In situ X-ray diffraction study on kinetics of decomposition of spinel Mg_2SiO_4 to periclase MgO and perovskite $MgSiO_3$

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We have conducted an in situ X-ray diffraction study of kinetics of decomposition reaction of spinel Mg2SiO4, which is one of the most important reaction occurred in the Earth's interior. The kinetics of this reaction is especially important for understanding rheology of the descending slabs and ascending hot plumes, and the origin of the deep focused earthquakes in the transition zone and the uppermost part of the lower mantle.

We have conducted the experiments using SPEED1500 multianvil apparatus installed in BL04B1 of SPring 8. The truncated edge lenght of the inner MA8 appratus was 2 mm. We used a LaCrO3 tube as the heating element, and Mo foil as the electrodes. The temperature was measured by a W25%Re-W3%Re thermocouple with 0.1mm diameter. The white X-ray beam with the height of 100μm and the width of 200μm was collimated to the sample and the reflected X-ray was detected by the solid state detector with a glancing angle 2θ= 5.0°C. The starting material was a sintered mixture of Mg2SiO4 spinel and fine grained gold powder. The grain size of spinel was about 10 μm in diameter. Pressure was evaluated from the volume of gold which was mixed with the spinel sample. After compression, temperature was increased to the desired value by a rate of 500°C/min. and held constant for in situ X-ray diffraction.

We made successful measurement of the rate of the decomposition reaction at 22~28 GPa and around 900~1300°C using the in situ X-ray diffraction technique. Figure 1 shows the results of the present experiment on the rate of the decomposition reaction as a function of temperature and the overpressure. Observation of the texture of the partially transformed run product by scanning electron microscopy implies that the reaction proceeded by a nucleation and growth mechanism. The present measurements of the reaction rate with different conditions imply that the reaction is enhanced strongly by increase in temperature and overpressure (Figure 1). The present results combined with those obtained previously suggest that it takes more than 10^6 years to complete the present reaction at 600~800°C, temperature of the slabs at the 660 km depth in the mantle. Thus, the metastable spinel phase may exist in the uppermost part of the lower mantle due to the sluggish reaction.

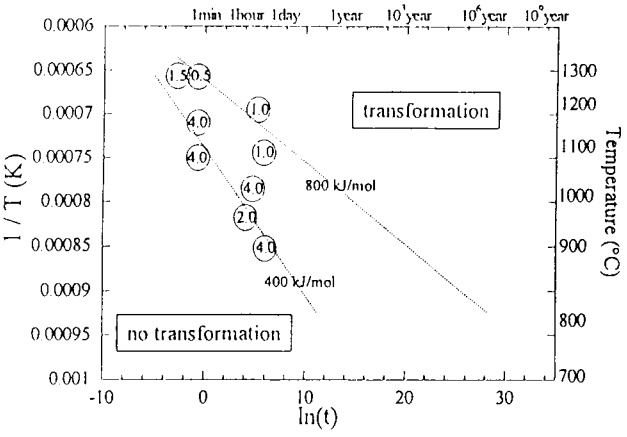

Figure 1. Experimental Time – Temperature – Transformation plot for the decomposition reaction of spinel to perovskite and periclase. The plotted points indicate the time taken achieve about 10% completion of the transformation during the isothermal heating. The value in open symbols shows the overpressure. The slope of the dotted line indicate the activation energy related to both nucleation and growth. Under the condition of small overpressure (~1 GPa), the activation energy of nucleation is very large. In contrast, under the condition of large overpressure (~4 GPa), activation barrier for nucleation is very small and negligible, and thus slope of the dotted line indicate the activation energy for growth.