3D-Printed Electrochemical Cell for \textit{In-Situ} Analysis

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Doan-Nguyen Group
Motivation

- Energy storage systems enable renewable energy technologies

Source: EPA
Growth in Electrical Energy Storage Research

Source: Xing Luo, et al.
**Electrochemical Storage**
- High Efficiency
- Batteries

**Battery Stack**
- Electrodes
- Electrolyte
- Separator

**Ex Situ vs In Situ**
- Structural-Performance Relations
- Picture / Video Analogy

Source: Qu, et al.
## State of In Situ Cell Technology

<table>
<thead>
<tr>
<th></th>
<th>Ex Situ Cells</th>
<th>In Situ Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Use</td>
<td>- Coin Cells</td>
<td>- CR2016 Case</td>
</tr>
<tr>
<td></td>
<td>- ~ $5</td>
<td>- ~ $25</td>
</tr>
<tr>
<td></td>
<td>- Modified Coin Cells</td>
<td>- Not Commercial</td>
</tr>
<tr>
<td>Reusable</td>
<td>- Swagelok Cell</td>
<td>- MTI XRD Cell</td>
</tr>
<tr>
<td></td>
<td>- ~ $200</td>
<td>- ~ $2,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- AMPIX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Not Commercial</td>
</tr>
</tbody>
</table>

Source: Alok Tripathi, et al.
Problem: Lack of standardization among *in situ* cells can lead to different results between labs.

1. High cost of commercial cells
2. Detailed designs unavailable for non-commercial cells
3. Lack of quality control in non-commercial cells
4. Different experiment conditions necessitate different cell designs
Solution: *In situ* cell designs consisting solely of 3D-printed and commercial components.

- Long-Term Vision: online repository with cell designs for various experimental conditions
- Short-Term Goal: create proof-of-concept cell
Cell Architecture
CAD Model

- Wingnuts
- Cell Cover
- Gasket
- Shim
- Cell Top
- Washer
- Separator
- Spacer
- O-Ring
- Cell Bottom
- Screws
- Window
- Cathode
- Anode
- Spring
- Shim
Cost Analysis

<table>
<thead>
<tr>
<th>Parts</th>
<th>Quantity</th>
<th>Cost Per Unit</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Springs</td>
<td>1</td>
<td>$0.60</td>
<td>MTI</td>
</tr>
<tr>
<td>Spacers</td>
<td>2</td>
<td>$0.49</td>
<td>MTI</td>
</tr>
<tr>
<td>Washers</td>
<td>1</td>
<td>$0.08</td>
<td>McMaster</td>
</tr>
<tr>
<td>Bolts</td>
<td>3</td>
<td>$0.03</td>
<td>Grainger</td>
</tr>
<tr>
<td>Wing Nuts</td>
<td>3</td>
<td>$0.09</td>
<td>McMaster</td>
</tr>
<tr>
<td>Shims</td>
<td>2</td>
<td>$4.49</td>
<td>McMaster</td>
</tr>
<tr>
<td>O-rings</td>
<td>1</td>
<td>$0.06</td>
<td>Grainger</td>
</tr>
<tr>
<td>Gasket</td>
<td>1</td>
<td>$2.13</td>
<td>McMaster</td>
</tr>
<tr>
<td>Bottom</td>
<td>1</td>
<td>$0.18</td>
<td>3D-Printed</td>
</tr>
<tr>
<td>Cover</td>
<td>1</td>
<td>$0.10</td>
<td>3D-Printed</td>
</tr>
<tr>
<td>Top</td>
<td>1</td>
<td>$0.13</td>
<td>3D-Printed</td>
</tr>
<tr>
<td>Window</td>
<td>1</td>
<td>$0.22</td>
<td>Grainger</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>$13.82</strong></td>
<td></td>
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</table>
Assemblies

*In Situ* Configuration

*Ex Situ* Configuration
Open Circuit Voltage (OCV)
Electrochemical Impedance Spectroscopy (EIS)

![Graph showing EIS Tests - Ex Situ Configuration]
Test Analysis

- **OCV Tests**
  - \textit{In Situ} Configuration: 0.86\% percent loss over 7 hours
  - \textit{Ex Situ} Configuration: 8.53\% percent loss over 24 hours

- **EIS Tests**
  - Before Screws Tightened: \(~2,100\) ohms of interfacial resistance
  - After Screws Tightened: \(~1,800\) ohms of interfacial resistance
Conclusions

• Low relative cost of cell
• Cell able to effectively hold open circuit voltage over extended period
• High interfacial resistance
  • Reduced by increasing pressure on cell
• Overall, cell shows potential to be first of “standardized” set of *in situ* cells
  • Next, the cell should be cycled to further test performance
Acknowledgements

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• Thanks to Catrina Wilson and Dr. Jerry Gourdin for their advice
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