Shear localization and shear instability induced by the olivine-spinel transformation of fayalite at 8 GPa

*Yuichiro Mori[1], Tomoaki Kubo[1], Takuya Iwasato[2], Yuji Higo[3], Yoshinori Tange[3]

1. Kyushu University, 2. Shin-Nippon Nondestructive Inspection Co., Ltd, 3. JASRI

Deep-focus earthquakes have been observed to occur within subducting oceanic plates at depths of 300 to 700 km. It has been proposed that phase transformations of mantle minerals induce strain localization and shear instability responsible for earthquakes. Previous studies showed that the olivine-spinel transformation of Mg_2GeO_4, which is an analog of Mg_2SiO_4, induce AE activities associated with thin shear bands composed of nanograins of spinel phase (e.g., Schubnel et al., 2013). However, the pressure conditions are still relatively low around 3-5 GPa. In the present study, we used the olivine-spinel transformation in silicate olivine Fe_2SiO_4 to observe shear instability at higher pressures.
Deformation experiments were conducted at 6-10 GPa, 400-800˚C using D-DIA apparatus, SPEED Mk. II at BL04B1, SPring-8. Pressure was generated by MA 6-6 type cell assembly. Monochromatic X-rays (60keV) were used to obtain radiography images and two-dimensional X-rays diffraction patterns every 5-10 minutes, from which transformation kinetics and creep behaviors were monitored. In addition, we used MA6-6 type AE measurement system to search for the condition of shear instability. The starting material is fayalite (Fe_2SiO_4) powder. We annealed it at 3 GPa and ˜700-900˚C in the olivine stability field after cold compression prior to deformation in the spinel stability field. All deformation experiments were conducted with constant anvil displacement rate of 200-500 μm/h and constant temperature ramping rate of 0.07-0.11˚C/s).
At the smaller overpressure (dP) of ˜2 GPa, we observed the initiation of the transformation at 750˚C. In the case of the larger dP of ˜5 GPa, the transformation started at the lower temperature of 600˚C. Strain rates and final strains were 9.5×10^{-5} /s and 51%, and 1.6×10^{-4} /s and 44%, respectively. In the latter case, we detected AEs around the sample region associated with the olivine-spinel transformation. Both AE event rate and AE magnitude increased abruptly as reaction proceeded. SEM and EBSD observations revealed that fine-grained spinel nucleates along the olivine grain boundaries and preferentially grows perpendicular to the principal stress direction forming the interconnected spinel network in both runs. These transformation and deformation textures are relatively homogeneous in the run at smaller dP and higher T without AEs. In contrast, shear localization was observed in the run at larger dP and smaller T with AE activities. The spinel grain size seems to be smaller in the latter case, which may cause the different deformation behavior. These results suggest that shear localization and shear instability occur associated with the olivine-spinel transformation at the higher pressure condition of ˜8 GPa, however further studies are needed to constrain the factors inducing shear instability.

Keywords: deep earthquakes, phase transformation, high pressure experiments, deformation experiments, in-situ X-ray observation

