On Fundamental Relationship between Activity and Stability in Solid Oxide Cells

Xiao-Dong Zhou*

Center for Clean Energy Engineering, Departments of Chemical and Biomolecular Engineering, Mechanical Engineering, and Materials Science and Engineering
University of Connecticut, Storrs, CT 06269, USA
**xiao-dong.zhou@uconn.edu*

The aim of this presentation is to address three fundamental questions related to solid oxide cells:

(1) Are the oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) truly the rate-limiting steps in the high-performance of solid oxide cells, and how can we definitively quantify the area specific resistance of the oxygen electrode?
(2) What causes the phenomenon known as "electrochemically driven phase transformation," and how can our understanding of this process be applied to create electrodes that are both high-performing and durable?
(3) How can we develop reliable accelerated testing protocols for both solid oxide fuel cells and solid oxide electrolysis cells, and which physical processes are being accelerated through these tests?

The accurate quantification of electrode polarization in fuel cells and electrolyzers holds critical importance but presents a significant challenge due to the extensive overlap in polarizations from both the anode and cathode, whether in DC or AC measurements. This overlap creates a notable gap in our understanding of electrode behavior and in the development of electrochemical devices that are both high-performing and durable. In this presentation, I will introduce a reliable method for measuring the polarization of individual electrodes within a solid oxide cell. This technique is versatile and can be easily adapted for use in various types of electrochemical cells. Additionally, we will explore the limitations associated with using the distribution of relaxation times (DRT) analysis for determining the polarization of individual electrodes.

We will then address the origin for the phase transformation observed in an oxygen electrode during operation, as opposed to what is seen with thermally annealed materials. By integrating electronic conduction at the interface layer, we can significantly reduce the occurrence of phase transformation. This understanding of "electrochemically driven phase change" is crucial for the development of reliable accelerated testing protocols. Such protocols are essential in solid oxide fuel cell research to speed up the investigation of durability issues, quickly identify potential failure mechanisms, and ultimately estimate the lifespan of electrochemical cells. In our study, we compared solid oxide fuel cells operated at constant current density with those subjected to accelerated testing methods, which involve intermittent current injections. We have formulated a general accelerated testing framework, which will be presented in detail.

Finally, we will present a theoretical model that underlies those three questions and can be used to address stability and durability issues in solid oxide cells.

Acknowledgements: The presenter would like to thank Prof. Anil Virkar, Dr. Emir Dogdibegovic, and Dr. Yudong Wang, for their invaluable contributions to the work presented. This work was made possible through the support of projects DE-FE0026097, DE-FE0031667, DE-AR0001346, and DE-FE0032110.

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