Development of Chromium and Sulfur Getter for SOFC Systems

Prabhakar Singh, Steven Suib, Boxun Hu*
University of Connecticut, Storrs, CT 06269

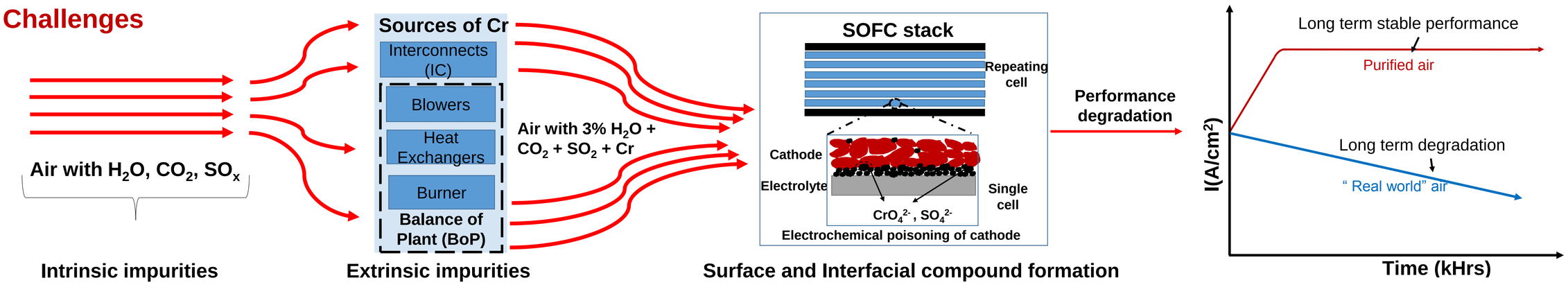
Abstract: The proposed program will develop cost effective getters and sensors for co-capturing and monitoring chromium and sulfur impurities present in the air stream entering solid oxide fuel cell power systems to mitigate cathode poisoning and related long term performance degradation. It is also the objective of the proposed program to transfer the technology to solid oxide fuel cell (SOFC) industries. The sub-objectives of the program includes (a) identification and optimization of materials chemistry for the co-capture of sulfur present in the airflow and the chromium species originating from the metallic stack and BOP components, (b) synthesis of high surface area tailored getter materials and high surface area coatings (nanofiber and multi–modal nano particles for porous coatings to increase capture efficiency and getter utilization), (c) design and develop in-situ sensors to monitor the getter lifetime (d) demonstrate the co-capture technology under SOFC system operation condition at technology readiness level (TRL) 5. Getters will be fabricated and provided to SOFC industries.

Background: The long term degradation of cathodes due to intrinsic and extrinsic impurities such as trace amounts of sulfur (75 ppb) and chromium vapors, respectively, remains a major cause of irreversible performance losses in the SOFC power systems. Understanding of the cathode degradation due to sulfur in the ambient air has attracted little attention until recently and formation of $SrSO_4$ is observed at the electrode/electrolyte interface leading to ohmic and polarization losses. Furthermore, humidified air aggravates corrosion and oxidation of chromium containing alloys that leads to higher chromium vapor pressure compared to dry air. Cathode degradation arises from the gas phases such as CrO_3 and $CrO_2(OH)_2$ generated from the metallic interconnects, and balance of plant (BOP) components, H_2O, CO_2, and SOx/H_2S present in the ambient air stream. Therefore, co-capture of chromium and sulfur before these species poison the cathode is the key to mitigate the degradation and improve the SOFC stack lifetime to achieve technology readiness level of (TRL5).

Program objectives: Develop materials for co-capture of sulfur from airflow and chromium species originating from the metallic stack and BOP components

- Develop high surface area (HSA) getter materials and coatings to increase sulfur and chromium capture efficiency
- Design and develop *in-situ* sensors to monitor the getter lifetime

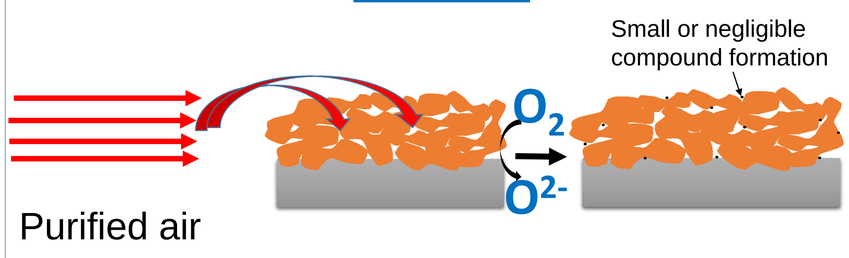
Challenges



Schematic illustration demonstrating the rise of the sulfur and chromium poisoning leading to the long term irreversible degradation in SOFC systems

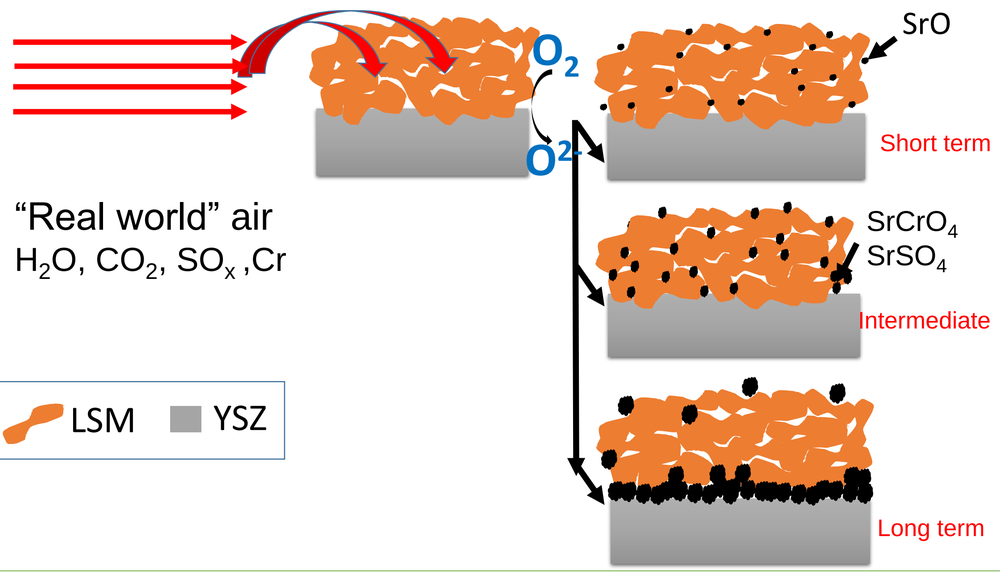
Cathode degradation mechanism

Baseline



- Smaller or negligible degradation
- No changes in chemistry, interface and surface morphology

Long term degradation



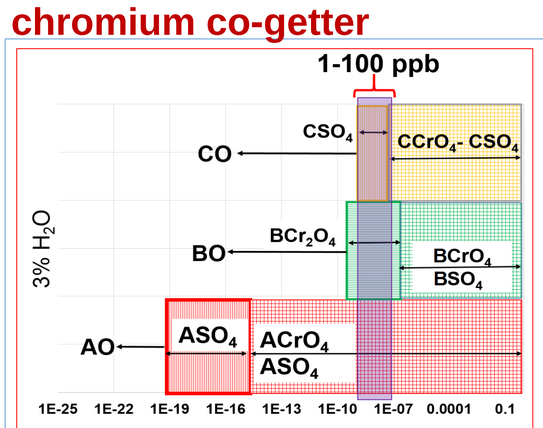
- A-site dopant exolution, surface deposition

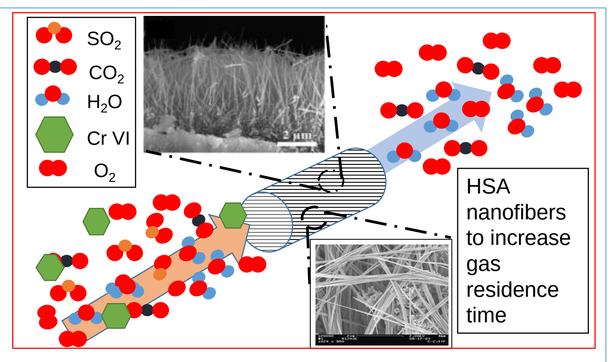
Chromium poisoning
$MO(s) + CrO_x(OH)_x(g) \rightarrow MCrO_4(s)$
Sulfur poisoning
$MO(s) + SO_2(g) \rightarrow MSO_4(s)$

- Irreversible degradation
- High polarization losses
- Interfacial deposition limits the oxygen access at the triple phase boundary (TPB) sites

Baseline: Negligible degradation of SOFC electrochemical cell under purified air, Chronological degradation: Different stages of degradation occurring over time in an electrochemical cell under the " real world" air containing both extrinsic and intrinsic impurities through surface and interfacial compound formation

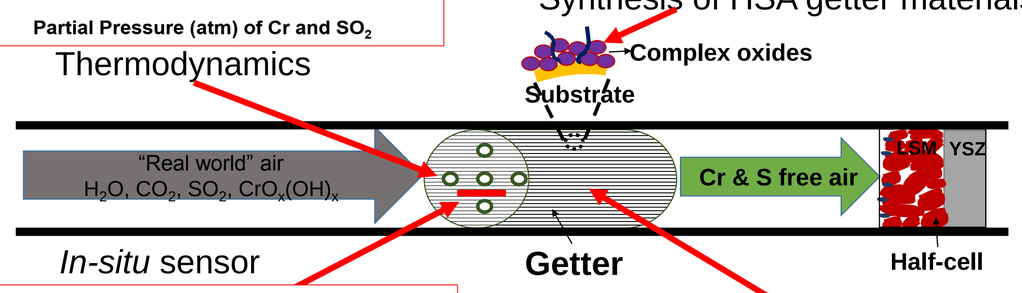
Proposed approaches for the development of sulfur and chromium co-getter

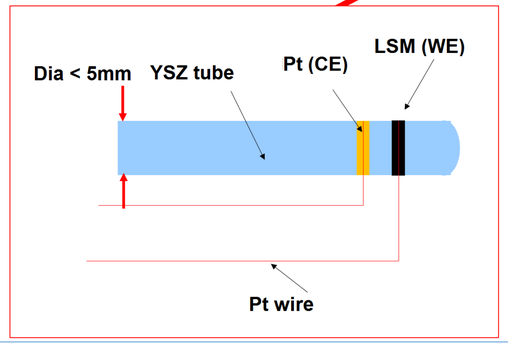




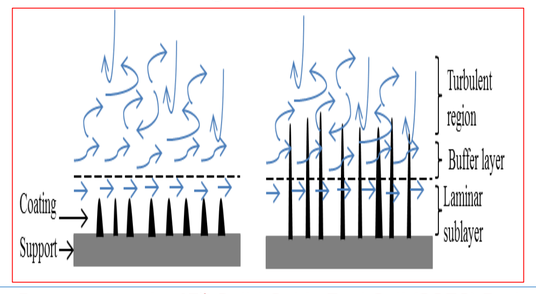
Synthesis of HSA getter materials

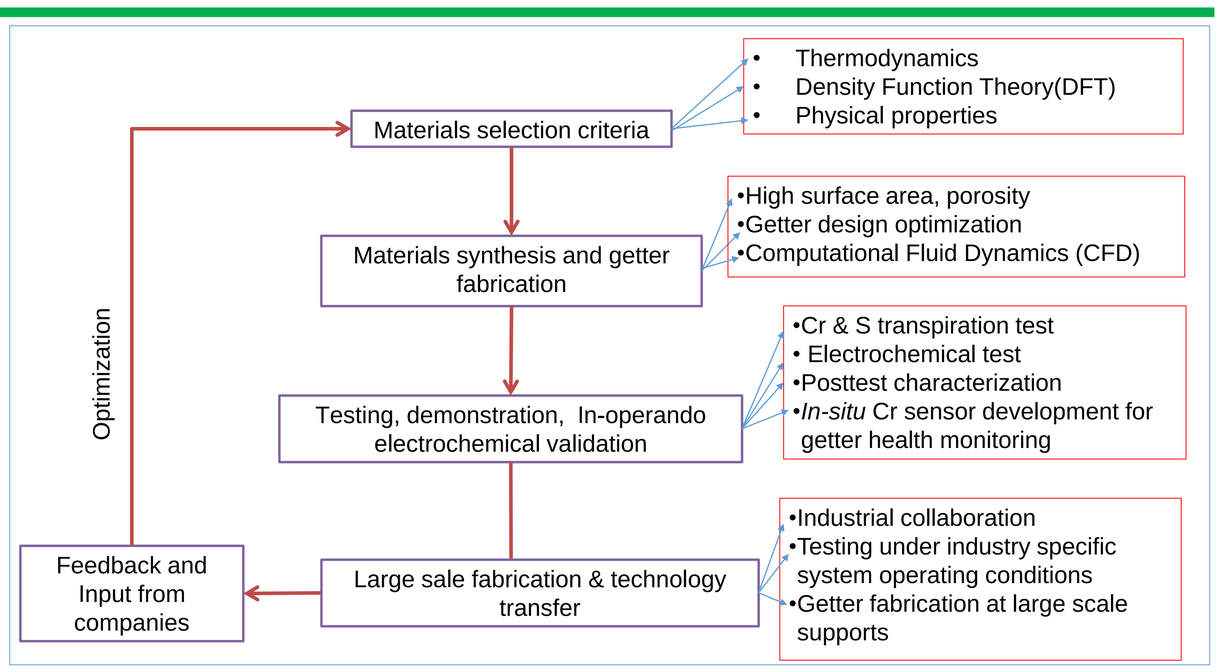
Thermodynamics





Getter design optimization





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