# Multi-Constituent Airborne Contaminants Capture with Low Cost Oxide Getters and Mitigation of Cathode Poisoning in Solid Oxide Fuel Cell

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**Abstract:** Thermochemical models for the formation of trace Cr, S, Si, B gaseous contaminant species, under high/ intermediate temperature solid oxide fuel cell operating conditions, have been developed. Transport of the contaminants through the air stream and their subsequent interactions with cell electrode has been experimentally examined. Electrode deactivation, resulting in an increase in the ohmic and non-ohmic polarizations due to chemical and structural changes, have been analyzed. Low cost "getter" formulations have been developed, synthesized and tested for the capture of gaseous contaminants. Processes responsible for electrode deactivation and electrochemical performance degradation will be analyzed. Applications of getters in related electrochemical systems will be discussed.

## Objectives:

- Develop a comprehensive understanding of the origin, formation processes and nature of the gas phase airborne contaminants, present in the air stream entering elevated temperature electrochemical systems.
- Identify trace airborne gas phase contaminants (intrinsic and extrinsic) and their interactions (chemical, electrochemical and structural) with conventional air electrode materials (LSM, LSCF etc.).
- Identify cost effective getter materials and processing techniques for the fabrication of getters. Synthesize and experimentally validate getter performance.
- Fabricate getters for stack and BOP applications. Validate the above at stack/ system levels. Transfer technology to SOFC industries.

## Technical Findings:

- Sources of airborne impurities have been identified. Thermochemical stability of gaseous contaminants have been examined.
- Trace gas phase airborne contaminants are predominantly acidic in nature and have affinity to react with basic constituents of the air electrode. This results in the formation of thermodynamically stable and electrochemically inactive reaction products.
- Silicates, chromates, chromites, sulfates and borates can form at the electrode surface and at electrochemically active sites resulting in the poisoning and irreversible structural changes.
- Electrochemical and transpiration tests, using experimental getters show excellent blockage of gas phase impurities from entering into cathode electrode.
- Getter materials, support structure and HSA getter deposition processes have been developed. Fabricated getters are being characterized.

## Background & Introduction:

High-temperature electrochemical systems including solid oxide fuel cells (SOFCs), solid oxide electrolysis cells (SOECs), and oxygen transport membranes (OTMs) have found applications in energy conversion, energy storage and oxygen separation. At elevated temperatures and in the presence of oxidants and fuels, the above systems have been found to remain susceptible to the electrocatalytic poisoning and performance degradation due to the presence of trace gas phase contaminants which can be endogenic or exogenic in nature. Intrinsic and extrinsic gaseous impurities, present in the ambient air and containing Cr, S, Si, Bi and B species, lead to irreversible electrode poisoning and performance degradation. Solid-solid and solid-gas interactions at the cell and stack level. Transport of the contaminants in gaseous form {CrOx(OH)y, SOx, Si(OH)x, and HBOx} and further reaction with the electrode forms stable reaction products and surface compounds (chromate, silicate, borate and sulfate) blocking the electrochemical sites. Both ohmic and non-ohmic polarizations increase with time. Gas phase impurities accumulate in the electrode leading to continued electrochemical performance degradation.

The trace contaminants assisted poisoning mechanisms for state of the art cathode materials such as LSM and LSCF have been examined. The interaction of contaminants and their reaction with cathode materials was validated with thermochemical analysis. The accelerated tests have been carried out to evaluate gas phase silica contaminant formation, transport and interaction with air electrodes. The materials chemistry, reaction mechanisms, test procedure and materials limitations have been discussed and presented. The work is still under investigation. The results of Si contamination accelerated tests, poisoning mechanism of electrodes, changes in material chemistry and mitigation of Si contaminant by capturing it as developed getter will be communicated in following reports.

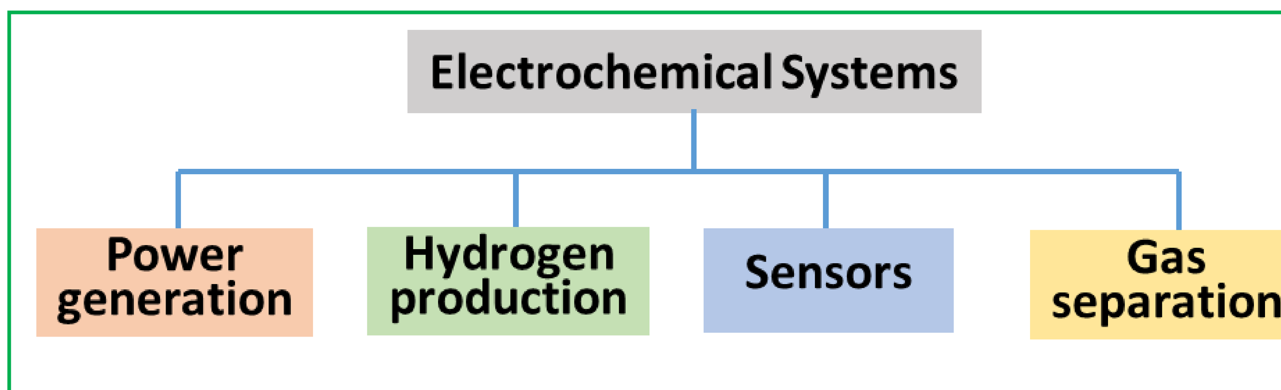


*Fig 1. Applications of Electrochemical devices*

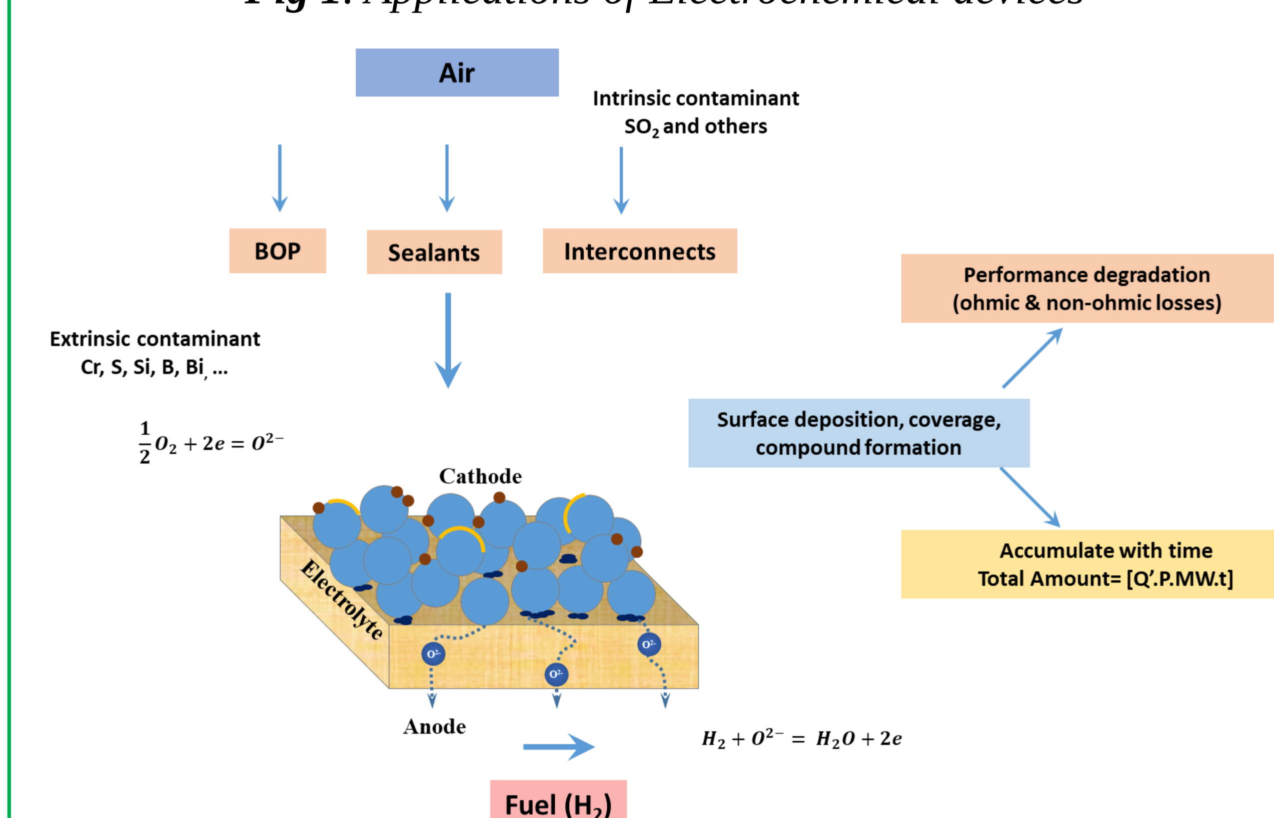


*Fig 2. Schematics of sources of intrinsic and extrinsic contaminates and their interaction with cathode under SOFC operating conditions*

## Experimental:

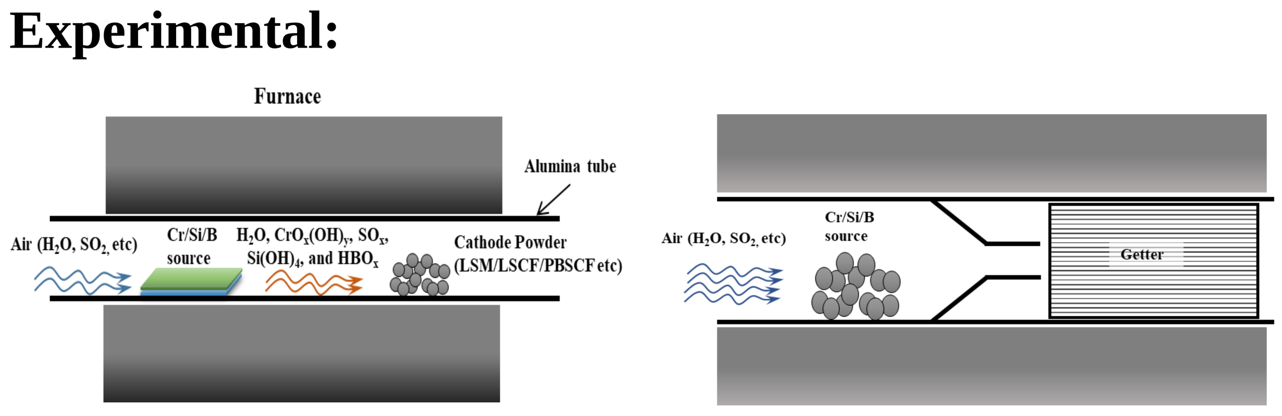


***Fig 3.** Schematics of (a) accelerated Si contamination test (b) Getter efficacy test and table with experimental test parameters*

| Material | Temperature | Atmosphere | Source | Time |
|---|---|---|---|---|
| LSCF | 600- 800°C | Air + $H_2O$ | Glass, $Cr_2O_3$,$SiO_2$ | 50-500h |
| LSM | 600- 800°C | Air + $H_2O$ | Glass, $Cr_2O_3$,$SiO_2$ | 50-500h |
| PBSCF | 600-800°C | Air + $H_2O$ | Glass, $Cr_2O_3$,$SiO_2$ | 50-500h |

## Results:

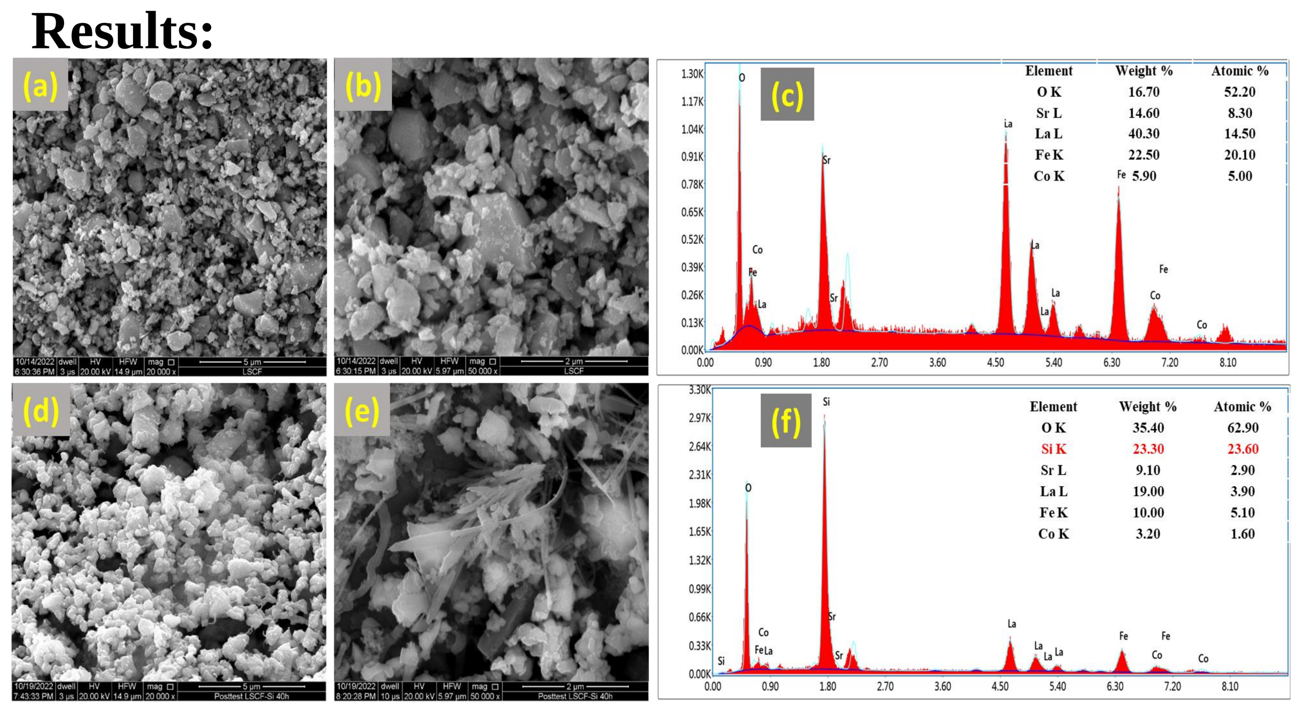

***Fig 4.** Morphology and EDS analysis of LSCF (a-c)before and (d-f) after the accelerated Si transpiration test. Posttest LSCF shows the surface coverage and the presence of Si rich compound.*

## Getter development and Characterization :

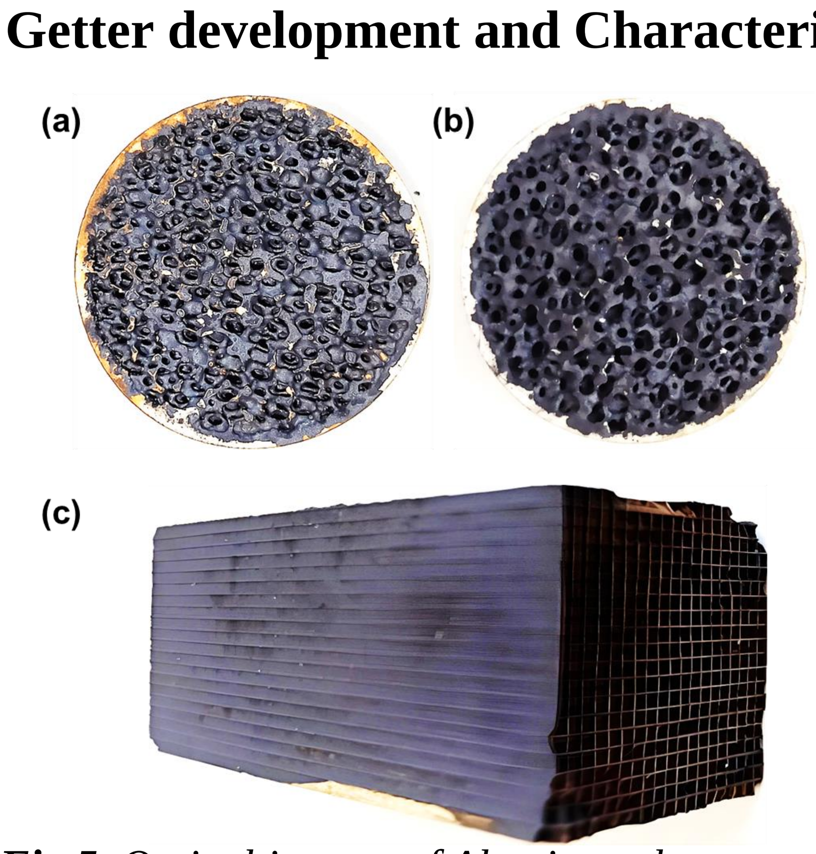

***Fig 5.** Optical images of Alumina substrate with getter coating slurry (a) single coat (b) double coat and (c) Cordierite substrate With getter coating*

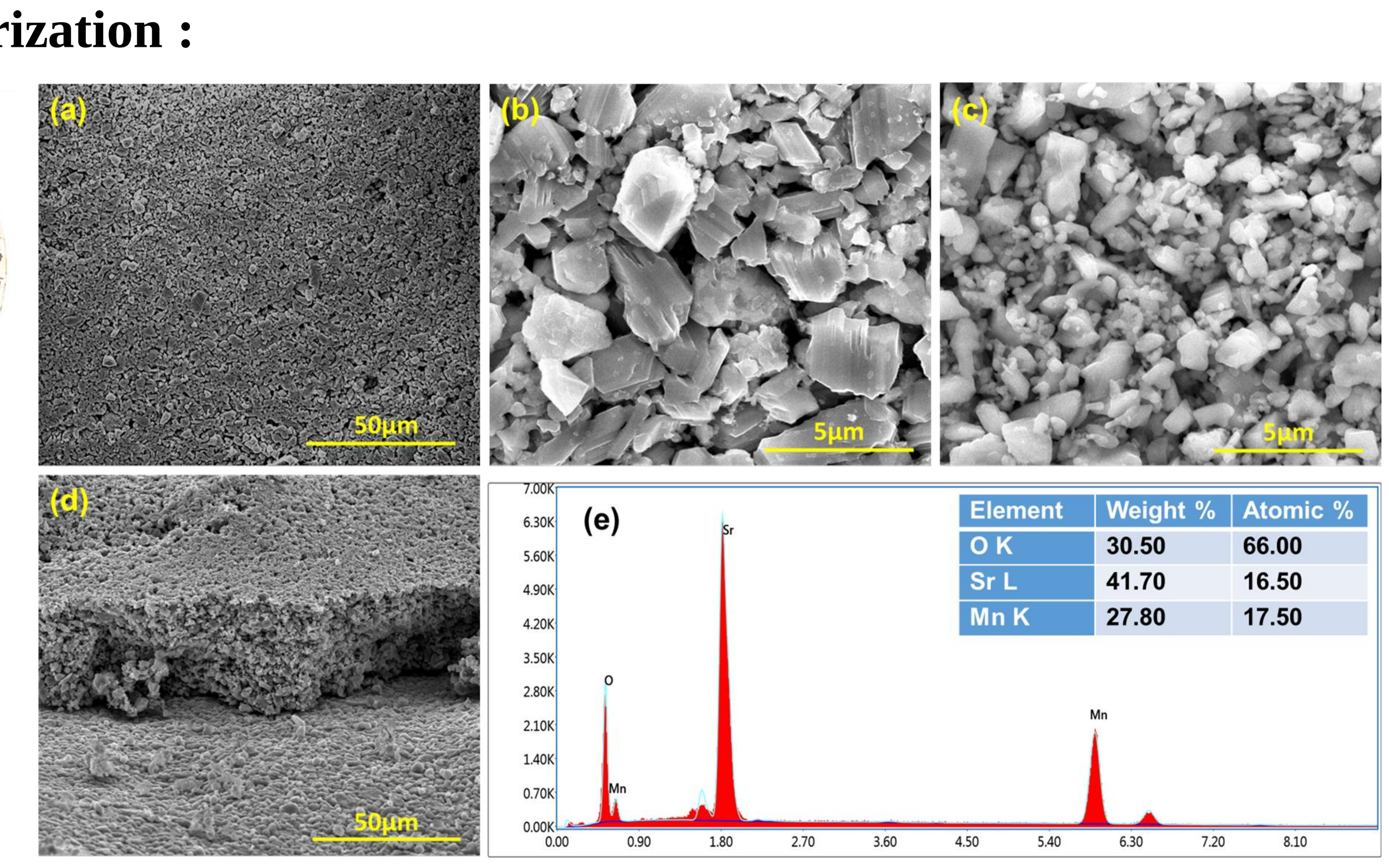

***Fig 6.** SEM micrograph of getter coating on (a & b) alumina substrate (c) cordierite substrate (d) cross section and (e) EDS spectrum*

## Summary:

- Ambient air containing intrinsic ($SO_2$) and extrinsic gaseous impurities (compounds of Cr, Si, B), formed during interactions with BOP and stack components, leads to electrochemical poisoning and performance degradation of the cathode. stable reaction products (chromate, borate, silicate, sulfate) form in the electrode.
- Surface morphological observations show electrode surface rearrangement and dopant segregation.
- SMO (Sr-Mn-O) based getter have been synthesized and developed.

## Reference:

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