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Quantitative measurement of short compositional profiles using analytical transmission electron microscopy

Elke Meissner,[1,*] Thomas G. Sharp,[2] and Sumit Chakraborty[3]

[1]Bayerisches Geoinstitut, Universität Bayreuth, D-95440 Bayreuth, Germany
[2]Department of Geology, Arizona State University, Tempe, Arizona 85287-1404, U.S.A.
[3]Institut für Mineralogie und Geochemie, Universität zu Köln, Zülpicher Strasse 49B, D-50674 Cologne, Germany

Abstract

Analytical transmission electron microscopy (ATEM) was used to quantitatively measure sub-micrometer compositional profiles produced experimentally by Fe-Mg interdiffusion experiments in olivine. Although analysis of minerals by ATEM is common, compositional profiles suitable for quantitative modeling of diffusion are not generally measured in minerals with ATEM. To demonstrate the suitability of ATEM for diffusion studies in minerals, we have investigated Fe-Mg interdiffusion in experimentally annealed olivine. Because the compositional gradients were induced under well-controlled laboratory conditions, the accuracy of the measurements could be tested by comparing compositional profiles measured by both ATEM and EMPA as well as by retrieving diffusion coefficients from both TEM and EMPA data. The agreement in diffusion coefficients shows that point defect equilibration in the interfacial region of the diffusion couple occurs extremely rapidly at 1200 °C. The ability to obtain diffusion data from such short anneals enables various experiments that were not previously possible—for example, to study diffusion rates at high pressures where long f_{O_2} buffered anneals are not generally feasible. ATEM profile measurement is compared with other techniques such as SIMS and RBS and some limitations and applications of ATEM profile measurements are also discussed.