Zn-Air Batteries: Understanding Zn electrodes, New Air Electrodes

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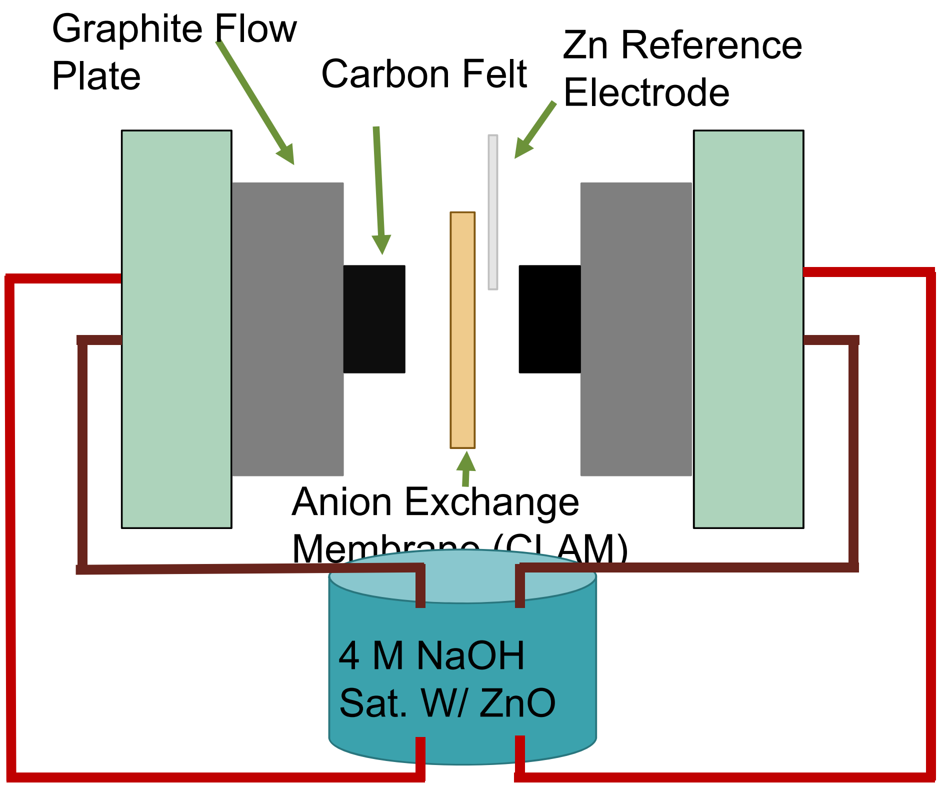
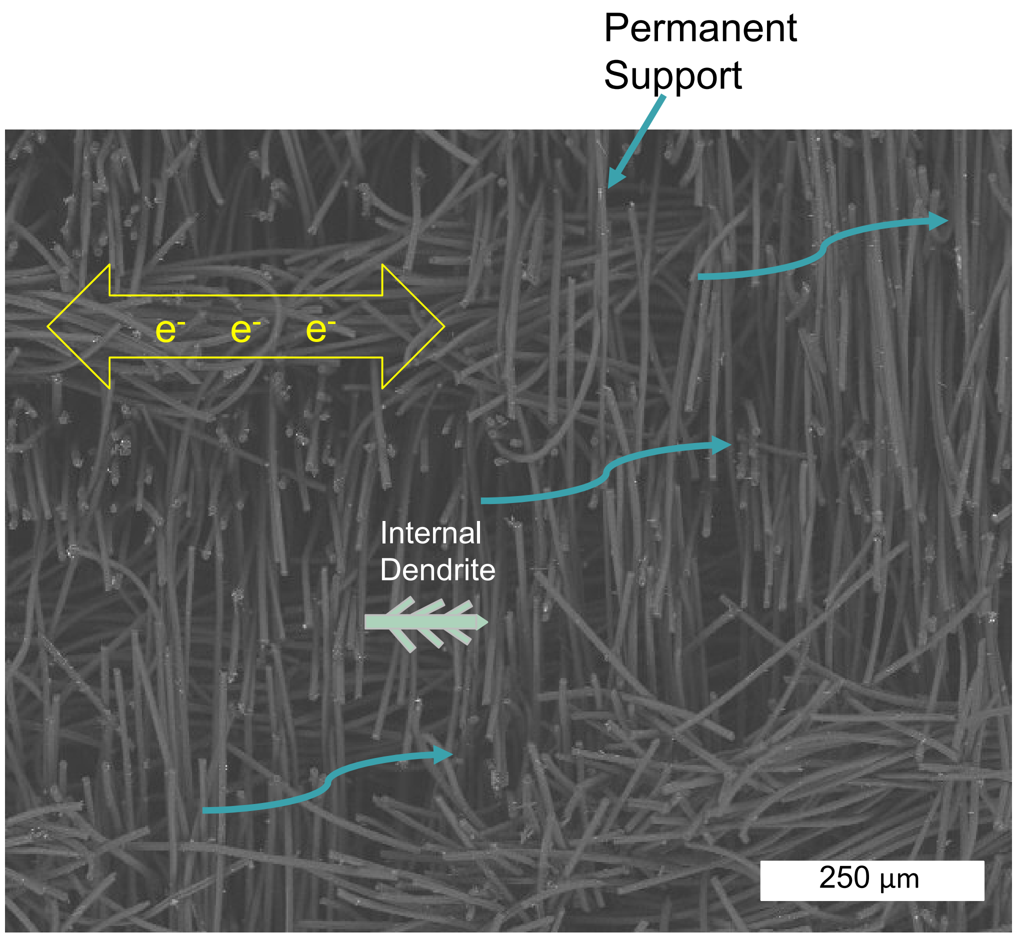
A Flow-Assisted Zn Electrode



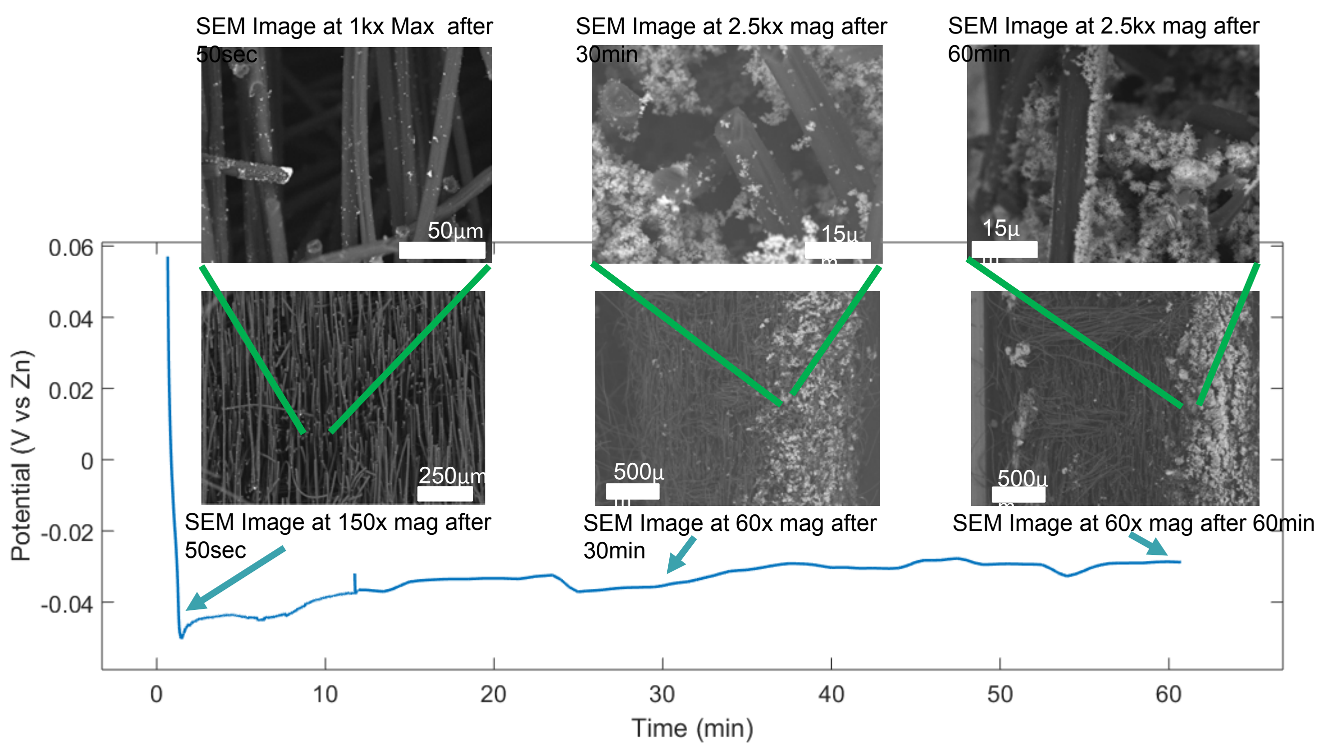


SEM image 2.5EA Carbon Felt at 150x Mag

Zn Electrodes: Zn in carbon felt

Progression of Electrodeposition on Bare Felt

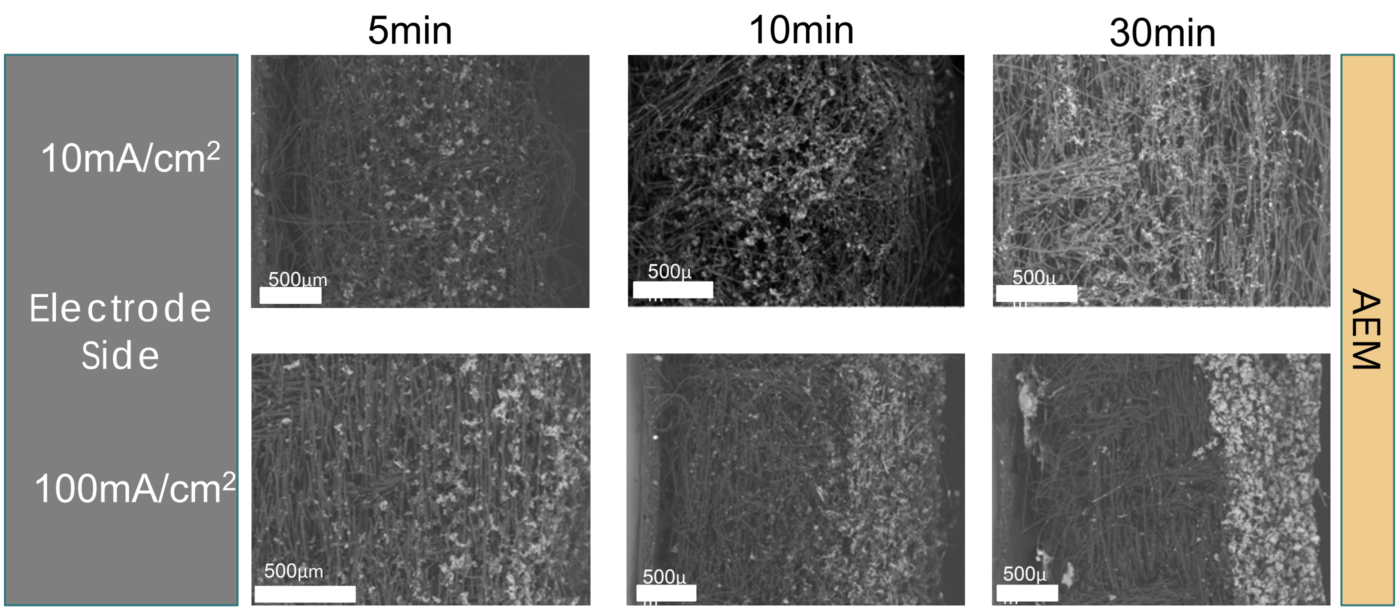
40mA/cm² Deposition Step on Bare Felt



Experimental:
40mA/cm² deposition
10ml/min flow rate
WE: 2.5EA Felt
CE: 2.5EA Felt loaded with Zn plate
RE: Zn wire
Electrolyte:
4M NaOH sat w/ Zn

Charging Zn Electrodes: Zn in carbon felt

Deposition Dispersion Changes with Current Density



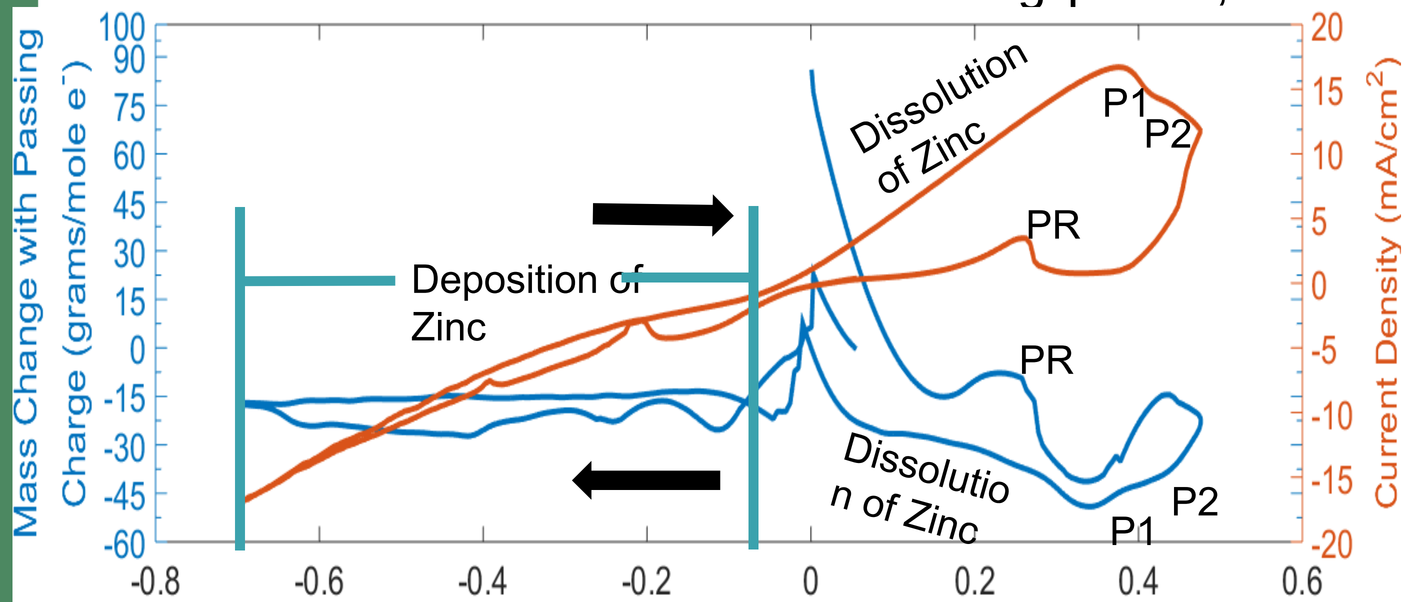
Experimental:
SEM Images at different times during 10 and 100mA/cm^2 current deposition
Flow rate 15ml/min
WE: 2.5EA Felt
CE: 2.5EA Felt loaded with Zn plate
RE: Zn wire
Electrolyte:
4M NaOH sat w/ Zn

- Higher current density: deposition localized near the membrane
- Lower current density: deposition is evenly dispersed through felt
- **Indicates an imbalance of the growth process at high current density**

Possible New Diagnostic Approach for Flow Distribution

Discharging Zn Electrodes: Unraveling the Chemistry

EQCM: Correlating Mass Change with Current Allows for Analysis of Electrochemical Reaction taking place; ID's Native Oxide Film



Number of electrons involved	Zn	ZnO	$Zn(OH)^-$	$Zn(OH)_2$	$Zn(OH)^-_3$	$Zn(OH)^{2-}_4$	Zn => ZnO	Zn => $Zn(OH)^-$	Zn=>$Zn(OH)_2$
1	-65	-81	-82	-99	-116	-133	-16	-17	-34
2	-32.5	-40.5	-41	-49.5	-58	-66.5	-8	-8.5	-17

- Obtain molar mass changes of species at the interface
- Show passivation removal occurs as ZnO and $Zn(OH)_2$ converted to Zn
- Passivation process does not show signs of precipitation
- Species coming off of the surface correspond to a change in reaction product from Zincate to ZnO and $Zn(OH)_2$
- Suggests reaction changes based on local concentration of zincate at surface

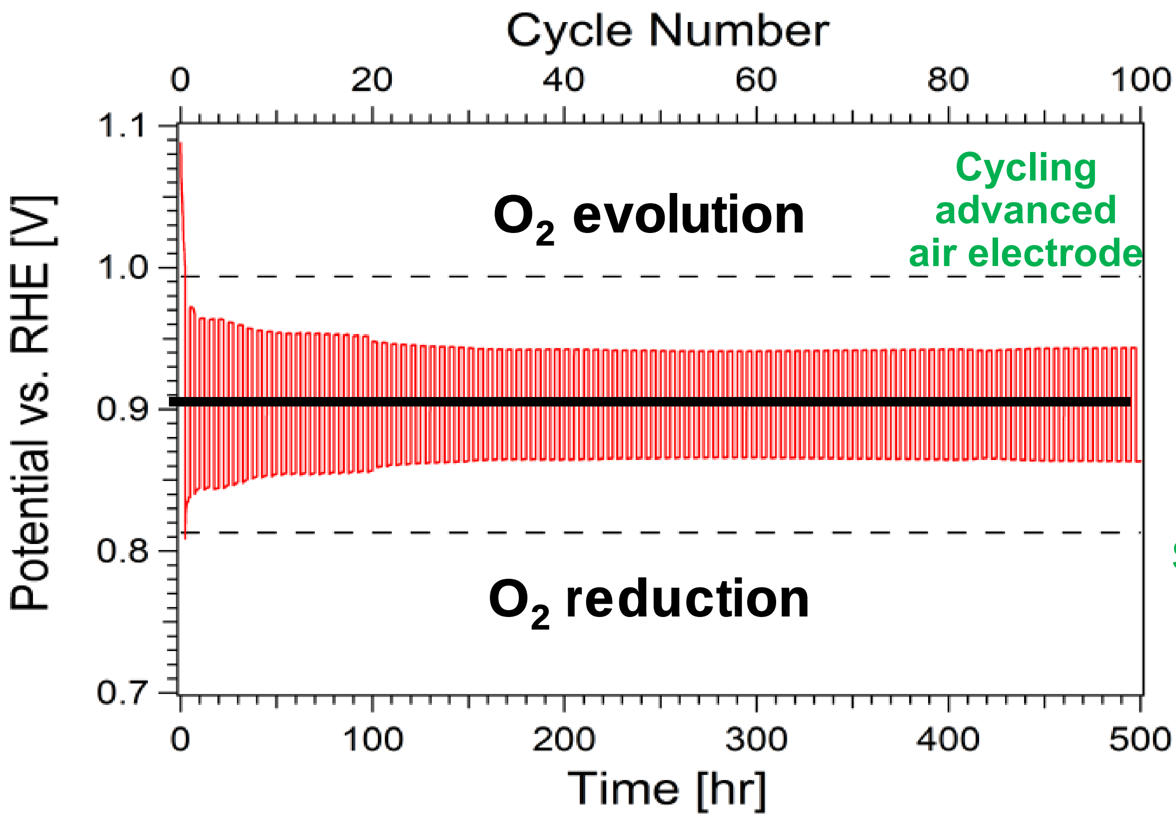
Zn-Air System: positive oxygen electrode

Radical Efficiency Improvement

Air electrode: one electrode can improve multiple battery types

Low voltage of OER enable use of carbon in electrodes!

New completely non-precious catalyst in development

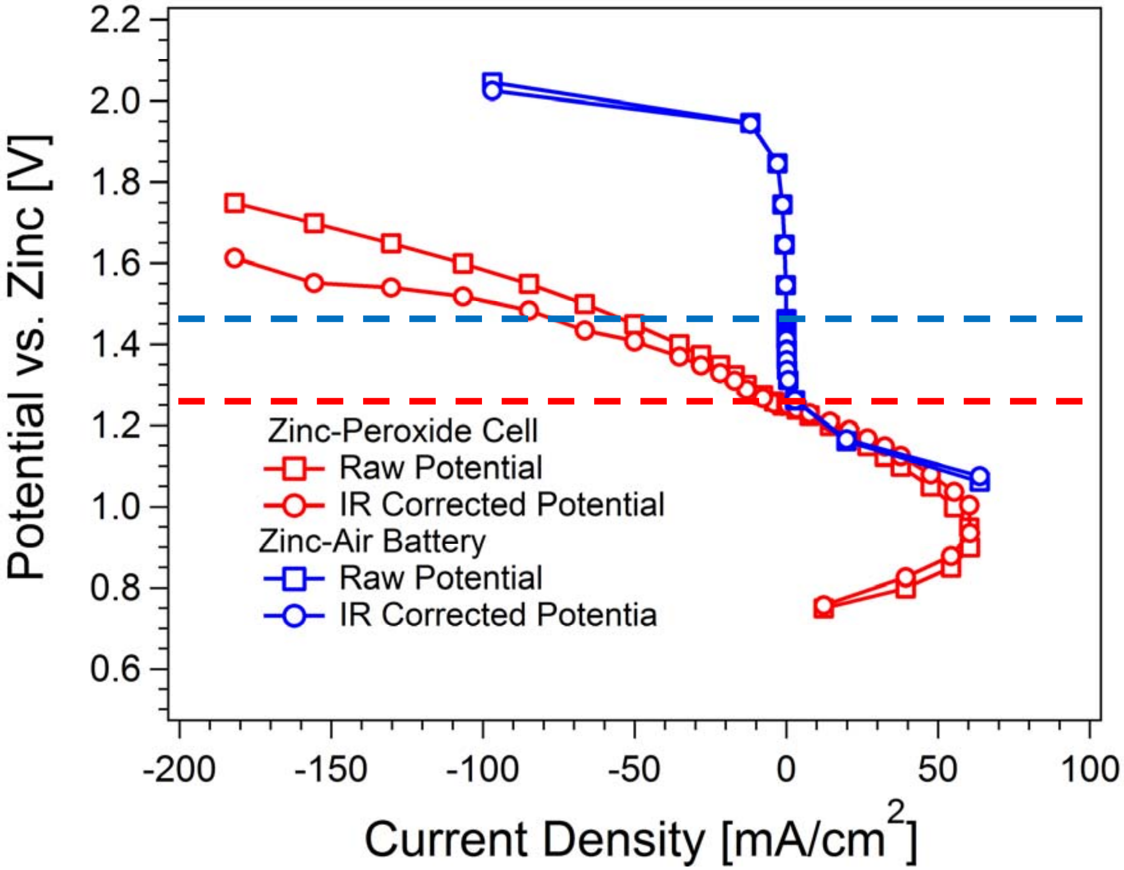


Cycling at 40 mA/cm^2

95% efficiency in each direction!

Symmetric Cell cycling (3-electrode cell)

Zn-Peroxide Comparison to Zn-Air Battery



Zn-air
OCV~1.5 V
Typical charging potential, efficiency
20 mA/cm^2 1.95 V, 70%
50 mA/cm^2 2 V , 67%
100 mA/cm^2 2.05 V , 63%
150 mA/cm^2 Cannot sustain this current
Must use expensive catalysts, supports.

Zn-Peroxide
OCV~1.3 V
Typical charging potential
20 mA/cm^2 1.32 V, 99%
50 mA/cm^2 1.45V , 89%
100 mA/cm^2 1.6 V , 75%
150 mA/cm^2 1.7 V , 69%
NO expensive catalysts, supports.

To Do List: Build a bigger system with improved mt.

Acknowledgements

1. **Thanks to Imre Gyuk and OE**
2. Thanks to my team and collaborators at ORNL and UTK and the Bredesen Center.
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