



Fe-Mg interdiffusion coefficients in orthopyroxene determined using nanoscale thin films of olivine as a diffusion couple

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Despite clear relevance for determining closure temperatures of geothermometers and for determining cooling rates from compositional profiles, Fe-Mg diffusion rates in orthopyroxene have not yet been determined directly due to experimental difficulties. Available information on Fe-Mg interdiffusion comes from (1) Mg tracer diffusion coefficients obtained from isotope tracer studies using enriched ^{25}MgO films [1], (2) calculations of interdiffusion rates based on the (diffusion-controlled) order-disorder kinetics measured in orthopyroxene [2], and (3) indirect estimates from the comparison of diffusion widths in coexisting garnets and olivines, in which Fe-Mg diffusion rates are relatively well known [e.g., 3].

We have directly measured Fe-Mg interdiffusion coefficients parallel to [001] in two natural orthopyroxene single crystals (approximately $\text{En}_{95}\text{Fs}_5$ and $\text{En}_{90}\text{Fs}_{10}$) using diffusion couples consisting of an olivine thin film ($\text{Fo}_{30}\text{Fa}_{70}$, typically 20 - 50 nm thick) deposited under vacuum on pre-heated, polished and oriented pyroxene single crystals using a pulsed laser ablation deposition technique. Samples were annealed for 4 - 337 hours at 800 - 1100 °C under atmospheric pressure in a continuous flow of $\text{CO} + \text{CO}_2$ to control the oxygen fugacity between 10^{-16} and 10^{-12} bar within the stability field of pyroxene. Film thickness and compositional profiles were measured using Rutherford backscattering Spectroscopy (RBS) on reference and annealed samples,

and Fe concentration depth profiles were extracted from the RBS spectra and fitted numerically.

Comparison of our data with other Fe-Mg diffusion data shows that these diffusion coefficients are (1) similar to Mg tracer diffusion coefficients measured in orthopyroxene at somewhat more reducing (e.g. $fO_2 = 10^{-16}$ to 10^{-19} bar) conditions at the same temperatures [1], (2) similar to Mg tracer diffusion in garnets measured at higher pressures of 10 kbar at an oxygen fugacity corresponding to the C-O equilibrium in graphite present systems [4], and (3) slower than Fe-Mg diffusion rates in olivine by a factor of ~ 10 at the same oxygen fugacities [5].

When our diffusion coefficients are applied to compositionally zoned crystals of orthopyroxene, common in meteorites, mantle rocks, lower crustal rocks and a variety of plutonic and volcanic igneous rocks, better constraints on the cooling histories of these rocks can be derived. Furthermore, comparison of cooling rates from zoned orthopyroxenes with estimates using compositionally zoned crystals of other minerals (e.g., olivine) within the same rock can be used to improve the results and test if they are consistent for different minerals.

References: [1] Schwandt et al. (1998), *Contr. Mineral. Petrol.* 130: 390-396; [2] Ganguly and Tazzoli (1994), *Am. Mineral.* 79: 930-937; [3] Smith and Barron (1991), *Am. Mineral.* 76: 1950-1963; [4] Ganguly et al. (1998), *Contr. Mineral. Petrol.* 131: 171-180; [5] Chakraborty (1997), *J. Geoph. Res.* 102: 12317-12331.