SIMS analysis of hydrogen in nominally anhydrous minerals (NAMs): Technical Challenges and Implications

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Numerous studies in the past three decades have demonstrated that nominally anhydrous minerals (NAMs) -- such as olivine, pyroxene, plagioclase, and garnet -- can contain from a few to hundreds of parts per million (ppm) water, mainly as structurally bound OH. These discoveries fundamentally changed the view that major mantle minerals are "dry" and established NAMs as important reservoirs and carriers of water in planetary interiors [e.g., 1-4]. SIMS has played a critical role in detecting and measuring such low water abundances because of its high sensitivity, micrometer-scale spatial resolution, and ability to analyze zoned or inclusion-rich samples *in situ* [5-7]. This presentation discusses the analytical challenges and caveats inherently associated with SIMS analysis of water in NAMs, and highlights its broad implications for geosciences.

There are five important aspects that must be carefully addressed when measuring extremely low water contents in NAMs by SIMS: (1) sample preparation; (2) sample residence time in vacuum; (3) instrumental and analytical conditions; (4) standard selection and calibration strategy; and (5) examination and selection of targeting spot during analysis. To achieve the lowest detection limits and the most accurate results, all these factors must be optimized.

SIMS analysis of water in NAMs has yielded broad and significant implications in geosciences. It has led to major re-evaluations of its mantle water budget, mantle rheology, melting behavior, and volatile recycling through subduction [2-4]. For planetary materials, SIMS analysis of NAMs, in addition to apatite and melt inclusions, has shown that the Moon is not completely dry, but retains indigenous magmatic water, providing new perspectives on lunar origin and differentiation [8-10]. Comparable analyses of NAMs in Martian meteorites indicate that Mars possessed heterogeneous mantle reservoirs containing water and other volatiles, with later exchange among mantle-derived magmas, crust, and atmosphere [11-12]. In primitive asteroids and differentiated parent bodies, water in NAMs provide constraints on accretion, thermal metamorphism, aqueous alteration, and volatile retention during early Solar System evolution [13]. Continued improvements in SIMS analytical techniques will advance our understanding of water and other volatile inventories in rocky planets and asteroids.

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