

IntelliSyn™ - A New Class Of Multifunctional Smart Additives For Advanced Corrosion Protection

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ABSTRACT

The authors have developed a new class of patent-pending multifunctional smart additives that deliver performance features like corrosion resistance, water repellency and surface self-cleaning for water-based, solvent-based or powder coatings. Upon exposure to changes in pH caused by metal corrosion, the additives release encapsulated corrosion inhibitors preventing further metal deterioration. Simultaneously, they impart hydrophobicity to coatings, preventing water intrusion and resulting in surface self-cleaning effects. This multifunctionality delivers long-lasting corrosion protection without the use of heavy metals or other hazardous materials. The patent-pending platform technology allows for use of numerous types of corrosion inhibitors, thereby complying with current environmental regulation and allowing for compliance with future regulation, as well the opportunity to specifically target different metal alloys. Presented ASTM B117 salt spray testing demonstrates that these smart additives improve the corrosion protection performance of powder based, waterborne and solventborne coatings on carbon steel panels, presenting a step forward in corrosion protection for the coatings industry.

Key words: Coatings, Protective Coatings, Smart Coatings, Chemical Inhibitors, Marine, Corrosion, Oil and Gas Production, Bridges and Infrastructure

INTRODUCTION

Left unprotected, metals corrode quickly which over time contributes to the loss of structural integrity and the failure of buildings, bridges, oil & gas platforms, airplanes, cars and many other metal assets, all of which pose a risk to human safety and the surrounding environment. In 2016, the National Association for Corrosion Engineers (NACE) – now known as AMPP – published a landmark study, well-known to those attending this conference, that estimated the direct cost of corrosion to the world economy as \$2.5T per year, equivalent to 3.4% of the Gross World Product (1). In the United States, the annual cost of corrosion is estimated at 3.1% of gross domestic product (2), equivalent to \$635B (2018). When including indirect costs, such as asset downtime, ship dry-docking and the impact of bridge collapses, the cost of corrosion is estimated at twice that amount.

Due to its global nature, all societies deal with corrosion which is especially problematic in coastal areas where metals are exposed to humid salty air. High value assets in marine environments, e.g. ships, offshore oil and gas platforms and wind turbine farms, are composed almost entirely of metal and constantly exposed to seawater, rain, waves, wind, sun, industrial chemicals, and abrasion from heavy work. This highly corrosive environment, coupled with their remote location or requirement for dry-docking, makes them difficult and expensive to build and maintain. Asset owners have developed comprehensive and costly maintenance schedules to stay ahead of metal corrosion in this demanding environment and prevent government fines and shutdowns.

Protective coatings deliver an important defense. In the most corrosive coastal, marine and offshore environments, three-layer or even four-layer coating systems are the industry standard for corrosion protection (Figure 1). Despite its use in offshore and marine environments for over 30 years, 3-coat systems often don't meet industry needs, lasting as little as 5-7 years before a major maintenance cycle is needed. For example, in interviews performed by the Company's team, both small and large oil & gas companies expressed the need for new coating systems that would *double the time between maintenance cycles* to 10-15 years, cutting maintenance cost by up to 50% over the 50-year service life of a platform. Interviews with coatings inspectors and coatings experts from leading paint & coating companies, echoed the same demand for, and lack of, longer lasting coatings.



Figure 1 Three-coat system on prepared steel

In coating projects, the major cost is labor. For example, offshore coating application costs 10-20 times as much as onshore, and crew labor, transportation, lodging and food makes up 90-95% of the total project cost, while coating materials only account 5-10%. Moving from a 3-coat paint system (primer, midcoat, topcoat) to a 2-coat system (primer, topcoat) could yield savings of 25-30% *per maintenance cycle* through reduced labor. Simpler and faster paint application would also yield significant cost savings to asset owners. This demand for higher productivity is a driving force towards the use of fewer and thicker coats, and faster curing coatings to reduce downtime and ensure rapid return to service.

To date, the best corrosion management method is surface preparation and painting, along with proper design, regular maintenance and inspections. However, due to the lack of long-lasting solutions from traditional coatings manufacturers, some oil & gas companies are trialing new technologies and even going so far as to **develop their own coating systems**. This is unprecedented, as the industry has historically relied on their strong ties to established coatings suppliers to deliver durable products and provide warranties. However, to control costs in a highly competitive and price-variable market, asset owners are open to creating new business models and seeking novel coating solutions to mitigate their corrosion problems.

The Solution: Smart Additives

SynMatter's founders invented the patent-pending smart additives platform technology, which is a new class of multifunctional smart additives that contain corrosion inhibitors and are superhydrophobic. These superhydrophobic additives impart high hydrophobicity to coatings even at low concentrations, preventing water intrusion and thereby reducing the incidence and extent of corrosion. On top of this increased **passive barrier protection**, the corrosion inhibitor payload of the smart additives offers **active corrosion protection**. Should the coating deteriorate, suffer damage or develop microcracks during use, the onset of corrosion causes a localized increase in pH that triggers the release of the inhibitors from the smart additives (see Figure 2). The inhibitors move to the corrosion site where they form a protective layer, preventing any further corrosion from occurring. This encapsulation and corrosion-triggered delivery approach is specifically chosen to avoid release of inhibitors under any conditions other than corrosion to deliver long-term metal protection and enable the use of environmentally friendly and effective materials.

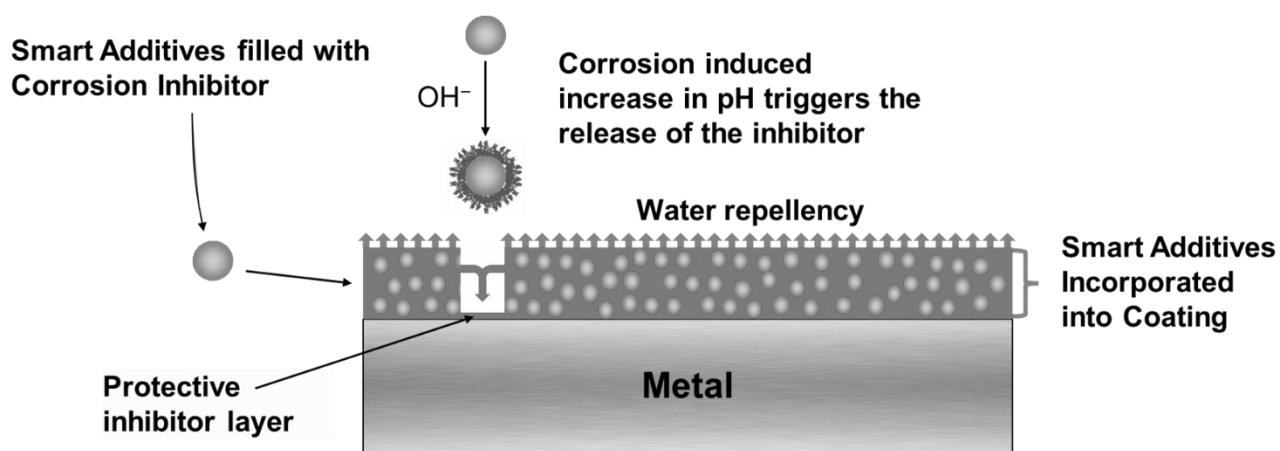


Figure 2 Schematic of smart additives coatings additives activity in coatings

EXPERIMENTAL PROCEDURE

The smart additives were produced in a patent-pending, water-based, one-pot synthesis, followed by cleaning with water. The resulting slurry was spray dried using Triowin SD-1500 spray dryer. Additives containing organic and inorganic corrosion inhibitors were produced.

Some additives were further treated using a proprietary method to create superhydrophobic additives. Both untreated and superhydrophobic smart additives were formulated into several coating systems. For this paper, **untreated additives** will refer to additives that have not received the water repellent surface treatment, whereas **superhydrophobic additives** have received the water repellent surface treatment.

Untreated and superhydrophobic additives were incorporated into a commercially available black powder paint at 1-3 wt%. A single coat was applied to CRS panels using an electrostatic powder paint spray gun and cured to manufacturer specifications: 205 °C for 20 minutes. One coat was applied at thicknesses of 25-45 µm.

Untreated and superhydrophobic additives were formulated into a waterborne acrylic coating at 5wt%. The coatings were applied to cold-rolled steel panels using a drawdown bar to thicknesses of 100-150µm and cured to manufacturer specifications.

Untreated and superhydrophobic additives were formulated into a commercially available oil-based alkyd at 5 wt%. The coatings were applied to SSPC SP-10 blasted cold-rolled steel panels using a drawdown bar. The oil-based alkyd was topcoated with a waterborne 1K acrylic clearcoat resulting in final coating thicknesses of 75-110 mils. All coatings were cured to manufacturer specifications.

The water repellency of both the particles and coatings were measured.

To measure the contact angles of pure particles, they were evenly spread on a metal panel. After removing all free powder, the panels were placed on a level surface and a 10 µl drop of water was placed onto the particles using a micropipette. To measure the contact angles of coatings, coated metal panel were placed on a level surface and a 10 µl drop of water was placed onto the particles using a micropipette. Images of droplets were taken using a magnifying lens. The contact angle was calculated using ImageJ and the contact angle plugin (developed by Marco Brugnara). Three drops were measured at three locations on three sets of panels.

To measure the roll-off angle, 10 µl, 20 µl, 30 µl, 50 µl, 100 µl and 200 µl drops of water were placed onto a coated metal panel on a leveled rotary table using a micropipette. The rotary table was tilted at 1° increments until the droplet rolled off which yielded the roll-off angle. Three drops in three locations on three panels per coating were tested and the results were averaged.

Taped and scribed panels were placed in a corrosion test chamber and subjected to ASTM B117 salt fog testing. Tested panels were photographed at regular intervals throughout the test. Some coatings were subjected to saltwater immersion testing, where coated panels were immersed in a 5.0% NaCl solution.