

## Biobased polymers for corrosion protection of metals

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## Brief Résumé

- 1989  
B.S. McPherson College (KS)
- 1988-1989  
Sterling Drug
- 1989-1991  
Becton-Dickinson
- 1992-1997  
Whistler Center for Carbohydrate Research  
Purdue University
- 1998-2000  
Postdoctoral Associate  
NCAUR-USDA
- 2000-present  
Research Scientist  
NCAUR-USDA



## National Center for Agricultural Utilization Research

- Bacterial Foodborne Pathogens and Mycology (BFP)
- Bioenergy (BER)
- Bio-Oils (BOR)
- Crop Bioprotection Research (CBP)
- Functional Foods (FFR)
- Renewable Product Technology (RPT)
- Plant Polymer Research (PPL)



## Electroactive biopolymers

- ▶ Chemical sensors
- ▶ Biological sensors
- ▶ Anticorrosion
  - ▶ Energy devices
  - ▶ Photochemistry
  - ▶ Solar energy
  - ▶ Environmental sensitivity
- ▶ Chelation
- ▶ Catalysis
- ▶ Enzyme immobilization
- ▶ Polymer-drug conjugates
- ▶ Artificial muscles & nerves
- ▶ Drug targeting & delivery
- ▶ Circuit components

## Hall Effect

### Lorentz

Figure 1

### Van der Pauw

The Hall Effect occurs when a magnetic field acts upon a current creating stress i.e. voltage which can be measured. This allows an estimation of charged density and charge mobility in a material.

## Ion conductance

Relationship between concentration of charge species, polymer mobility and ion mobility

Finkenstadt, V. L. and Willett J. L. Journal of Polymers and the Environment. 12(2):43-46. 2004.

Represent a complicated scientific idea in simple terms:

## Corrosion

- Naturally occurring electrochemical process (oxidation)
- Multi-billion dollar issue world-wide
- NIST estimates that up to 25% of an industrial (infrastructure) budget deals with preventing or remediating corrosion
- Current control methods involve VOCs or toxic substances or expensive applications

Bennett, LH; Kruger, J; Parker, RL; Passaglia, E; Reimann, C; Ruff, AW; Yakowitz, H; Berman, EB. 1996; Economic effects of metallic corrosion in the United States; National Institute of Standards and Technology: Washington, DC

## Biofilms

- Biofilms may contain polysaccharides, proteins, fatty acids, and dead/live cells
  - Biofilms from microbial populations are infamous for accelerating corrosion when colonized on metal substrates
- BUT...
- Some biofilms were noted to actually inhibit corrosion

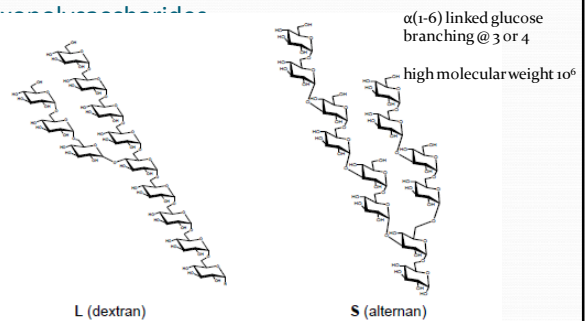
## Unusual and unexpected

- Microbial influenced corrosion happens all the time when bacterial adhere strongly to metal surfaces by the biofilm composed of exopolymers. Corrosion, in many instances, is accelerated.
- However, some do not. The exopolymer (mostly polysaccharide) of *Leuconostoc mesenteroides* seem to be unique.

## Bacterial exo-polysaccharides

- *Leuconostoc mesenteroides* subsp. *dextranicum*, subsp. *Mesenteroides*
  - gram-positive, nonpathogenic, anaerobic bacteria
  - Important for food hygiene because they cause slime on high sugar foods and are salt-tolerant
- Grown in cell free culture
- Purified by successive ethanol/water precipitations and dialysis
- 25 different strains and 2 fractions based on solubility
- The exopolysaccharide (or slime) is commonly referred to as "dextran"
  - Reported here: EPS<sub>1</sub>, EPS<sub>2</sub>, and EPS<sub>3</sub>

## Statistical structures of anticorrosive



### Anti corrosion behavior is strain-specific!

B1355N EPS cast out of aqueous solution onto SAE 1010 steel showed no corrosion activity .



A similarly structured and prepared EPS (B512) had immediate flash corrosion during drying and substantial rust formation in a few days

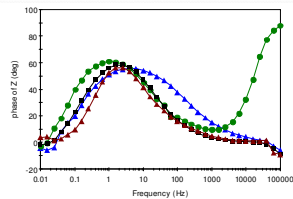
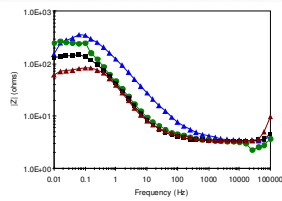


### Experimental

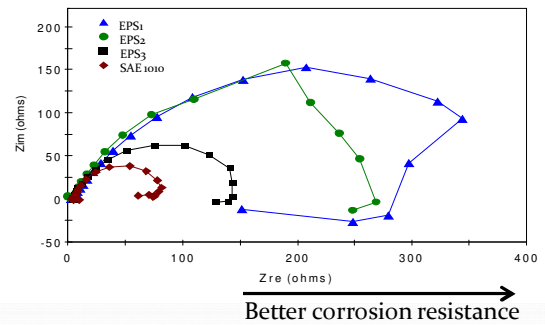
- Electrochemical Impedance Spectroscopy
  - Parstat 2273 (Princeton Applied Research)
  - Gamry PTC1 Paint Cell (triple electrode setup)
  - PowerCORR software
  - AC voltage of 10mV for a frequency range of 100 kHz to 10 mHz
- 5% w/v NaCl and 0.5M H<sub>2</sub>SO<sub>4</sub>
- SAE 1010 low carbon steel

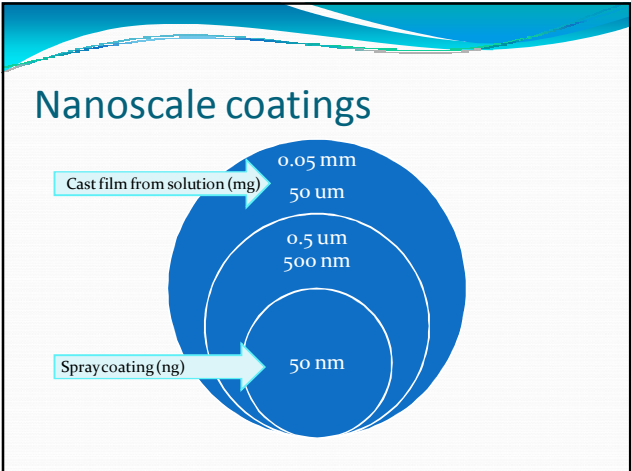
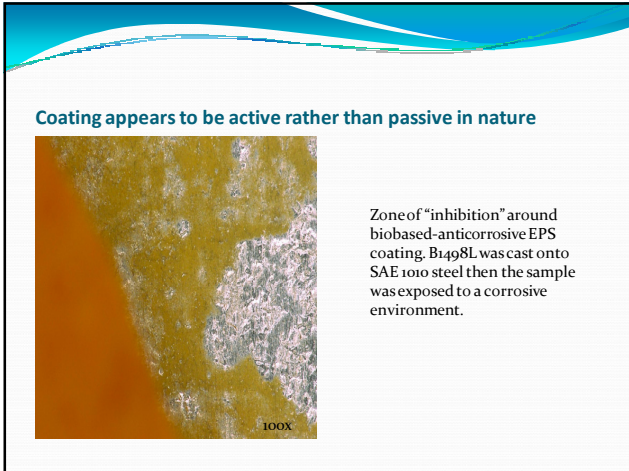
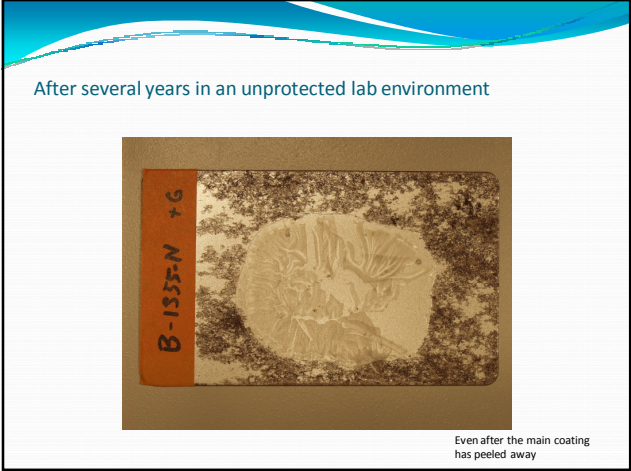
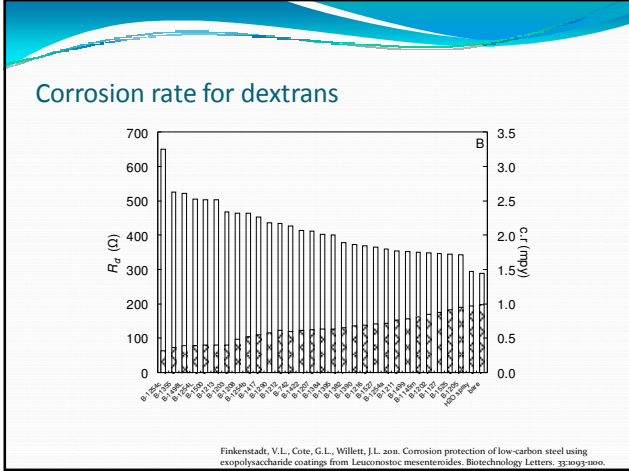


### EIS data



### Complex Impedance

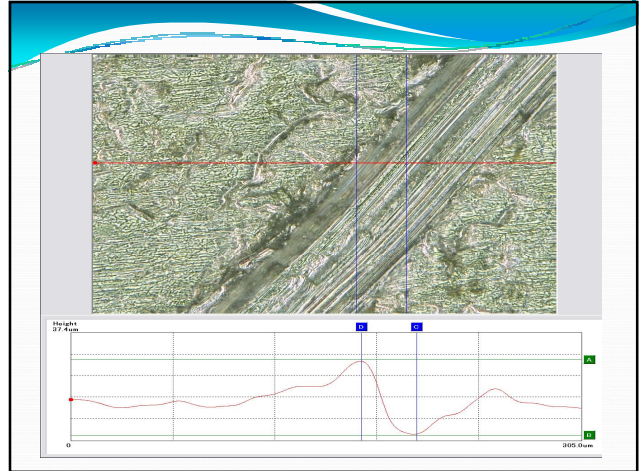
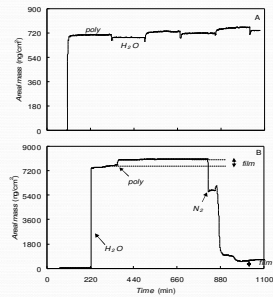




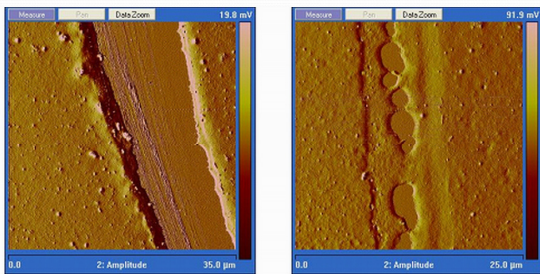


### Film deposition from a dilute solution

- Homogeneous, well adsorbed film weighing  $\sim 720 \text{ ng/cm}^2$



### Self healing properties



### Future:

- Detailed analysis to elucidate the protection mechanism
- Film characterization
  - Structure
  - Diffusion
  - Interfacial phenomena
  - Thermodynamics
  - Adhesion
  - Durability
- Spray technology for water-based applications

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National Program 306: Quality and Utilization of Agricultural Products

## Research Chemist/Material Scientist

Solve problems  
Make things work  
Find new things  
Communicate to different audiences

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