pH Sensitive Microcapsules for Delivery of Corrosion Inhibitors

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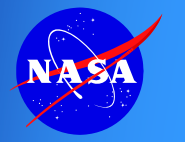
Smart Materials Concept

- The use of "smart materials" for corrosion sensing relies on a material undergoing a transformation through its interaction with the corrosive environment.

- Such transformations can potentially be used for indicating and detecting corrosion damage. Ideally, the sensing function could be integrated with additional actuation and control functions, designed to control corrosion damage.

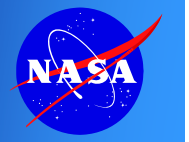


Smart Materials Concept

Examples of corrosion sensing coatings:

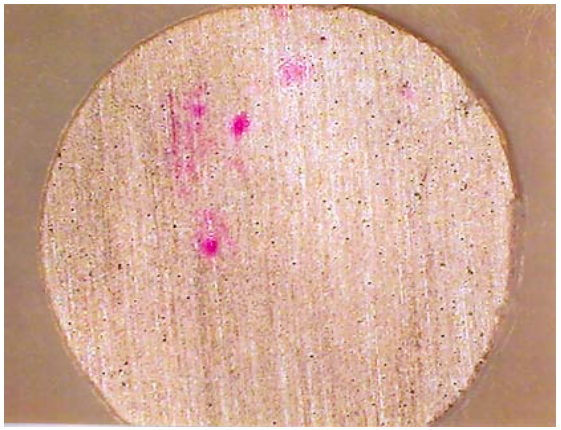
- **Paint systems with color-changing compounds that respond to the pH changes that result from corrosion processes.**
- **Changes of coating compounds from non-fluorescent to fluorescent states.**
- **Release of color dyes on coating damage from incorporated dye-filled microcapsules.**

The best coatings for corrosion protection provide not only barriers to the environment, but also a controlled release of a corrosion inhibitor, as demanded by coating damage and the presence of a corrosive environment. Past examples include coatings containing metallic zinc, such as the zinc-rich paint systems, and chromate.



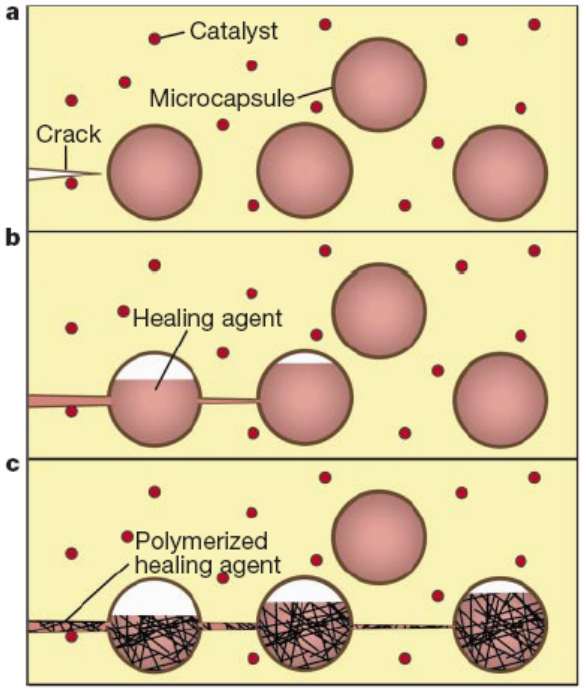
Space Shuttle and Corrosion

Smart Coatings for Corrosion Applications



Sample coated with acrylic + phenophthalein (critical PH =10) following exposure to 1M NaCl for 8 days.

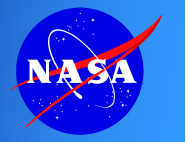
http://www.mse.eng.ohio-state.edu/fac_staff/faculty/frankel/frankel.html



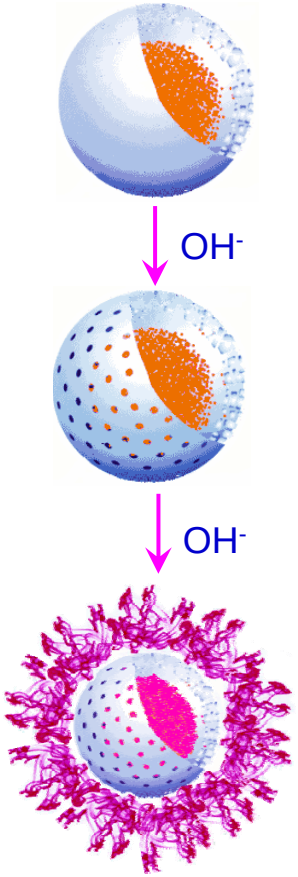
S. R. White, Nature, 409, 794-797, 2001

Objective of Research

- Develop a paint system that can detect and repair corrosion at a very early stage without human intervention
- This system should be easily adapted for delivery of new corrosion inhibitor compounds.



Technique Approach



Microcapsule containing pH indicator (inhibitor, self healing agents)

The shell of the microcapsule breaks down under basic pH conditions through the ester hydrolysis reaction

pH indictor changes color and is released from the microcapsule under basic conditions

Electrochemical Nature of Corrosion

- Overall Reaction

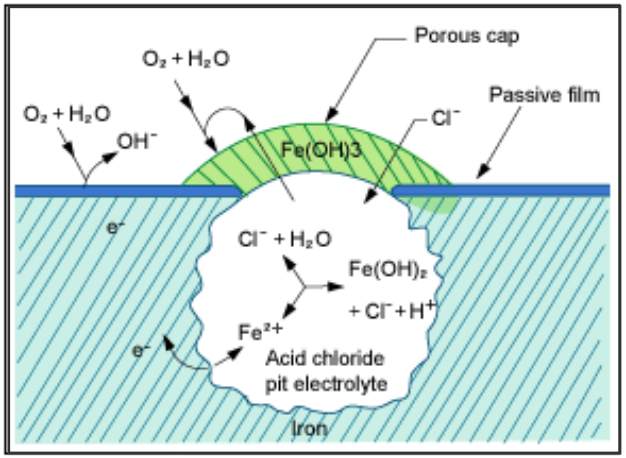
$$2H_2O + O_2 + 2Fe \rightarrow 2Fe^{2+} + 4OH^-$$

- Anodic Reaction

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

- Cathodic

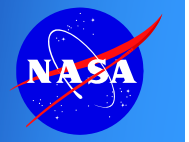
$$2H_2O + O_2 + 4e^- \rightarrow 4OH^-$$



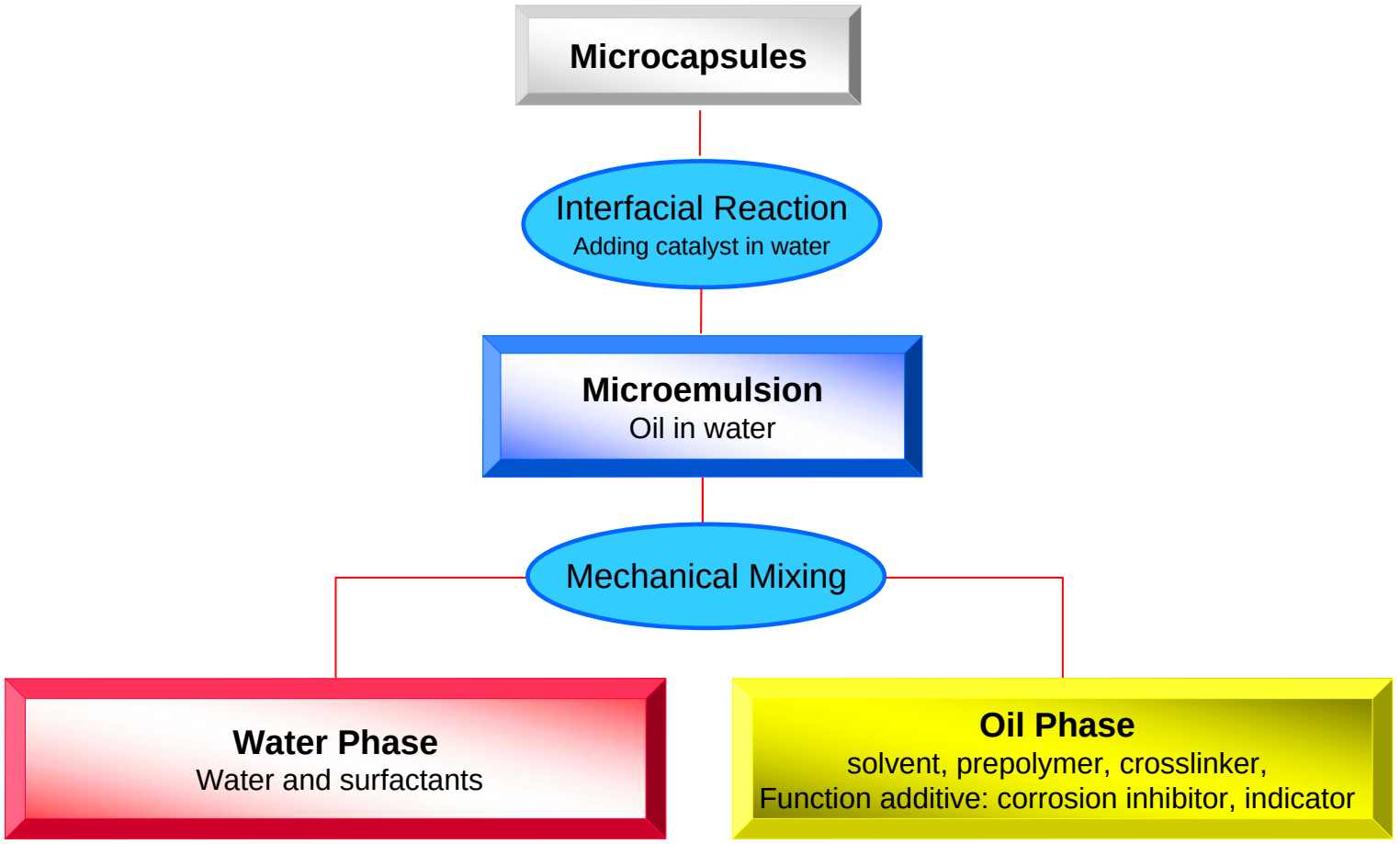
basic pH conditions at localized corrosion cathodic sites

Experimental Approach

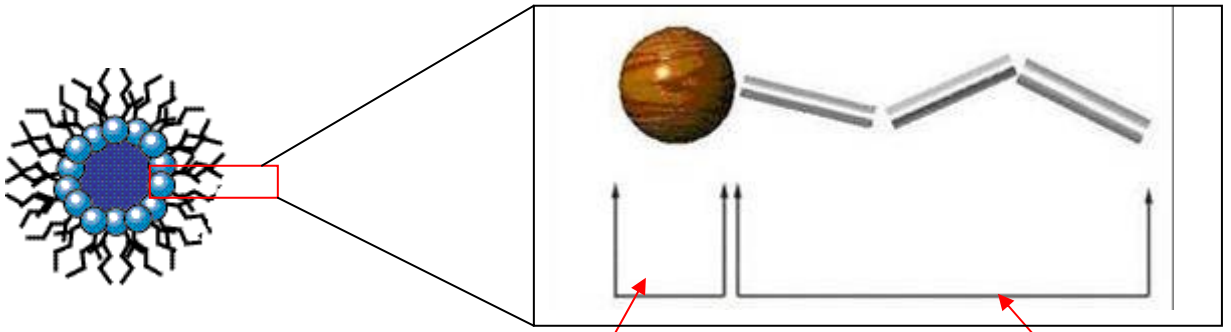
- Synthesis of Microcapsules
- Test Microcapsules for pH response
- Refine encapsulation process for improved pH response
- Develop paint system with microcapsules (10-15 wt%)
- Paint system is currently being tested



Microcapsule Synthesis



Microemulsion Formation

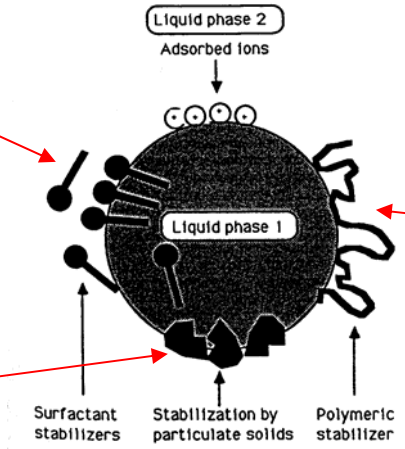


Amphiphile

Hydrophilic

Lipophilic

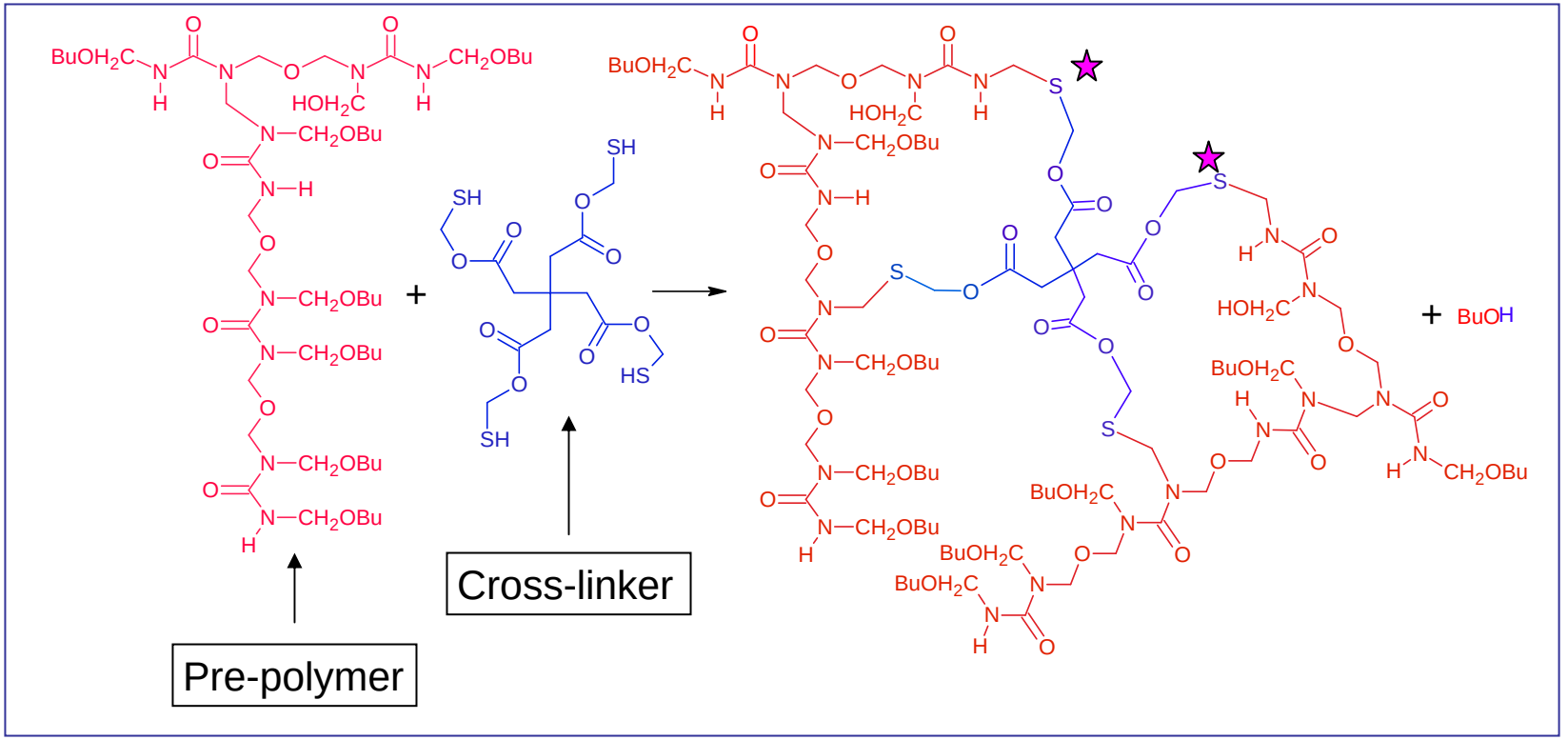
Surfactant Stabilizer



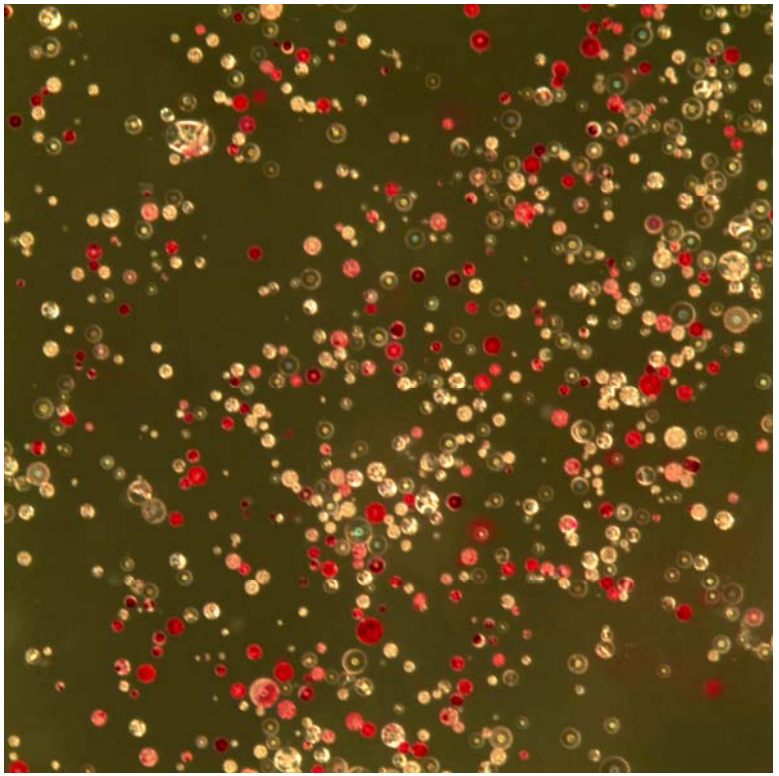
Polymeric Stabilizer

Particle Stabilizer

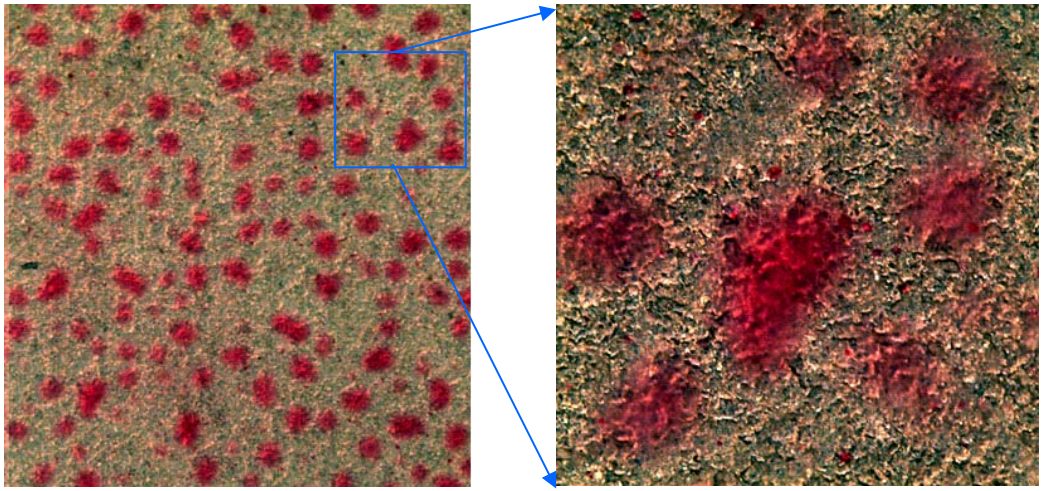
Interfacial Polymerization



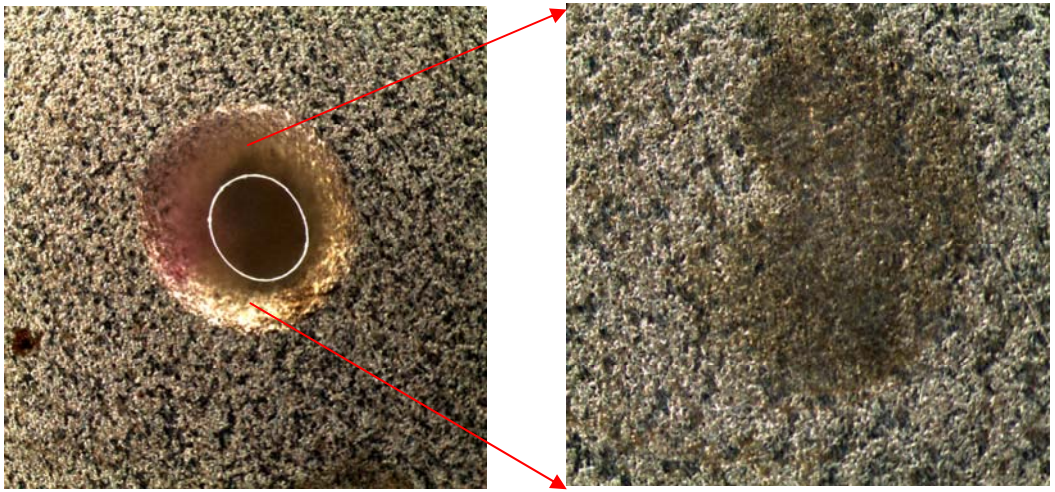
- A polymerization reaction that occurs at the interface of two immiscible liquids
- The bonds denoted by ★ are susceptible to break under basic pH conditions.



Color change due to Microcapsules in solution responding to basic pH conditions



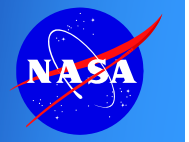
Microcapsules in paint responding to basic pH conditions



Microcapsules indicating presence of localized corrosion

Benefits of Microcapsule Design

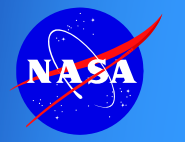
- Early detection is important for economic and safety reasons
  - Made possible by the small size of capsule and large concentration of pH indicator
- Versatility of the microcapsule design
  - Allows for different core components to be substituted to increase functionality.
  - Can be incorporated into different dispersion systems



Future Possibilities

Core Component Additions/Changes

- Corrosion inhibitor – Increases corrosion resistance of the system
- Fluorescent pH indicator – Easy to detect, even in very small amounts
- Film forming – Repairs mechanical abrasions or scratches by pre-polymer core additive



Acknowledgements

- **NRC (National Research Council)**
- **NASA-SOMD and CDDF Funding**
- **NASA**

  Eduardo Lopez del Castillo, Paul Hintze, Peter Marciniak, Patrick Faughnan, Nancy Zeiling
- **Univ. of Central Florida**

  Erik Brinley
- **ASRC Aerospace**

  Jerry Curran, Frank Gryn, Mark Kolody, Ray Anderson