

Growth of enstatite and enstatite-forsterite reaction rims under wet conditions during isostatic annealing and triaxial deformation

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To investigate the influence of differential stress and microstructure on reaction rates, we studied experimentally enstatite-forsterite double rim formation in between periclase and quartz according to the reaction $\text{MgO} + v\text{SiO}_2 \rightarrow (1-v)\text{Mg}_2\text{SiO}_4 + (2v-1)\text{MgSiO}_3$. In addition, we investigated enstatite single rim growth between quartz and forsterite following the reaction $\text{Mg}_2\text{SiO}_4 + \text{SiO}_2 \rightarrow 2\text{MgSiO}_3$. Isostatic annealing and triaxial compression experiments in both systems were performed in a gas-deformation apparatus at 1000°C temperature and 400 MPa confining pressure. Experimental run durations were in between 4 and 30 h with applied axial stresses between 0 and 46 MPa. Deformation experiments were performed on polycrystalline starting materials. For annealing experiments, we used pairs of polycrystalline aggregates and in addition pairs of oriented single crystals. Dehydrating talc served as a source of water during the experiments, leading to water-solid fractions between 2.2 and 2.8 wt%, depending on the starting assembly.

During annealing, reaction kinetics of the forsterite-enstatite double rim were very fast in the initial stage, but then slowed down dramatically caused by grain coarsening with increasing run duration. The entire enstatite-forsterite double layer widths vary between 2 and 25 μm , depending on time and starting materials microstructure. Double rims between single crystal reactants are considerably thicker compared to reaction rims produced between polycrystalline starting materials. The decelerating growth rate with time can be explained by normal grain growth of product phases in the case of polycrystalline reactants assuming grain boundary diffusion-controlled reaction kinetics. However, grain growth of double rims between single crystals is much faster than expected from diffusion controlled growth. Combined with the large rim thickness between single crystal reactants, the latter indicates solution precipitation control. This interpretation fits to the observed triangular shaped pits at the initially flat single crystal interfaces. Under non-isostatic conditions, the width of enstatite-forsterite double rims is almost independent of the applied axial stresses. Also, observed microstructures of the double rims are virtually similar in isostatic annealed and deformed samples.

Enstatite single rims grown between quartz and forsterite starting materials vary in width between 0.8 and 9.4 μm with enstatite grain sizes smaller 5 μm . Similar to the double rim formation between quartz and periclase, the enstatite single rims are thicker between single crystal reactants than for polycrystalline starting materials and the rim thickness do not change with the magnitude of differential stress during deformation.

Our observations suggest that the reaction kinetics of enstatite single rim and enstatite-forsterite double rim growth is not affected by differential stress. The stress-strain induced change in the driving force of enstatite and forsterite is negligibly small at our experimental conditions. These results are in agreement with previous observations in the carbonate system.