Hydrogen/Iron Regenerative Fuel Cell for Grid Storage Applications

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In the search for a low cost, efficient, reliable and stable energy storage system for grid applications, a novel redox system was fabricated and tested. This system employs hydrogen as a fuel and iron(II)/iron(III) electrochemical couple, as the positive electrode, in a nano-porous proton conducting membrane¹ (NP-PCM) regenerative fuel cell (RFC). This system was initially examined as a primary fuel cell by Fatih et al.², using a Nafion membrane, and reached maximal power density of 0.17 W/cm².

The regenerative fuel cell hardware was described elsewhere³. The membrane electrode assembly (MEA) was constructed from carbon paper electrodes for both half cells, with about 1 mg/cm² Pt alloy at the hydrogen electrode and 4 mg/cm² XC-72 carbon and 0.1 mg/cm² Pt alloy at the iron electrode. Several iron salts were evaluated, with their conjugated acids. The total iron concentration varied from 1 to 1.5 M and the acid concentration varied from 2 to 3.5 M.

Without cell optimization, polarization measurements (fig.1) showed relatively high power densities, with maximum of 0.27 W/cm² for the iron sulfate in sulfuric acid electrolyte. After minor optimization efforts we got an increase in the maximum power density to 0.35 W/cm² (fig. 1). Cycle life measurements, taken at constant current or constant power, revealed stable performance with a high utilization of the theoretical iron redox couple capacity (fig. 2, table 1). The highest efficiency values were obtained at 0.1 A/cm² (93% for the current and 85% for the energy conversion efficiency). Increasing the current density to 0.2 A/cm² resulted in a small decrease in the energy efficiency (table 1). At constant high power tests (0.2 W/cm²), the energy conversion efficiency was 79% and the iron redox couple capacity utilization was 69% (table 1). These results indicate that the hydrogen/iron regenerative fuel cell is a promising candidate for grid energy storage applications.

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**Figure 1:** Polarization measurements of hydrogen/iron RFC with different electrolytes taken at 60-65°C.

**Figure 2:** Cycle life measurements taken at 0.1, 0.2 A/cm² and at 0.2 W/cm² on discharge and 0.22 W/cm² on charge, voltage range: 0.45-0.85 V, 60°C.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>0.1 A/cm²</th>
<th>0.2 A/cm²</th>
<th>0.2 W/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of theoretical capacity</td>
<td>80</td>
<td>73</td>
<td>69</td>
</tr>
<tr>
<td>QE %</td>
<td>93</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td>VE %</td>
<td>92</td>
<td>87</td>
<td>81</td>
</tr>
<tr>
<td>EE %</td>
<td>85</td>
<td>83</td>
<td>79</td>
</tr>
</tbody>
</table>

**Table 1:** Capacity and efficiency values, measured at different current/power densities, voltage range: 0.45-0.85 V, 60°C. QE- current efficiency, VE-voltage efficiency and EE- energy conversion efficiency.

**References**