# V.E.5 Highly Dispersed Alloy Cathode Catalyst for Durability

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Contract Number: DE-FG36-07GO17019

Subcontractors:
- Johnson-Matthey, Reading, UK
- Columbian Chemicals Company, Marietta, GA
- Texas A&M University, College Station, TX
- Brookhaven National Laboratory, Upton, NY

Project Start Date: May 1, 2007
Project End Date: April 25, 2010

## Objectives

- Optimize catalyst performance and decay parameters through quantitative models.
- Design a high performance supported alloy catalyst system with loading ≤0.3 mg PGM/cm$^2$.
- Demonstrate 5,000 cyclic hours with less than 40% loss of electrochemical area.

## Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Cost
(C) Performance

## Technical Targets

The following technical targets establish goals for the project:

- Pt group metal total content: 0.5 g/kW rated
- Pt group metal total loading: 0.3 mg PGM/cm$^2$
- Durability with cycling ≤80°C and >80°C reaching 5,000 and 2,000 hours, respectively
- Electrochemical area loss ≤40%
- Mass activity at 900 mV$_{RHE(IR\text{-}Free)}$: 0.44 A/mg Pt
- Specific activity at 900 mV$_{RHE(IR\text{-}Free)}$: 720 μA/cm$^2$
- Cost: $8/kW

## Approach

UTC Power will develop a fundamental understanding of state-of-the-art catalyst materials, and use this understanding to develop advanced catalyst systems. UTC Power will focus on: 1) elucidation of cathode performance degradation mechanisms and development of key material characteristics that determine performance and stability, 2) development of advanced Pt-based binary and ternary catalysts guided by molecular modeling, 3) synthesis of highly-dispersed (~2 nm metal particles) ternary alloys by co-formation of advanced carbon supports and catalytic nanoparticles, 4) optimization of electrode structure through tailoring carbon support surface chemistry and ionomer-catalyst ink properties, and 5) verification of performance and stability through full-size single cell and 20-cell stack testing. To accomplish these tasks, UTC Power has teamed with Brookhaven National Laboratory (BNL), Texas A&M University (TAMU), Johnson Matthey Fuel Cells (JMFC), and Columbian Chemical Company (CCC).

BNL's role in the project is to understand the relationship between fundamental catalyst material characteristics and catalyst stability/performance. BNL will use advanced analytical tools to probe the correlation between electronic properties, crystal structure and particle size on activity and durability during potential cycling, and to characterize electrocatalyst degradation during potential cycling in the membrane electrode assembly (MEA). The overall scope of JMFC activities in the project will encompass Pt alloy cathode catalyst development, evaluation and scale-up of selected leading candidate materials, and the development, scale-up and supply of MEAs comprising the best new catalyst material (see Figure 1). MEAs will be fabricated using best available gas diffusion layer, membrane and seal materials that will contribute to the achievement of the performance and durability targets. Dr. Balbuena's group at TAMU has extensively analyzed the oxygen reduction reaction (ORR) mechanism on Pt(111) surfaces using a set of computational tools including atomistic electronic structure methods. On this project, molecular modeling studies will focus on quantifying metal catalyst stability towards metal dissolution as functions of nanoparticle size, overall composition, exposed surfaces structure/composition, and surrounding atoms/molecules in the fuel cell environment. CCC has experience with a number of proprietary carbon supports and has developed Pt deposition techniques to realize highly active and stable catalysts. CCC will use their proprietary carbon supports and deposit binary and ternary Pt alloys onto them. The surface of the supports and the deposition process will be optimized to meet DOE requirements. Catalysts synthesized at the various subcontractors will be used to fabricate MEAs. The MEA laboratory at the United Technologies Research Center (UTRC) will be used to optimize the fabrication procedure by varying the pressing conditions, ionomer content, membrane type, etc.

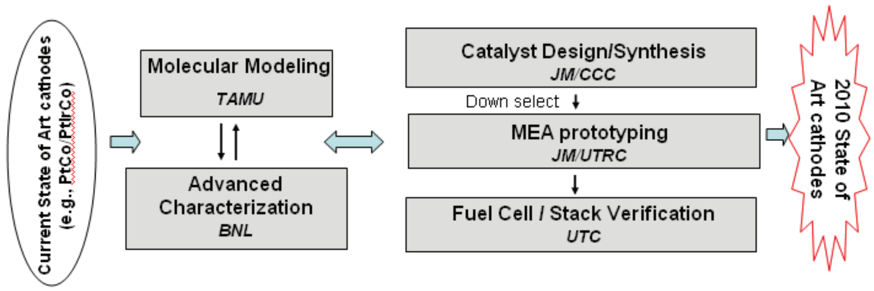
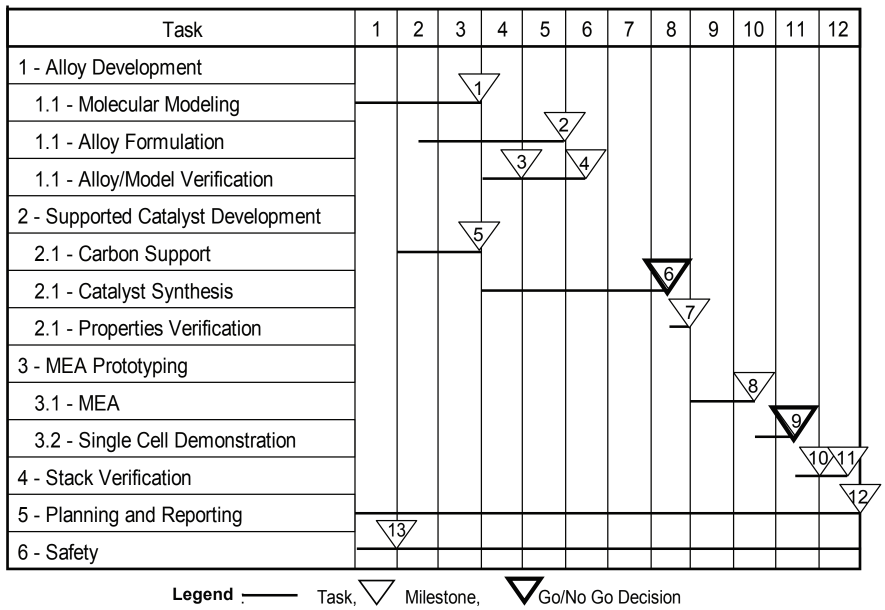



**FIGURE 1.** Highly Dispersed Alloy Catalyst Project Approach

**FIGURE 2.** Project Time Period (Quarters)




## Accomplishments

- Kick-off meeting with subcontractors held.
- Developed a schedule and timeline for the DOE targets for 2010 and detailed work scope for the next year with subcontractors (see Figure 2).
- Synthesized five batches of 40% $Pt_{50}Ir_{25}Co_{25}$ on Ketjen Black for benchmarking with subcontractors.