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# 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 membrane[1] (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/cm$^2$.

The regenerative fuel cell hardware was describes elsewhere[3]. The membrane electrode assembly (MEA) was constructed from carbon paper electrodes for both half cells, with about 1 mg/cm$^2$ Pt alloy at the hydrogen electrode and 4 mg/cm$^2$ XC-72 carbon and 0.1 mg/cm$^2$ 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 3.5M. Without cell optimization, polarization measurements (fig.1) showed relatively high power densities, with maximum of 0.27 W/cm$^2$ 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/cm$^2$ (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/cm$^2$ (93% for the current and 85% for the energy conversion efficiency). Increasing the current density to 0.2 A/cm$^2$ resulted in a small decrease in the energy efficiency (table 1). At constant high power tests (0.2 W/cm$^2$), 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.

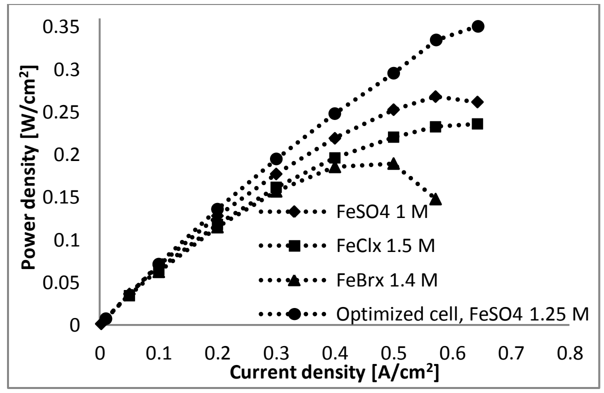


**Figure 1: Polarization measurements of hydrogen/iron RFC with different electrolytes taken at 60-65°C.**

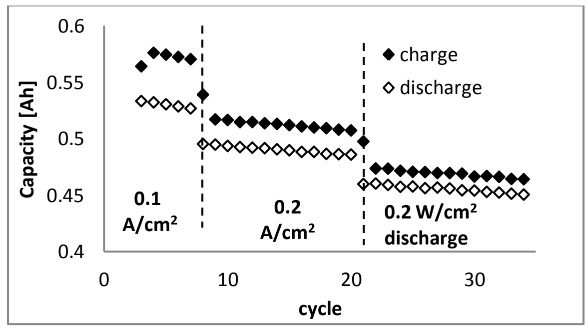


**Figure 2: Cycle life measurements taken at 0.1, 0.2 A/cm$^2$ and at 0.2 W/cm$^2$ on discharge and 0.22 W/cm2 on charge, voltage range: 0.45-0.85 V, 60 °C.**

| Conditions | 0.1 A/cm$^2$ | 0.2 A/cm$^2$ | 0.2 W/cm$^2$ |
|---|---|---|---|
| % of theoretical capacity | 80 | 73 | 69 |
| QE % | 93 | 96 | 97 |
| VE % | 92 | 87 | 81 |
| EE % | 85 | 83 | 79 |

**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

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