

Smart Coating for Corrosion Sensing and Protection

Wenyan Li and Luz M. Calle
NASA Corrosion Technology Laboratory
Kennedy Space Center, FL 32899

The best coating for corrosion protection provides, not only a barrier to the environment, but also a “smart” release of a corrosion inhibitor as demanded by coating damage and the presence of a corrosive environment. Chromate containing coatings are a good example of this type of coating.¹ They release the inhibiting hexavalent chromium when exposed to a corrosive environment.²⁻⁶ Release of this species passivates metal exposed at defects in the coating. The overwhelming success of chromate-containing paints and conversion coatings, despite the environmental hazard, can be attributed to their performance as a ‘damage responsive’ material.

Smart system prototypes with “self-healing” properties have been reported by Kumar and Stephenson. Their coatings contain self-healing microcapsules whose core constituents can be released when the microcapsules are ruptured.⁷

It is well-known that when localized corrosion occurs, the anode area often has an acidic pH and the cathode has an alkaline pH.⁸ The objective of our research is to develop a coating that incorporates pH-triggered release microcapsules, for the early detection and protection of corrosion. The dual function of this new smart coating system is performed by pH-triggered release microcapsules. The microcapsules can be used to deliver healing agents to terminate the corrosion process at its early stage or as corrosion indicators by releasing dyes at the localized corrosion sites. The dyes can be color dyes or fluorescent dyes, with or without pH sensitivity. The current study on corrosion sensing using fluorescent dyes has been concentrated on including pH sensitive fluorescent dyes directly into paints. This approach presents many challenges such as the low solubility of the dyes and the loss of fluorescence in cured coatings.⁹ The use of the pH-triggered release microcapsules can overcome these problems.

In this investigation, microcapsules were formed through the interfacial polymerization process. A typical microcapsule size is around 20 micron with a narrow size distribution. The average size of the microcapsules can be adjusted from 5 to 100 micron by adjusting the emulsion formula and the microcapsule forming conditions. The pH sensitivity of the microcapsule can also be controlled by adjusting the emulsion formula and the polymerization reaction time.

Both corrosion indicator (pH indicator) and corrosion inhibitor containing microcapsules were formed and incorporated into paint systems. Test panels of selected steels and aluminum alloys were painted using microcapsule-containing paints. Testing of compatibility between the microcapsule system and different paint systems has been started and is still in progress. So far, some poly(acrylic acid) modified polyurethane paint systems show good compatibility with these microcapsules.

The initial results of microcapsule containing paint show visible color changes at induced corrosion sites and improvement of corrosion protection. Further investigation of the performance of the coating using electrochemical techniques and long term exposure are still in progress.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the funding of this project by the Kennedy Space Center's Director Discretionary Fund (CDDF) and project management support from Ms. Nancy Zeitlin. Appreciation also goes to summer intern graduate student Erik Brinley (University of Central Florida) for his dedicated involvement. Funding for Wenyan Li's National Research Council Postdoctoral Associateship was provided by NASA.

REFERENCE

1. M. Kendig, Past, Present and Future 'Smart' Protective Coatings, presented at Conference Advanced Research & Development of Coatings for Corrosion Protection: Offshore Oil & Gas Operation Facilities, Marine Pipeline & Ship Structures, April 14-16, 2004, Biloxi, Mississippi, Organized by Colorado School of Mines.
2. H. A. Katzman, G. M. Malouf, R. Bauer, G. Stupian, *Appl. Surf. Sci.* **2**, 416 (1979).
3. M. Kendig, A. J. Davenport, H. S. Isaacs, *Corros. Sci.* **43**, 41 (1993).
4. J. Zhao, G. S. Frankel, R. McCreery, *J. Electrochem. Soc.* **145**, 2258 (1998)
5. L. Xia, E. Akiyama, G. Frankel, R. McCreery, *J. Electrochem. Soc.* **147**, 2556 (2000).
6. M. Kendig and R. Buchheit, *Corrosion* **59**, 379 (2003).
7. A. Kumar and L. D. Stephenson, Self-healing coatings using microcapsules and nanocapsules, *Corrosion 2004 Conference Proceeding*, Paper No 04278.
8. F. J. Maile, T. Schauer, and C. D. Eisenbach, *Prog. Organic Coatings* **38**, 111 (2000).
9. V. S. Agarwala, Sensor for Hidden Corrosion Damage, presented at Life Cycle Systems Engineering Workshop, November 4-5, 1997, Sparkman Center, Redstone Arsenal, originated by Systems Management and Production Center of University of Alabama in Huntsville.