Atom probe tomography of olivine and clinopyroxene grain and phase boundaries in deformed wehrlite

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The dynamics of the upper mantle is controlled by the rheology of olivine (ol) and pyroxene (px). Rheological experiments demonstrate that grain boundary sliding along ol-px phase boundaries is faster than sliding along ol-ol grain boundaries [1,2], and that olivine deformed via diffusion creep is weaker when grain boundaries contain impurities [3].

Here we use atom probe tomography (APT) to measure the chemistry of ol-ol, ol-clinopyroxene (cpx), and cpx-cpx grain boundaries from a fine-grained, experimentally-deformed wehrlite. Ol-ol and ol-cpx tips were analyzed in a LEAP4000HR (Harvard University) while the cpx-cpx tip was analyzed in a LEAP5000 (University of Alabama). Chemical profiles of compatible and incompatible elements are used to estimate the chemical widths of grain boundaries.

Chemical grain boundary width depends on the element that is analyzed. Incompatible elements enriched on ol-ol grain boundaries include Na, Al, P, Cl, K, Ca, and Ni. Enrichment on cpx-cpx grain boundaries is observed very weakly for Al and Ca. Ol-cpx grain boundaries are estimated from incompatible (Cl) and compatible elements (Na, Mg, Al, Si, Ca, and Fe). The average chemical width for ol-ol is 3.3 nm while the average chemical width for ol-cpx is 4.6 nm. Ol-ol estimates are consistent with prior estimates of grain boundary widths by APT [4]. For chemical profiles observable in both ol-cpx and ol-ol, the ol-cpx widths are approximately 40% wider than those observed in ol-ol.

These results complement the results shown in reference [1], and imply that the chemistry of grain and phase boundaries could affect strain localization observed in nature (e.g. lithospheric shear zones). The widths of grain and phase boundary chemistry is uniquely measurable by APT and allows for improved understanding of mantle rheology and transport (or storage) of incompatible elements.

[1] Zhao, N., et al., (2017), *Abstract MR41D-0424: presented at 2017 Fall Meeting,* AGU. [2] Sundberg, M., and R. F. Cooper (2008), *J. Geophys. Res.*, **113**, B12208. [3] Marquardt, K., and Faul, U. H. (2018), *Physics and Chemistry of Minerals*. [4] Bachhav, M., et al., (2015), *Microsc. Microanal.,* **21 (Suppl 3)**.