Fundamental study of surfactant behavior at the metal/electrolyte interface for corrosion inhibition

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Objective: Investigate the relationship between the surfactant structures formed at the metal/electrolyte interface & their corrosion inhibition property to understand the molecular mechanisms of inhibition and develop the formulations with better performance.

Challenge: Molecular mechanisms of corrosion inhibition using surfactant-based systems are not well understood, leading to inefficient use of the inhibitor chemicals.

Intellectual Motivation: Understanding of the corrosion inhibition mechanisms at molecular level will help improve the performance of surfactant-based corrosion inhibitor systems. This can be achieved by establishing the relationship between the mechanical and electrochemical properties of these surfactant films measured during the corrosion inhibition process.

Industrial Relevance: Knowledge of molecular mechanisms of corrosion inhibition can be utilized to develop cost-effective inhibitor formulations.

HYPOTHESIS

Improving the mechanical properties of surfactant structures at the metal/electrolyte interface will result in more impervious barriers, thus, improving corrosion inhibition.

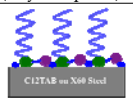
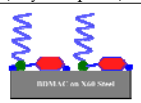
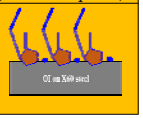
RESEARCH APPROACH

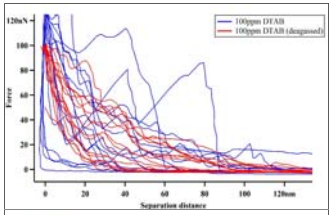
Specific tasks	Accomplishments so far
Evaluation of the corrosion inhibition performance of model inhibitor films	• Identified the techniques like LPR and EIS for electrochemical measurements • Established the protocol for EC measurements of the test system • Determined the corrosion inhibition efficiencies of model inhibitors (DTAB) on carbon steel (AISI1010 grade) surfaces
Characterization of the surfactant-based inhibitor films	• Identified the performance metrics applicable techniques like AFM for characterization of inhibitor films • Evaluated the film properties for model inhibitors (DTAB, BDMAC) • Evaluated the film properties for Oleic Imidazoline inhibitor under test conditions provided by industry partners

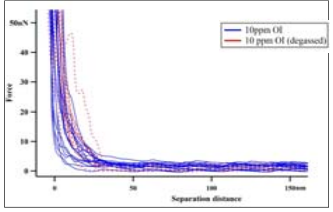
(**LPR**: Linear Polarization Resistance; **EIS**: Electrochemical Impedance Spectroscopy)

RESULTS AND DISCUSSION

- **Substrate**: X60 grade steel (previously AISI1010 steel)
- **Inhibitors**: Dodecyl Trimethyl Ammonium Bromide (DTAB), Benzyl Dodecyl Ammonium Chloride (BDMAC), Oleic Imidazoline (OI)
- **Test Solution**: 1% NaCl solution at pH 5 (previously DI water)

Inhibitor	DTAB (100ppm)	BDMAC (100ppm)	Oleic Imidazoline (10ppm)
Peak force	10 nN	7.4 nN	7.5 nN
Elastic Modulus	8 MPa	8 MPa	6 MPa
Interaction with substrate	Weaker coulombic (Physisorption)	Intermediate coulombic (Physisorption)	Strong Covalent (Chemisorption)
Schematic of interaction			





EFFECT OF DISSOLVED OXYGEN

- Big scatter in data for DTAB reduced after removing the dissolved oxygen
- Force curve data for OI showed very small effect of removal of oxygen
- Effect of oxygen in overall inhibition process

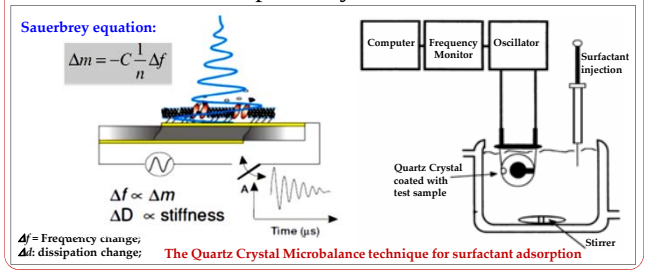
		Peak Force (nN)	Elastic Modulus (MPa)
OI	with dissolved oxygen	7.5	6 (?)
	without dissolved oxygen	6.5	29
DTAB	with dissolved oxygen	10	8
	without dissolved oxygen	8.3	13

SUMMARY

- Oleic imidazoline seems to be a better corrosion inhibitor than the model inhibitors, irrespective of the presence of oxygen in the system.
- The stronger chemical interaction of oleic imidazoline molecules with the steel surface renders the OI film better corrosion inhibition properties.
- The presence of dissolved oxygen seems to have some role in packing of inhibitor molecules and the overall inhibition process.

Specific tasks for next 6 months

- Electrochemical Impedance studies to determine the transport properties of corrosive species through the inhibitor films
- Investigation of adsorption kinetics from adsorption density measurements using Quartz Crystal Microbalance and ellipsometry



The Quartz Crystal Microbalance technique for surfactant adsorption

Acknowledgement: This material is based upon work supported by the National Science Foundation under Grant No. 1362060 and by CPaSS industry members.

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