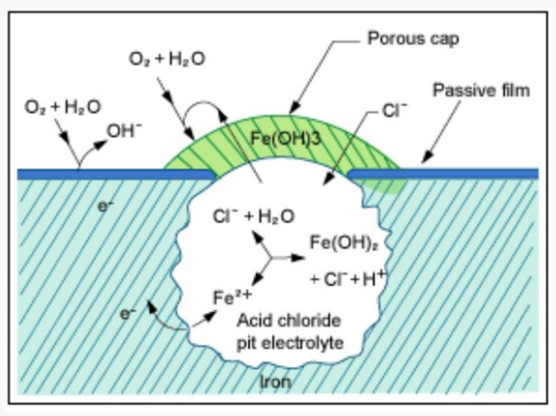
Characterization of Corrosion Inhibitor Containing Microparticles for Environmentally Friendly Smart Coatings

Benjamin Pearman, PhD
John F. Kennedy Space Center: Corrosion Technology Laboratory

Corrosion: Everyone's Problem

Metals corrode in presence of oxygen, water & salt
Cost: ~3% of World GDP ≡ $2.2 trillion per year
KSC: Most corrosive environment in the world

- Adjacent to Atlantic ocean (salt, humidity)
- Sunshine & heat
- Acidic rocket fumes



KSC Mission

Sustainable development of a multi-user spaceport for government, military and commercial customers

→ Environmentally friendly corrosion protection system

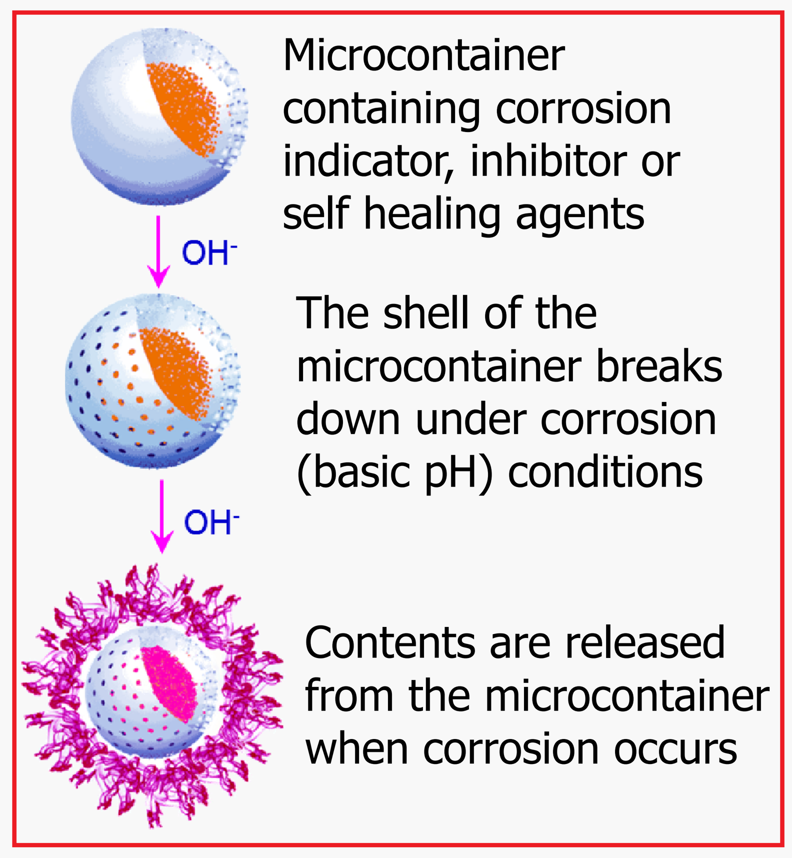
KSC Corrosion Technology Lab: Problem & Approach

Problem

Direct replacement of current inhibitors with environmentally friendly alternatives not possible due to coating compatibility and inhibitor solubility issues

Approach

- Encapsulate inhibitors into coating compatible microcontainers with
- Autonomous, corrosion triggered release
- Characterize release properties and corrosion test performance



Encapsulation

Encapsulation of:

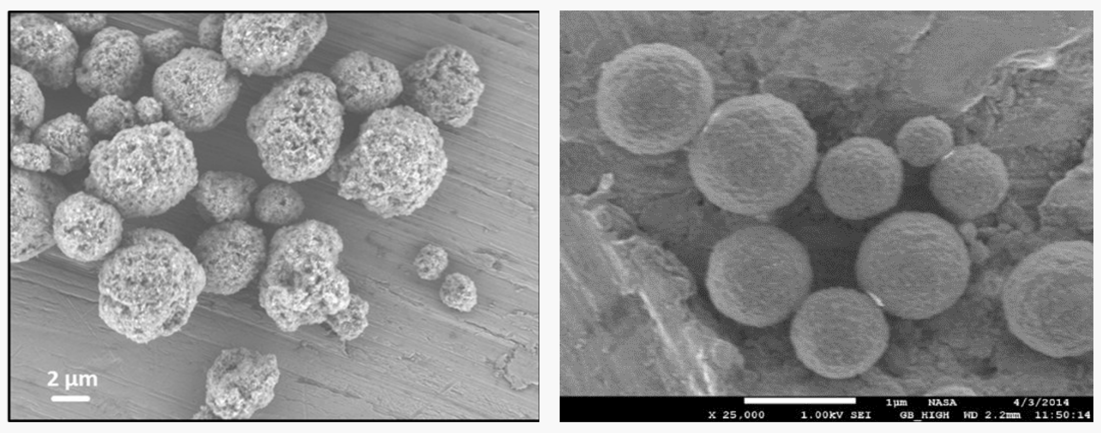
- Organic & inorganic inhibitors

into

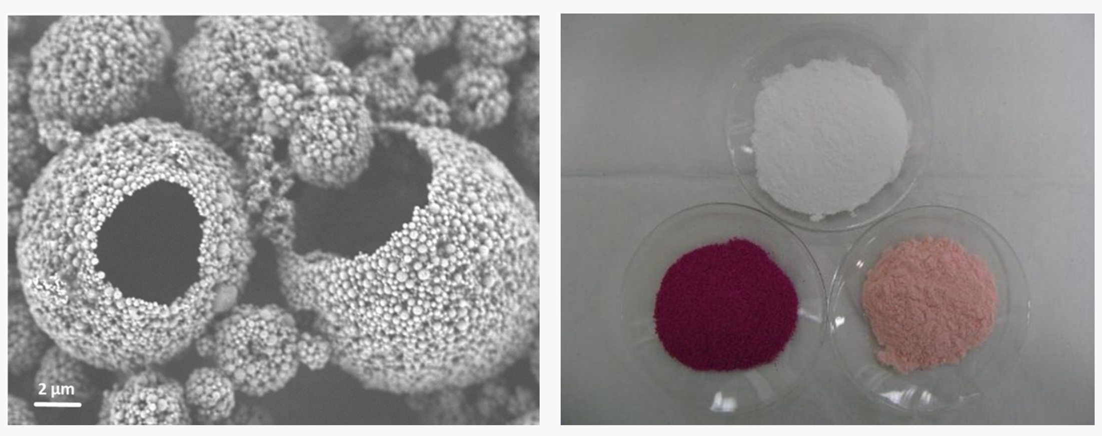
- Organic & inorganic microparticles

Resulting free-flowing powders enable:

- Simple and safe handling
- Incorporation into existing coatings systems



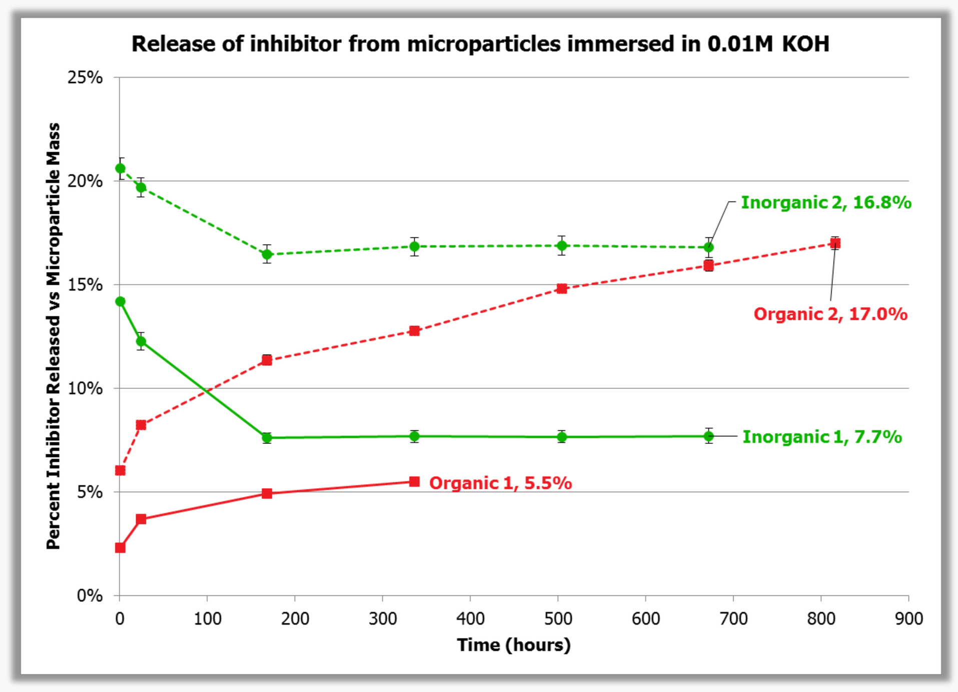
Microparticles: Inorganic ↑ & ↓; Organic ↑; Free-flowing powders ↓



Inhibitor Release

Organic Particles
Low initial release
Long consistent release
(up to 18 weeks)

Inorganic Particles
High initial release
Absorption properties

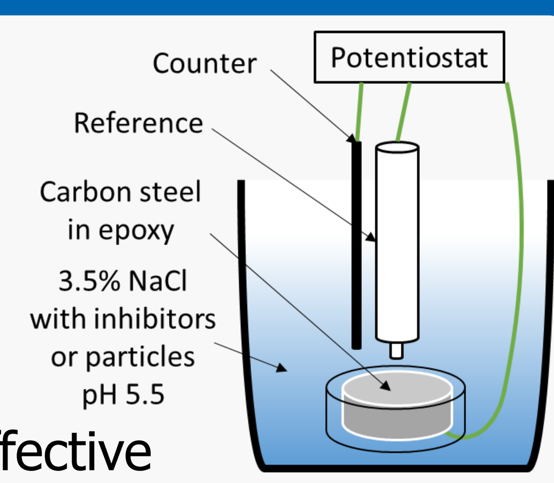


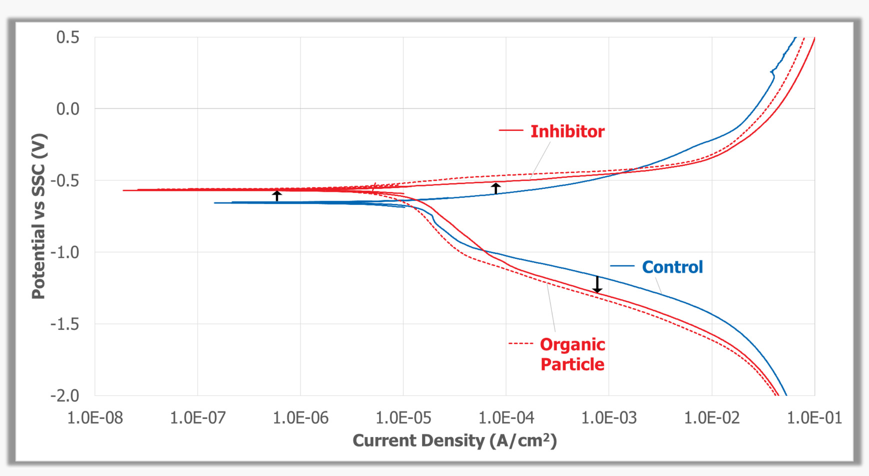
- Tunable release properties for short– and long-term corrosion protection
- Analysis of particle payload & release properties guide formula changes
- Improved formula: Doubling of inhibitor content and release amounts

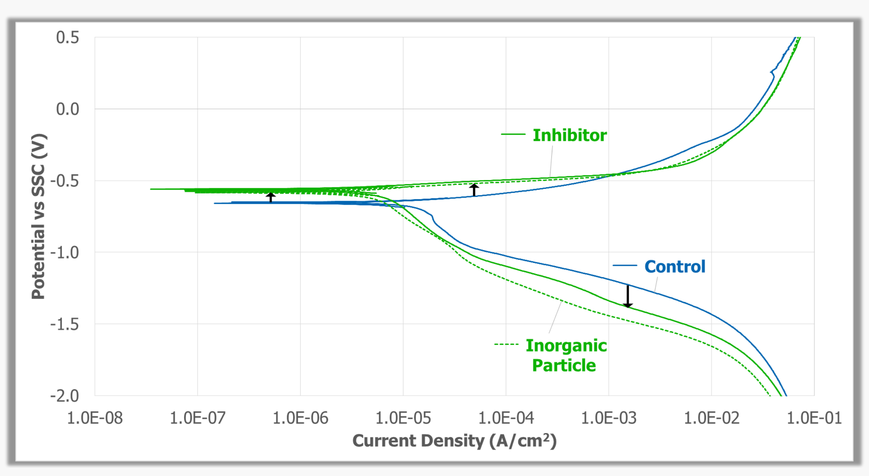
Corrosion Testing: Polarization

Inhibitors or particles in solutions result in:

- Increases in corrosion potential
- Shifts in anodic & cathodic curves
  - → Inhibitors significantly reduce corrosion
  - → Microparticles show same inhibition: just as effective

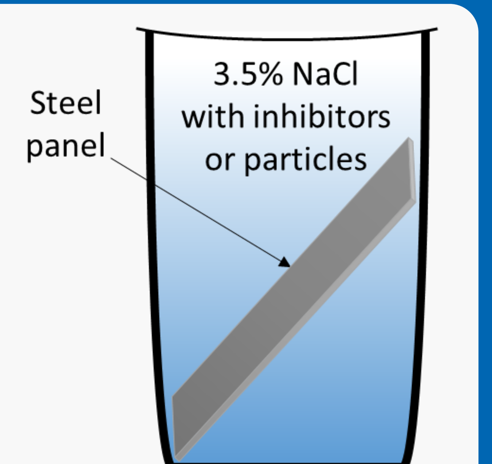


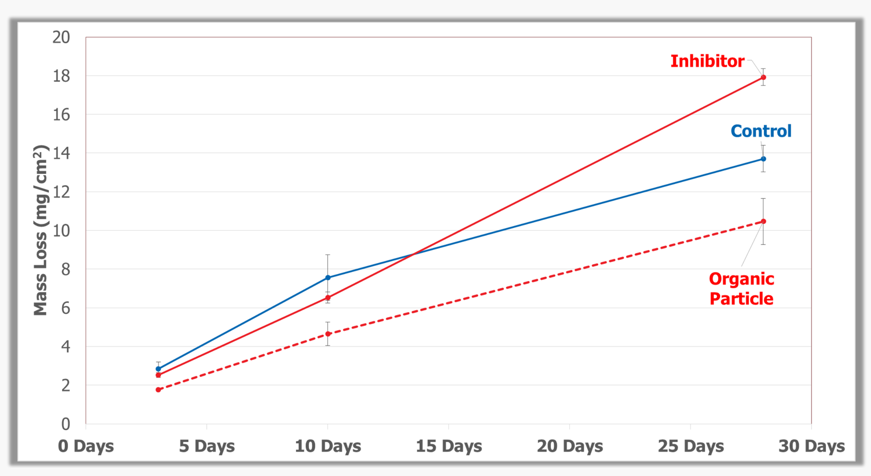


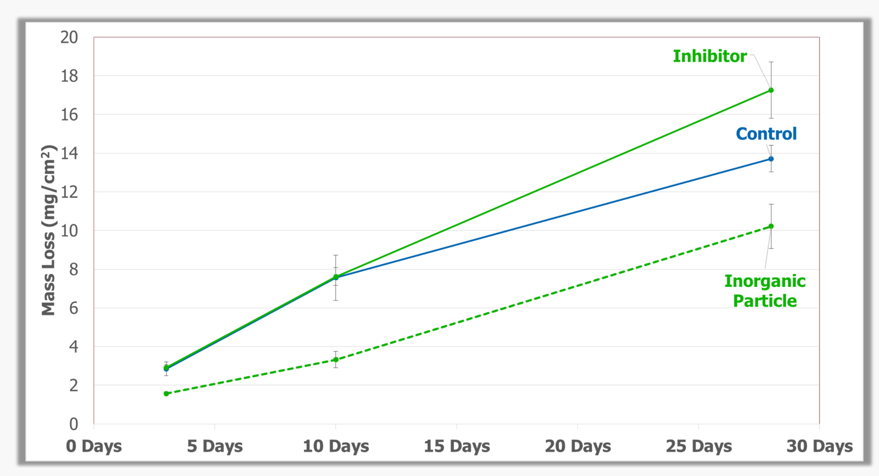


Corrosion Testing: Mass Loss

- Inhibitors: same/worse corrosion rate than control
- Particles: reduce corrosion rate over 4 weeks
  - → Outperform pure inhibitors
  - → Targeted delivery of inhibitor to corrosion sites
  - → Improved corrosion protection







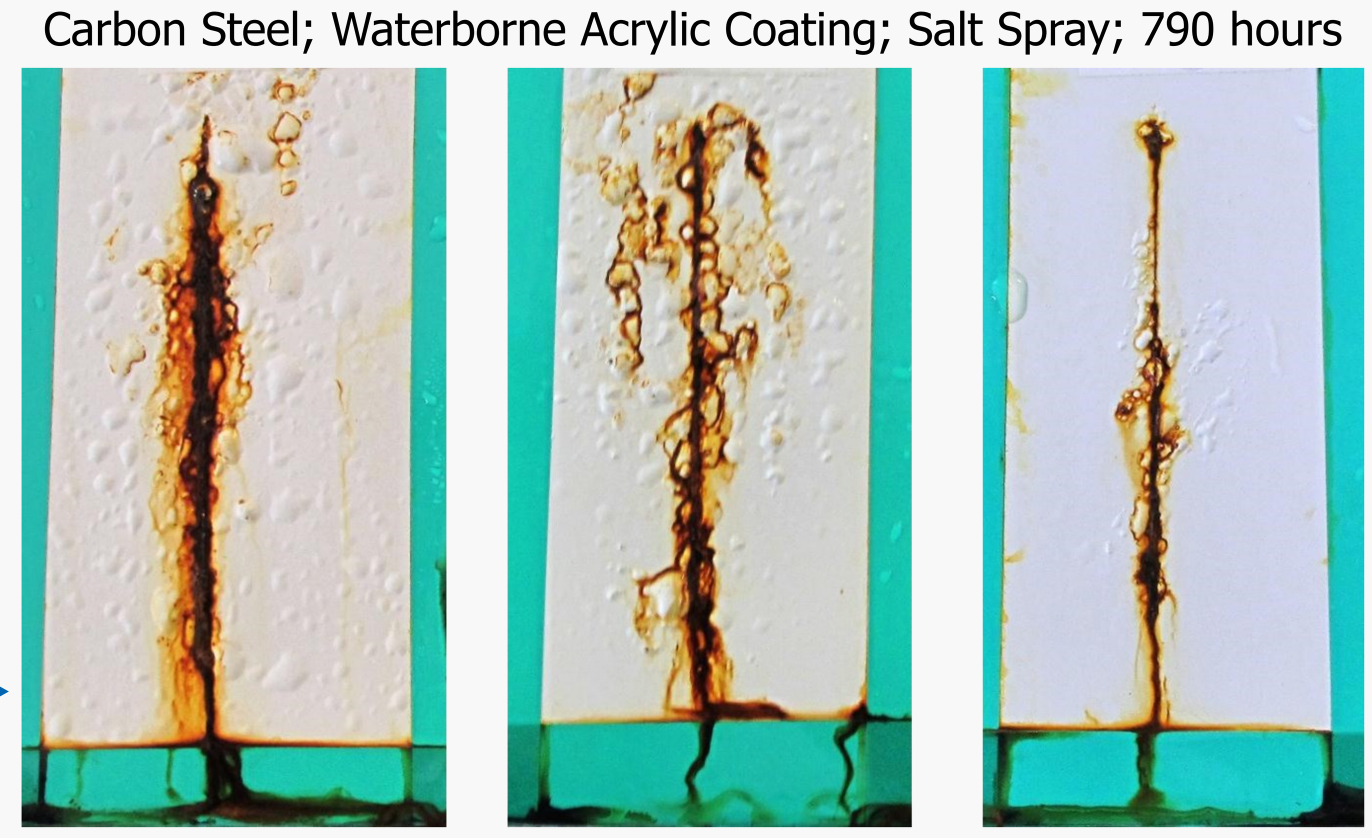
Conclusion

- Encapsulation of organic & inorganic corrosion inhibitors into organic & inorganic delivery systems
- Corrosion triggered release observed
- Tunable release properties for short– and long–term protection
- Study of release properties leads to higher payloads and release amounts
- Corrosion inhibition of microparticles meets or exceeds that of pure inhibitors
- Coating compatible microparticles provide superior corrosion protection

Future Work

- Assess release property efficacy in coating systems and for other metals
- Determine corrosion inhibition efficiency of other promising inhibitors and microparticles
- Test suitability of inhibitors and delivery systems for other metals (e.g. Aluminum)
- Study coating compatibility issues
- Characterize using other corrosion tests, e.g. salt spray & atmospheric exposure
- Shelf-life determination
- Adaptation to other NASA applications

Carbon Steel; Waterborne Acrylic Coating; Salt Spray; 790 hours



Control | Pure inhibitor | Inorganic particles with inhibitor

National Aeronautics and Space Administration

This project was funded by NASA's Ground Systems Development and Operations (GSDO) Program. This is one of three NASA programs based at the agency's Kennedy Space Center in Florida. The program was established to develop and use the complex equipment required to safely handle rockets and spacecraft during assembly, transport and launch.

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