

## Chemically induced formation of pull-apart structure of Cr-spinel

Tsubasa Arai<sup>1</sup>, Tomoyuki Mizukami<sup>1</sup>, Takayoshi Nagaya<sup>2</sup>, Simon Wallis<sup>3</sup>, Tomoaki Morishita<sup>1</sup>,  
\*Yusuke Soda<sup>1</sup>

1. Kanazawa Univ., 2. Tohoku Univ., 3. Nagoya Univ.

Cr-spinel is known as the most rigid mineral among constituents of mantle peridotite. However, it is often seen that it forms pull-apart structures in deformed peridotite as a result of brittle fracturing. Understanding of mechanical conditions for fracturing of Cr-spinel could give a clue for stress estimation. Therefore, comprehensive study on the cause of fractures in Cr-spinel is important. In this study, we performed petrological and microstructural analyses of Cr-spinel and host deformed dunite in Higashi-akaishi ultramafic body in Sanbagawa metamorphic belt. The occurrence can be related to physical and chemical conditions in subduction zones.

Characteristic microstructures of Cr-spinel are developed as a function of an increasing amount of antigorite in the host dunite in the following order: chemical modification from rim to core, pull-apart structures, polycrystalline textures and, finally, disseminated clusters of micro-grains. The microstructural evolution of Cr-spinel implies that there are some chemical effects on the fracturing. The chemical modification of Cr-spinel shows a systematic trend characterized by an increase of Cr# (atomic ratio of Cr / (Al + Cr)) and a subsequent increase of Fe towards end member of magnetite. Extents of chemical modification along cracks are lower than those along rims, indicating that tensile cracks are formed after commencement of chemical modification along rims. The critical mineral chemistry for fractures is defined as  $Al / (Cr + Al + Fe^{3+}) < 0.15$ . EBSD analyses revealed that sub-grains are dominantly formed in the altered rims and also that tensile cracks are propagated from sub-grain boundaries. Recrystallized micro-grains contain minor sub-grain boundaries and show random orientations, suggesting that they are neoblasts formed by nucleation and growth. The formation of neoblasts is concomitant with Fe-rich parts of Cr-spinel.

The above observations indicate that dislocation-controlled recrystallization depends on chemical compositions of Cr-spinel. Climb velocity of dislocation depends on a self-diffusion coefficient of the slowest diffusing species and self-diffusion coefficient of the slowest Cr in Cr-spinel increases with increasing Cr#. Therefore, it is interpreted that the chemical modification characterized by the increase of Cr# enhanced dislocation motions resulting in the localized sub-grain formation to the chemically modified domains.

We estimated fracture stress (i.e. fracture toughness) of Cr-spinel using a fracture model for a cylinder with a peripheral crack, assuming the widths of chemically modified domains as the potential depths of sub-grain boundaries that act as preexisting cracks. Strength of Cr-spinel is variable depending on mineral chemistry and width of crack and the estimated values for two samples are 84 and 243 MPa. On the other hand, differential stress estimated from dislocation density of olivine is lower than these values. The discrepancy can be explained by concentration of stress due to difference of elastic coefficients of Cr-spinel and surrounding olivine. To support this idea, the maximum intragranular tensile stress in Cr-spinel based on fiber-loading theory is higher than the fracture stress from a cylinder model.

The microstructural analyses reveal that compositional change of Cr-spinel under hydration reactions enhances its plastic deformation to develop weak planar defects such as sub-grain boundaries and grain

boundaries. Fracturing of Cr-spinel can be explained by the chemically induced defects and stress concentration due to the high elastic constant of spinel. It does not require an extremely large stress although the critical strength is variable depending on the Cr# of spinel.