Supporting Information

Experimental Methods

Samples of $La_2Mo_2O_9$ were prepared using conventional solid state synthesis, as previously reported[15]. $La_{0.8}Sr_{0.2}MnO_{3-\delta}$ samples were obtained from Praxair Surface Technologies, USA. Two sets of samples were then prepared for further analysis, as described previously[15]. Briefly, for the first set of sample, the powders of LM and LSM were uniaxially and isostatically pressed to form 13mm diameter dense pellets. The faces of these pellets were polished and the dense pellets placed together and annealed at temperatures of 1050 °C and 1150 °C. For the second set of samples, solutions of $Sr(NO_3)_2$ and $(NH_4)_6Mo_7O_{24}.4H_2O$ were prepared and deposited onto the surfaces of pellet samples. An aqueous solution of $Sr(NO_3)_2$ (99% pure, Hopkin & Williams) with a concentration of 0.25 M was dropped on top of the polished face of a LMO pellet and dried at 80°C. The amount of the desired element on the surface of the pellet was fixed at 5 mg/cm^2. After the evaporation of the solution, the diffusion of strontium in LMO was performed by annealing the sample at 1150 °C for 12 hours in static air. The diffusion of molybdenum in LSM was also studied by dropping an aqueous solution of $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ (99% pure, BDH Analar Chemicals) with a concentration of 0.25 M on the polished face of a LSM pellet. The solution deposition and diffusion annealing conditions were identical to those used for diffusion of strontium in LMO. Full details of the sample preparation is provided in ref S1. All samples were examined by powder X-ray diffraction (PANalytical X'Pert Pro, Cu K_α) to probe any phase changes on annealing.

A Focused Ion Beam Secondary Ion Mass Spectrometry (FIB-SIMS) instrument (FEI FIB200-SIMS) was used for SIMS analysis and *in-situ* surface imaging. A high-

brightness gallium liquid-metal ion source is used to generate the ion beam to bombard the sample surface, with the voltage at 30 kV and an estimated beam size of 50 nm. Depth profiling was carried out over an area of 20 x 20 μm^2 with a beam current of ~3 nA. After sputtering, the depth of the crater was measured by FIB-SIMS, and cross-verified by white light scanning interferometry (Zygo NewView). The rates of sputtering for LM and LSM pellets were calculated as 0.36 μm/sec and 0.29 μm/sec, respectively.

For characterisation of the solution deposited samples TOF-SIMS measurements were performed (TOFSIMS V IonTof, GmbH, Munster, Germany). For linescan measurements acquired through mapping of cross-sectional samples the instrument was operated in burst alignment mode, using a 25 keV Bi^+ analysis beam and a 2keV Cs^+ sputter beam. The sputtered area was 500 μm x 500 μm. For the depth profile measurements the instrument was operated in high current bunch mode with a 25 keV Bi^+ analysis beam and 2 keV Cs^+ sputter beam. Analysis areas in this case were 200 μm x 200 μm with the sputter area being 500 μm x 500 μm.

After solution deposition on the pellets and annealing of these samples at temperatures of up to 1150 ^{o}C, the samples were cooled down. A section of the pellet was then cut out and one of the cross-sectional surfaces was polished. TOF-SIMS "chemical" mapping was then performed on the polished cross-sectional surface (schematic representation in Figure S1). From the dataset, the distribution of a selected chemical element(s) in any area or direction of interest from any point of the TOF-SIMS "chemical" maps can be obtained through integration of the area selected. Using this integration technique effective linescans are obtained.

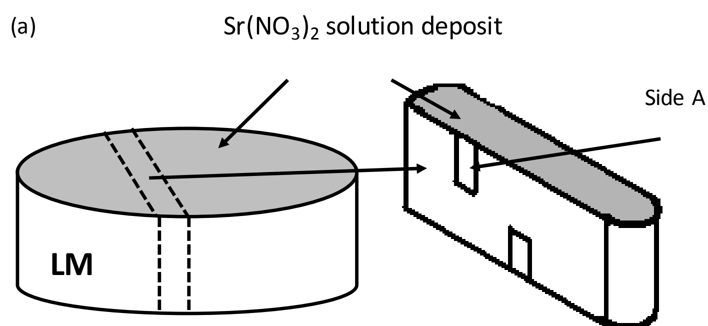

Figure S1. Schematic detailing the sample preparation for a TOF-SIMS line scan measurement of a sample of $La_2Mo_2O_9$ after deposition with $Sr(NO_3)_2$ solution and annealing at 1150˚C for 12 hours. A sample section is cut perpendicular to the original sample surface. This cut face is then polished and 500 x 500 μm areas analysed, indicated as Side A.

References.

[S1] U.K. Ravella, J. Liu, G. Corbel S.J. Skinner P. Lacorre, *ChemSusChem*, **2016**, 8, 2182-2192.