Novel earth-abundant bifunctional catalysts for oxygen evolution and reduction reactions

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PROJECT PROFILE

Topic: [Fe-Air batteries] | Vertical: [Materials and Systems Innovation]

Strategic Pathway: [Optimize]

Project start and finish: FY26-FY27

PROBLEM

- Abundant and low-cost materials for Fe-Air batteries (Fe, air, and H_2O), environmental benignity, and inherent safety
- High theoretical specific capacity and volumetric capacity (960 mAh g^{-1} and 7557 mAh cm^{-3}, respectively)
- Low round-trip efficiency (RTE, around 50%) due to sluggish oxygen evolution reaction (OER)/oxygen reduction reaction (ORR) kinetics at the air cathode and parasitic reactions like hydrogen evolution reaction (HER) at the iron anode
- Huge attention has been devoted to suppressing the HER, while the OER/ORR at the air-cathode has been much less emphasized

APPROACH

Three approaches are employed to address the low RTE issue of Fe-Air batteries by integrating the ORNL teams' experience in bifunctional catalyst design, battery fabrication and test

- Develop earth-abundant novel $CuMnO_x$ catalysts to boost the OER/ORR
- Fabricate Fe-loaded on high conductive and surface area carbon materials to improve the charge/discharge rate
- Employ electrolyte/electrode additives in the anode to suppress the HER and mitigate the passivation

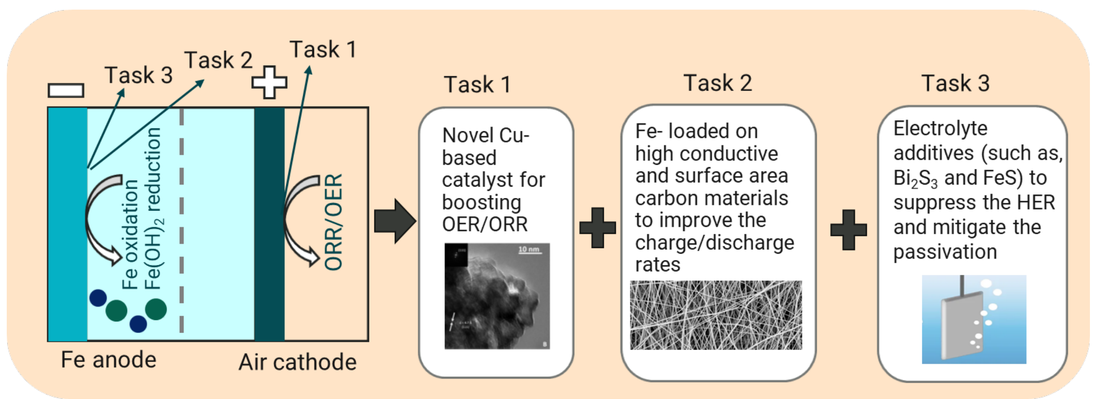

Fig. 1. Illustration of tasks to enhance the RTE of Fe-air batteries.

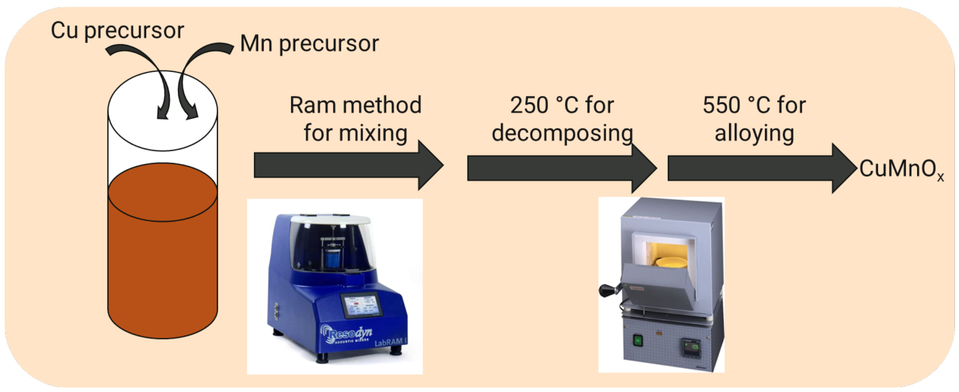

Fig. 2. Illustration of $CuMnO_x$ catalyst synthesis for OER/ORR in task 1.

RESULTS

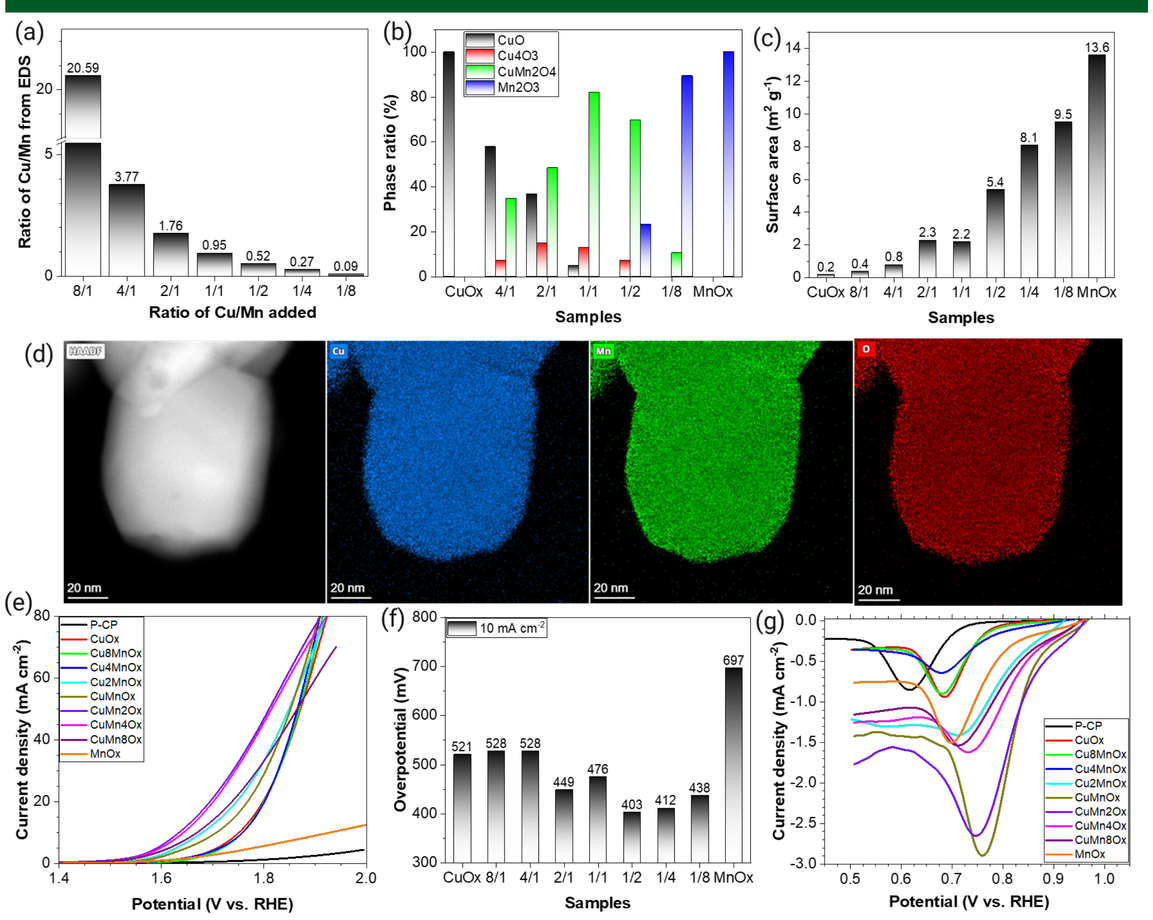

Fig. 3. Figures of key results. (a) atomic ratio of Cu/Mn for $CuMnO_x$ catalysts. (b) Phase ratio of $CuMnO_x$ catalysts from XRD analysis. (c) Specific surface areas from BET analysis. (d) STEM/EDS images of $CuMnO_x$ catalyst. (e) Linear sweep voltammetry (LSV) curves for OER activity evaluation. (f) Overpotential at 10 mA cm^{-2} for OER from LSV curves. (g) LSV curves for ORR activity evaluation.

CONCLUSIONS & IMPACT

- $CuMnO_x$ catalysts were synthesized successfully with different atomic ratio of Cu/Mn
- According to the XRD analysis, a total of 4 different compound phases are observed, CuO, Cu_4O_3, $CuMn_2O_4$, and Mn_2O_3. The CuO phase decreases with the increase of Mn content, and Mn_2O_3 shows an opposite trend. The $CuMn_2O_4$ phase shows the peak as high as 82.1% in sample 5 (Cu/Mn/=1/1)
- The specific surface area increases as a function of Mn content
- The distribution of Cu, Mn, and O is uniform based on the STEM/EDS images
- The Mn-rich catalysts (except MnO_x) exhibits a higher activity towards OER at low current density, while the trend changes at high current density due to their poor reaction kinetics
- Generally, the catalysts with the similar Cu/Mn ratios (high $CuMn_2O_4$ content) exhibit a higher activity for ORR, such as samples 5 and 6
- The development of bifunctional catalysts with high activity can decrease the overpotential of the air-cathode, and then increase the RTE, resulting in the decrease of cost for energy storage and conversion

FUTURE DIRECTIONS

This early career project just started in the beginning of FY 26, and we will continue work on it as planned

- Integrate the high conductive and surface area carbon support and small Fe particles (nm-µm scale) to improve the charge/discharge rate
- Employ electrolyte/electrode additives in the anode to suppress the HER and mitigate the passivation

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