AMBIENT TEMPERATURE CURE GLASS COATINGS FOR CORROSION PROTECTION

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ABSTRACT

Surface treatments used for the protection and property enhancement of aerospace alloys are an indispensable technology. The purpose of this proposed research will be to examine the strengths and weaknesses of new ambient temperature cure glass (ATC Glass) coatings. Manufactured by Adsil LC, ATC Glass is high-performance silica based coating, and can be used to protect a variety of surfaces. This project will be centered around aerospace composites, specifically aluminum. Current corrosion coatings in use such as Hexavalent Chromium coatings (Alodyne, Irridite) as well as anodizing, all fall short of being ideal protectants. These coatings are either difficult to apply, are highly toxic, or lack superior corrosion protection properties. ATC Glass boasts easy application, low toxicity and superior corrosion protection. Corrosion is a major problem in both the global economy and in the aerospace industry. The annual U.S. cost of corrosion exceeded $500 billion in 2000 which equates to $1200 per citizen. Corrosion is also a major problem in today's aerospace industry, with even minor corrosion posing a serious danger. Because of the widespread use of corrosion resistant surface treatments, and the lacking performance of the available coatings, development of new alternative coating technologies would have a significant and important impact. Testing of ATC Glass was conducted by applying the coating to specially prepared aluminum samples which were then subjected to both controlled and outdoor environments. Based on this testing it was found that the ATC Glass coating did significantly reduce corrosion on the aluminum samples in comparison to uncoated samples. Based on these findings and the ease of application as well as low toxicity of the coating, ATC Glass is highly recommended as a protective coating for the prevention of corrosion.

INTRODUCTION

The understanding and subsequent prevention of corrosion in aerospace and the production industry in general is a far reaching, very important, and costly issue. Corrosion is a costly and dangerous problem for both industry and private citizens. Billions of dollars are wasted every year because of the consequences of corrosion, yet with proper preventative measures much of this loss could nullified. Ambient Temperature Cure Glass (ATC Glass) is a new and innovative coating technology which presents a possible preventative solution to many corrosion problems. ATC Glass coating is manufactured by Adsil LC and is a low toxicity, silica based coating which can be easily applied to a variety of surfaces and acts as a surface barrier against corrosion. The purpose of this research is the testing and subsequent evaluation of the protection characteristics of ATC Glass coating in various environments. Hawaii plays host to a multitude of extreme environments within a short distance of each other making it a perfect location for this type of research.

AMBIENT TEMPERATURE CURE GLASS COATING

The performance testing of Ambient Temperature Cure Glass coating is the subject of this report. ATC Glass coating is manufactured by Adsil LC and is available in a number of different formulations for use on different substrates. Testing for this project was done on a polished 6061-T6 aluminum substrate and the appropriate ATC Glass formulation, Microguard AD95 was used. The aluminum samples measured 2 x 2 x 0.125 inches and were micropolished on one side (Figure 1). Both solid square samples and samples with a hole drilled in the center of the 2 x 2 inch face were used. The drilled samples would later be coupled to other materials for the study of study galvanic corrosion.

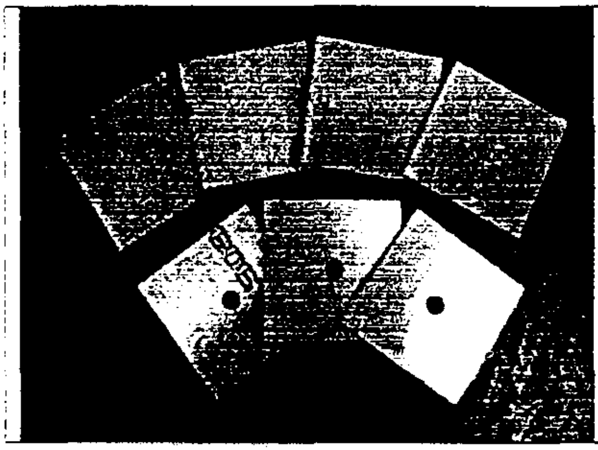


Figure 1-The 6061-T6 square aluminum samples are shown below. Both solid samples and samples with mounting holes were tested.

Application of the ATC Glass coating was done by two different parties during the testing. The application process is relatively simple, consisting of first degreasing the sample using acetone or Alumibrite™. The coating is a two part formulation consisting of a catalyst and base. After mixing, the coating is applied using a hand held atomizing bottle followed by wiping the excess liquid coating off using a clean sponge or cotton cloth (www.adsil.com). The product is then usable within 24 hours and completely cured within approximately 5-7 days. Although a slightly elevated ambient temperature with constant airflow does speed curing time, heat curing is not required. Bonding of the coating with the substrate surface occurs by atom-to-atom covalent bonding, yielding a highly protective and durable coating. The initial batch, batch one, of samples was coated locally by Adsil certified Blue Water Marine. The second batch, batch two, was sent to Adsil for treatment. The first batch was only coated on the polished side of the sample while the second batch was coated on both sides and edges.

TESTING APPARATUS

Initial plans called for both controlled indoor testing as well as outdoor testing in various environments. Actual testing during the duration of the two semesters this research was in progress centered mainly around the controlled laboratory testing; with the outdoor testing taking place in the near future.

The controlled laboratory testing was carried out in the University of Hawaii's Corrosion Laboratory. There were two segments in the controlled testing. The first segment consisted of placing samples from batch one in the Hawaii Corrosion Laboratory's controlled temperature and humidity chamber(Figure 2). The chamber is maintained at a temperature of 30 degrees Celsius and relative humidity of 85%. The coated surface of the samples was misted with a either a dilute NaCl or an artificial ASTM sea-salt mixture prior to being placed coated side up in the chamber. The Adsil coatings were found to be hydrophobic, promoting beading on their surface. The first batch of samples was exposed for a time period of six months.

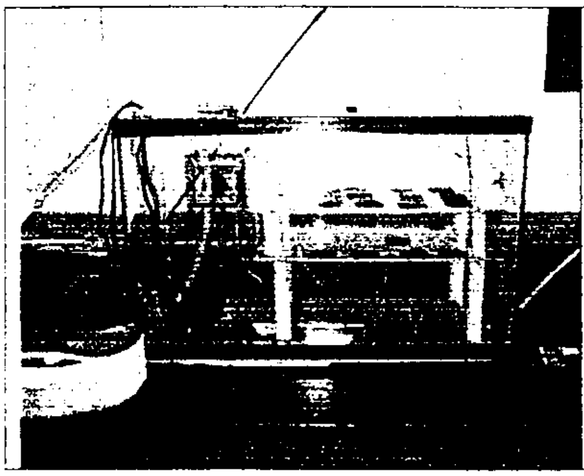


Figure 2-The controlled temperature and humidity chamber is shown with samples arranged on the horizontal shelving.

The second segment of the controlled laboratory testing involved samples from both batch one and batch two submerged in NaCl and artificial sea-salt solutions. Samples from batch one were placed uncoated side down in 500ml beakers and covered with the solution. These samples were exposed for a period of six months. Batch two samples were those coated on both sides, and were mounted in a submerged upright orientation in 250ml beakers (Figure 3). The samples from batch two were exposed for a shorter period of two months. Submersion in an aqueous environment results in more aggressive corrosion process compared to exposure in the controlled temperature and humidity chamber. This is because of the constant presence of electrolyte on the surface of the sample when submerged. The electrolyte allows local corrosion to occur at any point on the sample where the coating is compromised.

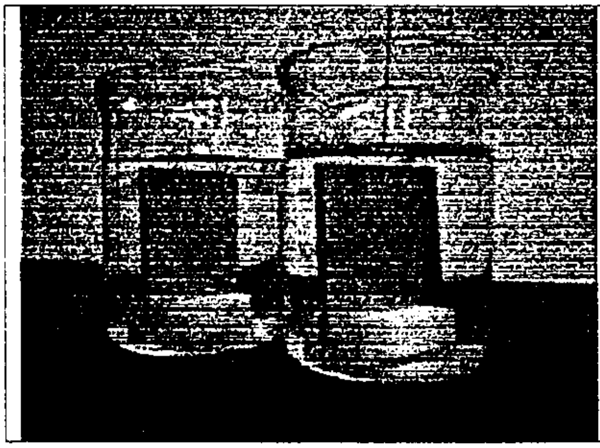


Figure 3-Samples from batch two had both sides coated with ATC Glass coating and were submerged vertically in NaCl and artificial sea-salt solutions.

The outdoor testing of samples in various climates was planned but not completed during the span of this research. Samples were to be placed on custom test racks (Figure 4) which in turn would then be placed in various environments. The test racks are capable of holding a multitude of different samples in various orientations. In addition each rack is also equipped with a full weather station. The first rack was deployed in April 2002, and additional racks will be deployed in the following months. Hawaii is an ideal test site for this type of research because of the wide range of climates within a close proximity to each other. Within a relatively small area the environment can range from barren dessert, to tropical rainforest, to coastal, to industrial, and even frozen alpine. This wide variety of climates combined with the controlled laboratory test conditions allows performance testing of ATC Glass under almost any conditions it might face in industry.

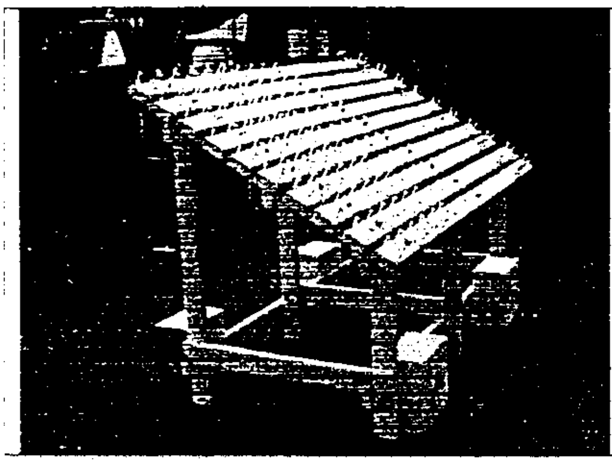


Figure 4-A test rack sits almost complete and ready for deployment. Samples are mounted on custom standoffs on the upper surface of the rack. Photo by George Hawthorne.

THE CORROSION OF ALUMINUM

Corrosion of aluminum typically occurs by the formation of the oxide corrosion product Al_2O_3 on the surface of the aluminum. This oxide coating quickly forms a protective layer over the aluminum's surface preventing further corrosion. Oxide build up can be clearly seen in the form of white Al_2O_3 deposits if layer is thick enough or spalls off of the surface such as in cracks and nicks.

COATING PERFORMANCE RESULTS

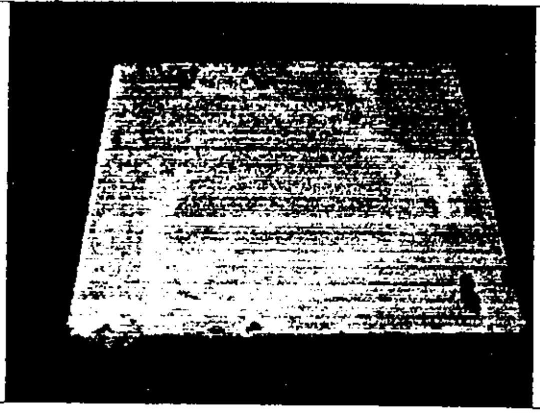
All results presented in this document pertain to the performance of ATC Glass coating on the samples under controlled conditions in the University of Hawaii Corrosion Laboratory. Although actual performance testing was placed on an accelerated scale, the following results are a good indicator of the performance of ATC Glass coating under real life conditions.

The samples from batch one, which were exposed for a period of six months, showed no visible signs of corrosion on their upper coated surfaces. The bottom uncoated surface showed minor but clearly visible aluminum oxide development in several areas denoting corrosion.

The samples from batch one, which were submerged for a time period of six months, showed the greatest differential in the amount of corrosion on the coated and uncoated surfaces. The upper coated surface of all samples showed little if any corrosion. The only corrosion present on the upper surface was present in small areas where the ATC Glass coating had been scratched off or damaged during handling. The uncoated bottom surface of the samples showed excessive corrosion product formation and discoloration as shown in Figure 5.

Figure 5-Submerged samples from batch one show a clear distinction in corrosion on the coated

upper surface (right) and the uncoated lower surface (left). Note the excessive Al_2O_3 development on the lower surface.



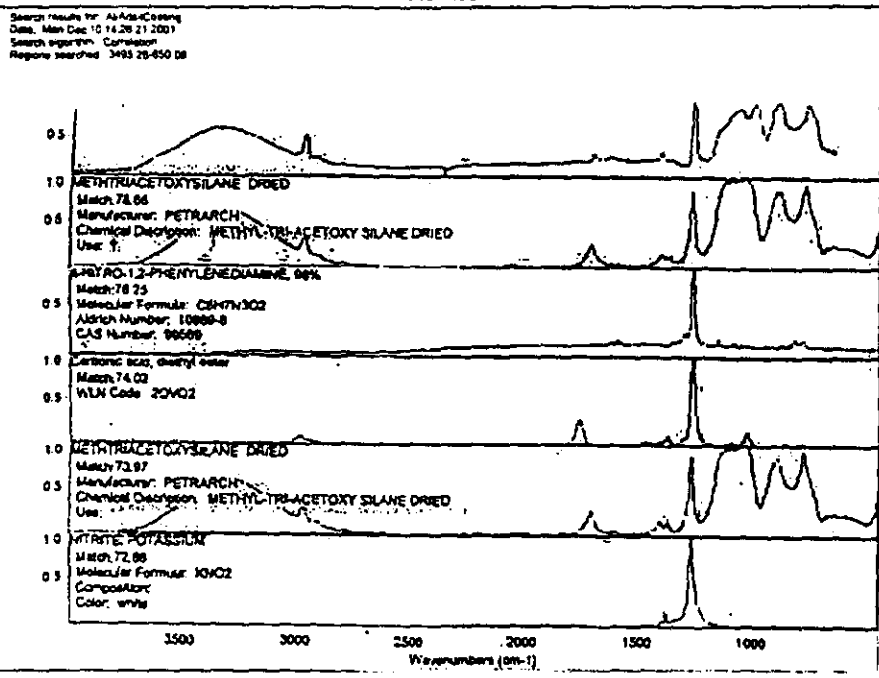
Samples from batch two which were completely coated and submerged for a period of 2 months showed no apparent signs of corrosion visible to the naked eye.

INTERPRETATION OF TEST REPORTS

Based on the differences in corrosion product build up on the uncoated versus coated aluminum surfaces the conclusion can be drawn that ATC Glass coating is effective in inhibiting corrosion. It must also be noted that although the coating effectively stops corrosion and appears to be very abrasion resistant, it is possible to scratch through the coating and thereby start corrosion sites. In addition ATC Glass coating is not self healing so depending on the totality of the coating these nicks may or may not have accelerated corrosion rates.

Plans were made for a scanning electron microscope imaging and elemental analysis of the ATC Glass coating, but due to unfortunate equipment failure this was not possible. The results of a spectral analysis of the coating are shown in Figure 6 below. Based on these results the Adsil coating appears to be similar to the dried material methyltriacetoxy silane. The chemical formula for this material is $C_7H_{12}O_6Si$ (http://myhome.netsgo.com).

Figure 6-The spectral analysis results of ATC Glass coating as well as several other compounds are shown. By comparison, ATC Glass most closely resembles make up of methyltriacetoxy silane.



CONCLUSION

Adsil LC's Ambient Temperature Cure Glass coating was tested to determine its performance as a preventative coating against corrosion on aluminum. Testing was carried out in a controlled laboratory environment and in the near future will extend to outdoor testing in various climates. The surfaces of laboratory samples treated with ATC Glass coating were much more corrosion resistant than the surfaces that were not coated. It was found that ATC Glass coating did significantly reduce corrosion rates and provide corrosion protection on aluminum substrates.

Future improvements on this project could include outdoor exposure in a variety of climates as well as increased exposure time in both controlled and outdoor settings. Additional substrates such as ferrous and composite substrates could be integrated into the testing.

ACKNOWLEDGEMENTS

The author would like to extend thanks to the Hawaii Space Grant College and NASA for providing this research opportunity. Thank you to Dr. Hihara for providing mentoring and remaining patient with my abnormal schedule. Additional thanks to George Hawthorne for his work on the test racks and to Blue Water Marine for their help with coating the samples. Special thanks to Adsil LC for providing helping with the research and coating samples.

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