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High-pressure decomposition reaction of albite under differential stresses

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Introduction

Phase transformations of minerals have an important role on the rheology of earth's crust and mantle. Flow properties and the dominant mechanism of deformation are possibly affected through changes of the crystal structure, grain size and polycrystalline texture during the transformation. In this study, we have carried out in-situ X-ray diffraction experiments on the high-pressure decomposition reaction from albite (ab), one end member of plagioclase, into jadeite (jd) and quartz (qz) under uniaxial differential stress. Plagioclase is one of the principal materials that construct the oceanic and continental crust and it is important that consider effects of the decomposition reaction on the crustal rheology.

Experimental Methods

High-pressure deformation experiments of albite were conducted using multi-anvil type deformation apparatus D-CAP 700 installed at the NE-7 beamline of PF-AR, KEK [1]. The plastic deformation and high-pressure transformation processes were simultaneously observed by time-resolved two-dimensional X-ray diffraction (2DXRD) measurements using monochromatic X-ray (energy 50 keV) and imaging plate. 2DXRD patterns were used to obtain the differential stress (Fig.1) and the transformed fraction of the sample (Fig.2). Differential stress was estimated from the distortion of the Debye ring (azimuth angle-dependence of d-values). Plastic strain of the sample was measured from the X-ray radiography images. Synthesized polycrystalline albite with grain size of about 20 micron was uniaxialy deformed in the stability field of both albite and its high-pressure phases with the constant strain rates of $0.3\text{-}6.1\times10^{-5}$/s at 1-4 GPa and 673-1073 K. The maximum axial strain of sample was reached to about 30%.

Results and discussion

Deformation mechanism of albite was investigated from the stress exponent n in the flow law and microstructural observations of recovered sample. In the deformation experiments of albite, the flow strength was obtained after reaching the steady state at about 5 percent strain. The n-value was estimated to be 2.3 from the relationships of the flow stress and strain rate at 873-1073K. The n-value and the elongated grain shape of albite suggest that the dominant deformation mechanism is dislocation creep.

The reaction started at overpressures from equilibrium boundary of 0.4-1.4 GPa and 873-1073K. In contrast with the deformation of albite, differential stresses measured from each phase had not reached steady state and changed with the transformed volume fraction. The differential stresses measured from both parental albite initially increased with the transformed fraction, suggesting the hardening due to the transformation. Microstructural observations revealed that nucleation of high-pressure phases occurred at grain boundaries of parental albite. Those domains have not connected each other ~50% transformation. Therefore albite possibly dominates the deformation of the sample. However in the later stage after the 80% transformation, the value of differential stress of jadeite rapidly dropped by one order of magnitude. We observed the formation of connection of the growth domains as the reaction proceeded, which may change the dominant deformation mechanism and cause the rapid decrease of differential stress of jadeite.

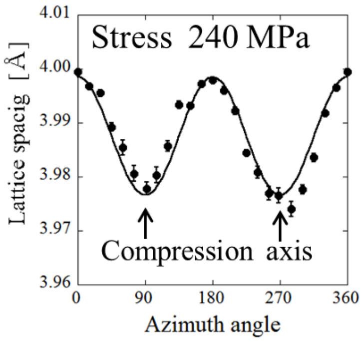

Fig. 1. Plots of the d-values of albite against azimuthal angle deformed at 2.0-2.6 GPa and 1073K with a strain rate of 1.7×10^{-5}/s. Results of the fitting using the lattice strain equation [2] are also shown.

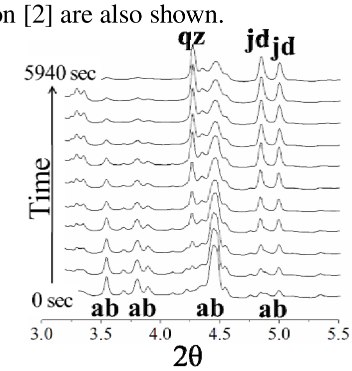

Fig. 2. Changes of X-ray diffraction patterns showing the decomposition reaction of albite (ab) to jadeite (jd) and quartz (qz) deformed at 2.6-3.2 GPa and 1073K with a strain rate of 2.2×10^{-5}/s.

References

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