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Potassium self-diffusion in a K-rich single-crystal alkali feldspar

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The rock-forming alkali feldspars belong to the most abundant minerals in the Earth's crust and are formed as a solid solution between the sodium ($NaAlSi_3O_8$, albite) and potassium ($KAlSi_3O_8$, orthoclase) end-member compositions. Well-founded knowledge of self-diffusion data in alkali feldspar is a prerequisite for interpreting existing interdiffusion data that, in turn control re-equilibration features in alkali feldspar that pertain to evolution and dynamics of the crust. Previous studies on alkali diffusion in alkali feldspar mostly concern the sodium component. Potassium self-diffusion has hitherto been investigated employing a bulk-exchange method to investigate grains from crushed feldspar. However, this method is unable to provide any information about tracer depth distributions and suitable diffusion models must therefore be presumed, rendering the method non-sensitive towards diffusion anisotropy or structural inhomogeneities. The here presented results of potassium diffusion were obtained on gem-quality single-crystal alkali feldspar utilizing the on-line diffusion chamber located at the ISOLDE facility in off-line mode. The natural, single-crystal sanidine from Volkesfeld, Germany, was implanted with ^{43}K at the ISOLDE/CERN radioactive ion-beam facility normal to the (001) crystallographic plane. Afterwards, isothermal annealing was done in a temperature range from 1021 to 1169 K followed by serial sectioning via ion-beam sputtering and recording of the corresponding γ-spectra of each section with a NaI-detector. The diffusion coefficients, derived from the obtained tracer penetration depth profiles, can be well described by the Arrhenius equation with an activation energy of 2.4 eV and a pre-exponential factor of 5×10^{-6} m^2/s. This is more than three orders-of-magnitude lower than the ^{22}Na diffusivity in the same feldspar with the same crystallographic direction ruling out a vacancy controlled diffusion mechanism for alkali diffusion in alkali feldspar. State-of-the-art considerations including ionic conductivity data on the same crystal type and Monte Carlo simulations of diffusion in random binary alloy structures reveal a predominance of indirect interstitial jumps (I-S/S-I) over direct interstitial jumps (I-I), pointing towards correlated motion of K and Na through the interstitialcy mechanism.

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