All Solid-State Iron-air Redox Battery for Advanced Energy Storage

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Metal-air batteries are an attractive option for electrical energy storage (EES) due to extremely high energy density and readily-available cathode oxidant (air). However, conventional metal-air batteries are limited by poor reversibility, fast capacity decade and electrode deformation, etc. Most of these problems are common in liquid-based metal-air batteries.

To cope with these problems, we recently demonstrated an all solid-state iron-air battery [1-3] with a completely new energy storage mechanism centered on the solid oxide fuel cell (SOFC) as the electrical functioning unit and iron/iron oxide redox couple as the energy storage unit. Fig.1 shows the working principle of this battery: the free-standing iron-based redox couple is situated at the fuel electrode chamber of the battery where a mixture of $\text{H}_2\text{O}/\text{H}_2$ is present to mediate the electrical-chemical energy conversion. The governing chemistry of the battery is:

$$\text{Fe} + \frac{x}{2} \text{O}_2 \xrightarrow{\text{discharge}} \text{FeO}_x$$

which suggests the nature of an iron-air battery. Different from conventional iron-air batteries, all of its components are solid materials, which avoids the strong chemical reactions occurred between liquid electrolyte and solid electrodes.

In our previous study, the all solid-state iron-air battery working at 800°C has been successfully demonstrated [1] and systematically studied [2]. In this study, we report our recent development in intermediate temperature battery (550°C). Fig. 2 shows the preliminary result of a most recently optimized iron-air battery. Within one cycle of t=2 hours under a current density of 10 mA/cm$^2$, the newly developed battery yields a discharge specific energy of 1,271 Wh/kg Fe, which is up to 93.5% of maximum theoretical specific energy. It also demonstrated a round trip efficiency of 85.4%, compared with the CSE=1,489 Wh/kg Fe. All these results show that the all solid state iron air battery is a promising electrical energy storage mechanism.

References