Electrochemical Coupling between Active Particulates and Aluminum Alloys

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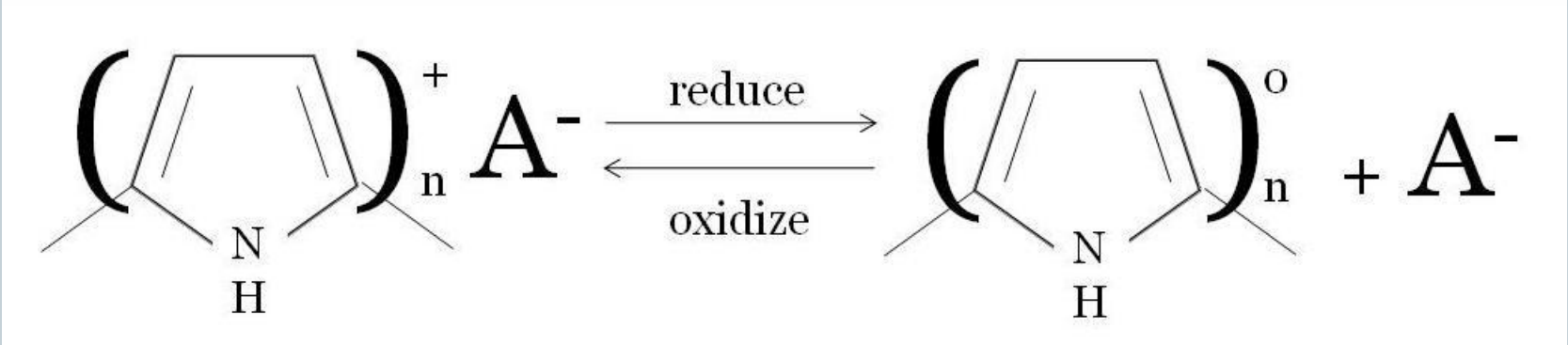
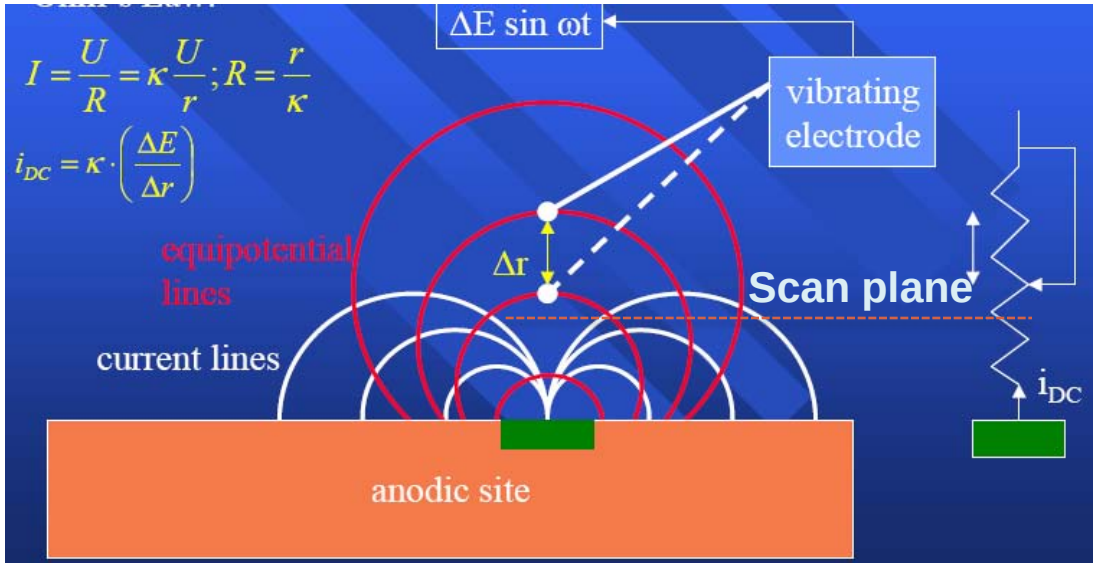
Why Conducting Polymers?

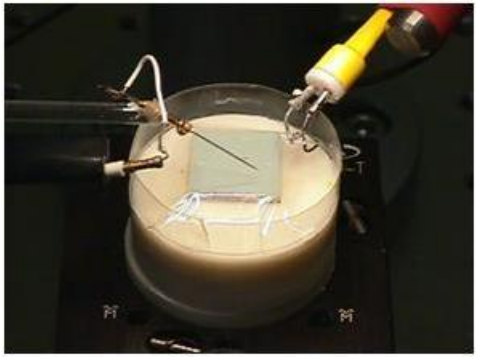
- Perhaps act as “Smart Coating”
  - Release of Corrosion Inhibiting Anions
- Mixed Potential between surface and ECP
- Perhaps acts as an oxidant to form passive layer



Scanning Vibrating Electrode Technique (SVET)

SVET measures the ionic current flux in solution at the micro scale through detecting the vertical component of the potential gradient near the corroding sites via a movable vibrating microelectrode, then converting the potential gradient to the current density by a calibration procedure



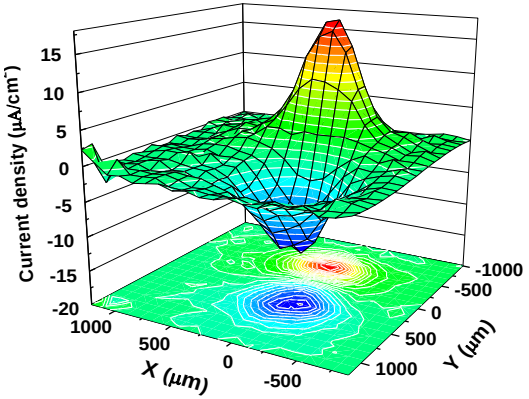


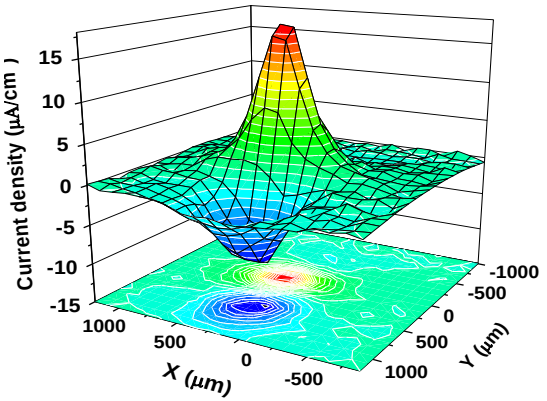
SVET Results

Al flake primer

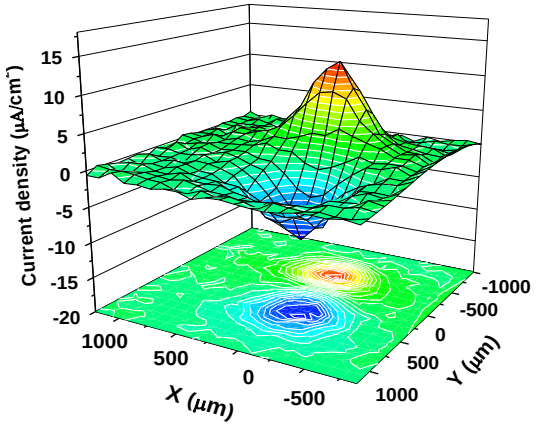
PAFC primer 1st generation

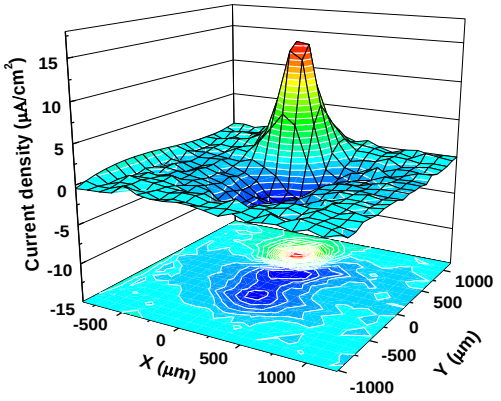
24h





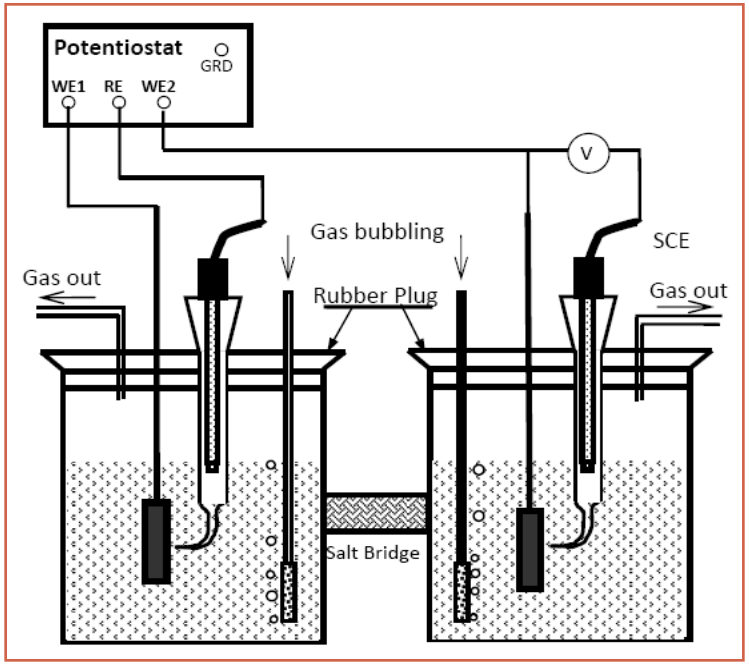
48h





Galvanic Coupling Measurement

A two-compartment cell used for the galvanic coupling measurement segregated the coating from the AA 2024-T3 substrate, which allowed investigation of the effects of atmospheric condition on the galvanic interaction.



Coating compartment (Purged with N_2 or air)

AA compartment (Purged with air)

- **Working area:**

  Coatings, 1.5 cm^2

  AA 2024-T3, a 0.04 cm^2 pinhole

- **Atmospheric condition**

  Coating compartment, purged with N_2 or air.

  AA compartment, purged with air.

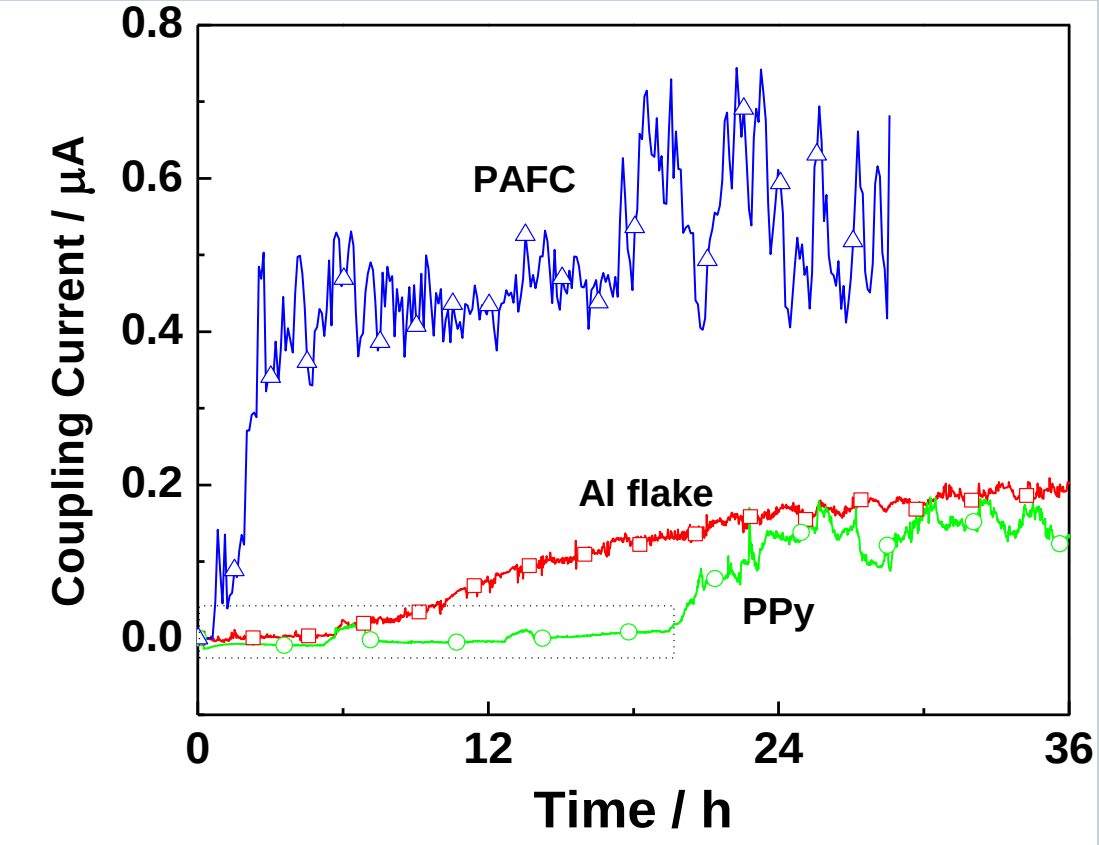
- **Electrolyte solution:**

  Dilute Harrison's solution (DHS),

  0.35% $(NH_4)_2SO_4$ + 0.05% NaCl

M. C. Yan, D.E. Tallman, G.P. Bierwagen, *Electrochimica Acta*, 54 (2008) 220-227

Galvanic Coupling between PAFC and AA 2024-T3

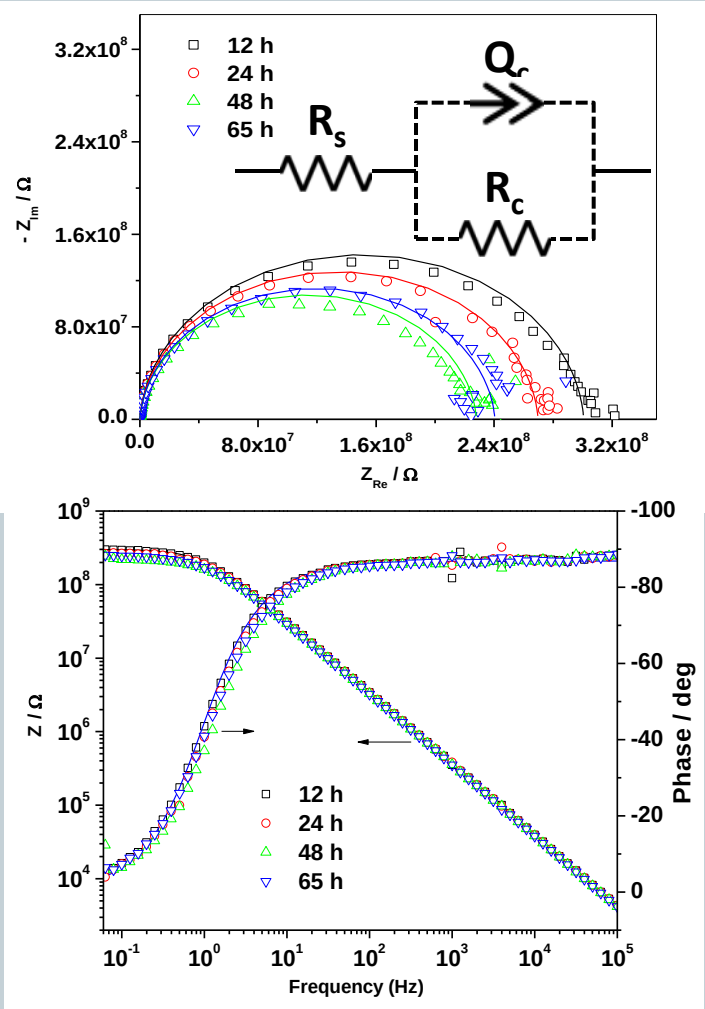


Coupling current for bare AA 2024-T3 (exposed through a pinhole simulating a defect) coupled with PAFC primer, Al flake primer and PPy primer, respectively.

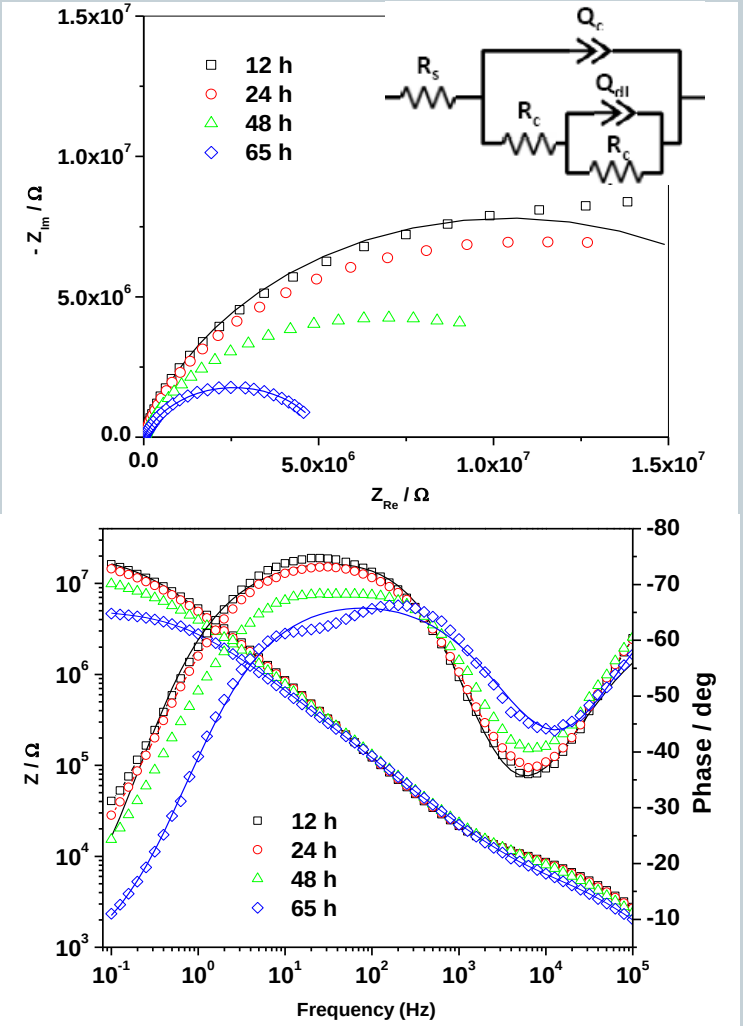
AA compartment: 0.04 cm^2 exposed area in aerated DHS. Coating compartment: 1.5 cm^2 exposed area in N_2 purged DHS. Positive current signifies cathode in the AA-compartment.

N_2 Purged DHS

Experimental data and fitted line are presented by points and solid lines, respectively.



Al flake primer on AA 2024-T3



EIS of PAFC primer on AA 2024-T3

Fitted parameters of the EIS spectra of Al flake primer and PAFC primer in N_2 Purged DHS.

Time (h)	Q_c		R_c (Ω)	Q_{dl}		R_{ct} (Ω)
	Y_0 ($S \cdot s^n$)	n		Y_0 ($S \cdot s^n$)	n	
Al Flake						
12	5.88×10^{-10}	0.9652	3.01×10^{8}	––	––	––
24	5.89×10^{-10}	0.9651	2.70×10^{8}	––	––	––
48	6.25×10^{-10}	0.9622	2.28×10^{8}	––	––	––
56	6.36×10^{-10}	0.9618	2.41×10^{8}	––	––	––
PAFC						
12	2.02×10^{-8}	0.7278	1.46×10^{4}	1.91×10^{-8}	0.8916	2.115×10^{7}
24	2.27×10^{-8}	0.7222	1.46×10^{4}	1.9810^{-8}	0.8792	1.866×10^{7}
48	3.42×10^{-8}	0.6962	1.63×10^{4}	1.78×10^{-8}	0.8699	1.392×10^{7}
56	9.77×10^{-8}	0.801	7.06×10^{3}	5.08×10^{-8}	0.7558	5.163×10^{7}

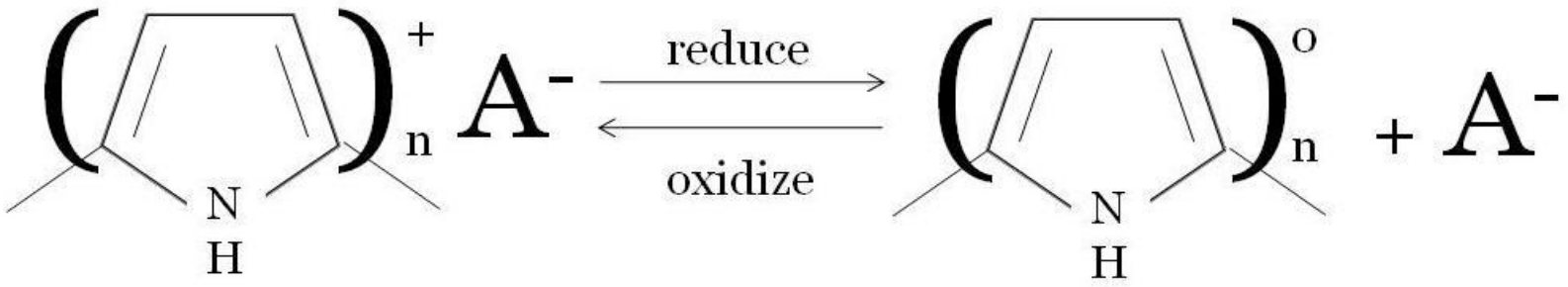
Incorporation of inhibitors in the PAFC coating

- Several corrosion inhibitors were incorporated in the PAFC coating:

  ✓Vanadate
  ✓Molybdate
  ✓Phosphate

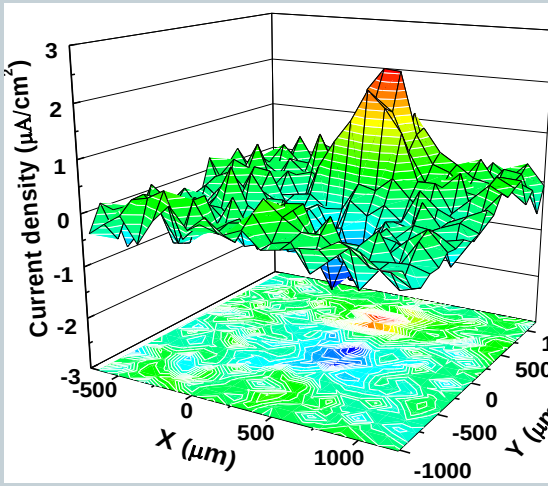
The effect of incorporation of inhibitors on the anticorrosion performance of PAFC coating for Al alloys was investigated.

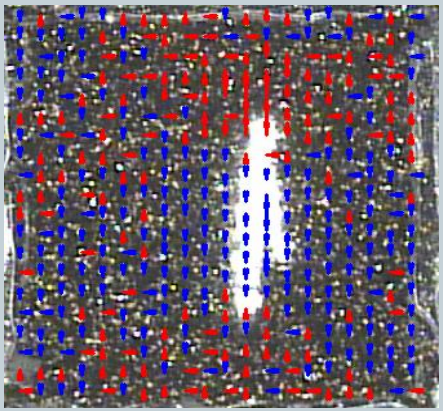
Controlling the Counterion



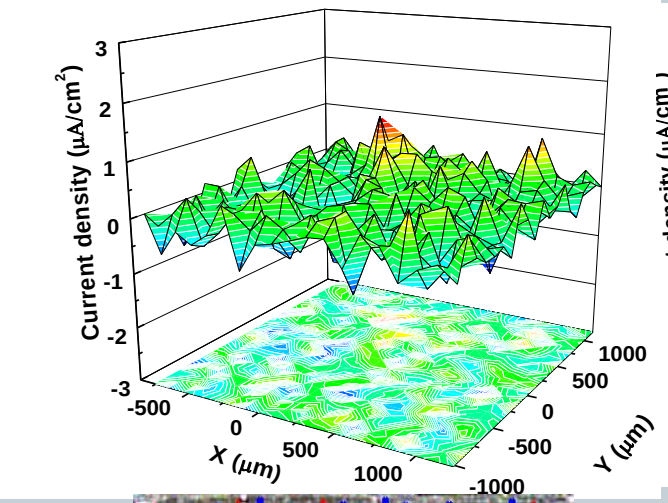
	Al Flake (g)	Sodium Phosphate (M)	Sodium Molybdate (M)	Sodium Vanadate (M)	Sodium Stannate (M)	Catechol (M)	Pyrrole (M)	Ammonium Persulfate (M)
Phosphate Composite	3.00	3.62	0.00	0.00	0.00	0.1	0.2	0.4
Molybdate Composite	3.00	0.00	1.35	0.00	0.00	0.1	0.2	0.4
Vanadate Composite	3.00	0.00	0.00	1.73	0.00	0.1	0.2	0.4
Stannate Composite	3.00	0.00	0.00	0.00	1.15	0.1	0.2	0.4

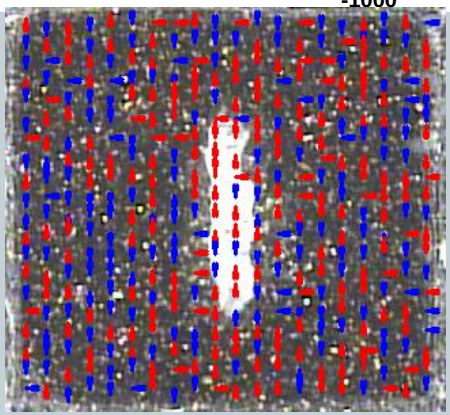
SVET



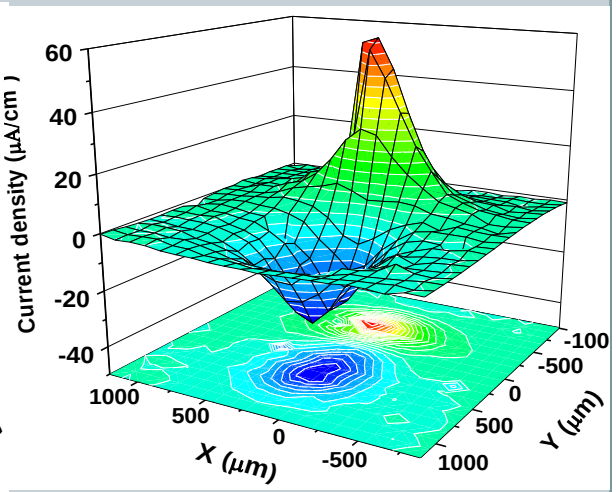


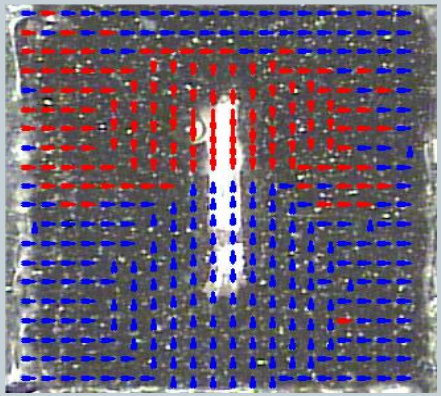
Vanadate





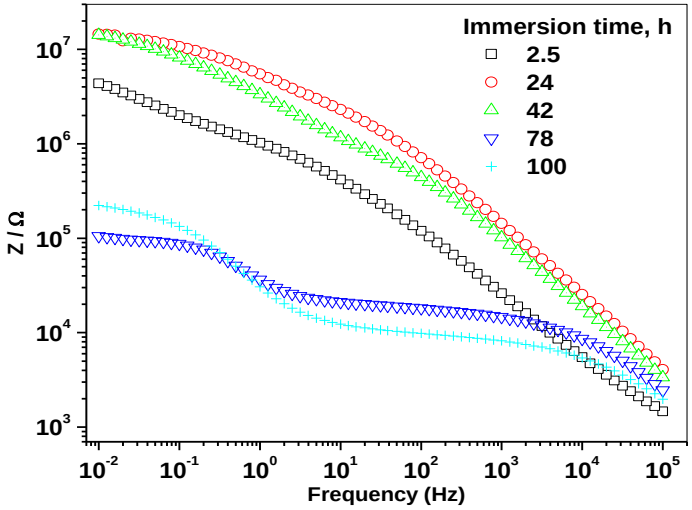
Molybdate



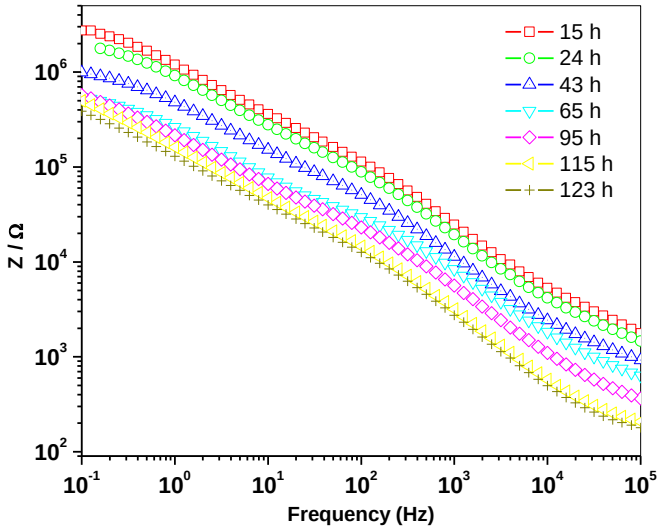


Phosphate

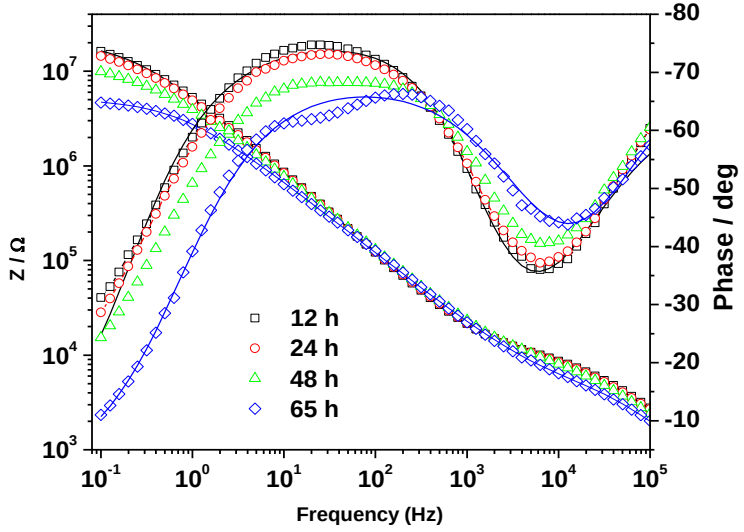
EIS in N2-sparged DHS



Molybdate

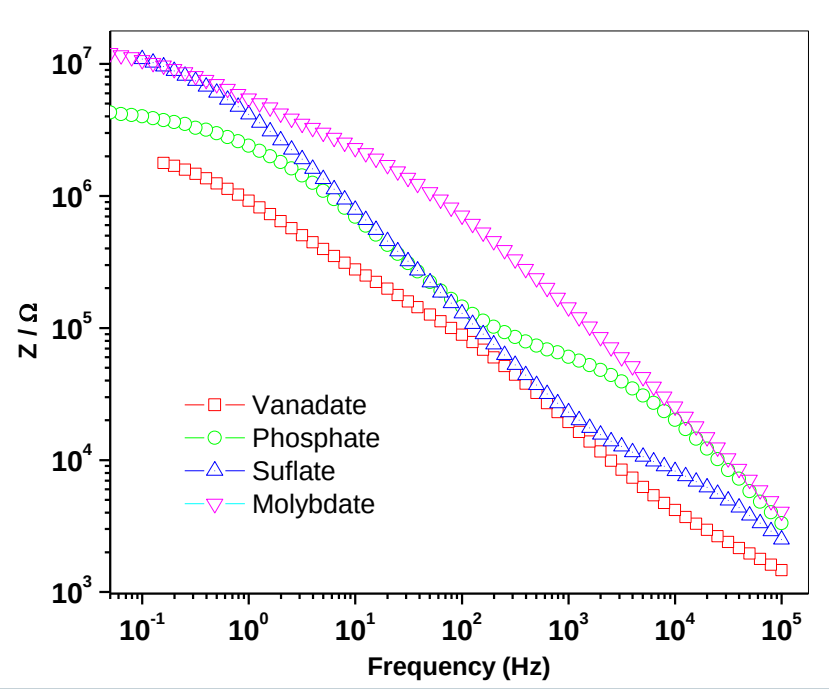


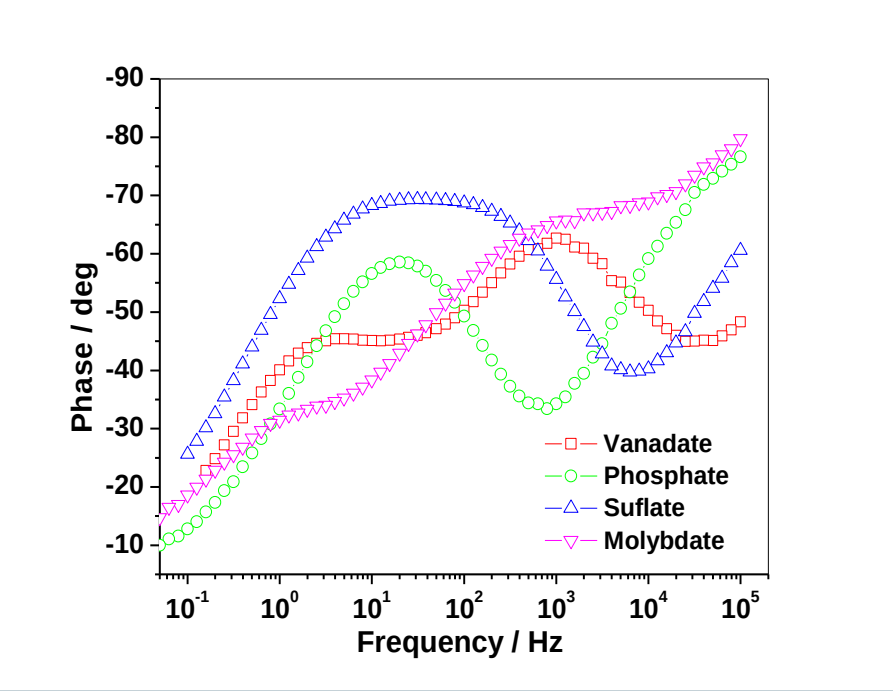
Vanadate



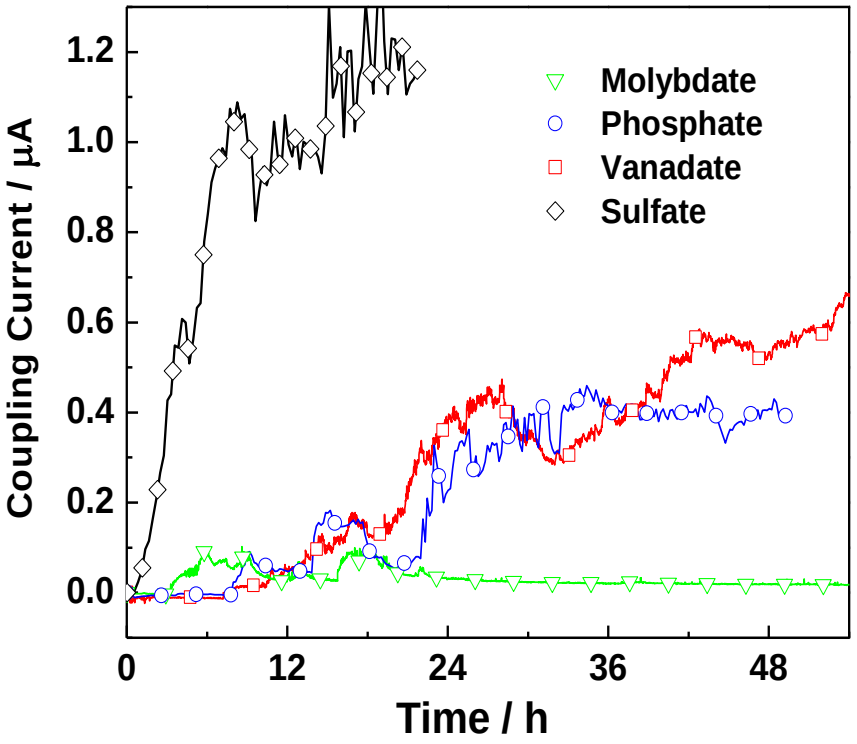
Sulfate

Effect of Inhibitor on EIS of the PAFC Coatings in N_2-Purged DHS

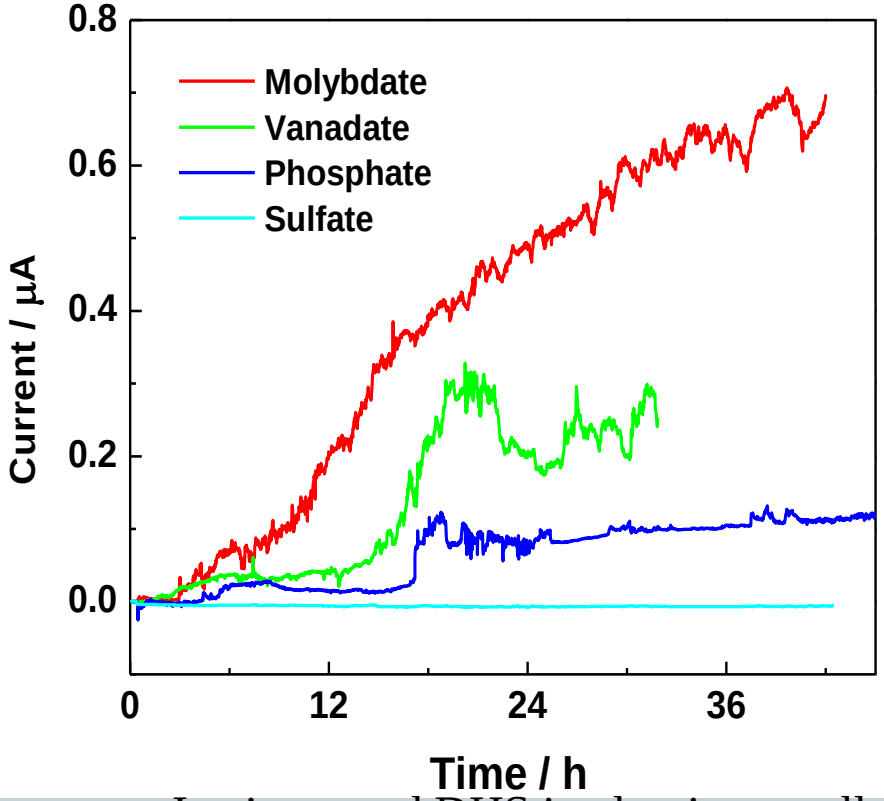




Galvanic coupling between PAFC/inhibitors and AA 2024-T3



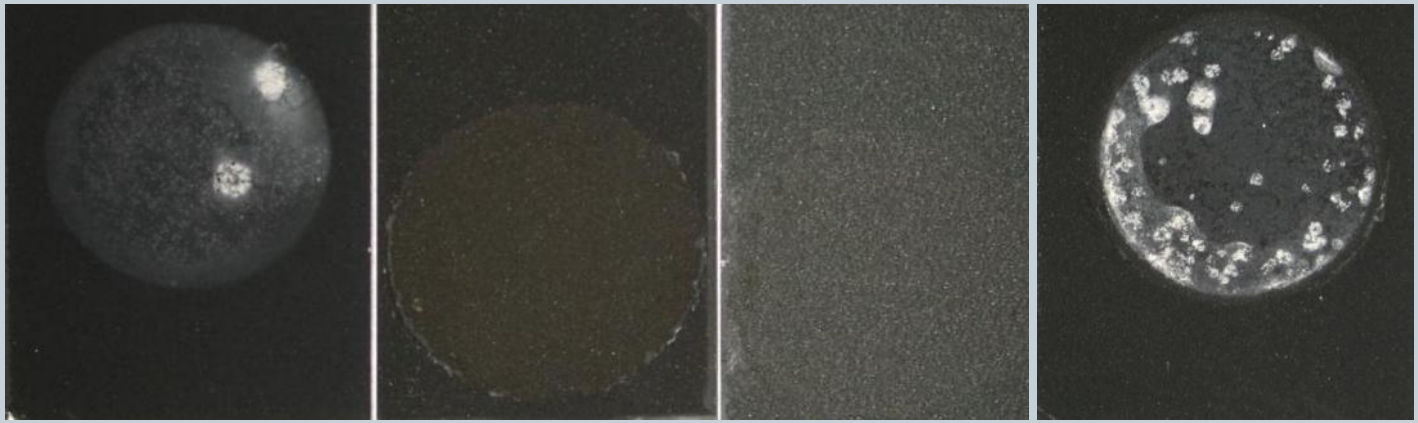
In N_2-purged DHS in two cell



In air-purged DHS in aluminum cell

Coupling current for bare AA 2024-T3 coupled with the inhibitor containing PPy/Al flake coatings in DHS.

30 Days Immersion in DHS



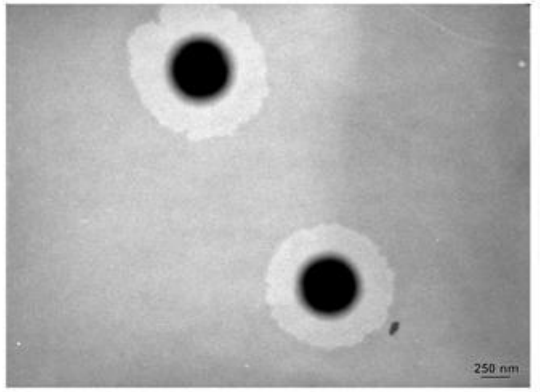
Phosphate Vanadate Molybdate Sulfate

Summary

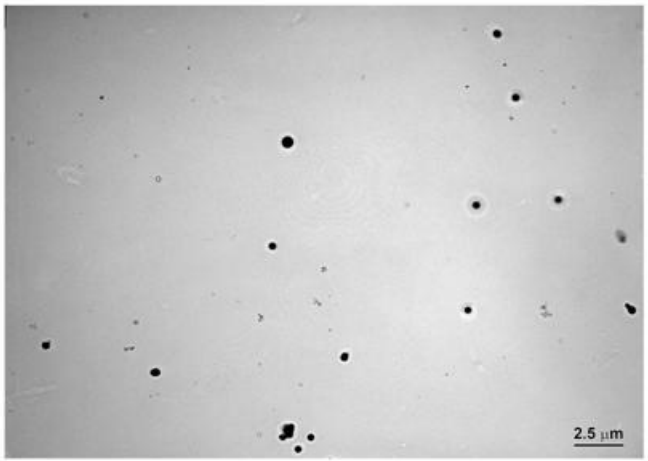
- The polypyrrole (PPy) Al flake composite (PAFC) coating combined the electrochemical active property of PPy with the improved barrier property provided by Al flake.

- No evident electrochemical interaction occurred between the PAFC and the AA 2024-T3 substrate in an open-to-air condition, as detected by SVET. However, the PAFC coating in a deaerated condition afforded sacrificial protection for the AA 2024-T3 substrate, as evidenced by the galvanic coupling measurement.

Future Directions—Novel Routes to Synthesis of Nano-Particulates of Polypyrrole



17921 Gelling / Vetter 58,700x
092135 / Aqueous Polypyrrole Dist., 11/04/09



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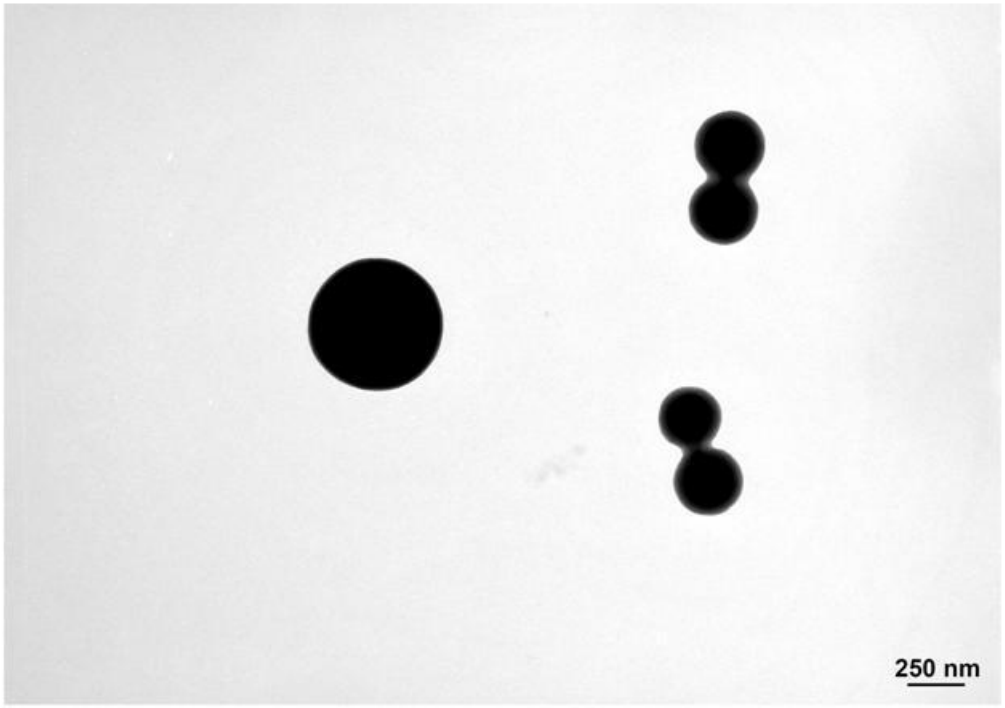

17918 GELLING / Vetter 58,700x
092135 / Aqueous Polypyrrole Dist., 11/04/09

Thank You.

Questions?