BREAKOUT GROUP 1: CATALYSTS
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BREAKOUT GROUP 1: CATALYSTS
KEY TECHNICAL BARRIERS

PGM CATALYSTS	NON-PGM CATALYSTS	ROBUSTNESS/DURABILITY	SUPPORTS	LAYERS & TRANSPORT	OTHER
• There is a poor activity to cost ratio of PGM catalysts for oxygen reduction • Need better understanding of structure-durability relationship of nanostructured catalyst configurations. • Do not know the nature of the PtO_x and Pt^{+x} species in the fuel cell operating range • Lack fundamental understanding of size, shape, facet, structure, etc. effects on stability, activity, and performance • Need understanding of the theoretical limitations of Pt and Pt alloy catalysts and whether these have been reached.	• Lack fundamental understanding of the active site in non-PGM catalysts. • Need well-structured non-PGM catalyst to replace Pt and Pt alloys • Need rational design of non-PGM catalysts	• Need to inhibit Pt dissolution and carbon support corrosion during FC operation • Need better understanding of Pt dissolution and interaction with support, ionomer, and oxides • Lack robust catalyst capable of operating over a wide range of operating conditions • Lack CO-tolerant anode catalysts that work without air bleed • Lack impurity-tolerant anode catalysts to enable lower catalyst loadings at low anode voltage	• Need new catalysts/ supports with improved corrosion resistance • Fundamentally need better methods to separate the catalytic processes from the engineering • Lack adequate tools to understand the catalyst/ionomer interface and degradation thereof • Lack of understanding of catalyst - proton conductor - electron conductor interfaces and interactions	• Lack of fundamental understanding on how to improve the performance of novel catalysts in MEAs • Catalyst utilization is not sufficient • Need more fundamental understanding of electron and proton transport to and from the catalyst • Extended surface catalysts are currently available only in ultra-thin electrodes (which pose unique challenges) • Need to design thick layers of non-PGM catalysts (≥50 µm) with effective mass transport and ionic/electronic conductivity • Lack of understanding of the interplay between the catalytic activity and transport phenomena and wettability at a range of hierarchical scales from nano to micro scale	• Lack effective catalyst for direct fuel cells • Current high-activity catalysts frequently have lower performance at high current density • Lack sufficient understanding about HOR/ORR selective catalysts • Lack analytical methods necessary to increase the understanding of catalyst phenomena • Need better understanding of RDE - MEA performance correlation (i.e., tests to better mimic MEA performance need to be developed)

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CRITICAL R&D NEEDS

FUNDAMENTAL STUDIES OF PT MATERIALS	PGM ANODE	PGM CATHODE	OTHER
• Fundamental understanding of catalyst/support interactions for improved performance and durability • Fundamental understanding of catalyst morphology/activity/durability relationships • Fundamental studies to optimize catalyst morphology (size, shape, facets) and stability (attachments) • R&D focused on the theoretical limits of Pt, Pt alloy and structures to assess performance limitations • Fundamental understanding of Pt alloy degradation mechanism/rate and effect on performance • Fundamental understanding of catalyst performance vs. structure relationship • *In situ* characterization of proton conductor-electron conductor-catalyst interface • Theory and modeling from atomic size to cm size • Correlation among catalyst performance, catalyst structure, and molecular modeling	• New catalyst material for direct oxidation of carbon-based fuels • Novel anode catalyst with high activity for organic fuels • Development of novel anode catalysts with high impurity/contaminant tolerance • Development of novel catalyst synthesis methods	• Studies focused on overcoming Pt oxide formation at voltages > 0.8V • Improved nanostructure design of cathode catalysts • Cathodes with resistance to anion poisoning in low water activity environment • Contaminant-tolerant Pt cathode catalyst • Further reduction of PGM content to reduce cost	• Develop new innovative test methods and procedures beyond existing methods • Develop *ex situ* tests for novel catalysts that mimic MEA • Develop methods to reclaim PGM catalyst in fuel cells • Need to consider the complete catalyst system (i.e. catalyst and support) in R&D efforts • Potential Performance Targets: 0.8A 0.8V (initial target) 0.85A 0.85V 0.9A 0.9V 0.95A 0.95V 1.0 A 1.0V (long term target)

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CRITICAL R&D NEEDS (CONT'D)

NON-PGM CATALYSTS	LAYERS AND TRANSPORT ENGINEERING	SUPPORTS	ROBUSTNESS/DURABILITY
• Fundamental research and development of non-PGM catalysts for oxygen reduction • Fundamental understanding of non-PGM catalysts active site/formation process • Non-PGM catalysts for the anode • Predictive modeling and simulation for non-PGM catalysts • Contaminant tolerant catalysts Anode: CO, S, halogen-tolerant Cathode: air contaminants-tolerant Crossover: tolerant • Lower cost synthetic route	• Correlation of structure to diffusion coefficient, solubility, and mass transport as a function of operating conditions Optimization of MEA structure for novel catalysts • Development of extended surface catalysts in more traditional "thick" electrodes (structure) • Understanding of the 3-phase interface and changes during operation specifically with respect to relative humidity transients • Identification of electrode requirements (materials/ structure) that enable the realization of "high activity" of catalysts	• Design facet-oriented Pt (alloy) catalysts on reactive (non-carbon) supports • Develop Pt alloys on non-carbon supports • Develop alternate supports for more durable catalysts	• Develop catalysts that can operate over a range of operating conditions, including high cell voltage ranges (>0.8V) • Develop a materials approach to inhibiting Pt dissolution • Quantify and identify dissolved Pt^{+x} species in ionomer • Need R&D of deactivation mechanisms • Need development of base-metal and sulfur-tolerant catalysts