# Hard X-Ray Analysis of Composition and Electronic Structure of Cathode Materials

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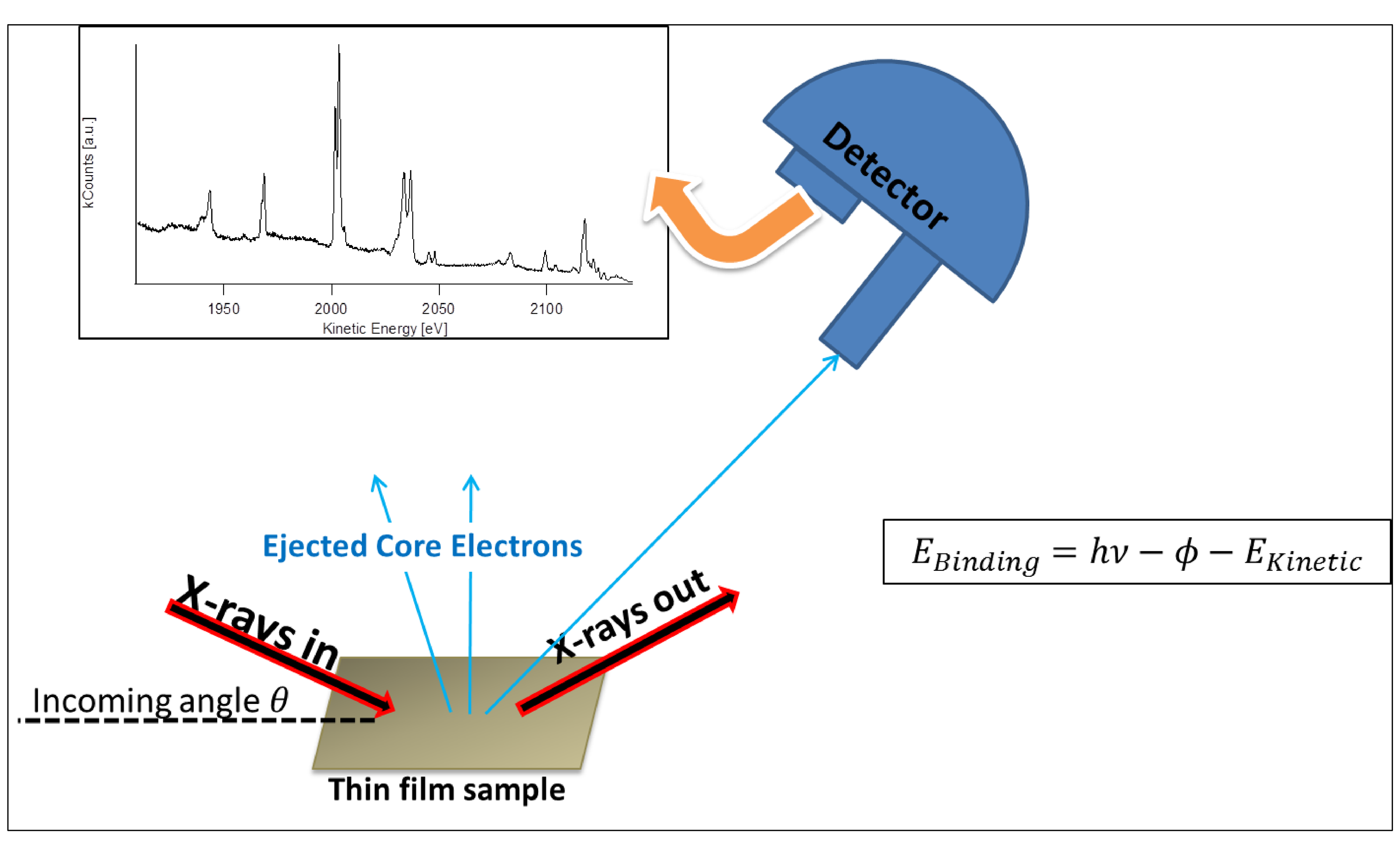
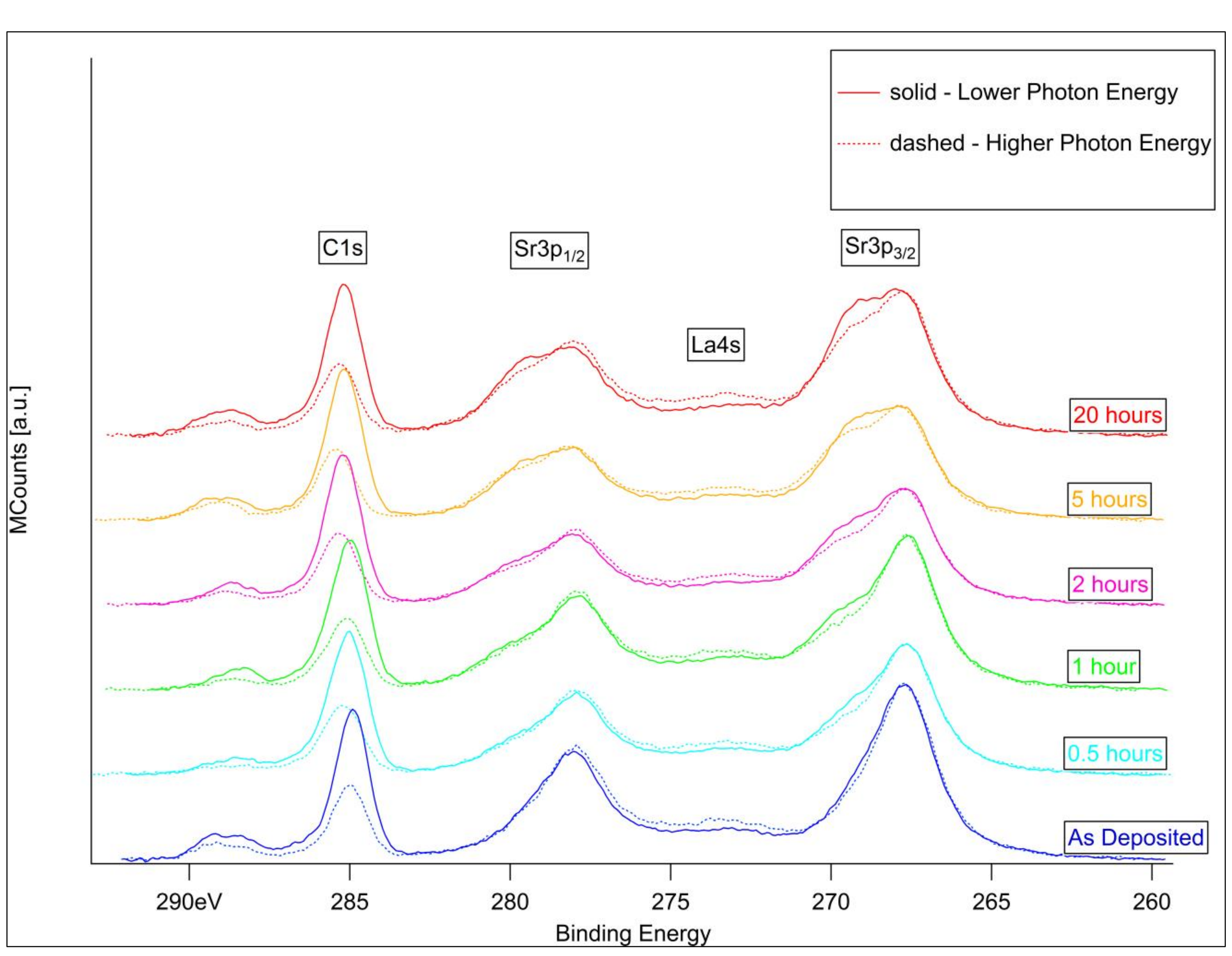
## Introduction

By understanding the compositional and electronic changes of the surfaces of thin films of solid oxide fuel cell (SOFC) cathode material, efficiency and cost of devices can be optimized. In this project, thin films were used to define a large gas-cathode interface. Total X-ray Reflection Fluorescence (TXRF) measurements show compositional changes occurring in the surfaces of LSM and LSCF upon annealing. Hard X-ray Photoelectron Spectroscopy (HAXPES) was used to reveal the electronic structure changes occurring.

## Hard X-ray Photoelectron Spectroscopy (HAXPES)

HAXPES offers some advantages over lower energy XPS techniques. Higher incident photon energies overcome surface contamination and result in improved signals without the need to heat in vacuum. Also, HAXPES allows for a tunable penetration depth, so correlations can be made between the depth dependence seen in composition by TXRF and oxidation states of cations.

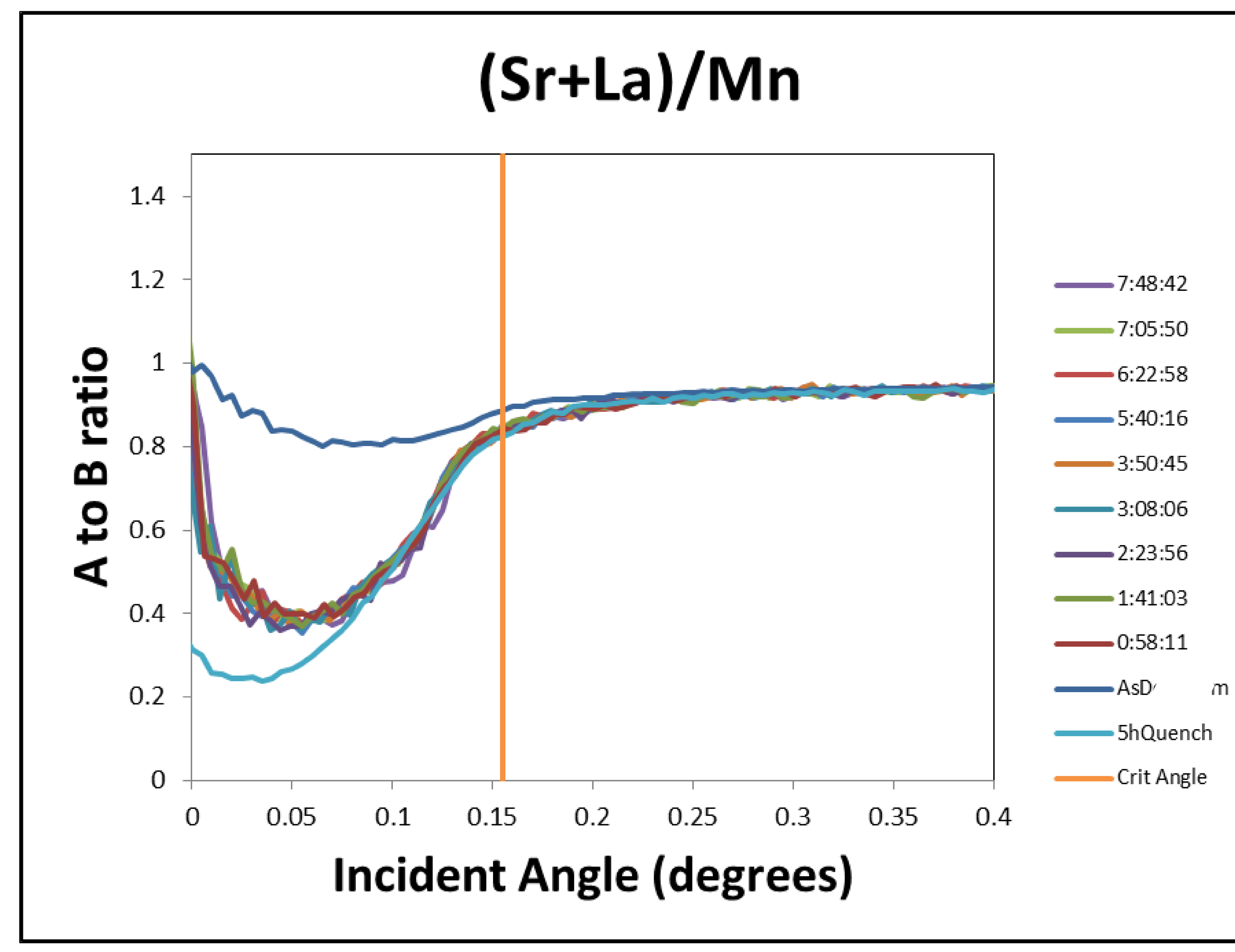


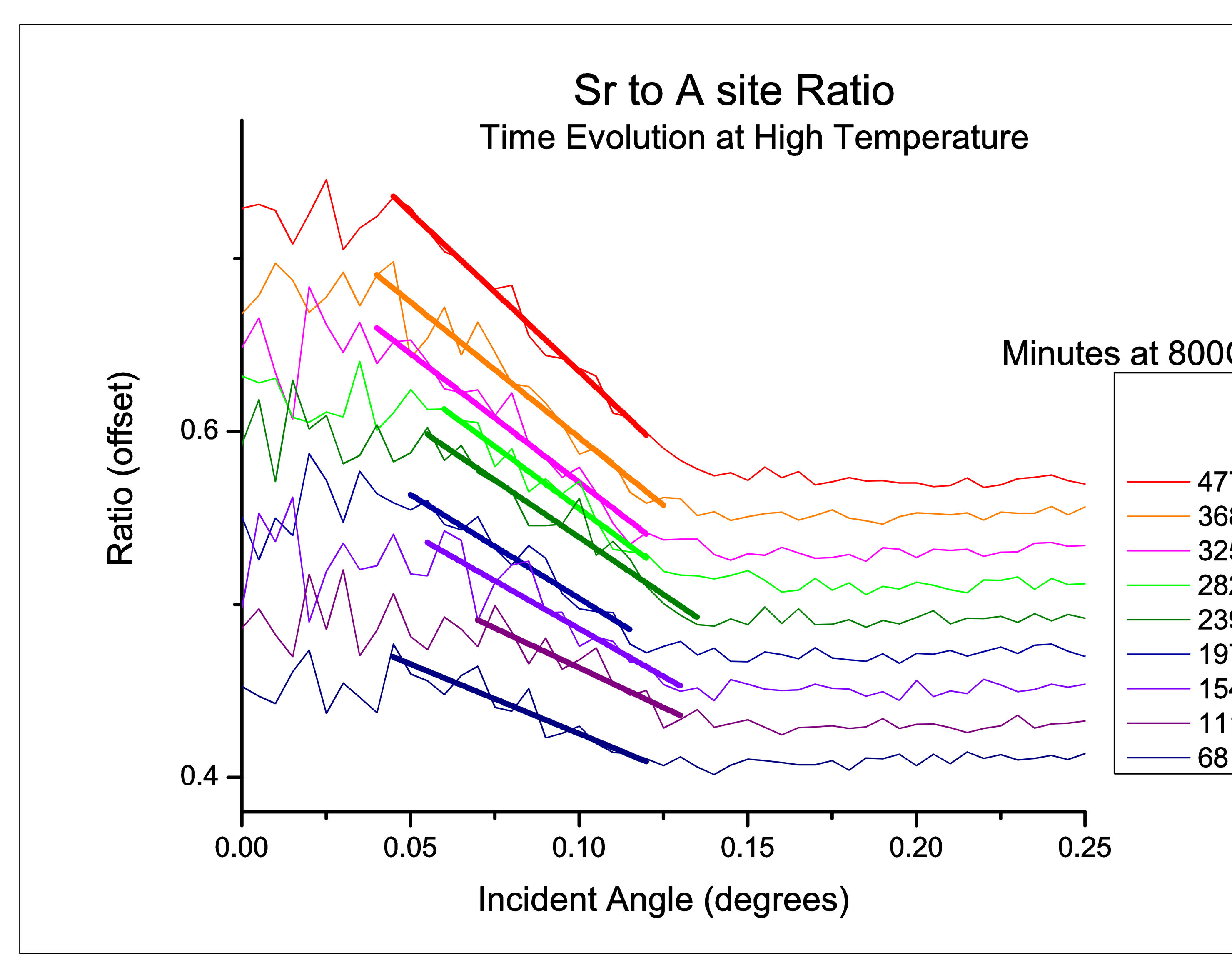

LSCF HAXPES spectra for carbon 1s, lanthanum 4s, and strontium 3p. Offset are data from an as-deposited sample as well as samples quenched from 800°C after various annealing times. Data was taken with incident photon energies of 2140eV and 3000eV.

## Total X-Ray Reflection Fluorescence (TXRF)

Probing with an incident angle larger than the critical angle $\alpha_c$, x-rays penetrate the entire sample and bulk properties are measured. Carefully controlling the incident beam, the sample is scanned through the critical angle. At low angles the beam is totally reflected and only the topmost nanometers of the film fluoresce.




*in-situ* A/B ratio for LSM measured by TXRF. At high temperature the manganese concentration is higher than that of an as-deposited sample. Quenching from temperature preserves the high temperature condition.




*in-situ* Strontium to A-site ratio for LSCF measured by TXRF. Below the critical angle the slope indicates a higher concentration that is present in the bulk. The increase of slope magnitude indicates further strontium enhancement over 500 minutes.

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