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Determination of hydrogen concentrations and speciation in terrestrial and chondritic olivines by atom probe tomography

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Chondrules are emblematic polycrystalline assemblages formed early in the inner part of the protoplanetary disk. They formed at high temperatures and are mainly composed of olivine, pyroxene and glass. As an archetypal nominally anhydrous mineral (NAM), water content in terrestrial olivine is low (< 240 ppm H_2O). Surprisingly, recent secondary ion mass spectrometry analyses of chondritic olivine suggested an anomalously high concentration of hydrogen, 10 to 100 times higher than what is found in terrestrial olivine [1]. The origin of this anomaly in olivine is uncertain and controversial [2, 3]. It may be due to the presence of hydrous precipitates or hydrous glasses or organic-rich inclusions. Analytical artefacts due to the sample preparation, or the large amounts of H-bearing phases in the fine-grained matrix surrounding the chondrules cannot be excluded. To better assess the presence of hydrogen in olivines in chondrules, we used atom probe tomography (APT) on a series of terrestrial and synthetic NAM (olivine and pyroxene) containing known concentrations of hydrogen, together with olivine selected in the Aguas Zarcas (AZ) CM 2.2 chondrite. Samples for APT were all prepared by lift out and annular milling using focused ion beam (FIB) from pure single crystals. Thus, no epoxy nor matrix were left, avoiding any potential contamination. Fine scale investigation of the same regions of crystals by transmission electron microscopy shows no evidence of aqueous alteration nor mineral/glass inclusions. The APT results unambiguously confirm that a significant amount of hydrogen is present in AZ chondrule olivine as compared to terrestrial (San Carlos, Arizona) olivine. Furthermore, hydrogen appears uniformly distributed, confirming the absence of hydrated inclusions at the nm scale. Mass spectra help to derive the speciation of hydrogen in AZ chondrite. Finally, an ongoing standardization of these APT mass spectra with terrestrial minerals help us to provide a robust estimate of this hydrogen content.

References:

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