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SMART COATINGS: REACTIVE MICROCAPSULES CONTAINING CORROSION INHIBITORS

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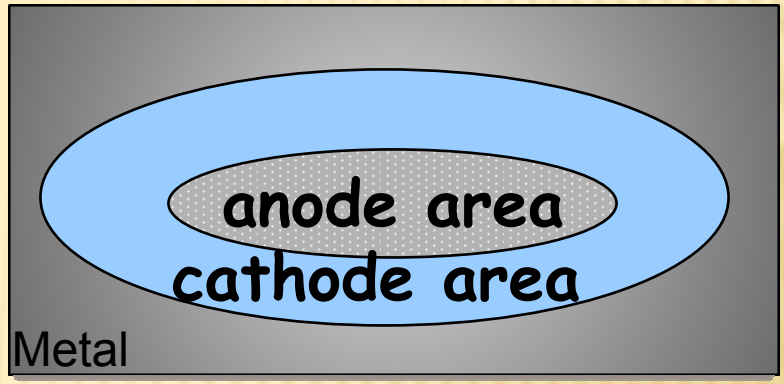
CORROSION REACTIONS IN METALS

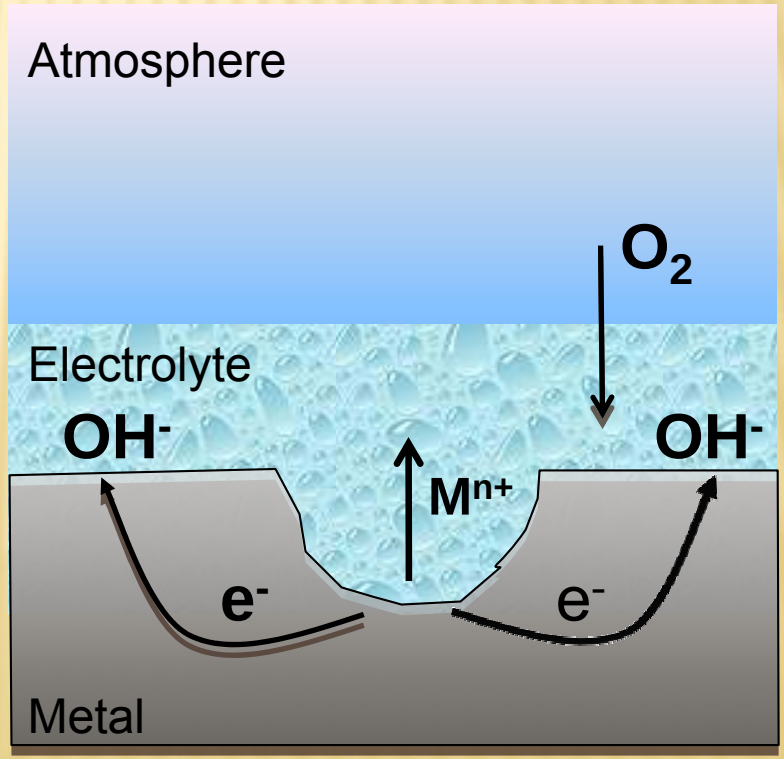
$Fe \rightarrow Fe^{+2} + 2e^-$

or

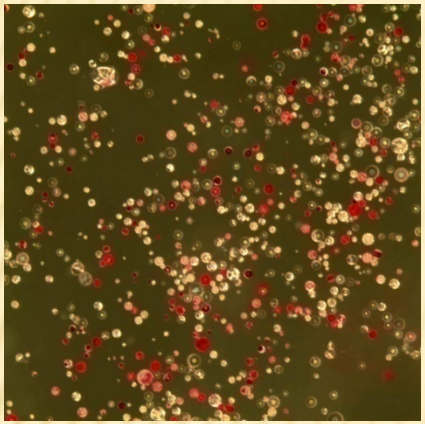
$Al \rightarrow Al^{3+} + 3e^-$

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

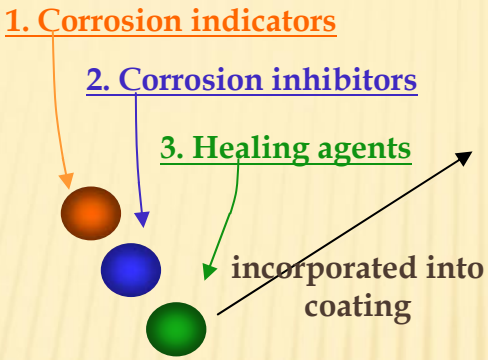


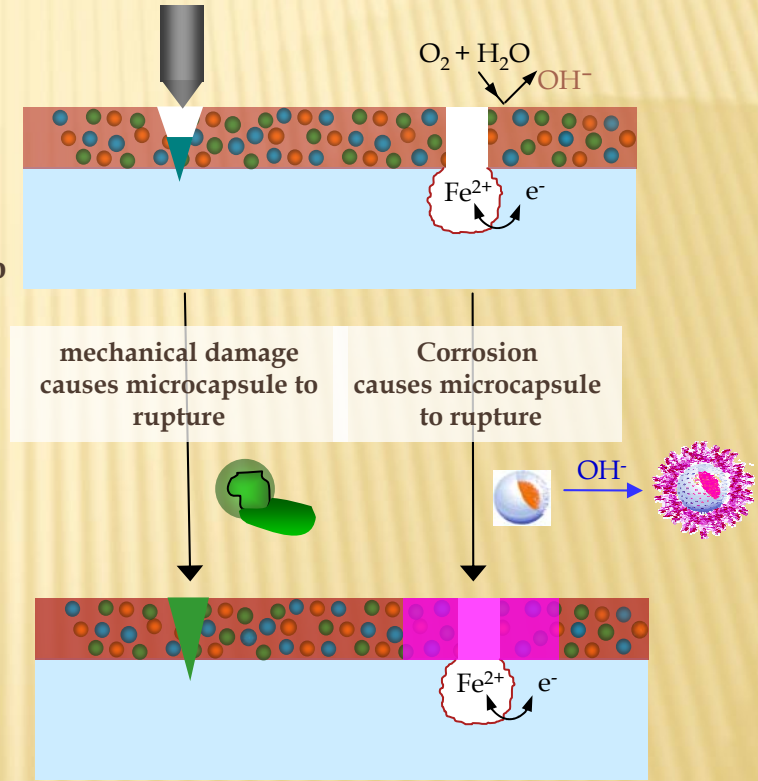


SMART COATINGS FOR CORROSION DETECTION



pH sensitive microcapsules





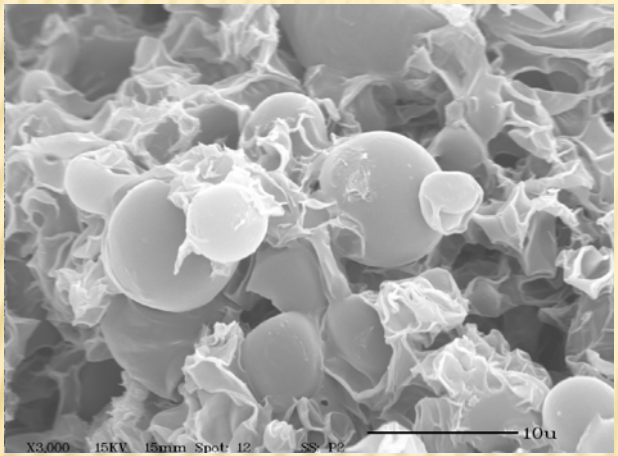
Smart coating will:

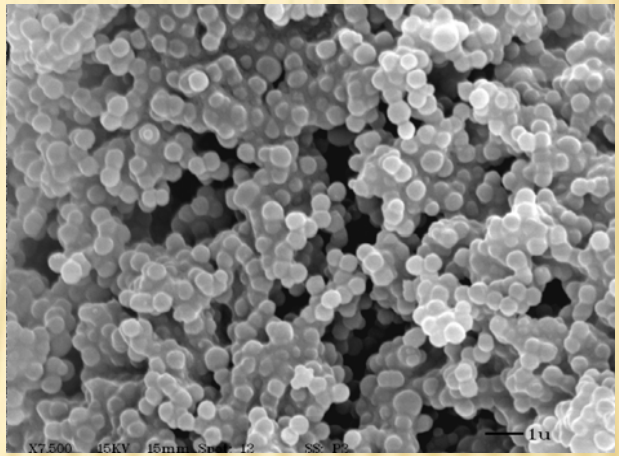
- Detect and indicate corrosion at its early stage.
- Release inhibitors to stop corrosion propagation.
- Heal mechanical damage to the coating.

MATERIALS

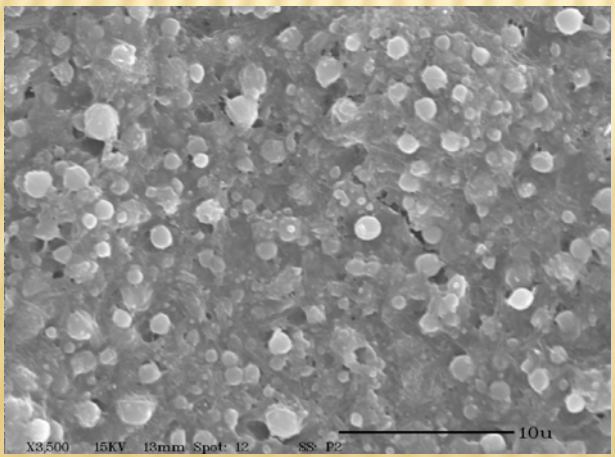
Microcapsules
Empty Oil Core/Empty Water Core
Water core with corrosion inhibitor Na_2MoO_4
Water core with corrosion inhibitor $Ce(NO_3)_3$

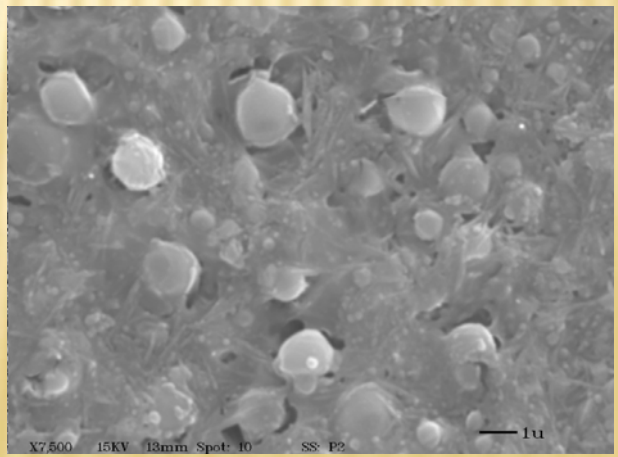
- Epon 828
- Amicure PACM-20





First Microcapsules As-Received





Microcapsules in Epoxy Coating

ELECTROCHEMICAL EXPERIMENTAL

Electrolyte

- Dilute Harrison's solution (0.35% $(NH_4)_2SO_4$ and 0.05% NaCl)

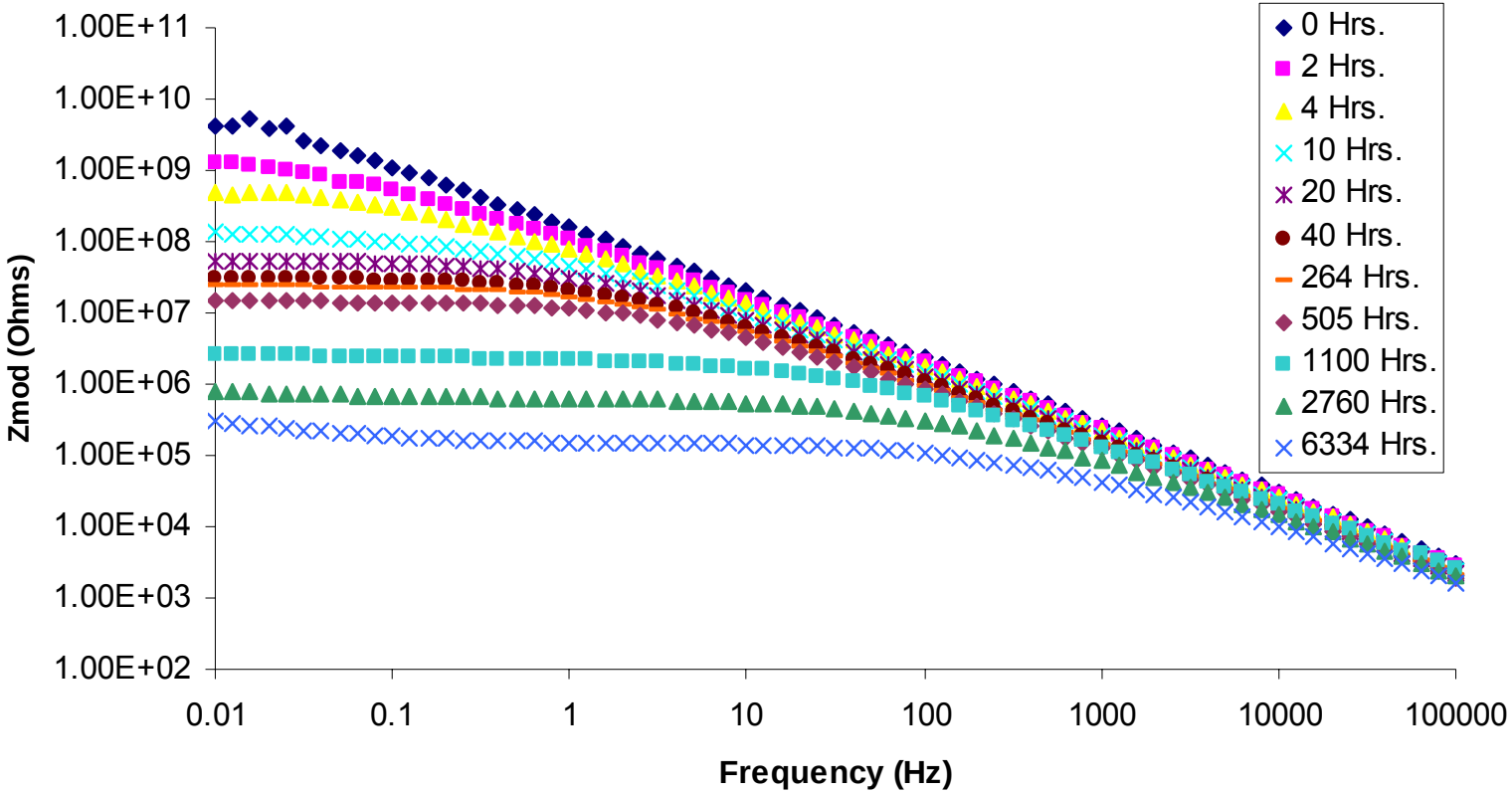
Electrochemical cell

- Polyvinylchloride pipe with an inner diameter of 2.6 cm attached to the substrate using Marine Goop® adhesive.
- Platinum coated mesh counter electrode
- Saturated calomel reference electrode (SCE)

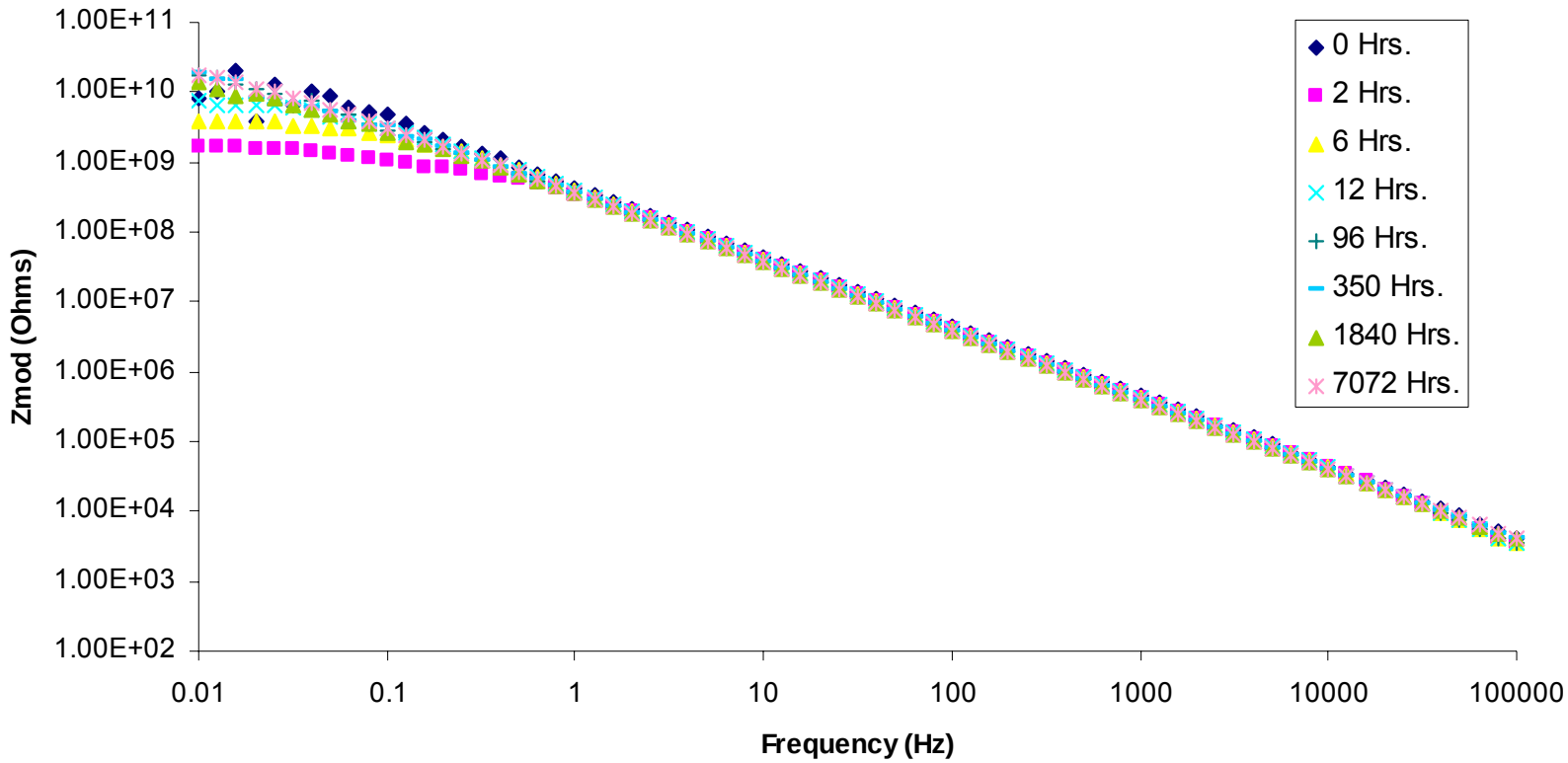
Gamry® Instrument's PC-4 or FAS1

- AC perturbation: 10 mV rms
- Frequency range: 100,000 Hz to 0.01 Hz

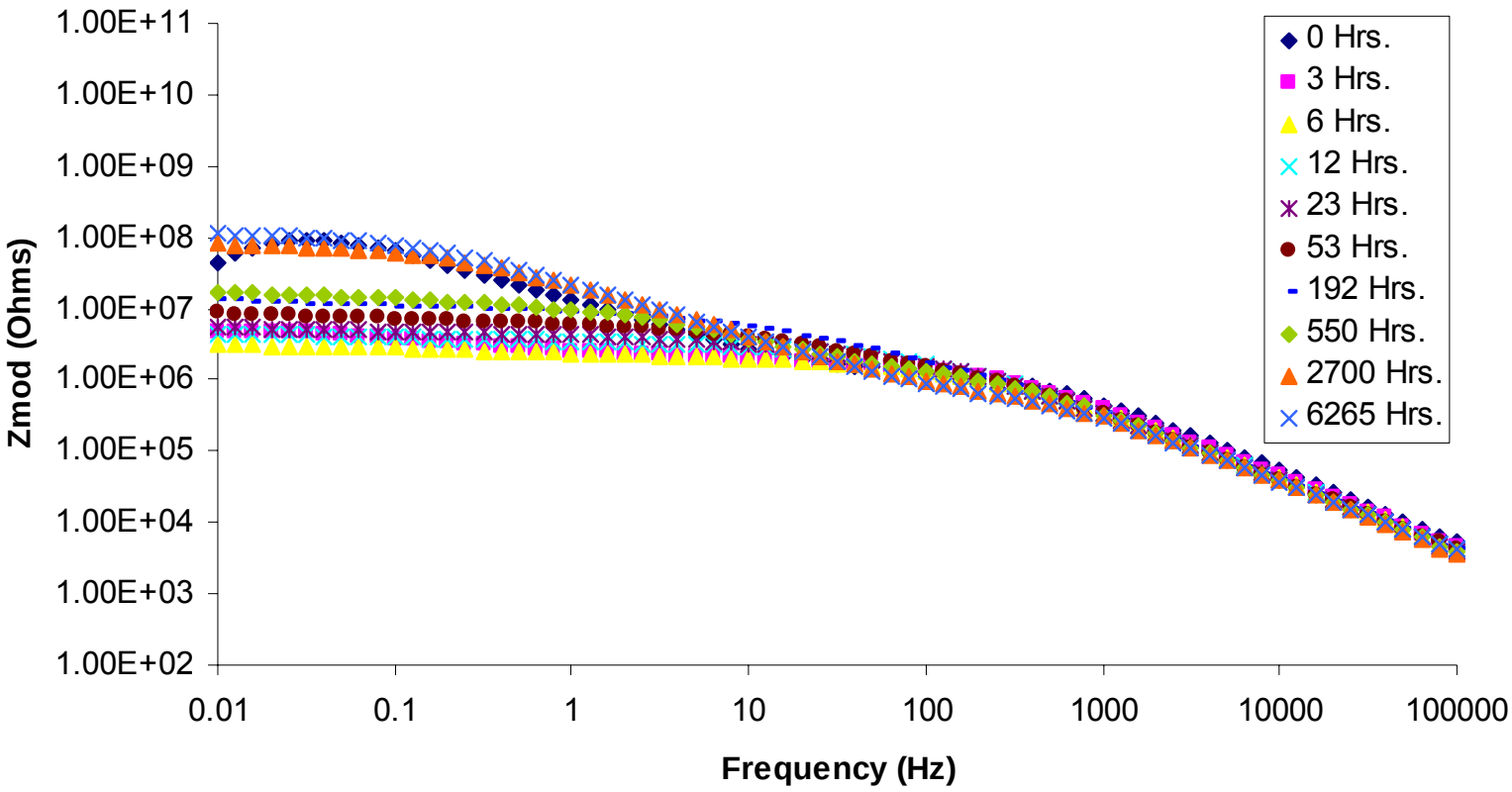
BLANK MICROCAPSULES

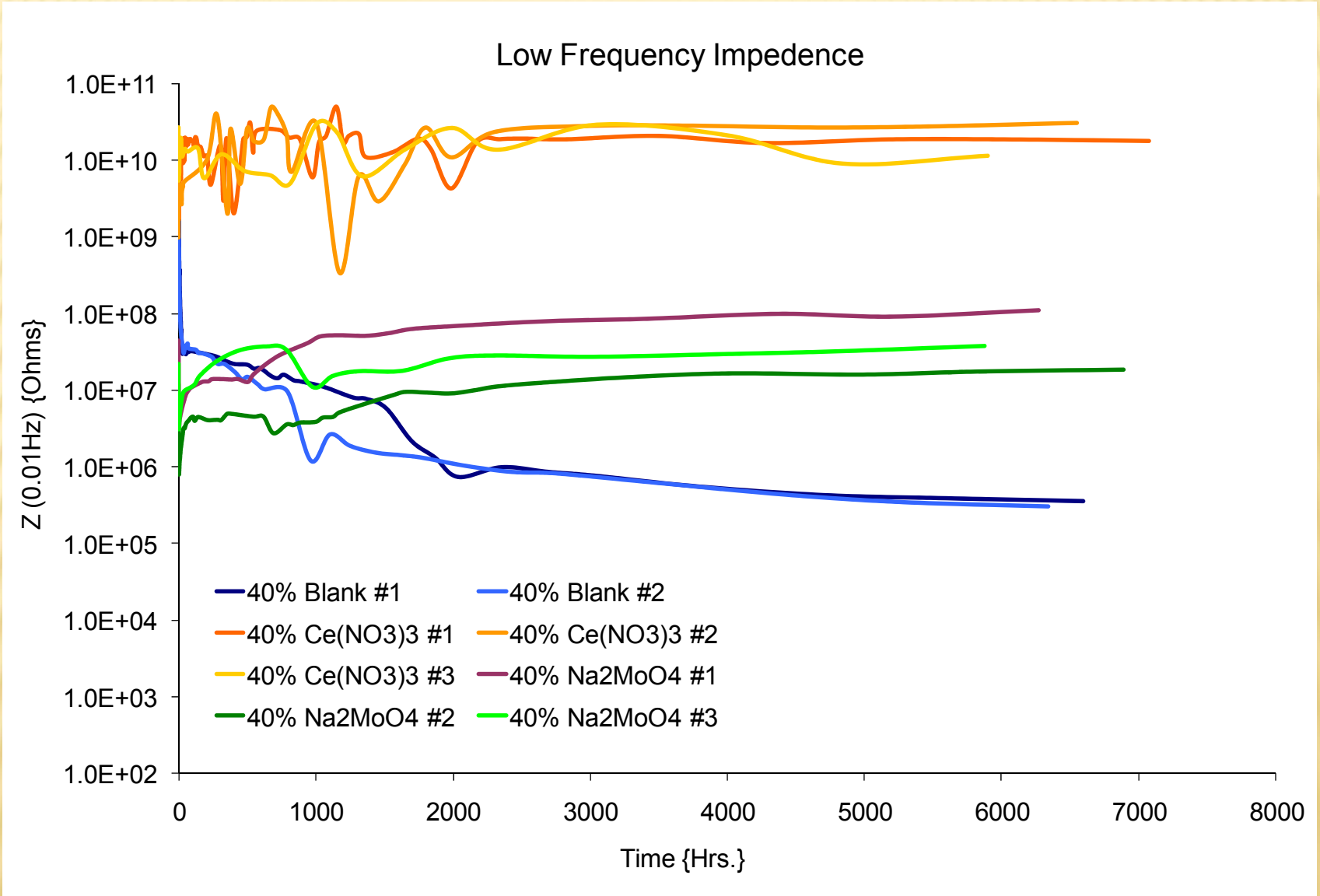


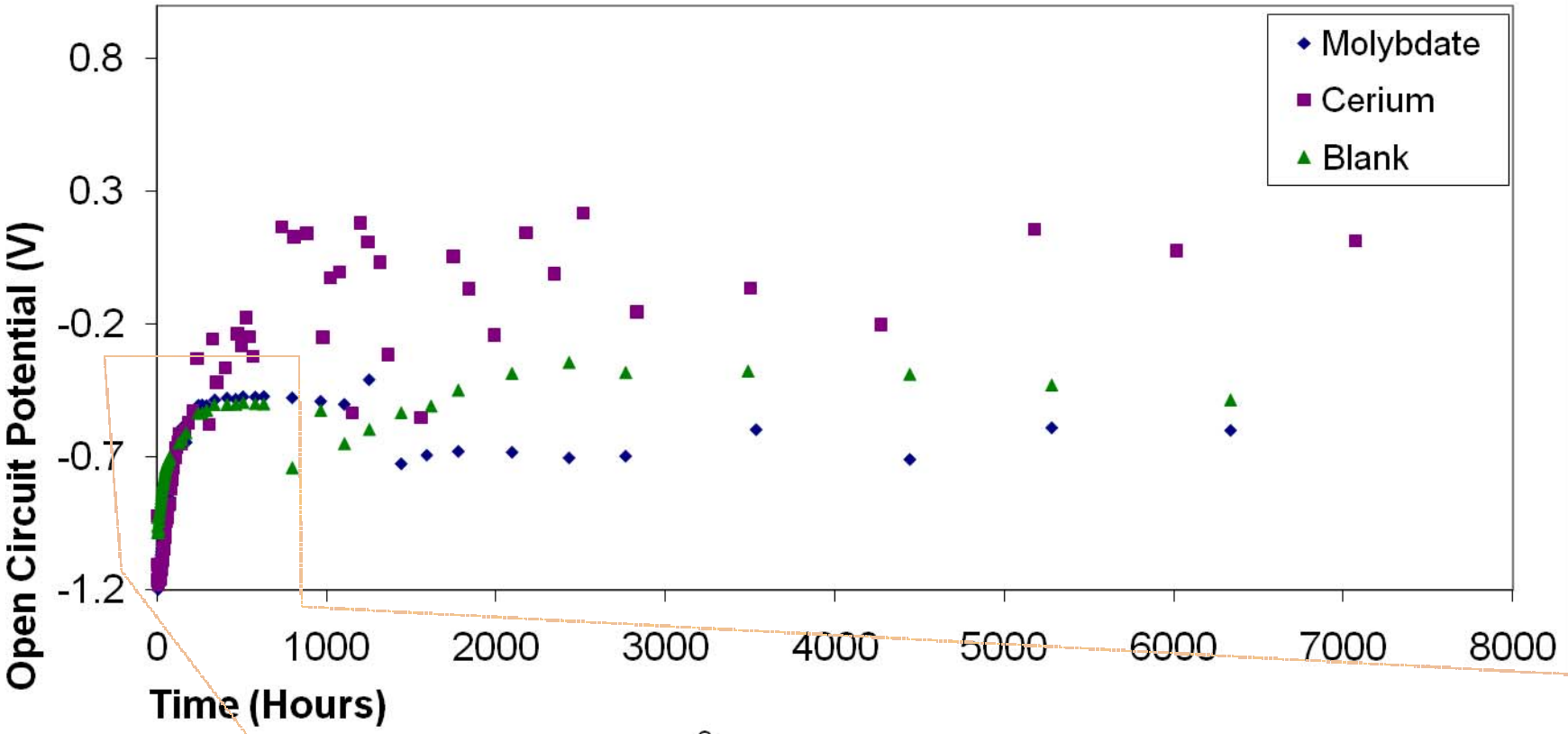
$Ce(NO_3)_3$ WATER CORE

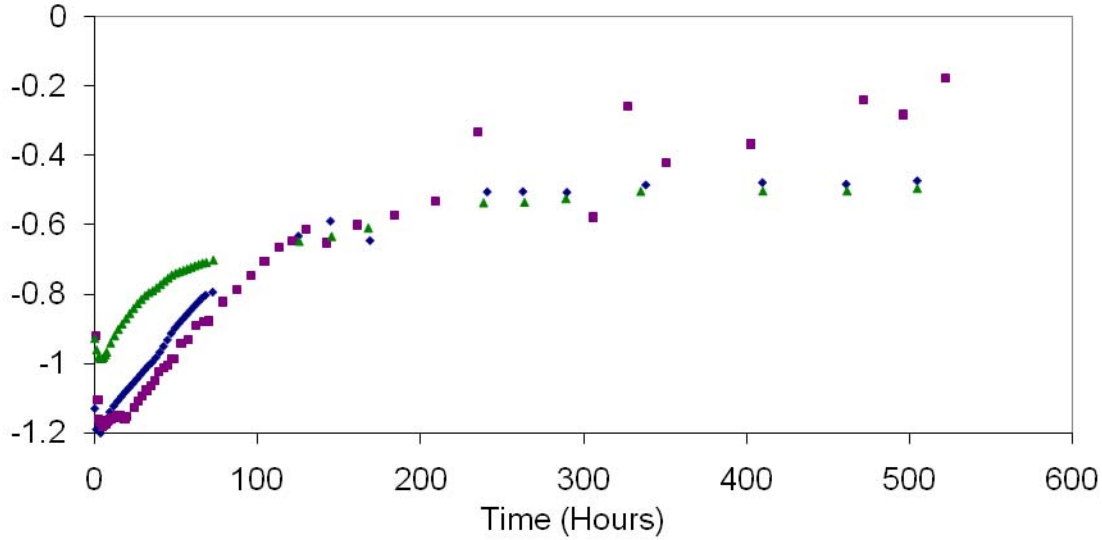


Na_2MoO_4 WATER CORE



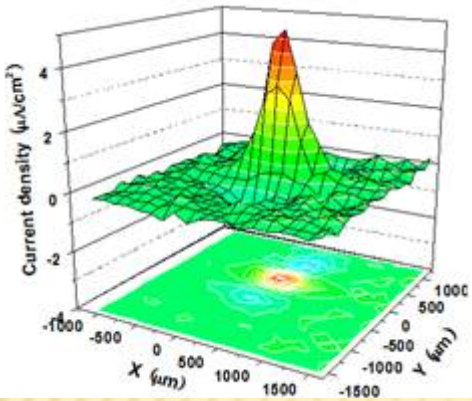

Low Frequency Impedence
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
Z (0.01Hz) {Ohms}
0
1000
2000
3000
4000
5000
6000
7000
8000
Time {Hrs.}
40% Blank #1
40% Blank #2
40% Ce(NO3)3 #1
40% Ce(NO3)3 #2
40% Ce(NO3)3 #3
40% Na2MoO4 #1
40% Na2MoO4 #2
40% Na2MoO4 #3

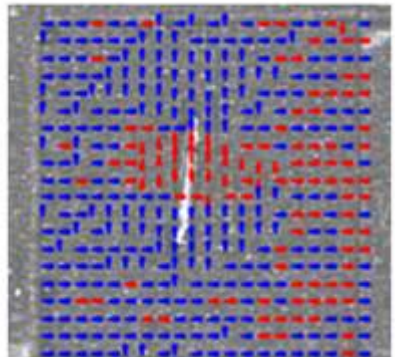




OPEN CIRCUIT POTENTIAL

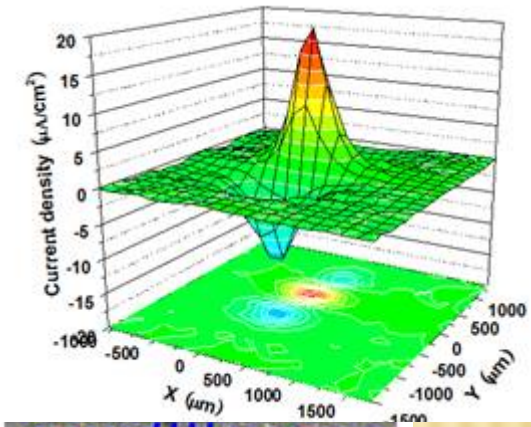
EPOXY AMINE CONTROL COATING

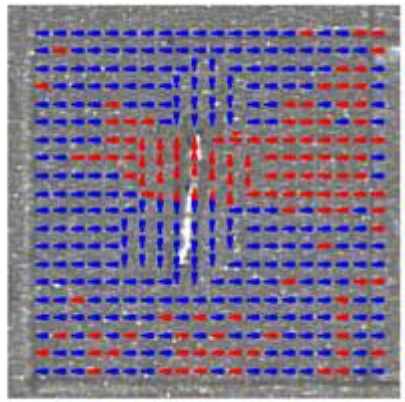


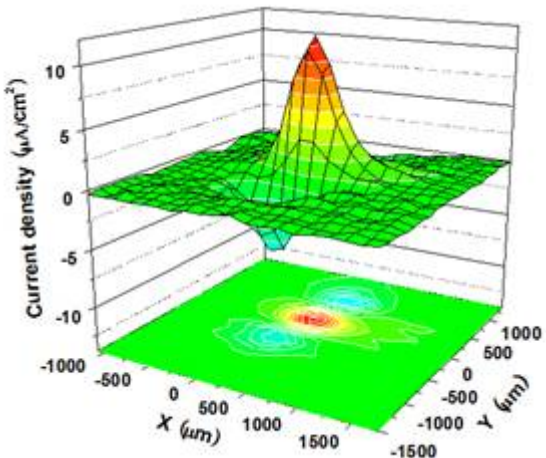


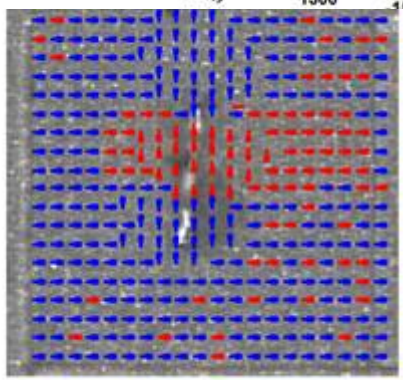
0 hours

10 hours



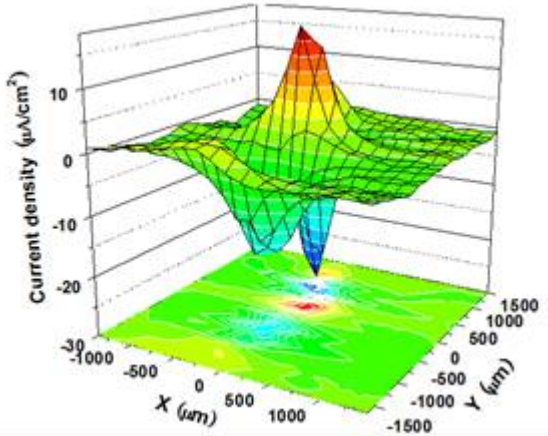


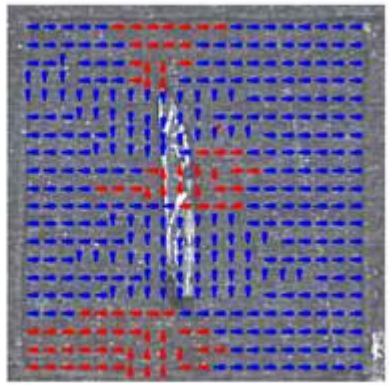




30 hours

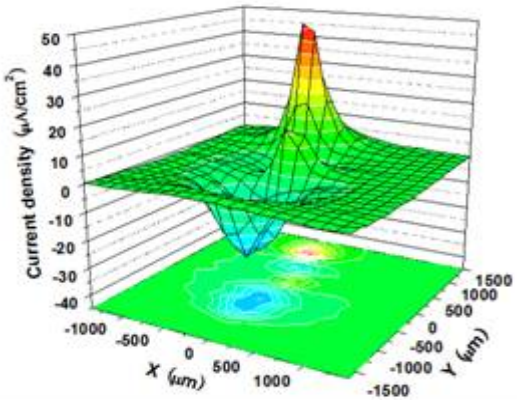
EPOXY AMINE BLANK (WATER) MICROCAPSULES

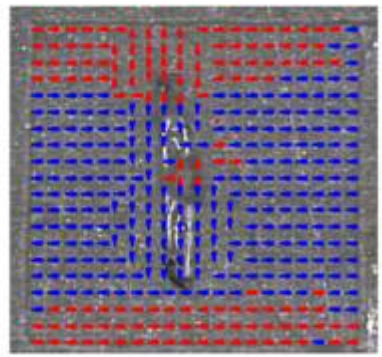


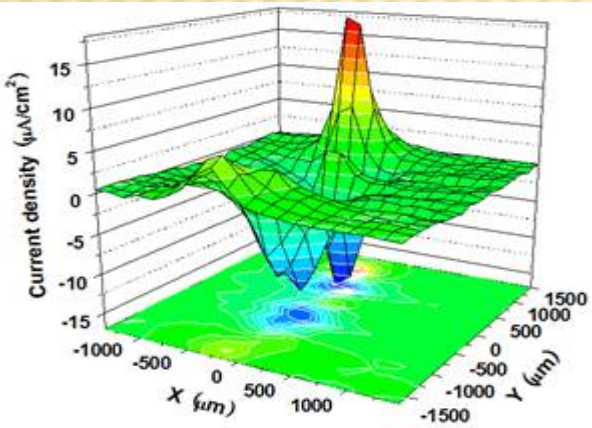


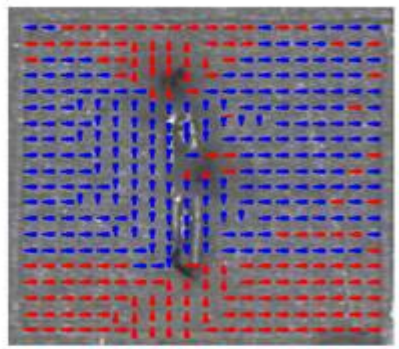
0 hours

10 hours

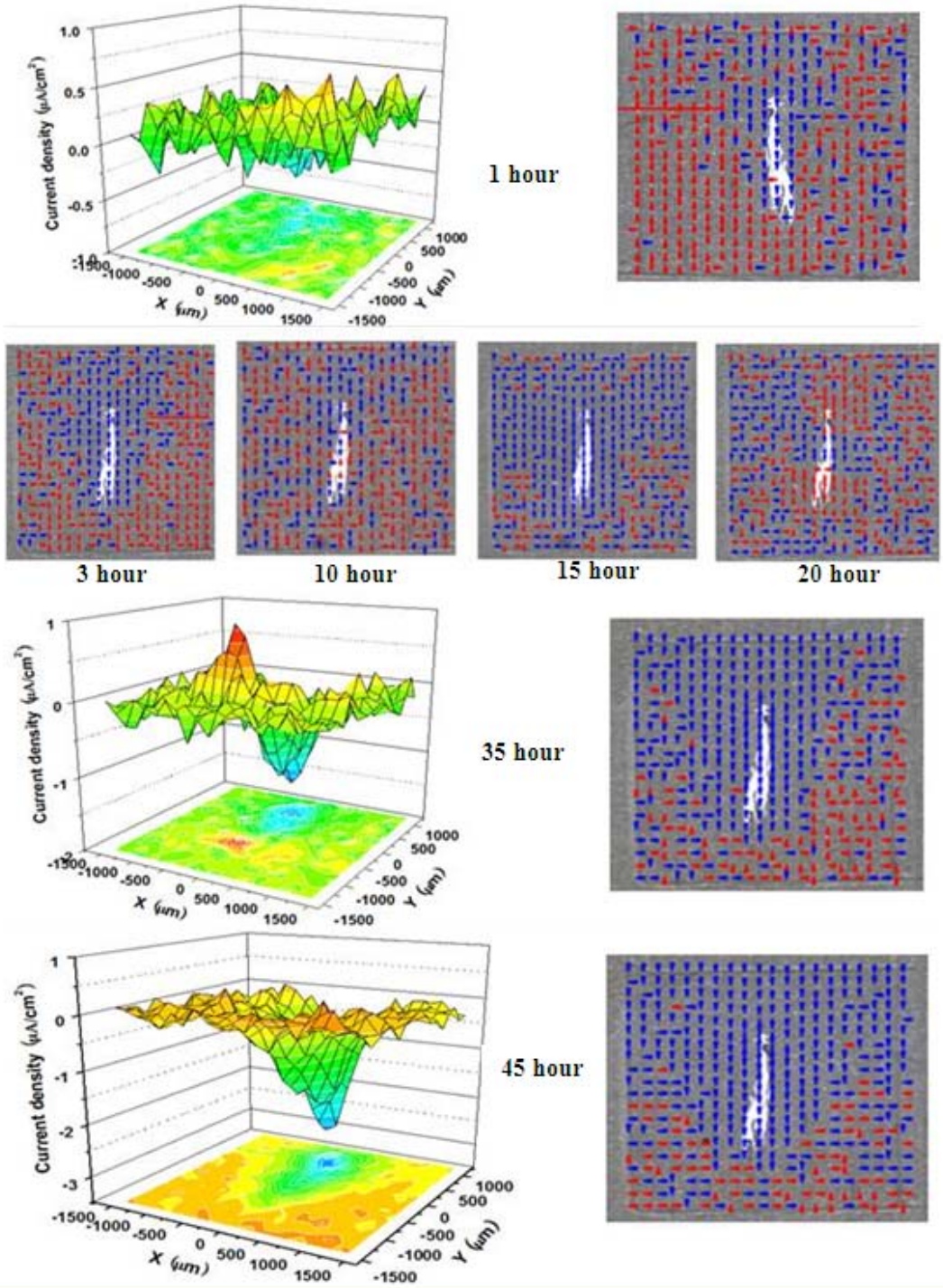








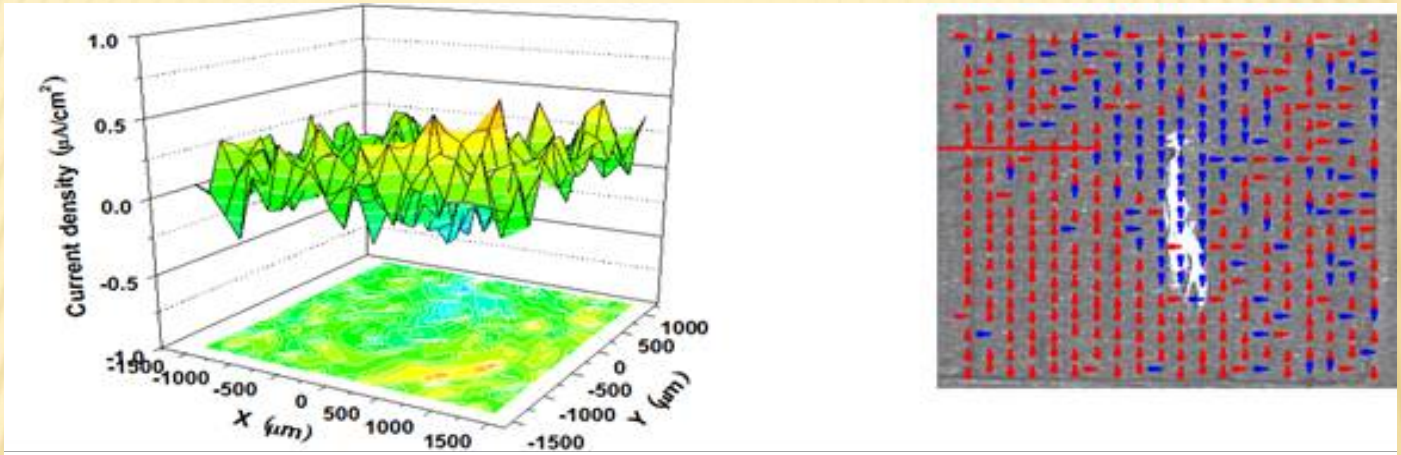
30 hours



Epoxy amine coating with 40% $Ce(NO_3)_3$ microcapsules at:

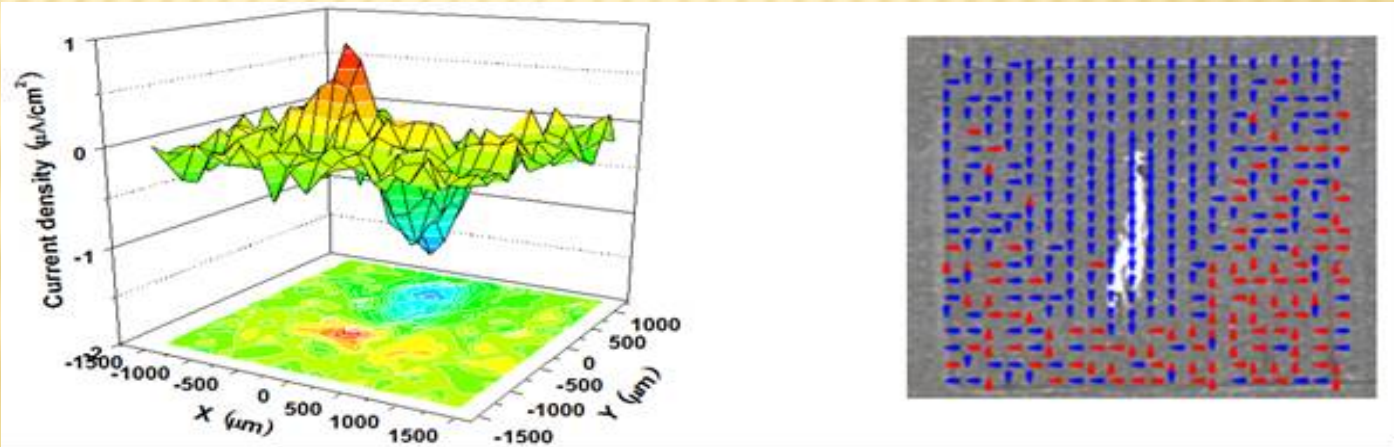
- 1 hour
- 3 hours
- 10 hours
- 15 hours
- 20 hours
- 25 hours
- 35 hours
- 45 hours

$Ce(NO_3)_3$ WATER CORE



1 Hour

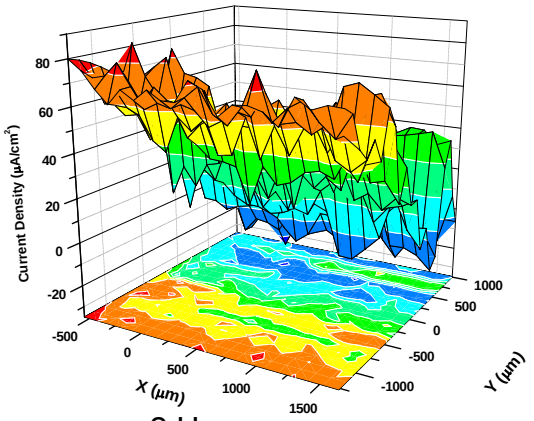
1 Hour



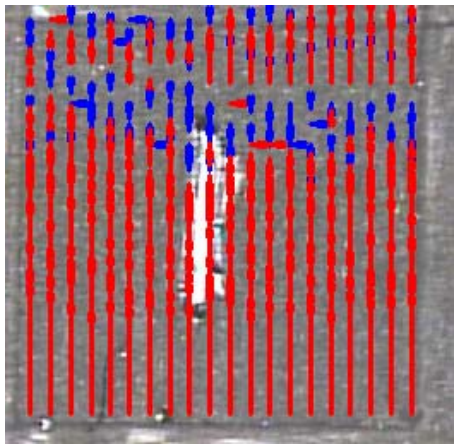
35 Hours

35 Hours

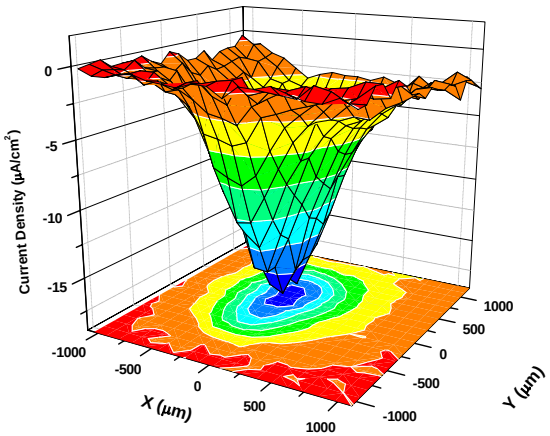
Na_2MoO_4 WATER CORE



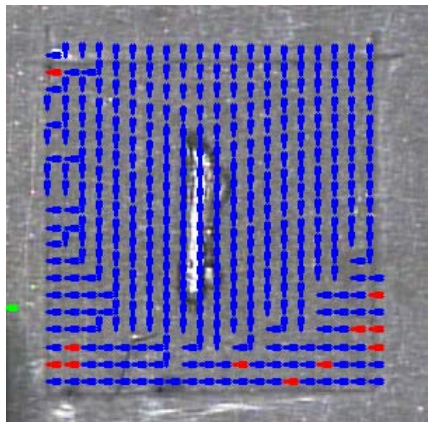
2 Hours



2 Hours



100 Hours



100 Hours

CONCLUSIONS

- Theory of microcapsules
  - Break down as a result of the products of cathodic reaction releasing green corrosion inhibitors, a dye, a pH indicator, or combinations
  - As capsules rupture the modulus of the coating system is reduced
- For Epoxy/Amine system
  - Decrease in Tg as more microcapsules were added
  - Decrease in gloss measurements as more microcapsules were added
  - Decrease in hardness as more microcapsules were added
  - Blank microcapsules showed to be thermally stable at about half the temperature as all the others with corrosion inhibitors
- Electrochemical
  - Corrosion inhibitor containing microcapsules do indicate corrosion protective properties
  - Blank microcapsules do not show any corrosion inhibitive properties

FUTURE STUDIES

- Varying the concentration of the microcapsules
- Incorporation of the microcapsules into other binder systems
- Long-term SVET studies to determine when the corrosion protective properties will fail
- Begin studies with primer/topcoat type system