Highly-Active and Contaminant-Tolerant Cathodes for Durable Solid Oxide Fuel Cells

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Introduction

- Contaminants commonly encountered in air (e.g., H_2O and CO_2) and/or Cr-containing interconnect materials may activate or accelerate the degradation of LSCF cathodes, thus degrading durability of cells.
- Model cells with well-designed electrodes characterized using powerful surface analysis techniques such as Raman spectroscopy provided us with critical insights into the degradation mechanisms of the LSCF cathode, offering scientific basis for rational design of more efficient electrode materials and structures to mitigate the effect of contaminants.
- Properly designed surface modifications of LSCF cathodes through solution infiltrations are the most effective approaches to achieving durable and high-performing cathode at low cost.

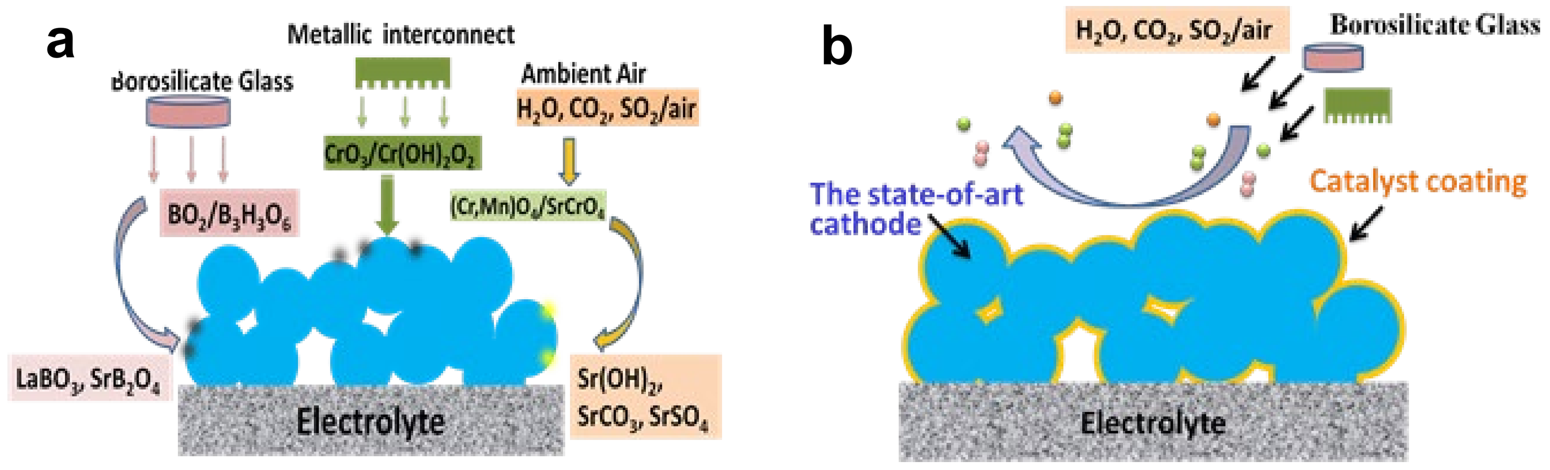

Figure 1 (a) Schematic diagram showing the sources of volatile Cr, B, and S species, and the respective reaction products on a cathode **(b)** schematic for a high-performance cathode consists of the state-of-the-art cathode backbone (e.g., LSCF) and a durable catalyst against various contaminants, making effective use of the best properties of two different materials (backbone and catalyst).

Experimental

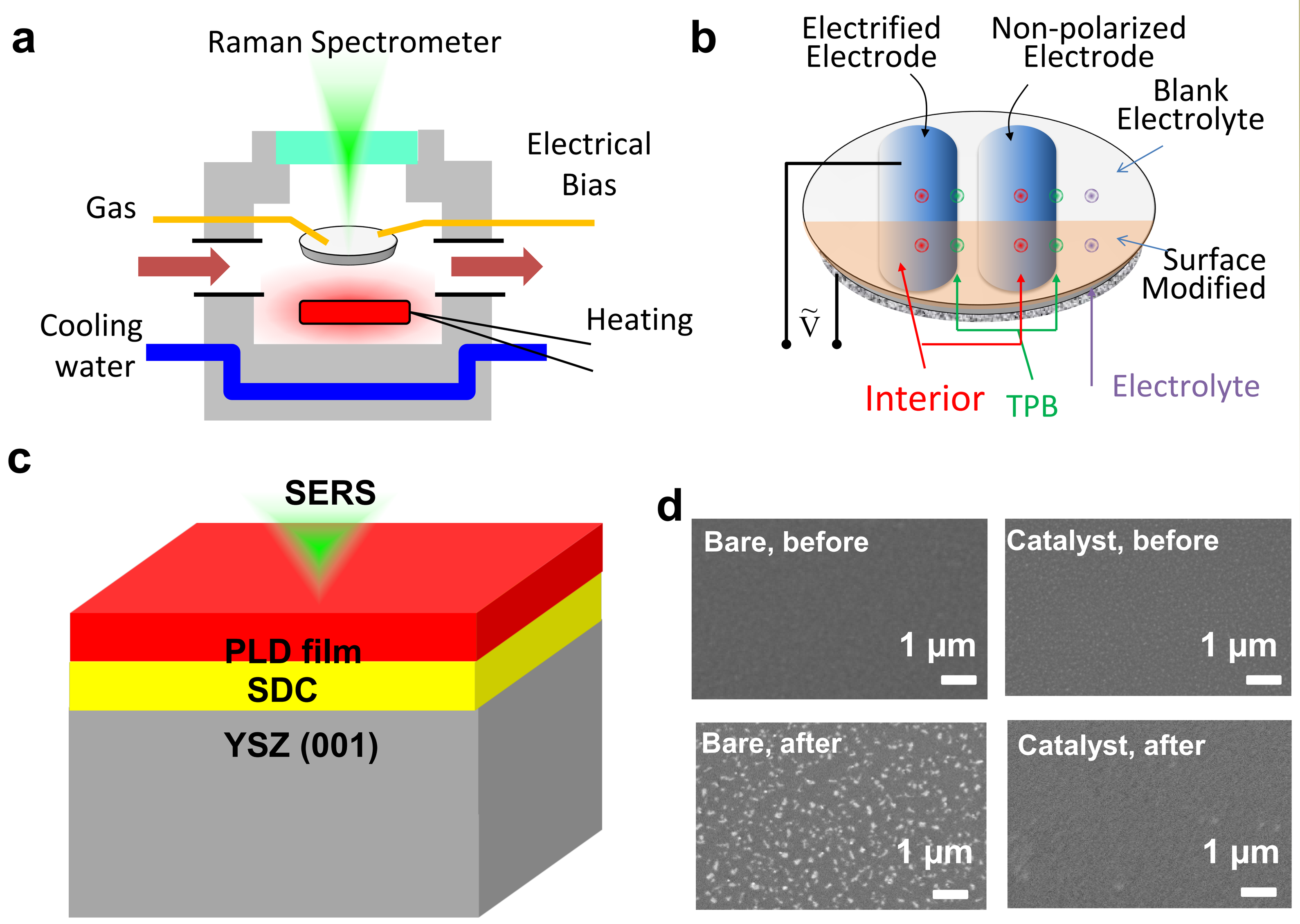

Figure 2(a) Schematic for the experimental setup for *in-situ* Raman spectroscopy coupled with electrochemical characterization ; **(b)** critical surface and interface regions in the *in operando* study of electrode behavior; **(c)** schematic of pulsed laser deposition (PLD) thin film for in situ Raman study; **(d)** SEM of fresh films and films after Raman testing in conditions with contaminations.

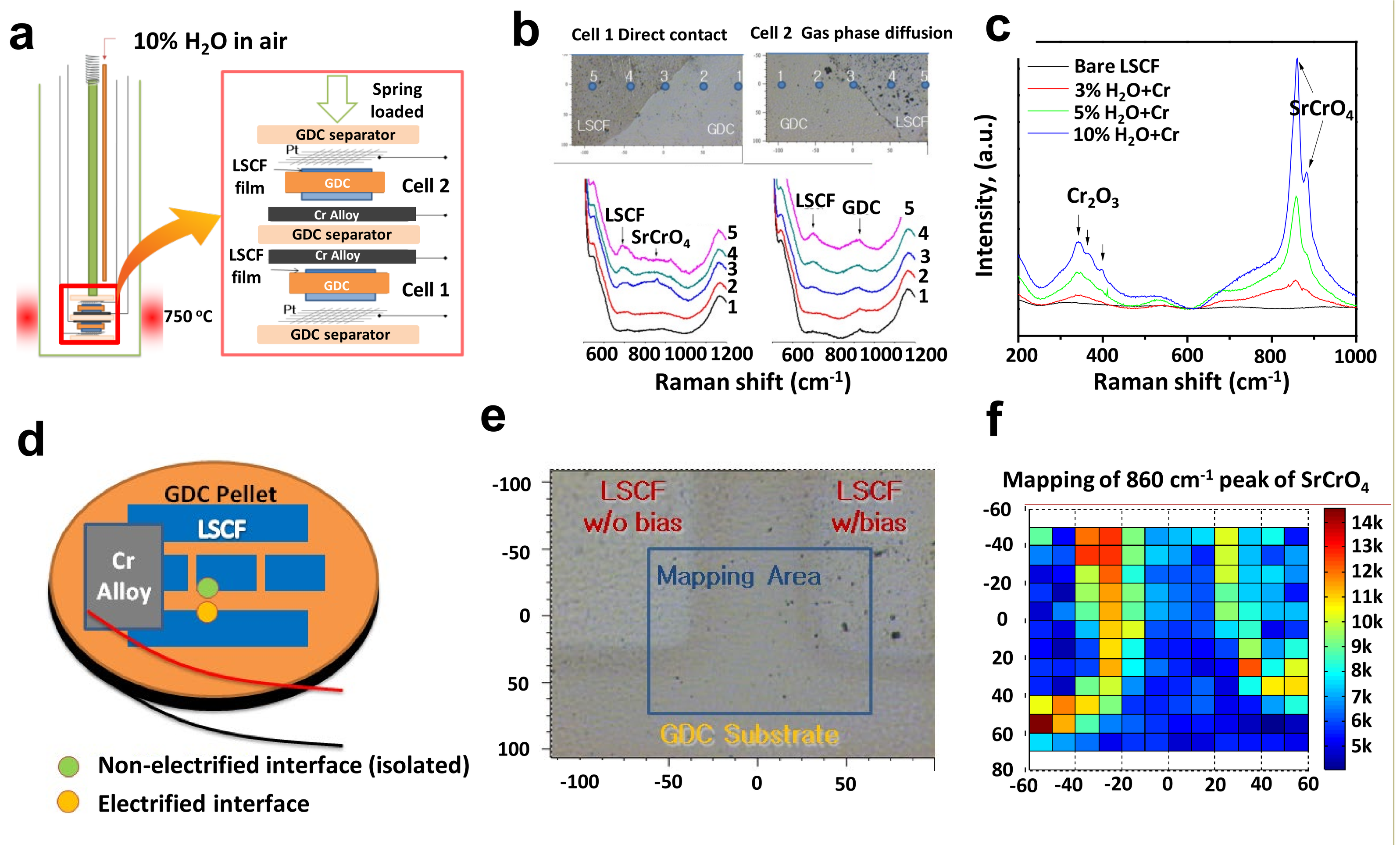

Figure 3 (a) Experimental setup for the Cr poisoning test of the LSCF thin-film electrodes in two different cell configurations. The thin-film electrode in Cell 1 was in direct contact with the Cr-containing alloy while that in Cell 2 was not in direct contact with the Cr-containing alloy; **(b)** Surface enhanced Raman spectra acquired near the boundaries between the LSCF thin-film electrode and the GDC substrate. The cathode in Cell 1 was in direct contact with the Cr containing alloy while that in cell 2 was not; **(c)** Typical SERS spectra of the porous LSCF electrode in contact with the Cr-containing alloy in an atmosphere with 3, 5, and 10 v% H_2O; **(d)** Schematics of the model cell with patterned electrodes showing the position of the laser spot for the in situ/in operando SERS study of the LSCF thin-film electrode (on a GDC substrate) in direct contact with the Cr-containing alloy with/without bias of 1.5V at 550 °C in air with 3% H_2O; **(e)** Optical images of the LSCF thin-film electrodes and the GDC substrate, with (right) and without (left) bias; **(f)** The SERS mapping of $SrCrO_4$ (peak at 860 cm^{-1}) on the LSCF electrodes after the Cr poisoning test (at 550 °C for 2 h), showing that $SrCrO_4$ preferentially concentrates on the LSCF-GDC boundaries.

Results and Discussion

1. Performance enhancement of cells with catalyst coated cathode exposed to contaminants

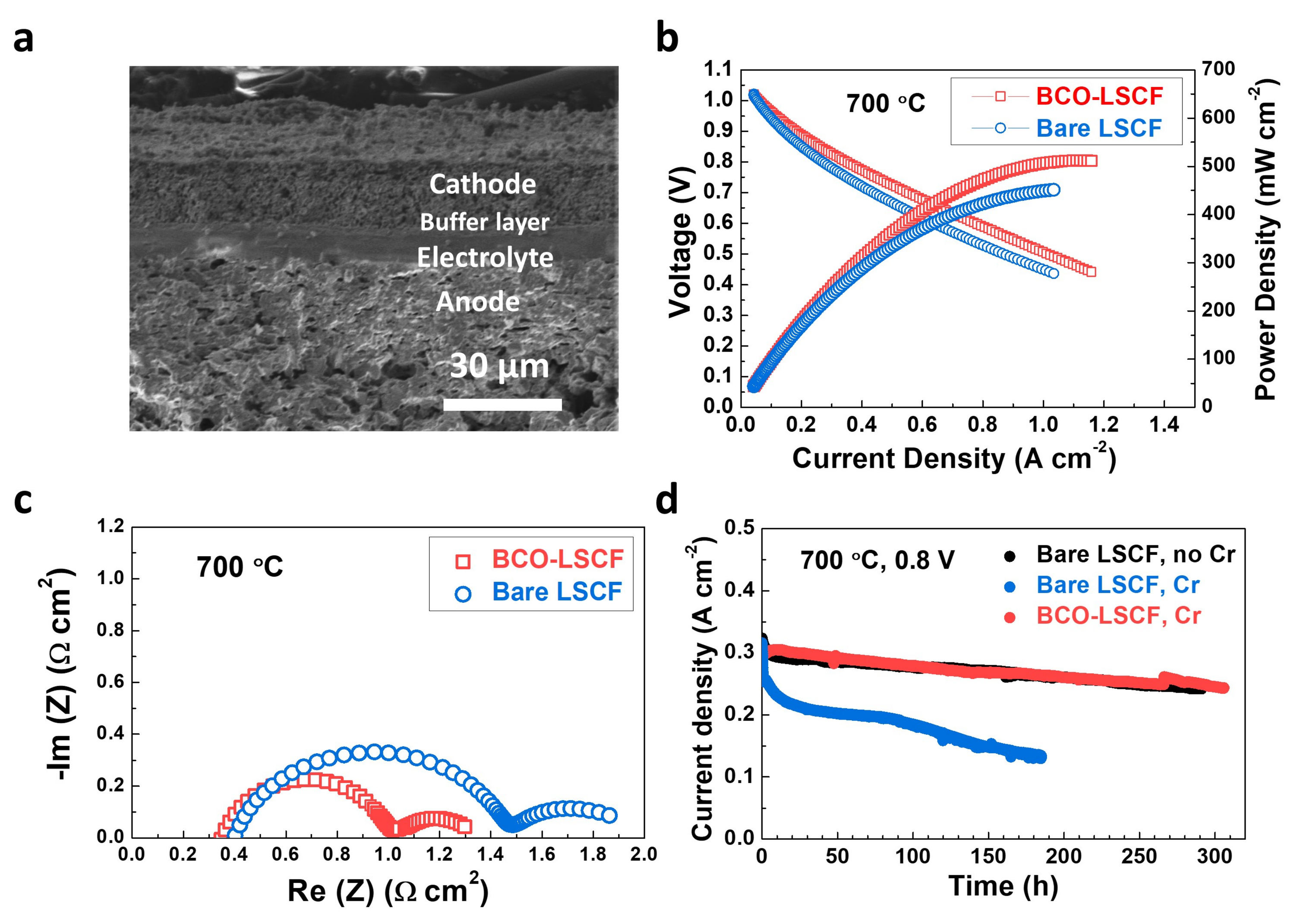

Figure 4 **(a)** A Typical cross-sectional SEM image of a Ni-YSZ anode supported cell; **(b)** Typical I–V–P and **(c)** EIS curves of the cells with a bare LSCF or BCO-LSCF cathode at 700 °C in direct contact with Crofer 22APU; **(d)** Durability test of single cells with bare LSCF cathode in clean air (black balls), bare LSCF (blue balls), and BCO-LSCF (red balls) in 3%H_2O-air and a direct Crofer 22APU contact.

2. Raman spectroscopic study of electrode w&w/o contaminants

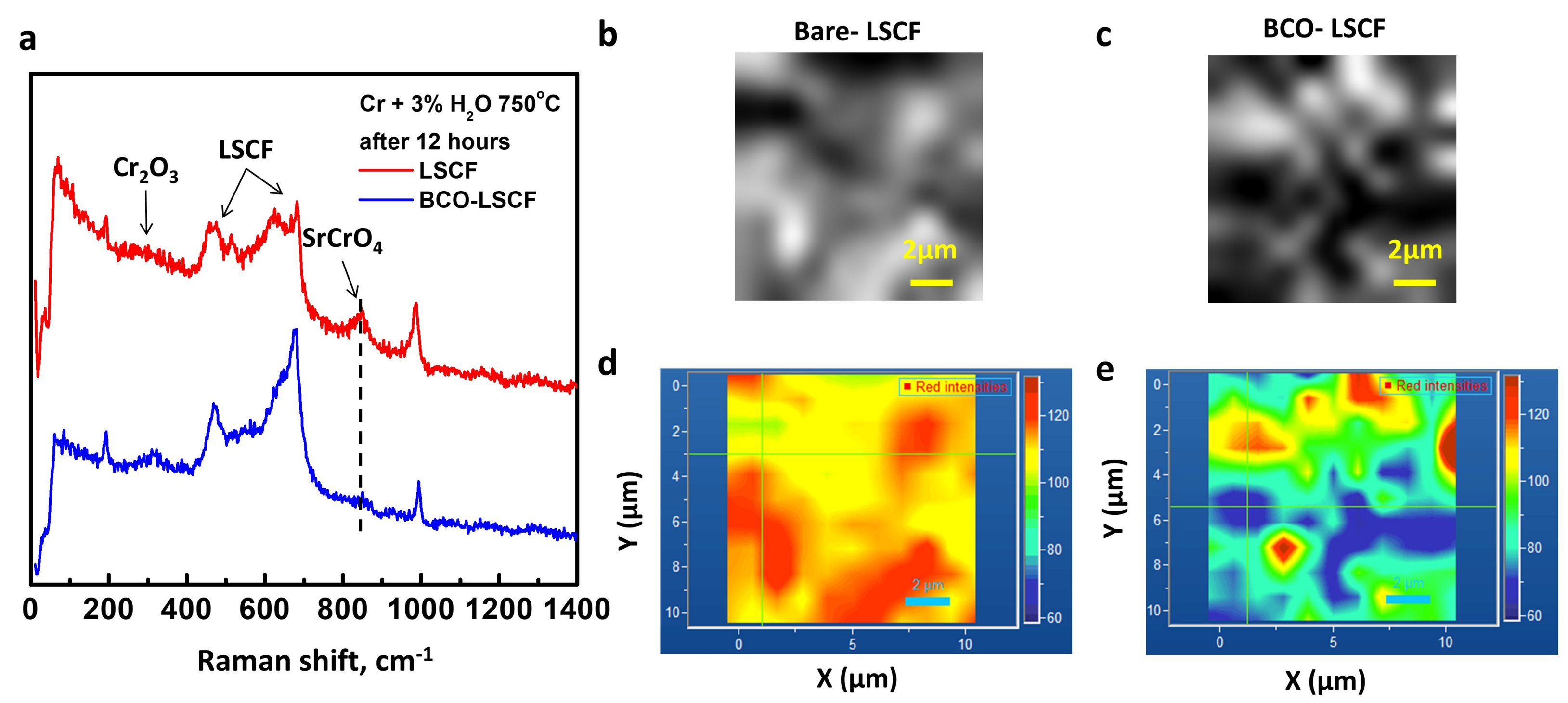

Figure 5 (a) Typical Raman spectra from a bare LSCF and a BCO-LSCF dense pellet after the Cr poisoning test (3% H_2O, 750 °C, 12 h); Optical image of bare LSCF (b) and BCO-LSCF (c) for Raman mapping; Raman mapping of -CrO_4 (peak at ~850 cm^{-1}) observed from the bare LSCF (d) and BCO-LSCF (e) dense pellet surface after the Cr poisoning test.

3. Development of contaminant-tolerant catalyst

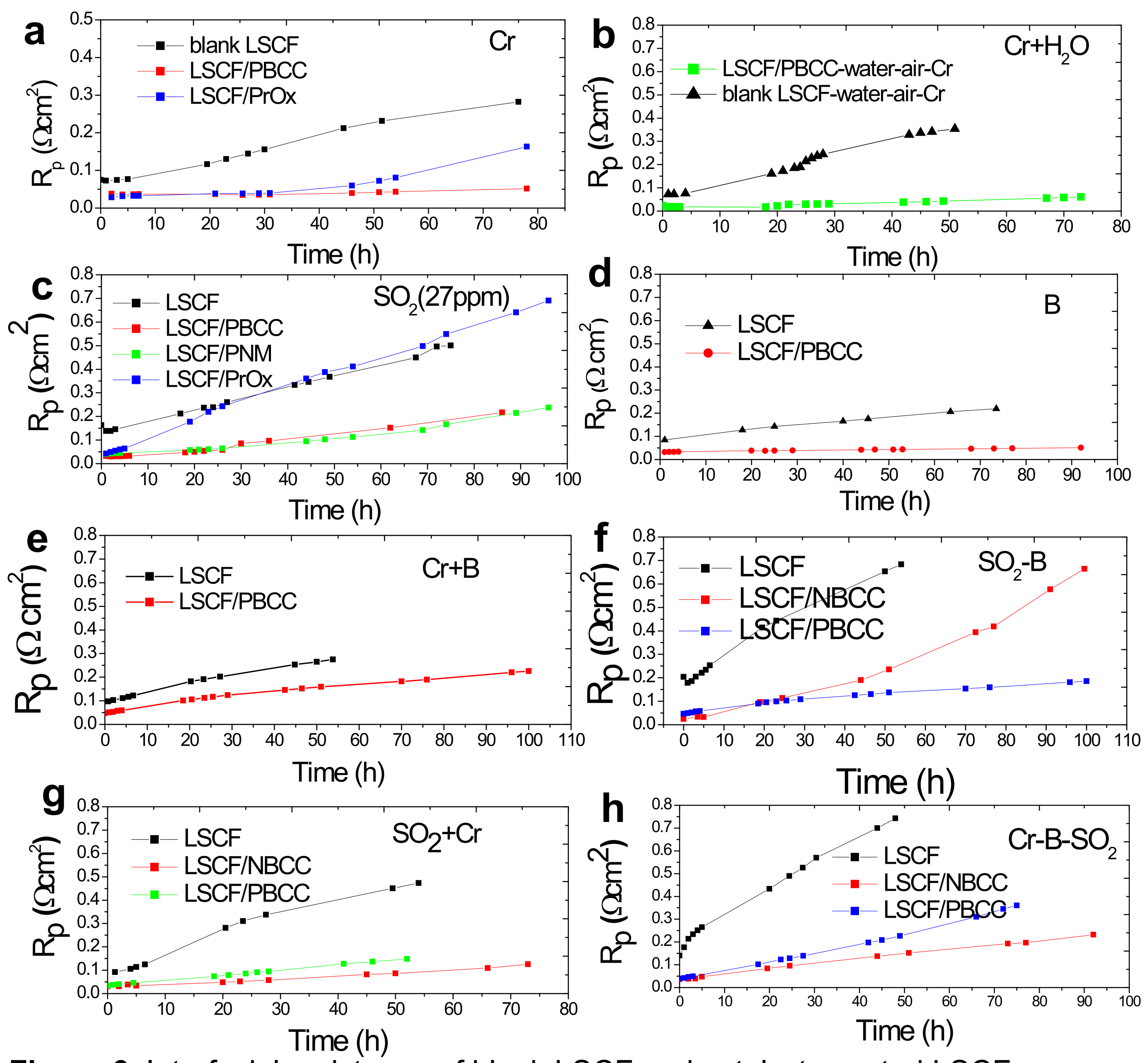

Figure 6 Interfacial resistance of blank LSCF and catalysts coated LSCF as function of time, when exposed to different contaminant. (a) in direct contact with Cr in dry air; (b) in direct contact with Cr in 3% H_2O; (c) 27 ppm SO_2 in air; (d) boron-silicon glass; (e) Cr and B-silicon glass; (f) B-silicon glass and air with 27ppm SO_2; (g) Cr and air with 27ppm SO_2; (h) Cr and B in air with 27ppm SO_2.

Summary

- Gained important insight into the degradation mechanisms of LSCF under ROC (air with Cr, B, S) using in situ SERS, long-term performance testing, and modelling & simulation
- Developed robust catalysts with enhanced tolerance against various contaminants while maintaining high ORR activity

Acknowledgement

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