Corrosion Protection by *Shewanella oneidensis* MR-1

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Outline

- Background
  - Microbiologically Influenced Corrosion (MIC)
  - Microbiologically Influenced Corrosion Inhibition (MICI)
  - Shewanella Oneidensis MR-1

- Objective

- Techniques

- Results:
  - Changes in impedance spectra for different metals due to the attachment of MR-1
  - Images of exposed surfaces

- Summary of Results
Microbiologically Influenced Corrosion- MIC

- Formation of differential oxygen-concentration cells (in the presence of oxygen) – oxygen depletion on the metal surface

- Accelerated corrosion (in the absence of oxygen)
  - SRB – pitting corrosion of mild steel

- Formation of biofilms

- Changes in environment (pH, concentration of ions or inhibitors... due to the metabolic activity of the microorganisms)

_Uhlig’s Corrosion Handbook – Microbiological Corrosion of Metals_
Microbiologically Influenced Corrosion Inhibition- MICI

- *Shewanella algae* and *S. ana* have been shown to prevent pitting of Al 2024, rusting of mild steel in AS.

- *Bacillus subtilis* have been found to reduce corrosion rates of brass and prevent pitting of Al 2024 in a growth medium and in AS.

- \( E_{\text{corr}} \) of Al 2024 became more negative in the presence of *Shewanella ana*, but became more positive in the presence of *B. subtilis*.

Shewanella oneidensis strain MR-1 is a metabolically versatile bacterium that can use a diversity of organic compounds and metals to obtain energy needed for growth and survival.

Shewanella has the ability to 'inhale' certain metal oxides and compounds and 'exhale' these in an altered state.

It can live aerobically, or anaerobically. It can grow naturally almost anywhere and does not cause disease in humans, animals or other organisms.

Shewanella can convert uranium dissolved in contaminated groundwater to a form incapable of dissolving in water; it’s used in environmental clean up; it’s shown to be an effective biocatalyst in microbial fuel cell and bacterial battery research.


http://www.shewanella.org

Objective

- To evaluate the protective properties of Shewanella oneidensis MR1 on the corrosion behavior of different metal electrodes and understand the differences in the interaction of MR1 with different metals.
Techniques

- Electrochemical impedance spectroscopy
- Epifluorescence Microscopy
- Scanning Electron Microscopy
Sterile LB

Active pitting was observed for Al 2024 exposed to sterile LB.

\[ E_{\text{corr}} = -0.566 \ (1\text{d}) \text{ and } -0.553 \ (7\text{d}) \ V_{\text{SCE}} \]

Significant increases in capacitance values and decreases in impedance values in the low-frequency region;

\[ E_{\text{corr}} = -0.981 \ (1\text{d}) \text{ and } -0.984 \ (7\text{d}) \ V_{\text{SCE}} \]

\[ E_{\text{corr}} = -0.686 \ (1\text{d}) \text{ and } -0.685 \ (7\text{d}) \ V_{\text{SCE}} \]

Impedance for actively corroding metal

\[ E_{\text{corr}} = -0.295 \ (1\text{d}) \text{ and } -0.205 \ (7\text{d}) \ V_{\text{SCE}} \]

\[ E_{\text{corr}} = -0.198 \ (1\text{d}) \text{ and } -0.265 \ (7\text{d}) \ V_{\text{SCE}} \]
In the Presence of MR1

Al 2024
The spectra for Al 2024 showed that it was passive for 7 days in the presence of MR-1.
$E_{corr} = -0.556 \text{ (1d) and } -0.560 \text{ (7d) } V_{SCE}$

Zinc
No changes in capacitance for a week and the low-frequency impedance increased as a function of exposure time indicating a decrease of corrosion rates.
$E_{corr} = -0.992 \text{ (1d) and } -0.976 \text{ (7d) } V_{SCE}$

Mild Steel
The spectra for mild steel in LB containing MR-1 showed slight changes with time.
$E_{corr} = -0.687 \text{ (1d) and } -0.689 \text{ (7d) } V_{SCE}$

Brass
There was a continuous increase of the impedance in the high-frequency region.
$E_{corr} = -0.271 \text{ (1d) and } -0.154 \text{ (7d) } V_{SCE}$

Copper
Continuous change in the high-frequency region; appearance of the second time constant after 3 days; similar spectra to those observed for metals covered by polymer films
$E_{corr} = -0.227 \text{ (1d) and } -0.133 \text{ (7d) } V_{SCE}$
Changes in Impedance of Copper

The diagrams show the changes in impedance of copper with respect to frequency (Log f (Hz)) and phase angle (degree). The graphs display the logarithmic scale of impedance (Log |Z| (ohm)) and phase angle, with specific markers indicating different times (2h, 1d, 3d, 5d, 7d). The circuit diagram on the right illustrates the components involved in these changes, including Rs, Rp, Cc, and Cdl.
Appearance of the Exposed Surfaces
MR-1 on Copper

USC – Department of Earth Sciences

USC - CEMMA - Center for Electron Microscope and Microanalysis
MR-1 on Mild Steel

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Summary of Results

- Impedance spectra showed that the electrodes were protected from corrosion in the presence of Shewanella oneidensis MR1. Electrodes exposed to sterile LB showed typical spectra for actively corroding materials.

- The changes in the impedance spectra due to bacterial attachment were quite different for the different materials.

- The appearance of the second time constant and continuous increase in the high-frequency impedance for copper resembled the spectra for polymer coated metals.