Advanced Catalysts for Fuel Cells

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Project ID #FCP22

Overview

Timeline

Project start date: 04/14/05
Project end date: 09/30/05
Percent complete: 8%

Budget

Total project funding:$100K
- DOE share: $100K
- Contractor share: $0K

FY04 funding : $100K
FY05 funding : $100K

Barriers and Targets

- Barrier: Reducing the amount of precious metal in MEAs
- Target: 0.1mg/cm^2 total precious metal and $3/kW on a precious metal basis

Partners(unfunded)

Prof. Bruce Koel,University of Southern California, for XPS Analysis
Prof. P. Kumta Carnegie-Mellon University for powder fabrication of nanomaterials

Objectives

Reduce the amount of noble metal catalysts used in MEAs to achieve the cost targets for fuel cells

- Identify new catalysts compositions for the electro-reduction of oxygen
- Focus on using non-noble metals in conjunction with noble metals to improve activity
- Near-term target of 2000 mW/mg (or 0.25 mg/cm^{2}) of noble metal based on the mass of noble metal
- Improve cathode potential by 0.1 V over state-of-practice for current densities of >500 mA/cm^2

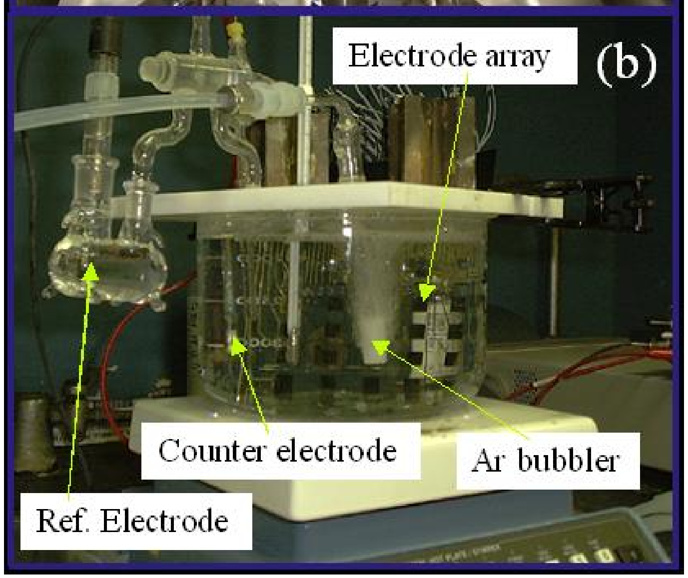
Approach

- Investigate **Pt-X-Y** (**X**= Ni,Co,Fe; **Y**=Zr, Ti, Cr) for oxygen reduction activity
- Study 10 nm sputter-deposited catalyst layers to develop composition-activity relationships
- Rapidly screen catalyst compositions using combinatorial multi-electrode array
- Develop physicochemical rationale for catalyst design using electrochemical and electronic properties data
- Demonstrate promising catalysts in full fuel cells

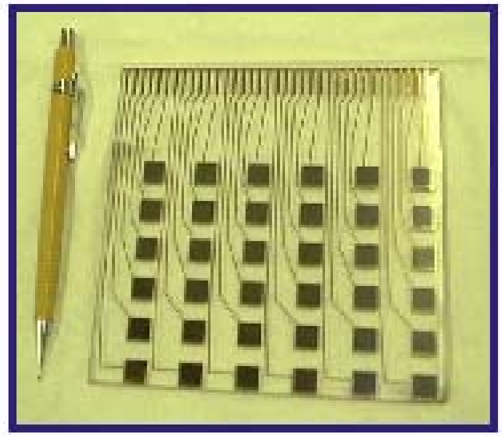
Technical Accomplishments

- Identified promising corrosion resistant non-noble metal compositions based on Ni and Zr from previous program.
- Established the viability of using compositions with substantially reduced noble metal content
- Demonstrated the validity of using co-sputtered thin film catalyst layers for studying composition effects
- Developed a combinatorial multi-electrode array for rapid electrochemical screening of catalyst layers
- Demonstrated the viability of preparing powder catalysts based on the compositions identified by sputter-deposition
- Demonstrated viability of sputter-deposited catalysts in full cells

Combinatorial Co-Sputtering of Alloys and Screening for Activity

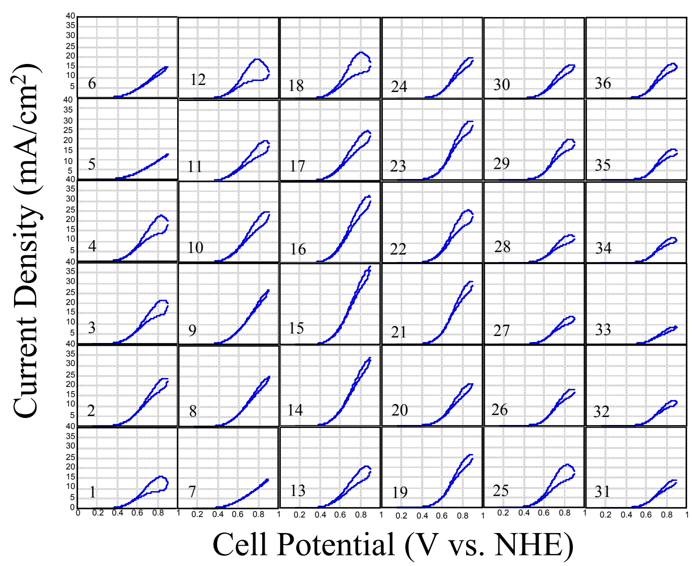


Multi-electrode Array Evaluation



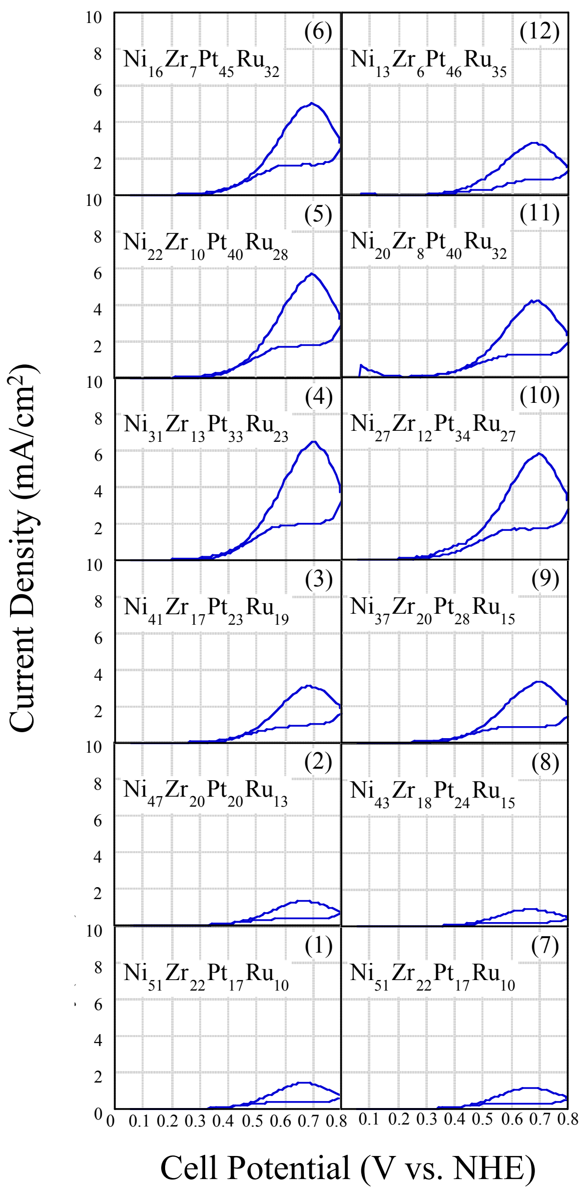
36-electrode array: Ti/Au patterned on 5x5" glass

100-150 Å Catalyst layers sputtered onto squares

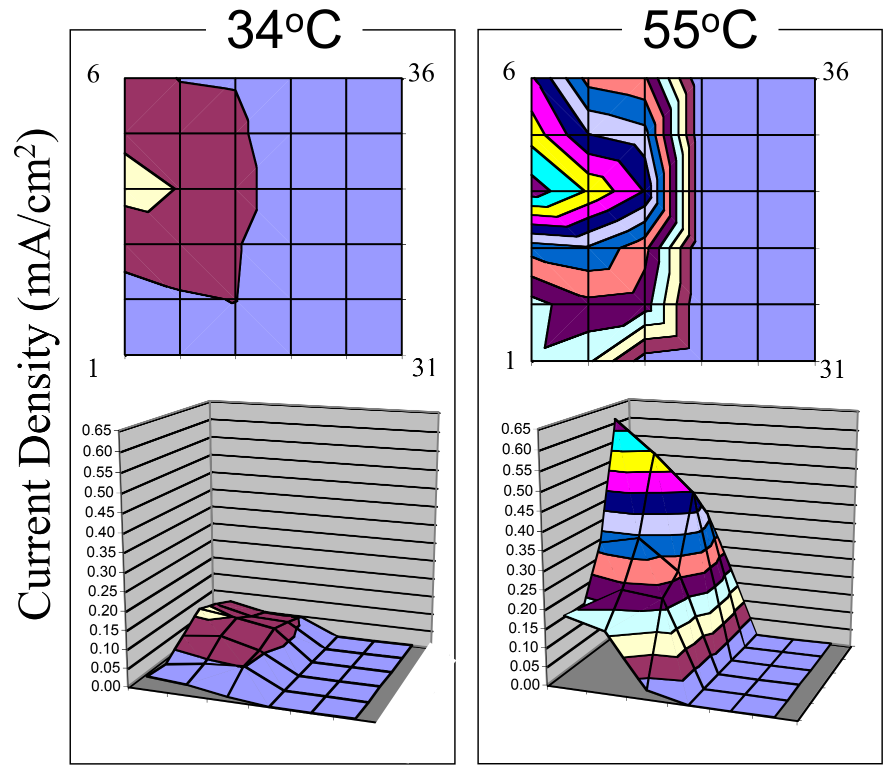


Rapid Combinatorial Electrochemical Screening of 36 compositions

Catalytic Activity of Ni-Zr Alloys towards Methanol Oxidation



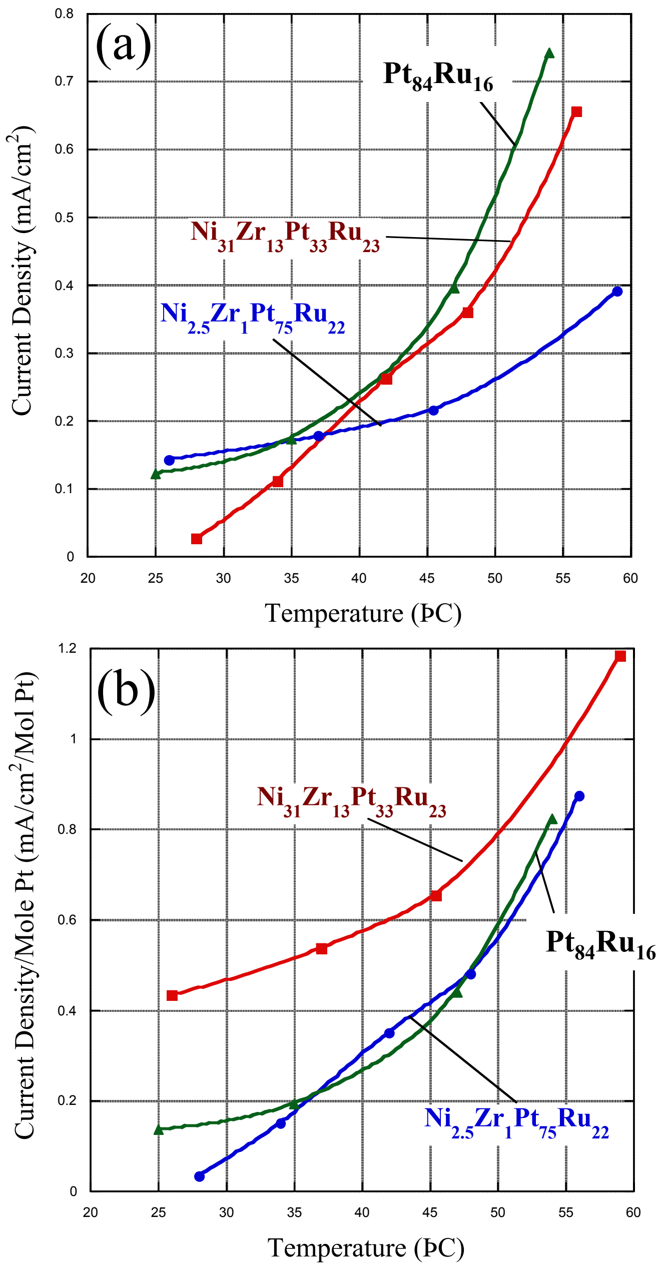
Performance variation with composition is observed



$Ni_{33}Zr_{13}Pt_{33}Ru_{23}$ identified to have the highest activity

Propose to perform similar studies for oxygen reduction with Pt-X-Y catalysts

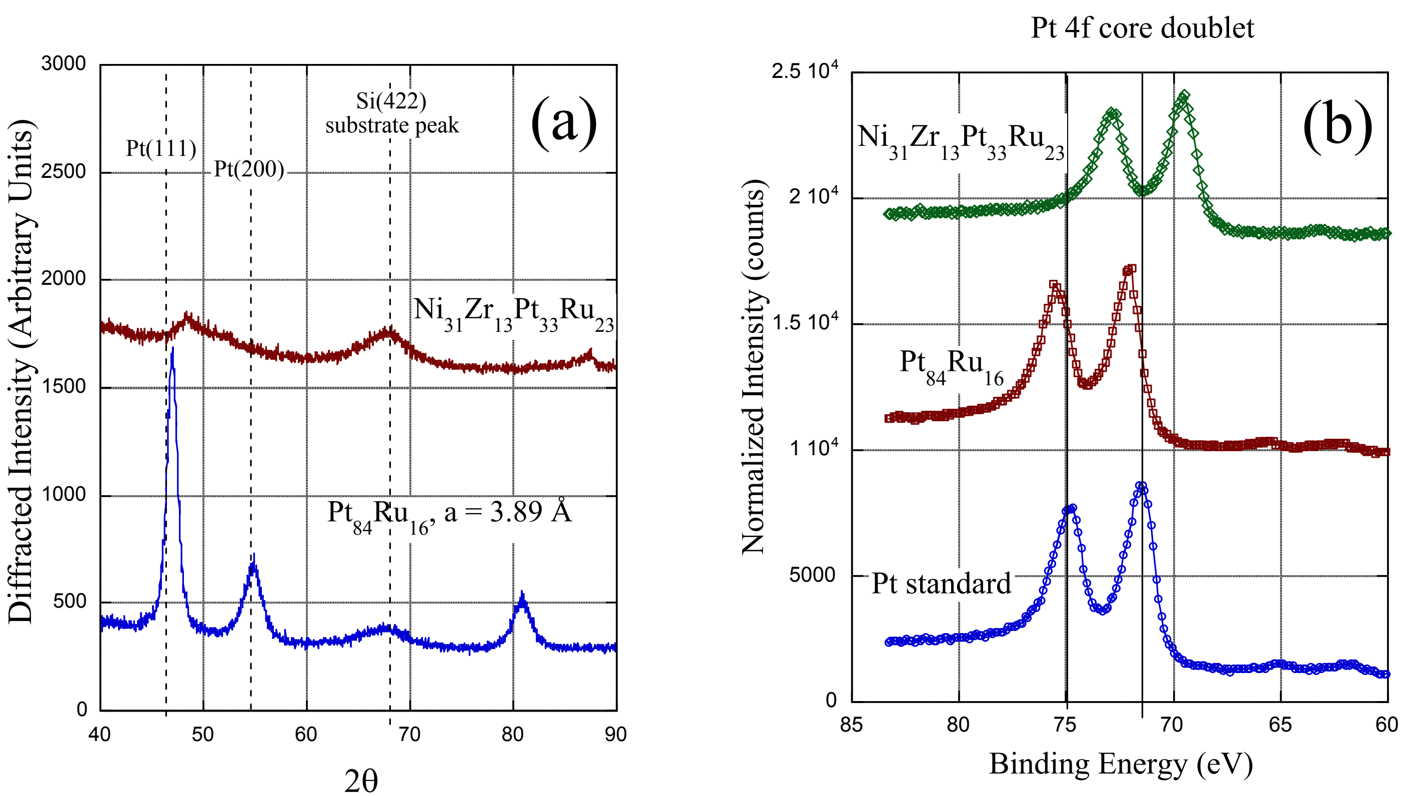
Reduction in the use of Noble Metal



$Ni_{31}Zr_{13}Pt_{33}Ru_{33}$ is comparable in performance to $Pt_{84}Ru_{16}$

Almost 50% reduction in Noble metal content compared to Pt-Ru catalysts.

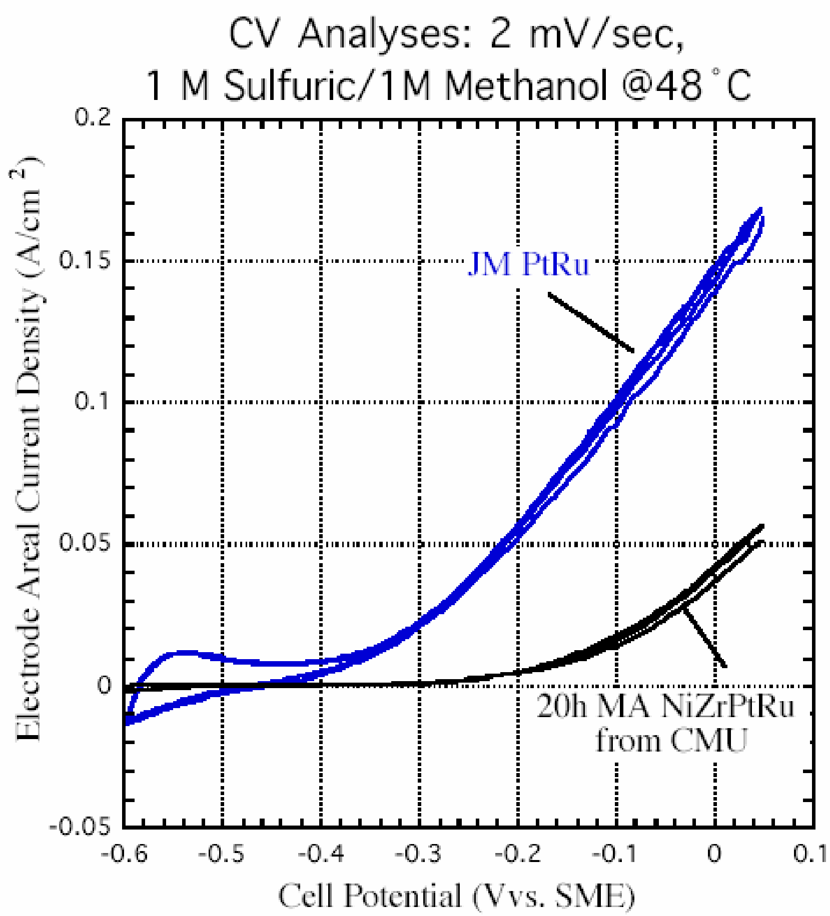
XRD and XPS Characterization of Ni-Zr Alloy Catalysts

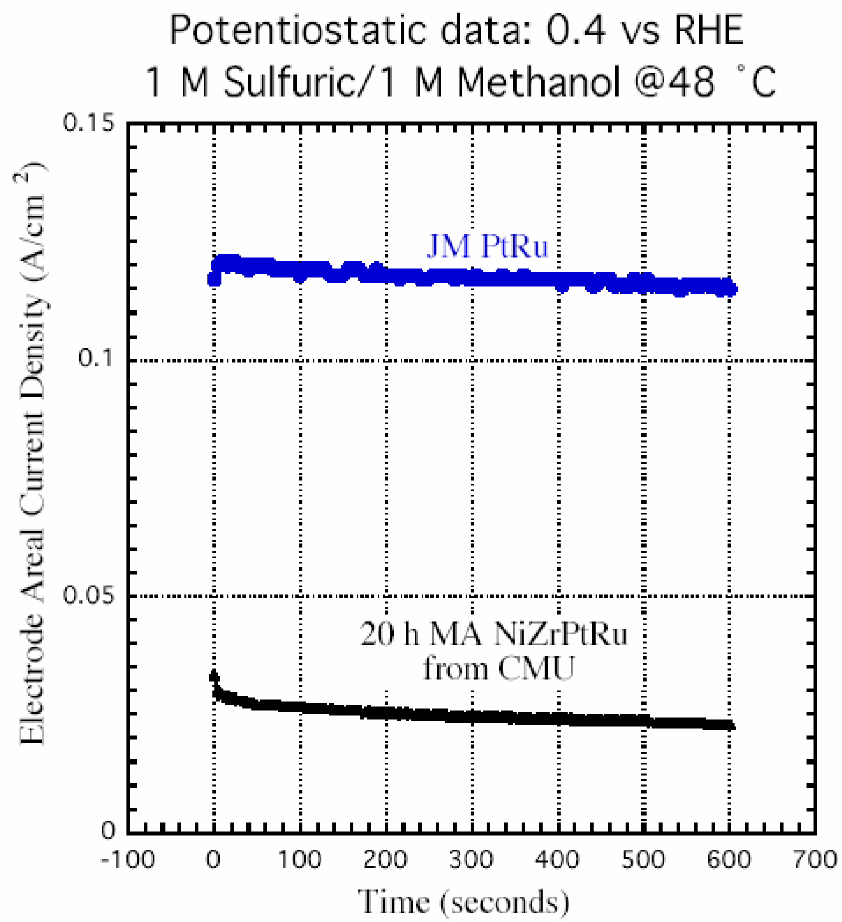


Significant differences observed in the crystalline phases and electronic environment of Pt/Ru and Ni-Zr-Pt-Ru

Differences in electronic environment and the nanophase character of Ni-Zr alloys will be exploited for enhancing oxygen reduction activity

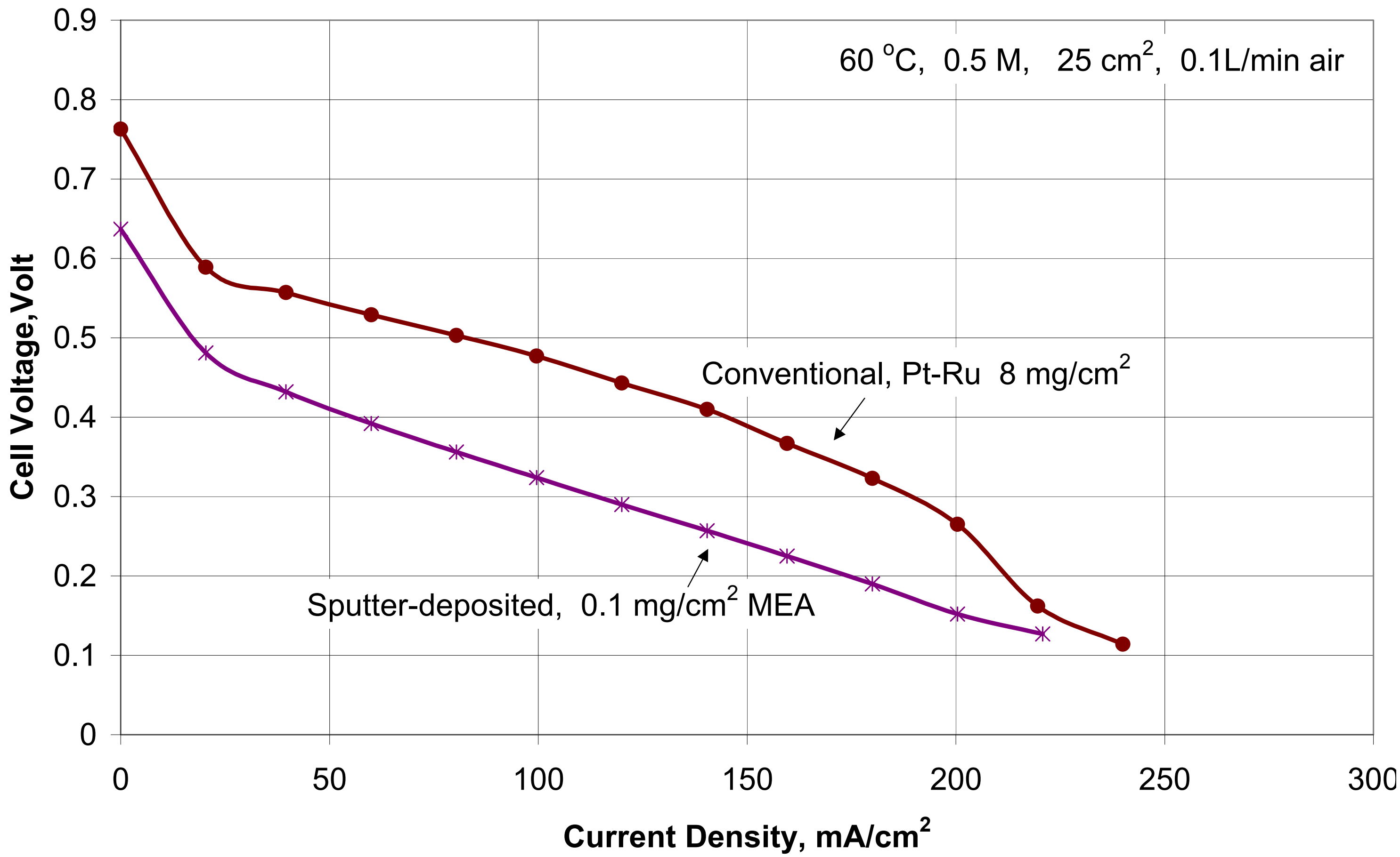
Viability of Making Non-noble metal –based Powder Catalysts





$Ni_{31}Zr_{13}Pt_{33}Ru_{33}$ powders are stable in acid media
The catalyst has about 30% of the activity of commercial all noble metal catalysts because of their low surface area
Currently examining approaches to increase surface area of powder catalysts

Evaluation of Sputter-Deposited Pt-Ru catalysts in MEAs



MEA evaluation confirms the improved utilization achieved with Sputter-deposited Catalyst layers

Results confirm feasibility of transitioning to MEAs

Responses to Previous Year Reviewers' Comments

- Generally all Reviewer's comments were positive
- One Reviewer suggested the need to transition the evaluation to full cells

  Response: Feasibility of making MEAs with sputtered catalyst layers was demonstrated (see previous chart). Similar techniques will be used for evaluation of oxygen reduction catalysts in the current effort.

Future Work (04/05 to 09/05)

- Prepare sputter-deposited **Pt-X-Y** (**X**= Ni,Co,Fe; **Y**=Zr, Ti, Cr) catalyst layers
- Rapidly screen catalyst compositions using combinatorial multi-electrode array technique for oxygen reduction activity
- Characterize the catalyst layers for structure and electronic properties (XRD and XPS)
- Develop physicochemical rationale for catalyst design using electrochemical and electronic properties data
- Down-select promising catalyst compositions
- Demonstrate promising catalysts in full fuel cells

Publications and Presentations

"**Low Pt Content DMFC Catalyst Discovery Using Combinatorially-Deposited Nanoscale Thin Films**" J.Whitacre, S.R. Narayanan, and T.I.Valdez, Presented at the ECS Meeting , October 2004

"**Investigation of Direct Methanol Fuel Cell Electrocatalysts Using a Robust Combinatorial Technique**" J.Whitacre, T. I. Valdez and S.R.Narayanan, Accepted for publication in the Journal of the Electrochemical Society, 2005.

Hydrogen Safety

Laboratory testing of MEAs for catalyst evaluation will involve the use of hydrogen.

Safety Measures:

- All test procedures are reviewed and approved by JPL's Safety and Occupational Hazard Office.
- Conducting experiment in explosion proof hood free from ignition sources ensures safe operation.