Development, Characterization and Evaluation of Transition Metal/Chalcogen Based Cathode Catalysts for PEM Fuel Cells

Stephen Campbell
Ballard Power Systems
March 29th, 2004

This presentation does not contain any proprietary or confidential information.

power to change the world®
Project Overview/Objectives

- To develop a non-precious metal cathode catalyst for PEM fuel cells which is as active and as durable as current PGM based catalysts at a significantly reduced cost.

- Development of composition and structure
- Process development (can be scaled up)
- Evaluation/ demonstration in fuel cells & stacks.
### Budget

<table>
<thead>
<tr>
<th>Project year</th>
<th>Federal</th>
<th>Applicant</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$549,267</td>
<td>$200,300</td>
<td>$749,567</td>
</tr>
<tr>
<td>2</td>
<td>$529,280</td>
<td>$82,320</td>
<td>$611,600</td>
</tr>
<tr>
<td>3</td>
<td>$491,206</td>
<td>$122,802</td>
<td>$614,008</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,580,139</strong></td>
<td><strong>$395,036</strong></td>
<td><strong>$1,975,175</strong></td>
</tr>
</tbody>
</table>

Funding in FY04 is $400,000 from DOE and $100,000 from Ballard (20%)
Technical Barriers and Targets

- DOE Technical Barriers for Fuel Cell Components
  - O. Stack Material and Manufacturing Cost
  - P. Durability

- DOE Technical Target for Fuel Cell Stack System for 2010
  - Cost 35 to 45 $ kW_{e}^{-1}$ depending upon platform
  - Durability 5000 hours (including thermal and realistic drive cycles)
Technical Approach

- To determine the optimum catalyst composition (metal, chalcogen) and structure using well-defined, thin film materials on glassy carbon.
  - Determine best metal, best chalcogen and ratio
  - Determine best structure/phase of that composition
- To duplicate this structure as well as possible on carbon black using manufacturable processes.
  - Develop aqueous/thermal process to produce similar structure/composition at high dispersion on a conductive carbon support
- To optimize the electrode structure in a fuel cell and demonstrate performance and durability.
  - Optimize catalyst loading and Nafion/catalyst structure in electrode.
Work done at UBC uses established laboratory equipment and practices.

Care is exercised when handling the selenium targets but these will remain enclosed in the vacuum system of the coater.

Standard safe laboratory practices and procedures are followed.

In the final phase the catalyst will be tested at Ballard in fuel cells.

This will be carried out in systems which have undergone rigorous HAZOP during design, build and maintenance.

This is the only part of the project that will use hydrogen gas.
## Project timeline

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/04 - 6/05</td>
<td>6/05 - 6/06</td>
<td>7/06 – 6/07</td>
</tr>
</tbody>
</table>

- **Phase 1 – Ex-situ thin film matrix**
  1. Rough screening using Co, Fe, Cr with Se, S
  2. Detailed optimization of composition and structure
  3. Down-selection of preferred catalyst

- **Phase 2 – Development of process for manufacture of dispersed catalyst structures.**
  4. Develop aqueous/thermal process to make dispersed catalyst.
  5. HRTEM characterization with RDE and XPS
  6. Delivery of catalyst to Ballard for fuel cell testing

- **Phase 3 – Fuel cell testing**
  7. Optimize catalyst structure (loading, Nafion content, etc)
  8. Performance and stability assessment
  9. Deliver stack for independent evaluation and return.
Technical Accomplishment Summary

- Research staff (post-doctoral fellows and graduate students) are in place and working.

- Glassy carbon substrate has been machined into discs to fit the rotating electrode holder.

- Initial baselines using sputtered platinum to be obtained in early April. Data to follow.

- Coater modifications completed.

- It is expected to be coating $\text{Co}_x\text{Se}_y$ thin films by mid-April. Data to follow.
Technical Accomplishment Summary

Two source magnetron sputtering chamber to deposit thin films

power to change the world®
University of British Columbia:-
- Prof. Bob Parsons; thin film deposition, sputter coating (phase I)
- Prof. Keith Mitchell; surface science analysis (XPS, Auger, XRD) (phase I)
- Prof. Dan Bizzotto; electrochemical characterisation (phases I & II)

Case Western Reserve University:-
- Prof. Frank Ernst; High resolution transmission electron microscopy (HRTEM) for characterisation of powder catalyst in phase II.
Future Work

For FY 2004
- Develop compositional screening matrix using Co, Cr, Fe and Se.
- Down-select composition with best activity/stability.
- Fully characterize the structure of the down-selected composition.

FY 2005-2006
- Add sulfur to the screening matrix and determine if better than Se.
- Develop process to make dispersed catalytic material supported on carbon.
- Determine that powder catalyst has similar composition and structure to thin film.
- Deliver down-selected catalyst composition as powder for in-situ fuel cell optimization
Future Work

- **FY 2007**
  - In-situ fuel cell optimisation of down-selected powder catalyst.
    - Catalyst loading to meet cost/ performance targets.
    - Optimize catalyst/ ionomer structure for performance and stability.
    - Manufacture cathodes for Mk513 short stack and build stack.
    - Performance and lifetime test to validate catalyst.
    - Deliver stack for independent evaluation.