Cost effective improvement of corrosion protection for DTM coatings using Inhibispheres®

Abstract

The addition of Inhibispheres® to a Direct to Metal paint is shown to increase the corrosion class of a coating from C1 to C3 (or better). This significant improvement in performance gives the formulator the option to design innovative coatings for use in more challenging corrosive environments while using more cost effective resin chemistry (than standard DTM) and at the same time not compromising on the high gloss aesthetic properties of the coating.

Introduction:

Direct to Metal (DTM) coatings are, as the name states, coatings that are applied to a metal substrate without the use of a primer. The resin chemistry is normally Acrylic or Polyurethane depending on whether it is a water based or solvent based coating. DTM coatings are applied on surfaces that require little to no pre-treatment. They are commonly used in the non-professional market, when basic corrosion protection is required and/or when a surface aesthetic is not as important (no specific requirement for a gloss topcoat or decorative coat).

Inhibispheres® are a range of corrosion inhibitors designed for use in paints and coatings. These materials are porous silicas with organic or organometallic corrosion inhibitors uniformly dispersed inside the solid silica matrix. Inhibispheres® offer the paint formulator a wide range of corrosion prevention options with 6 different products for the protection of both steel and aluminium. Organic inhibitors are very efficient in preventing corrosion on metal surfaces but their use in coatings is limited by their incompatibility with paint resin chemistry. Inhibispheres® allows the use of organic and organometallic inhibitors in coating through entrapment within the pores of the silica matrix. The Inhibispheres® themselves are mechanically resistant and can be used in a mill base without premature release of the inhibitor inside the particle. Being made primarily of silica, the Inhibispheres® can easily replace other paint fillers in a coating, thus minimizing the impact on the Pigment Volume Concentration.
Problem definition:
In coatings, the use of traditional corrosion inhibiting pigments gives a matt or reduced gloss finish to the paint. For gloss finishes with better corrosion protection capability, a 2-coat system is required (i.e. a primer and a topcoat). The primer coating offers corrosion protection through the use of a corrosion inhibiting pigment and the topcoat provides the required aesthetic finish (high gloss). In DTM coatings, the formulator balances the optical properties with the corrosion protection. Standard corrosion inhibitors are usually pigmented materials and their irregular shape and large size have a significant effect on the optical properties of a gloss coating. Thus, a compromise is usually made between these two features of the coating, as high gloss and robust corrosion protection are traditionally not possible to obtain in a single coat. This tends to limit the applications of DTM coatings to either protection of assets in less demanding environments (e.g. indoor) or where high gloss is not a key requirement.

The challenge for the innovative formulator is how to produce a single coat DTM system with durable corrosion protection and decorative aesthetic properties similar to a topcoat.

High level solution:
A corrosion inhibiting product with no effect on optical properties (gloss) that is easy to incorporate into a coating is required. The inhibitor needs to be as efficient or better than current traditional anti-corrosive pigments. The optical properties of the coating must not be compromised by the addition of the inhibitor. These requirements can be achieved using Inhibispheres® due to their size, shape, refractive index and the sustained release of their unique inhibitors.

Solution details:
Inhibispheres® are made via an emulsion polymerisation process using carefully selected precursors and a highly effective organic or organometallic corrosion inhibitor. Meticulous control of the synthetic conditions allows for the tailoring of particle size and distribution. This results in a spherical product that is perfectly uniform and monodisperse (Fig. 1). The practical advantage this gives is that the particles have a low refractive index due to the small particles size with D50 = ~0.5 µm.

The Inhibispheres® are essentially made of a porous silica with a sponge like morphology where the pores are filled with the chosen inhibitor. The inhibitors are specially selected to work with specific substrates (aluminium and/or steel) and are capable of working in addition to traditional corrosion inhibiting pigments.
To demonstrate their use in DTM coatings, Inhibispheres® performance has been investigated in a selection of commercial coatings. A high gloss polyurethane topcoat (1) with no corrosion inhibitor is compared against an analogous DTM (2) product from the same product range and manufacturer. Both have the same resin chemistry but the DTM contains a commonly used traditional pigmented corrosion inhibitor. The addition of the traditional pigmented corrosion inhibitor gives the commercial DTM a C1-C3 corrosion rating while sacrificing on gloss (see Figure 1). As a comparison, the topcoat was used with Inhibispheres® (3) to show how their addition into a coating can significantly improve the capability to inhibit corrosion while maintaining a high gloss finish on the coat. A second comparison can be made with Inhibispheres® in the PU gloss topcoat (3) against a two-coat system using a primer with a traditional anti-corrosive pigment and the same PU gloss topcoat (4).

Cold rolled mild steel panels (EN10130) were coated. The panels were then added to a NSST for 250 hours for accelerated testing. The corroded panels were scanned, and the coating removed around the scribe to visualise the corrosion.

The gloss of the coatings was measured (Figure 1) at both 60 (normal gloss) and 20 (high gloss) degrees. It is clear that the addition of Inhibispheres® at 2% has little to no effect on the gloss of the coatings. Even at a loading as high as 10% the Inhibispheres® materials have minimal effect on the gloss of the coating.
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The corrosion performance of the different coating and inhibitor systems was tested using ASTM B117. The panels were exposed for 250 hours to a corrosive environment (Table 1). There is some staining from rust on all the samples. When comparing the samples with the coating around the scribe removed, it is evident that sample 3 (Inhibispheres®) performs the best when compared to the other coating systems. The worst performing is clearly sample 1, which has the most creep from the scribe underneath the blistering in the coating caused by the corrosive environment. It is also clear that sample 2 is better than 1 and better even than 4 (2 coat system) but has undergone some blistering which 4 has not. Sample 3 (Inhibispheres®) has no blistering and the least amount of creep from the scribe of all the paints tested.

The creep for the samples with the coating removed was recorded in Figure 3 as an average of four measurements taken at the widest point on each of the four parts of the scribed X. The measurements make clear what is seen in the images in Table 1. The best performing material was the topcoat with the Inhibispheres® inside. A significant reduction in creep is seen.

<table>
<thead>
<tr>
<th>PU Topcoat (1)</th>
<th>PU DTM (2)</th>
<th>PU Topcoat + 2% IS (3)</th>
<th>PU Topcoat + Primer (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
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<tr>
<td><img src="image5.png" alt="Image 5" /></td>
<td><img src="image6.png" alt="Image 6" /></td>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
</tr>
</tbody>
</table>

Table 1. NSST panels for corrosion testing of PU coating systems at 250 hours. Top image (before scrapping) Bottom image (after scraping)
**Commercial benefit:**

A DTM coating with better gloss and anticorrosive functionality can be achieved. A small increase in the bill of materials (BOM) cost can yield a product with a significantly greater ability to withstand corrosive environments. You can take a C1 corrosion class coating to a C3 or better coating. It is obvious that sample 1 in Table 1 was at best a C1 coating. With the addition of the Inhibispheres® the coating was capable of showing better corrosion prevention than coatings with a C3 corrosion environment rating (both 2 and 4) while maintaining a high gloss finish. The BOM cost of 3 (Table 2) per litre increases by 14%. The selling price of a product with high gloss and better anticorrosive functionality is not known as no such product exists on the market now. However, the BOM cost of the commercial DTM is 38% more than the topcoat formulation. Thus, for a 14% increase versus 38% increase (a saving of 24%) in manufacturing cost, the resulting product, which offers better performance than a commercial DTM, could translate into a significantly higher selling price. For the end users, the benefit of using a high performing DTM coating remains substantial. The labour requirement for putting a single coat down compared with a two-coat system represent a significant gain in time and money. In summary, the use of Inhibispheres® in DTM formulations makes a compelling business case for both the paint manufacturer and the end user.

![Creep measurement from scribe](image)

*Figure 3. Measure of creep from the scribe for the corrosion panels*

<table>
<thead>
<tr>
<th>Coating system</th>
<th>Relative cost (BOM)</th>
<th>Number of coatings</th>
<th>Corrosion rating</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU Topcoat (1)</td>
<td>100%</td>
<td>1</td>
<td>C1</td>
<td>High Gloss</td>
</tr>
<tr>
<td>PU DTM (2)</td>
<td>138%</td>
<td>1</td>
<td>C1-C3</td>
<td>Gloss</td>
</tr>
<tr>
<td>PU Topcoat + IS 2% (3)</td>
<td>114%</td>
<td>1</td>
<td>C1-C3</td>
<td>High Gloss</td>
</tr>
<tr>
<td>Primer (4) PU Topcoat</td>
<td>56%</td>
<td>2</td>
<td>C1-C3</td>
<td>High Gloss</td>
</tr>
<tr>
<td>PU Topcoat (1)</td>
<td>100%</td>
<td>1</td>
<td>C1</td>
<td>High Gloss</td>
</tr>
</tbody>
</table>

*Table 2. Relative coating costs and properties*
Summary:
The benefits of using Inhibispheres® in a DTM coating over traditional anti-corrosion pigments are numerous:

• better corrosion performance,
• better optical properties,
• lower cost in manufacture compared to a commercial DTM,
• lower cost in use compared to both a 1 coat or a 2 coat-system.

From the end user perspective, a high gloss DTM coating containing Inhibispheres® offers a significant reduction in labour costs as well a gain in production time.

Call to action:

If you would like to discuss any of these materials for use in your coating systems, please contact Ceramisphere at info@ceramisphere.com or get in touch with one of our distributors to talk about how Inhibispheres® can help you in formulating innovative protective coatings.

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