Report from the CIDER Working Group on

Reconciling laboratory measurements on the electrical conductivity of hydrous olivine

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The *Electrical Conductivity of Hydrous Olivine Working Group* was formed with CIDER support to discuss and attempt to resolve a long-standing discrepancy in electrical conductivity measurements on hydrous olivine samples. Existing laboratory studies all agree that structurally incorporated hydrogen defects, colloquially referred to as water, enhance the electrical conductivity (EC) of olivine. However, the measurements from independent laboratory groups diverge by more than an order of magnitude regarding the sensitivity of olivine EC to the concentration of incorporated water. Such a large discrepancy leads to conflicting interpretations of magnetotelluric soundings on the role of water in upper mantle processes.

A recent analysis by *Gardés et al* (2014) suggested the discrepancy between published EC measurements can be resolved by accounting for errors in the estimated water concentration of individual samples. The water concentrations were typically measured with FTIR (Fourier Transform Infrared Spectroscopy), which has been shown to underestimate the water content in olivine by up to a factor of four. In an effort to better quantify this bias, we gathered over 30 hydrated olivine samples from several sources and used the nanoSIMS (Secondary Ion Mass Spectrometry) facility at the Carnegie Institution of Washington to measure the total water concentration in each sample for comparison with prior FTIR measurements.

We are in the process of compiling the sample descriptors and nanoSIMS measurements, which upon completion will be uploaded to the EarthChem online repository for public use. In addition, a manuscript describing the dataset, including sample compositions, FTIR spectra, and nanoSIMS measurements, is currently being prepared for publication. Table 1 lists details for the measured samples.

Workshop Outcomes

In August 2016, results from the nanoSIMS measurements were shared and discussed during a two-day workshop at the Department of Terrestrial Magnetism campus of Carnegie Institution of Washington. The meeting brought together 20 participants, which are listed in Table 2. Selected participants gave presentations reviewing instrumentation and laboratory practices on measuring EC with impedance spectroscopy and on measuring water concentrations with FTIR and SIMS.

Open discussions touched on a wide range of topics. Our working group reached consensus on a number of points regarding **FTIR laboratory protocols:**

- several FTIR spectra should be recorded per sample to improve measurement uncertainties
- FTIR spectra should be recorded both before and after measuring EC of a sample
- raw FTIR spectra should be included in published work, or uploaded to an online repository such as the PULI spectral database (http://puli.mfgi.hu)
- for single crystals, polarized FTIR should be used whenever possible
- when using unpolarized FTIR, avoid the Paterson (1982) calibration since it is difficult to backtrack and apply corrections
- if normalized unpolarized FTIR spectra are given, also report the non-normalized sample thickness and the baseline correction
- if using the Paterson (1982) calibration, report the area beneath the spectra

Our working group also prioritized **research needs going forward:**

- A recurring theme was the need to better understand "site-specific" hydrogen incorporation and diffusion and how it influences EC
- Studies have focused on measuring EC of hydrated olivine. Future work should also consider pyroxenes, which have the capacity to hold much more water than olivine and thus may contribute significantly to conduction
- More deuterium-hydrogen diffusion experiments on olivine as well as other nominally anhydrous minerals (pyroxenes, garnets)
- New techniques for measuring EC of hydrated samples at high temperatures are needed, currently not possible due to dehydration related issues
- More EC experiments on effect of grain size and grain boundary diffusion.
- What is the effect of carbon (and other impurities) along grain boundaries on EC of hydrous samples?
- Need tighter constraints on mineral-mineral water partitioning to better understand which hydrous mineral phases may dominate mantle EC

Table 1: Olivine sample characteristics. Unpolarized FTIR used Paterson (1982) calibration. Polarized FTIR used Bell et al (2003) calibration. ND: yet to be measured. TBD: water contents not yet determined from existing FTIR spectra. SZ: significant zonation with higher concentrations on the rims. *Samples not published as of March 2017.

Sample	Crystal (single/poly)	Source	H_2O wt ppm (SIMS/FTIR)	FTIR
s1	single	Yang (2012)	14/40	Polarized
f1	single	Yang (2012)	20/35	Polarized
f2	single	Yang (2012)	30/40	Polarized
f3	single	Yang (2012)	19/35	Polarized
1K453	single	Yoshino et al (2006)	272/220	Unpolarized
1K472	single	Yoshino et al (2006)	76/90	Unpolarized
1K473	single	Yoshino et al (2006)	678/220	Unpolarized
5K1126	poly	Yoshino et al (2009)	99/80	Unpolarized
5K1122	poly	Yoshino et al (2009)	ND/1600	Unpolarized
5K1112	poly	Yoshino et al (2009)	ND/1600	Unpolarized
PC28	single	Du Frane & Tyburczy (2012)	74/ND	only SIMS
6841	poly	Faul*	62/ND	Unpolarized
6850	poly	Faul*	40/ND	Unpolarized
1579	poly	Faul*	16/ND	Unpolarized
6772	poly	Faul*	78/ND	Unpolarized
K1697-A	single	Sun & Karato*	SZ/TBD	Unpolarized
K1694-B	single	Sun & Karato*	SZ/TBD	Unpolarized
SC1-2	single	Ferriss*	5/4	Polarized
Kiki1	single	Ferriss*	14/19	Polarized
5K2812	poly	Yoshino*	2568/ND	Unpolarized
5K2820	poly	Yoshino*	1821/ND	Unpolarized
5K2813	poly	Yoshino*	278/ND	Unpolarized
5K2821	poly	Yoshino*	235/ND	Unpolarized
5K2871	poly	Yoshino*	1727/ND	Unpolarized
5K2897	poly	Yoshino*	138/ND	Unpolarized
5K2900	poly	Yoshino*	225/ND	Unpolarized
1K2429	poly	Yoshino*	23/ND	Unpolarized
1K2448	poly	Yoshino*	4764/ND	Unpolarized
1K2434	poly	Yoshino*	298/ND	Unpolarized
1K2449	poly	Yoshino*	311/ND	Unpolarized
1K2541	poly	Yoshino*	303/ND	Unpolarized

Table 2: Workshop participants

Participant	Affiliation
Simon Clark	Macquarie University
Moussa Dia	William & Mary
Wyatt Du Frane	Lawrence Livermore National Lab
Uli Faul	Massachusetts Institute of Technology
Elizabeth Ferriss	Lamont-Doherty Earth Observatory
Gordana Garapic	State University of New York, New Paltz
Erik Hauri	Carnegie Institution of Washington
Shun Karato	Yale University
Jed Mosenfelder	University of Minnesota
Samer Naif	Lamont-Doherty Earth Observatory
Mattia Pistone	Smithsonian Institution
Adam Sarafian	Woods Hole Oceanographic InstitutionI
Emily Sarafian	Woods Hole Oceanographic Institution
Pavithra Sekhar	Virginia Tech
Peng Sun	Yale University
James Tyburczy	Arizona State University
Peter van Keken	Carnegie Institution of Washington
Lara Wagner	Carnegie Institution of Washington
Tony Withers	Western University
Takashi Yoshino	Okayama University

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