White Paper
Graphene Enhanced Coating
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Contents:

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Executive Summary

One coat corrosion resistant coating with a salt spray result of 11,800 hours.

Unique graphene enhancement.

VOC free and UV resistant.

Suitable for all types of site application methods, including where abrasive blasting is not possible.

Designed, developed and manufactured in the UK.

Business Challenge

Corrosion of steel has been a problem for as long as steel has been used for structural purposes. The reduction in the steel's physical state clearly has all manner of safety and performance issues not to mention cost. Some reports suggest that steel corrosion costs the global economy around £2 trillion per year[1], which equates to 3% of global GDP. The use of coatings or paints to protect the steel likewise has a long history with global sales of anti-corrosion coatings in the region of £18 billion per year[2].

Coating development tends to be gradual with incremental improvements in the base resins or the additives, with very little brand new happening.

The chemistry of our standard high performance protective coating resists corrosion. Salt spray testing of this standard coating to ISO 9227:2017 – Neutral Salt Spray, gives results between 1,000 and 5,000 hours depending on the coating thickness. This is an excellent result but at Blocksil we strive to achieve coating performance improvements.

Increasing corrosion performance by adding glass flake or Micaceous Iron Oxide (MIO) particles is a well established low cost method. These particles act by increasing the path a corrosive liquid has to take to get through the coating to the substrate. The flakes or particles can overlap each other and extend the path length for diffusion in the coating. The aspect ratio (where the surface area is a multiple of the size of the particle) of glass flakes can be as low as 1:10 and up to 1:80 for MIO.

Graphene has an extremely high aspect ratio. The number of atomic layers varies but the graphene used by Blocksil typically has a 1 to 10 nanometre thickness with 1 to 15 microns lateral diameter, resulting in aspect ratios up to 1:1000.
To put this into perspective, the surface area of ten grams will cover a soccer pitch!
And graphene is much lighter, smaller and needs only a fraction of a percent added, and so makes no difference to the handling and application of the coating.

Solution

By introducing graphene into a protective coating we effectively bring a radically new corrosion resistant coating to market. The idea behind adding graphene to one of our already high performing coatings came from our technical team, lead by Chris Knowles, an experienced paint chemist.

Graphene was first isolated in 2004 at The University of Manchester, UK by using sticky tape to remove single layers from the surface of graphite and then depositing them onto a silicon wafer. The isolation of graphene was a breakthrough which ultimately won the 2010 Nobel Prize for Physics for Andre Geim and Konstantin Novoselov.
In its purest form graphene has a molecular structure comprising of a single layer of Carbon atoms bonded in a hexagonal structure. Graphene possesses an unsurpassed combination of mechanical, electrical, and thermal properties.

The graphene used in Blocksil's coating is manufactured by Applied Graphene Materials (AGM), UK using a patented synthetic, bottom up process that is repeatable, proven and almost completely free of graphitic impurities, Graphene Oxide or transition metals[3]. The essential process is one of cracking open Ethanol and then building up the Carbon atoms within the Ethanol. This technique is far less damaging to the Earth than other techniques such as mining.

Tested to ISO 9227:2017 – Neutral Salt Spray, with testing in continuous 5% Sodium Chloride solution at 35ºC, our graphene enhanced coating has taken us to 11,800 hours. The coating thickness on the sample panels was 35 to 50 microns.
To put this into recognisable terms, in the automotive industry coatings tend to be acceptable with up to 1,000 hours.

ISO 9227:2017 specifies the apparatus, the reagents and the procedure to be used in conducting the neutral salt spray tests for assessment of the corrosion resistance of metallic materials, with or without permanent or temporary corrosion protection.
It also describes the method employed to evaluate the corrosivity of the test cabinet environment.

It does not specify the dimensions or types of test specimens, the exposure period to be used for a particular product, or the interpretation of results. Such details are provided in the appropriate product specifications.
The salt spray tests are particularly useful for detecting discontinuities, such as pores and other defects, in certain metallic, organic, anodic oxide and conversion coatings.

The neutral salt spray test particularly applies to
- metals and their alloys,
- metallic coatings (anodic and cathodic),
- conversion coatings,
- anodic oxide coatings, and
- organic coatings on metallic materials.

The salt spray method is suitable for checking that the quality of a metallic material, with or without corrosion protection, is maintained[4].

The salt spray cabinet used is shown below with a schematic of how such a cabinet operates alongside (both images provided by AGM).

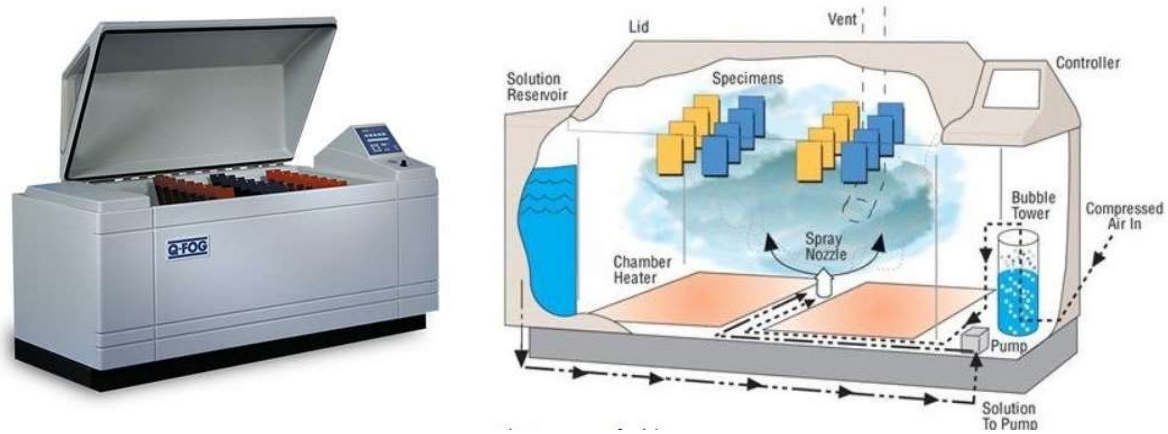


Image of the salt spray testing cabinet and a schematic showing how it works.

Regular inspection of the test panels took place every 500 hours or so, with the test being stopped at 11,800 hours as it was clear that no corrosion of the coated surface was taking place.

These next photographs show the grey coloured graphene enhanced coating as applied onto steel panels. Two sets of coated panels were tested, with a scribe through the coating to steel and without a scribe mark.

After11,800 hours the coating was mechanically stripped off the lower half of each panel. It is quite clear that whilst the scribed area has corroded, there is no corrosion damage to the coated area of the steel panel. There is also no lifting of the coating away from the corroded scribed area, further demonstrating the incredible adhesion of the coating to bare (un-primed) steel.

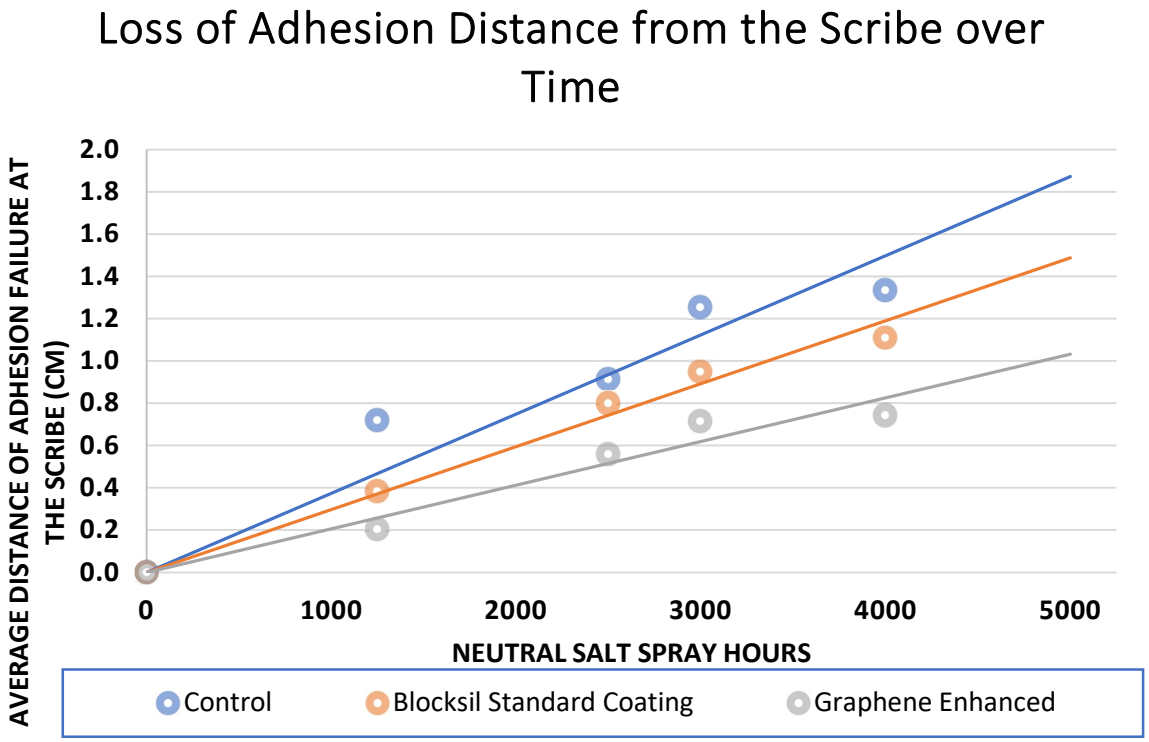
The third photograph shows the unscribed panel partially stripped. No corrosion at all is evident.

Photographs showing a scribed panel after 11,800 hours salt spray, the same panel with the grey coating partly removed, and after full lower half stripping. No corrosion happened beneath the graphene enhanced coating.

ISO 12944-2:2018 deals with the classification of the principal environments to which steel structures are exposed and the corrosivity of these environments. There are two key elements to be considered: the corrosive environment and the system durability.
The corrosive environment is categorised from C1, very low corrosive environment to C5, very high corrosive environment.
Durability is listed as being low, medium and high with a link to the number of years to the first major maintenance. High specifies more than 15 years to the first major maintenance based on 1,440+ hours of salt spray performance.
The test results from AGM comfortably places the Blocksil Graphene Enhanced Top Coat in the C5 and High categories.

It was believed that the graphene enhancement would improve adhesion and this was borne out with adhesion testing on a scribed panel over time. The adhesion was measured as a function of distance from the scribe over the course of 5,000 hours of salt spray testing.
A control panel of a conventional corrosion resistant coating was used as was our standard corrosion resistant coating. To clarify, it is our standard corrosion resistant coating that forms the base to which the graphene is added.

As can be seen on the graph below, the addition of graphene improved adhesion after 5,000 hours by 30% over our standard coating and by 45% over the conventional coating. Another impressive result.



Graph showing adhesion improvement over time of the graphene enhanced coating as compared with the unenhanced coating and a standard, control coating.

Testing has also been carried on the fire performance of the graphene enhanced coating.

Building use, as a steel roof coating.
The coating has been tested to and meets the requirements of EN 13501-5:2016, with no spread of flame, ignition or penetration. This European Standard provides the fire performance classification procedures for roofs / roof coverings exposed to external fire based on the four test methods given in CEN/TS 1187:2012 and the relevant extended application rules.

Railway use.
The coating has been tested to EN 45545-2:2013 and achieved the highest rating, HL3, with Set R7, which is external (that is, not inside the train carriage) use. This part of EN 45545 specifies the reaction to fire performance requirements for materials and products used on railway vehicles. The defined operation and design categories are used to establish hazard levels that are used as the basis of a classification system.

Additional testing such as the impact or drop ball test was carried out. Carried out in line with ASTM D 2794, this test is used to determine the penetration resistance and flexibility of coatings under fast deformation. In other words, to check to see if the coating breaks or cracks. The photograph shows a test panel after having the ball drop from a height of one metre.

The graphene enhanced coating did not break or crack even when the drop height reached one metre .

Photograph of the 1,000mm ball drop test panel showing no cracking or breaking of the graphene enhanced coating.

Blocksil is currently working on incorporating graphene into other coatings, paints and treatments to take advantage of the enhanced corrosion resistance and adhesion offered. For example, we are incorporating graphene into two pack primers, Polysiloxane paints, Vinyl primers and top coats, and many more. These developments will give obvious benefits to the clients, the applicators and the environment.

And others have incorporated AGM graphene into aerosol applied primers with a similarly impressive increase in anti-corrosion performance.

Such is the excitement in the technical world regarding graphene it can be found in novel face masks, batteries, military camouflage and even implantable bioelectronic sensors. Although graphene is a new technology, each industry and application promoter will be carrying out testing to simulate long term use, as we have done with our testing.

Are there any negatives to graphene enhancing the Blocksil Top Coat MT for industrial use? No. The graphene is inert and has no negative effect on our coating. Our coating has been fully fire tested, mechanically tested and fully evaluated on site.

Target Markets

Industries that could use the Blocksil Graphene Enhanced Top Coat and help reduce corrosion costs include:

- Buildings – commercial, industrial and domestic
- Infrastructure, such as bridges
- Structural steelwork

Countries that could use the Blocksil Graphene Enhanced Top Coat - worldwide.

Benefits

- Cost saving
- One coat application so quick to apply
- Solvent free so environmentally friendly
- Worldwide uses

Technical Specifications

- 30 year product warranty as part of a roof coating system
- Apply by brush, roller, or airless spray
- Colour range
- Salt spray ISO 9227:2017, 11,800 hours
- Satisfies EN 13501-5:2016
- Satisfies EN 45545-2-213 R1
- Slip resistant to BS 7976-2:2002+A1:2013 (PTV 33.0 in the wet) with optional fibres added
- Surface tolerant
- UV resistant
- VOC free
- Wide application window

Summary

The Blocksil Graphene Enhanced Top Coat MT is a unique coating with excellent corrosion resistance, ease of use and versatility.

It has environmental credentials with no Volatile Organic Compounds and, because it can be applied in one coat, the time spent on site is significantly reduced compared with other coatings.

References

1 National Association of Corrosion Engineers
2 Allied Market Research
3 Andy Gent, Applied Graphene Materials
4 iso.org