# ChE SEMINAR

## *Advanced Materials and Diagnostics for Electrochemical Energy Conversion and Storage*

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Seminar Room
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## ABSTRACT

Notwithstanding remarkable technological advances over the past few decades, electrochemical energy conversion and storage systems are currently limited by the high cost and poor lifetime of key components. The main cost drivers in fuel cells, electrolyzers, and/or redox flow batteries (for large-scale electric energy storage) are: a) the perfluorinated cation exchange membrane; and b) the PGM-based electrocatalysts. The primary degradation modes that currently limit device lifetime and further enhance stack cost (due to the required over-engineering/replacement) are: a) the corrosion of the supported electrocatalyst during transient operating modes (e.g. start-up / shut-down) resulting in electrode thinning and loss of electrocatalytic activity, and b) the free-radical-induced (or nucleophile-induced) degradation of the electrolyte membrane during fuel cell operation, resulting in membrane thinning and pin-hole formation and/or loss in ion exchange capacity. This seminar will present and discuss methods and results from ongoing projects, at the interface of electrochemical engineering and materials science, aimed at resolving the above issues. Briefly:

I) A new class of mixed-metal-oxide (silica-ruthenia and titania-ruthenia) electrocatalyst supports has been synthesized, characterized, and evaluated. Testing, at IIT and at an automotive OEM, has confirmed the exceptional corrosion resistance of this class of supports even when exposed to the most stringent accelerated stress tests. This approach will essentially obviate the issue of electrocatalyst support corrosion – a key technological advance for fuel cells and electrolyzers.

II) A novel in-situ-fluorescence-spectroscopy-based technique has been developed to measure, for the first time, the rate of formation of reactive oxygen species (ROS, specifically OH* and OOH*) within the electrolyte of an operating fuel cell, and to study free-radical-induced oxidative degradation of the polymer electrolyte. Remarkably effective “redox-couple” based regenerative free radical scavengers have been synthesized and have been demonstrated to lower the macroscopic rate of oxidative polymer electrolyte degradation by close to 2 orders of magnitude. This advance largely nullifies concerns regarding polymer electrolyte lifetime.

III) A series of pyrochlore-phase materials with low PGM content have ben prepared, characterized, and evaluated for the oxygen evolution reaction (OER) in electrolyzers. Outstanding OER mass activities have been obtained. Interestingly, these materials also exhibited good oxygen reduction reaction activity, suggesting their applicability in regenerative fuel cell devices.

IV) Hydroxide-ion-conducting alkaline anion exchange membranes (AEMs) permit the use of inexpensive non-PGM or low-PGM catalysts in fuel cells and electrolyzers. These AEMs typically exhibit poor ion transport and rapid chemical degradation. The influence of local cationic environment and counter-ion on degradation mechanisms in hydrocarbon-based AEMs has been investigated using 2D NMR spectroscopy (COSY, HMQC, HMBC). These AEMs have been successfully used (in conjunction with low-PGM and non-PGM electrocatalysts) in fuel cells and electrolyzers. Moreover, the Donnan exclusion principle has been exploited to effectively employ AEMs in redox flow batteries.

## About the Speaker

Vijay Ramani holds the Hyosung S. R. Cho Endowed Chair in Engineering and is a Professor of Chemical Engineering at Illinois Institute of Technology, Chicago. His research interests lie at the confluence of electrochemical engineering, materials science, and renewable energy technologies. Current research directions in his group include multi-functional electrolyte and electrocatalyst materials for polymer based electrochemical systems, analyzing the source and distribution of overpotential (losses) in electrochemical systems, mitigating component degradation in electrochemical devices, and in-situ diagnostics to probe electrochemical systems.

NSF, ONR, and DOE currently fund his research, with mechanisms including an NSF CAREER award in 2009 and an ONR Young Investigator Award (ONR-YIP) in 2010. He also received the 3M Non-tenured Faculty Award in 2010 and the Supramaniam Srinivasan Young Investigator Award from the Energy Technology Division of the Electrochemical Society in 2012. He is the immediate past Chair of the Industrial Electrochemistry and Electrochemical Engineering Division of the Electrochemical Society, and the current President of Area 1E of AIChE. He holds an Extraordinary Professorship in Chemical Resource Beneficiation at North West University, South Africa and an Adjunct Professorship in Chemical Engineering at IIT-Madras. Most recently, he was appointed Co-Editor of ECS Interface.

Vijay has a Ph.D. in from the University of Connecticut, Storrs, and a B.E. from Annamalai University, India, both in Chemical Engineering.