

Nanoscale tracking of oxygen diffusion pathways in oxide ion conductors

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Solid oxide cells which convert chemical energy to electrical energy offer a possible technology for both near and long term efficient and clean energy generation systems [1, 2]. In particular, mixed ionic-electronic conducting oxide (MIEC)-based ceramics, which combine electronic and ionic conductivity, exhibit a promising combination of catalytic and transport behavior for both stationary and portable power generation. [3]. The engineering of the electrochemical properties of MIEC materials at the grain boundaries and phase boundaries has shown great potential [4-6]. In order to improve upon the design of such materials, a better understanding of the nanoscale structure and especially the direct analysis of how the boundaries affect oxygen transport is valuable.

Atom probe tomography (APT) has the unique ability to probe the nanoscale 3-D distribution of species down to tens of parts-per-million concentrations. This has provided fundamental insights into the compositions and composition profiles in and around precipitates, grain boundaries, phase boundaries, and dislocations in metal alloys, electronic materials, and ceramic materials [7]. Additionally, since this time-of-flight technique has sufficient mass resolution to detect particular isotopes of species, as shown in Figure 1a, the introduction of tracer isotopic species can be used to distinguish sources of an element. For example, this technique has been used to investigate hydrogen embrittlement of steels using a deuterium tracer [8].

Here, annealing of lanthanum manganite and chromite films and multiphase MIEC structures at controlled temperatures and times was carried out in an atmosphere containing an ¹⁸O isotopic tracer followed by APT analysis of these materials. From the measured distribution of the ¹⁸O species, the diffusion of reactant oxygen is distinguished from that in the original oxide structures allowing fundamental investigations on oxygen kinetics at the nanoscale. As exemplified in Figure 1b, the local distribution of ¹⁸O (and other species) throughout the MIEC materials are visualized and quantified. This work presents a potentially important tool for assessing the nanoscale transport behavior in oxide ion conducting materials [9].

References

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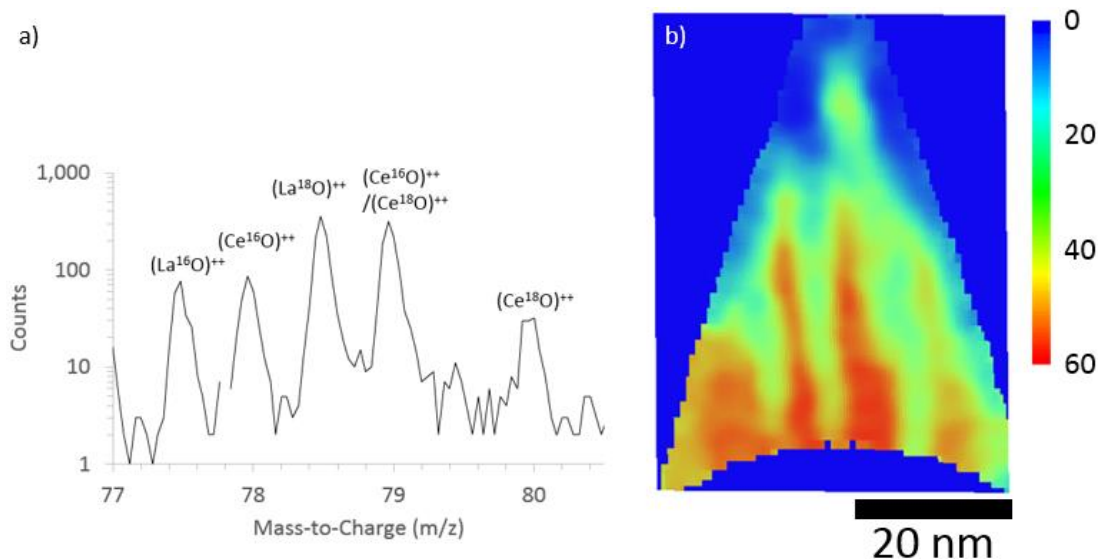


Figure 1. a) Portion of the APT mass spectrum from an MIEC material showing clear resolution of peaks related to the different oxygen isotopes. b) Slice through the APT reconstruction showing the atomic percent distribution of ^{18}O .

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