

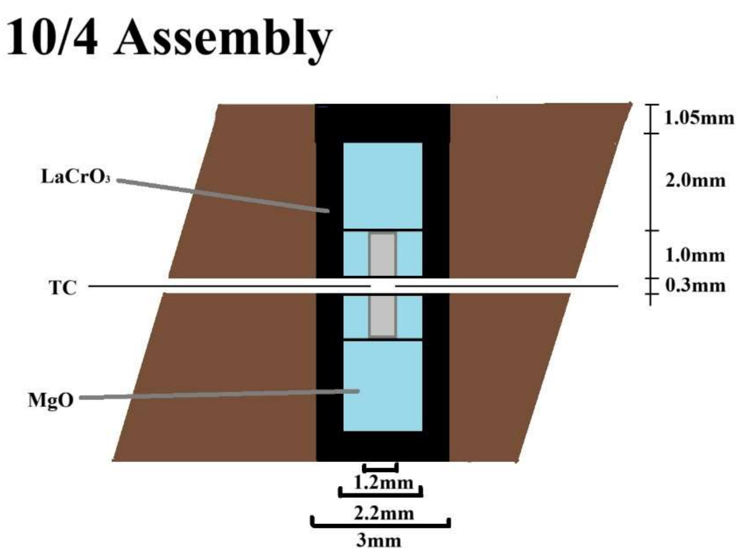

Figure 1. Schematic illustration of the octahedral assembly used in high-pressure experiments.

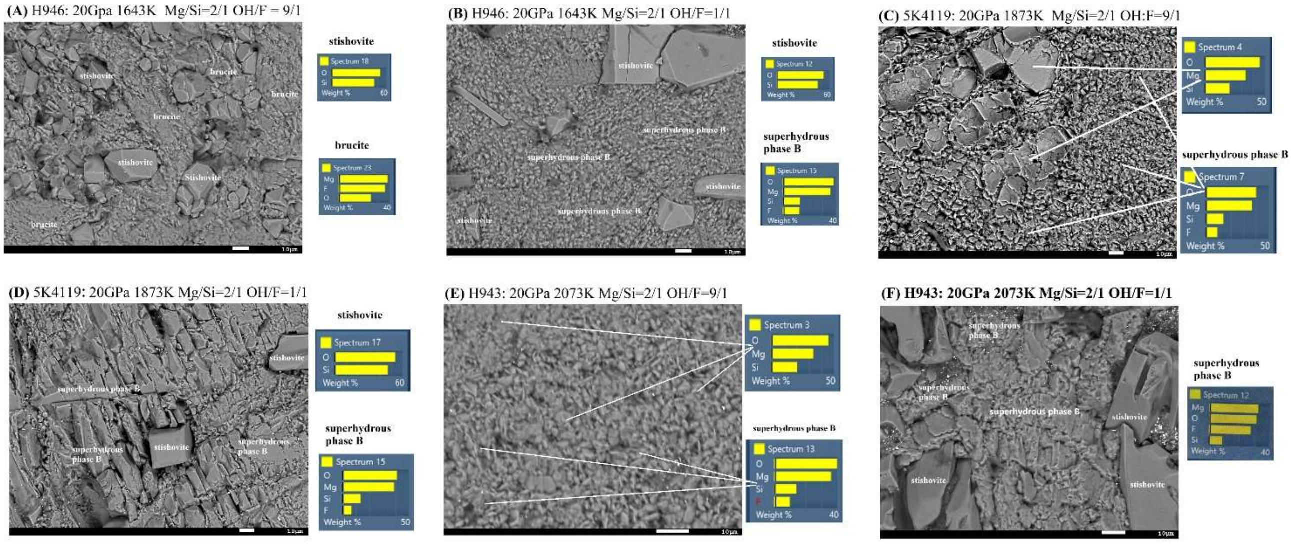

Figure 2. Scanning electron microscope (SEM) image of the synthesized minerals at 20 GPa.

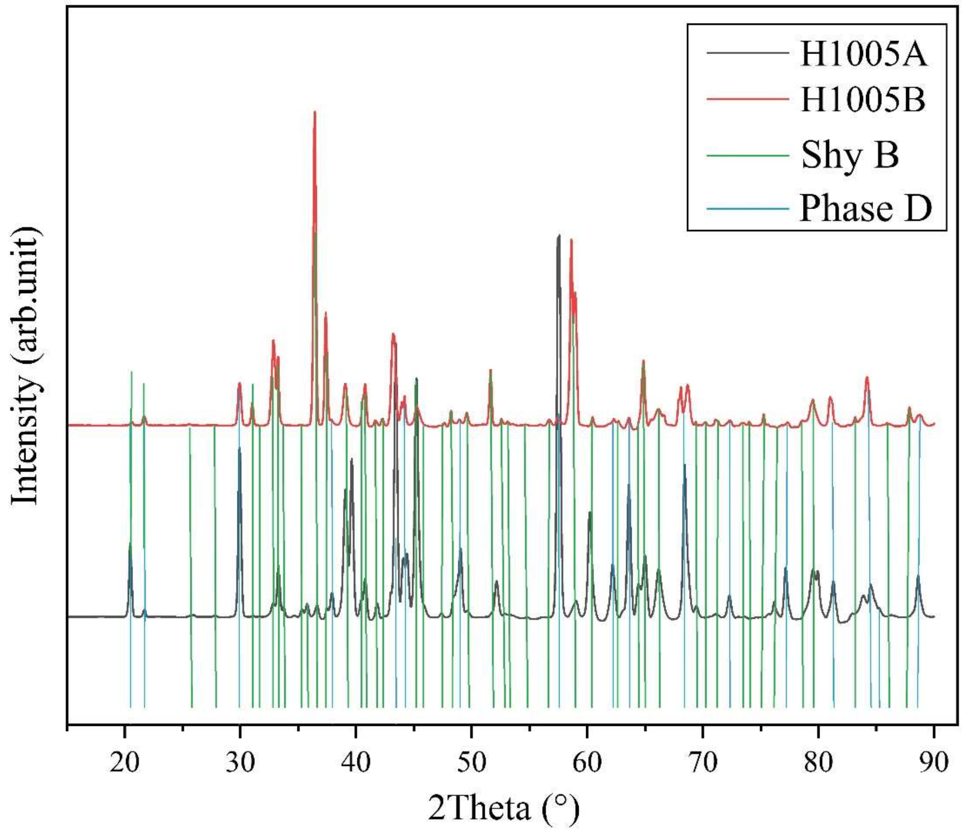

Figure 3. X-ray diffraction (XRD) patterns of representative synthesized samples containing different amounts of fluorine.

Table 1. Summary of runs

Run No.	cell type	T (K)	P (GPa)	Phase assemblage [a]
$2Mg(OH)_2+SiO_2$				
5K4002	10/4	1273	20	PhD + br
1K3824	10/4	1473	20	shyB + PhD + melt
5K4015	10/4	1673	20	PhD + melt (shyB)
$2Mg(OH,F)_2+SiO_2$ [b]				
5K4002	10/4	1273	20	shyB + PhD
1K3824	10/4	1473	20	shyB + PhD
5K4015	10/4	1673	20	shyB + PhD
5K4119	10/4	1873	20	shyB+ Rw
H943	10/4	2073	20	shyB+ Rw
$2Mg(OH,F)_2+SiO_2$ [c]				
H946	10/4	1673	20	st + shyB
5K4119	10/4	1873	20	st + shyB
H943	10/4	2073	20	st + shyB

a: Abbreviations: br; brucite, PhD; phase D, shyB; superhydrous phase B, Rw: ringwoodite
b: OH:F = 9:1.
c: OH:F = 1:1

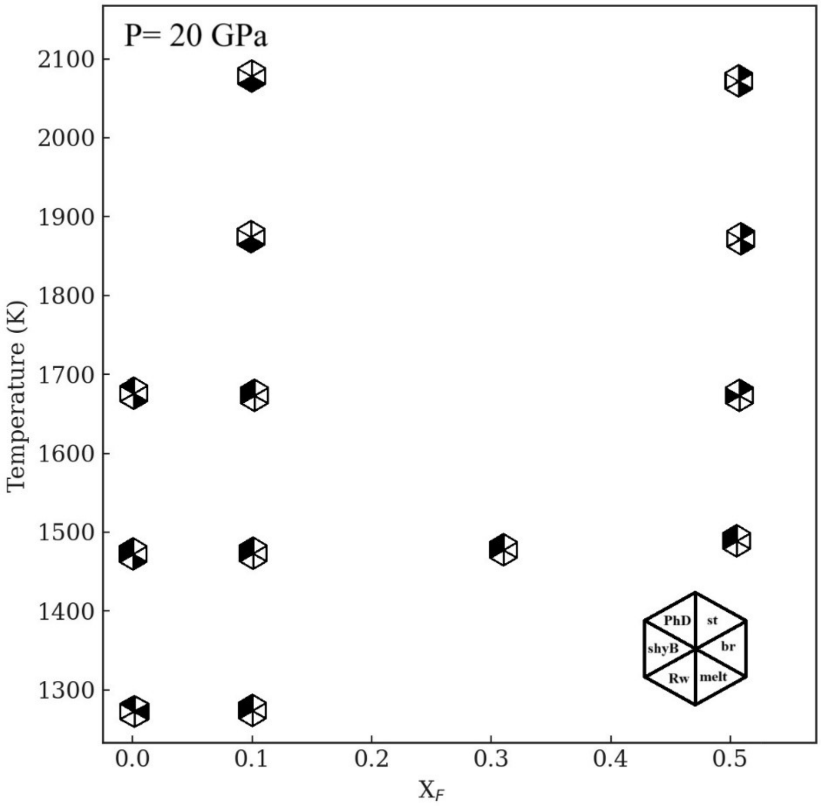

Figure 5. Mineral phase diagram of synthesized samples with different fluorine contents at 20 GPa.