Na-K-Interdiffusion in Alkali Feldspars

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Exchange experiments between crystallographically oriented plates of gem-quality alkali feldspar (X_{Or} 0.85) with NaCl/KCl melts have been conducted at 850˚ and 920˚C. The melt composition was varied systematically between X_{KCl} 0.6 and 1 to induce a shift of the feldspar composition towards more Na-rich as well as K-rich compositions (X_{Or} 0.74 to 1). We applied 40-times molar excess of cations in the melt to ensure constant concentration boundary conditions for cation exchange.

Depending on the direction of the composition shift diffusion profiles with different geometries develop. After a shift towards more K-rich compositions the diffusion profile shows two plateaus representing the unexchanged core and the exchanged rim in equilibrium with the melt, respectively. The exchange front between the two plateaus has an inflection point and propagates through the crystal with $t^{1/2}$. Its width depends on the composition difference between the exchanged and unexchanged domains of the grain as well as crystallographic direction.

The profiles that develop during a shift towards more Na-rich compositions lack an inflection point. If X_{Or} is shifted by more than 10 mole-% crack systems begin to develop due to composition strain associated with the substitution of K^+ by the smaller Na^+ion.

While the propagation rate of the fronts is roughly equal in all crystallographic directions, the profiles measured in the direction normal to (001) are always narrower than those normal to (010). This indicates a marked anisotropy in interdiffusion which appears fastest in the direction perpendicular to (001), i.e. c^*.

The observed geometry of the diffusion fronts can be explained by a composition dependence of the interdiffusion coefficient. This dependence was first described by Christoffersen et al. (1983) but these authors used a different experimental setup and only had reliable data for intermediate compositions. From our data we could extract the interdiffusion coefficient for high X_{Or} with help of the Boltzmann Transformation. The Na-K interdiffusion coefficient increases with a gentle slope from 0.3 to 0.8 x $10^{-15} m^2 s^{-1}$ for the composition interval between X_{Or} 0.80 and 0.97 and then rises steeply to values of 2.2 x $10^{-15} m^2 s^{-1}$. In the composition interval between X_{Or} 0.74 and 0.80 the interdiffusion coefficient decreases slightly from 0.4 to 0.3 x $10^{-15} m^2 s^{-1}$. On the whole this results in a "bowl shaped" composition dependence of the interdiffusion coefficient in the composition range X_{Or} 0.74 to 1. This deviates from what is expected from theoretical calculations using the Manning relation for interdiffusion (Christoffersen et al., 1983). The strong direction dependence of the diffusion profiles may indicate that interdiffusion is influenced by the coherency stress across the diffusion front.

References

Christoffersen et al. (1983): Interdiffusion of K and Na in alkali feldspar: diffusion couple experiments, -American Mineralogist, Vol. 68, pp. 1126-1133