Calcium Diffusion in Olivine Revisited

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Due to its widespread occurrence, high thermal stability and relatively simple anisotropic properties, olivine is commonly utilized for geospeedometry in both terrestrial igneous rocks and meteorites. Previous work [1] has shown that Ca diffusion is more than one order of magnitude slower that Fe-Mg diffusion in olivine at > 900 °C, which means that Ca diffusion profiles can be used to complement Fe-Mg speedometry or provide timescale information after Fe-Mg profiles have been thoroughly re-equilibrated.

We have conducted Ca diffusion experiments along [100] in synthetic forsterite at 1 atm. from 750 – 1300 °C, with silica activity (a_{SiO2}) buffered by either forsterite–diopside–enstatite or forsterite–diopside–periclase. The resulting profiles were measured via SIMS depth profiling using the SwissSIMS 1280-HR housed at the University of Lausanne. Time-series experiments have been carried out at 750 and 1100 °C. Our results are in good agreement with the dataset of [1], and expand the range of experimental temperatures reported in that study. In contrast to other divalent cations in olivine [2], there appears to be no dependence of Ca diffusion on a_{SiO2}. This observation could be explained by Ca ordering onto the M2 site in olivine, while M-site vacancies prefer the M1 site [3].

Following our successful reproduction of the results of [1] using SIMS, we are developing local electrode atom probe tomography (LEAP) for use in experimental diffusion studies; however, at the time of this writing we have only collected preliminary LEAP data from synthetic forsterite (Cameca LEAP 4000X-HR at ETH Zürich). Atom probe needles are currently being prepared from the time-series experiments in order to verify that the SIMS and LEAP analyses yield the same results. Subsequently, we will focus on devloping sample preparation and analytical protocols to push LEAP towards resolving the shortest possible diffusion profiles.

References:

[1] Coogan *et al.* (2005) *GCA* **69**, 3683-3694.
[2] Zhukova *et al*. (2014) *CMP* **168**, 1-15.

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[3] Brodholt (1997) *AmMin* **82**, 1049-1053.