Corrosion Rate Evaluation of SilcoTek Coatings using Polarization Resistance Scan

Technical Insight

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Background

Multiple methods exist to evaluate corrosion of a metal sample in a corrosive environment. For example, SilcoTek® has used the sample weight loss to calculate corrosion rate in a liquid immersion or salt spray environment, as well as Electrochemical Impedance Spectroscopy (EIS) to assess the stability of coated metal samples exposed to the electrolyte solution under test. These methods and results have been documented in other SilcoTek publications.

This Technical Insight focuses on using an electrochemical method, namely potentiodynamic polarization resistance scan, to gain corrosion rate information. Polarization resistance is a quick, mostly nondestructive testing technique commonly used in material corrosion studies to obtain corrosion rate information.

The material to be tested is polarized in the immediate vicinity (±10mV) of its Open Circuit Potential (OCP), the potential measured when no net current is flowing. As the potential of the material is changed, a current will be induced to flow between the working and counter electrodes, and the material's resistance to polarization can be found by taking the slope of the potential versus current curve. This resistance can be related to the rate of general corrosion for metals at or near their OCP using the Stern-Geary equation[1]. ASTM G59-97 (2014) states these measurements provide an accurate and rapid way to measure the general corrosion rate and are often used in real-time corrosion monitoring, as well as in ranking alloys and inhibitors in order of resistance to general corrosion[2].

A good introduction to the theory behind this method can be found here.

Goal

The goal of this Technical Insight is to evaluate the corrosion performance of SilcoTek-coated versus uncoated stainless steel samples in hydrochloric acid using polarization resistance. This test is a good way to check coating quality and coverage as well as to catch holidays, pinholes or defects in the coating that will allow leakage current through and be reflected in the scan results.

Experiment, Results, and Discussion

The polarization scan experiment was carried out using a Gamry paint test cell, shown in Figure 1. It consists of a saturated calomel reference electrode, a graphite rod counter electrode, and a working electrode made of the investigated specimen with an exposed area of 14.6 cm^2. The sample is exposed to an electrolyte of 5% hydrochloric acid solution.

The first set of samples are electropolished and chemically passivated 304 stainless steel. Figure 2 shows the comparison scan results of uncoated substrates versus SilcoTek's Silcolloy®-coated samples. The results indicate that the Silcolloy coating provided complete coverage of the sample surface and insulated the underlying metal from any noticeable corrosion pathways, so that a corrosion current by 3 orders of magnitude lower was achieved in coated samples. The results are reproducible, and no detectable pinhole or coating defect was present to introduce enough leakage current to be seen in the scan results.

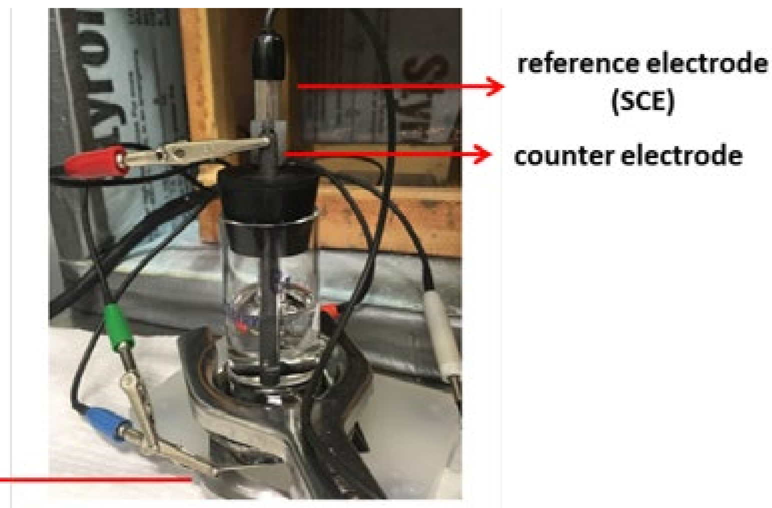


Figure 1: The polarization resistance scan experiment setup

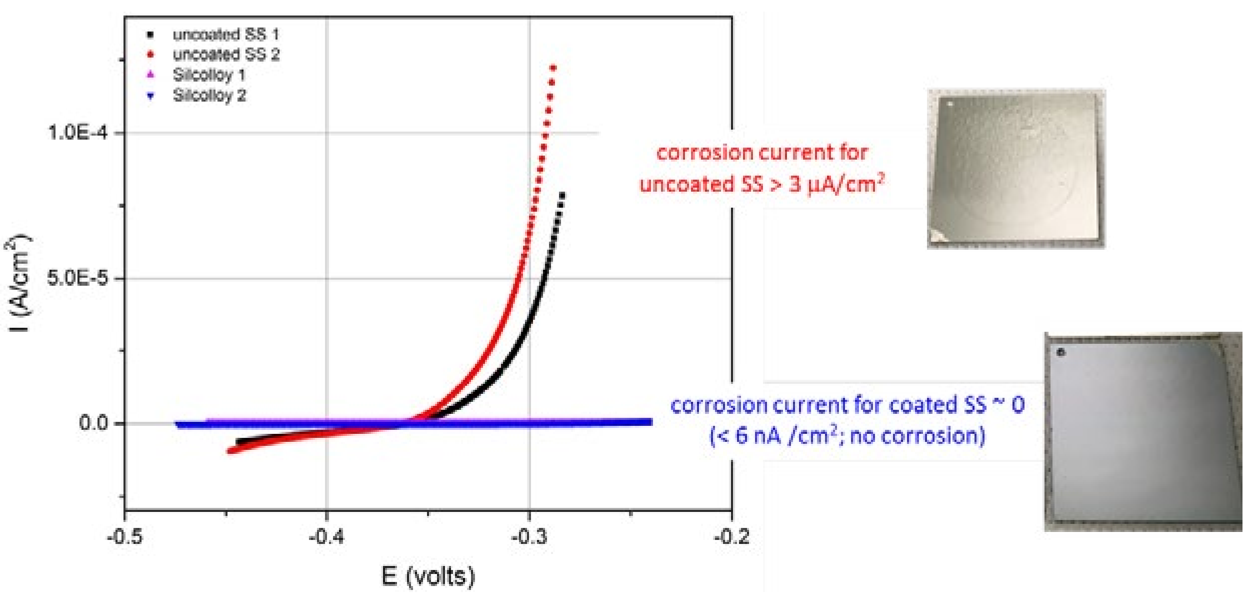
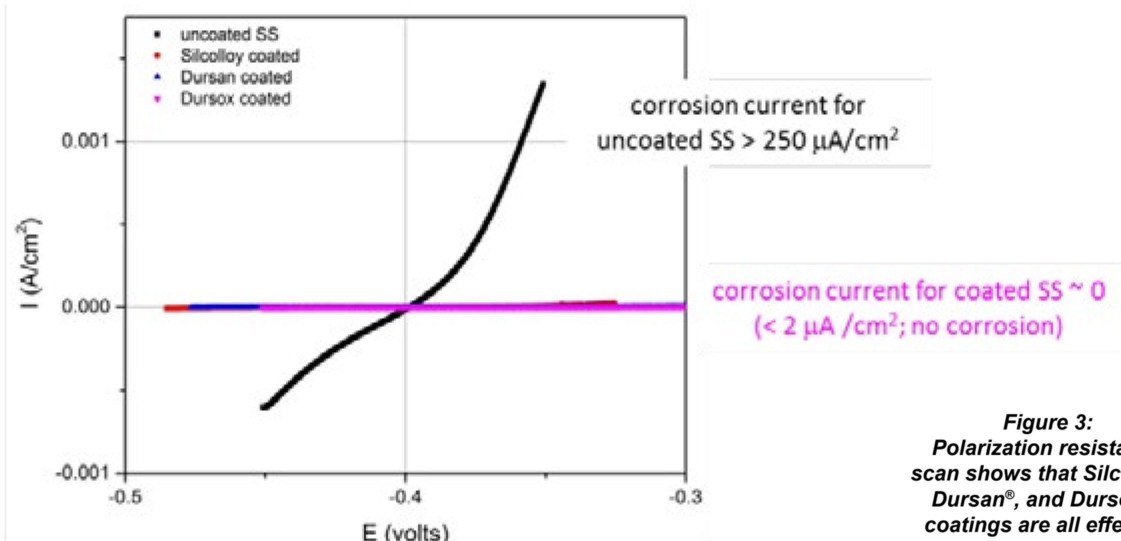


Figure 2: Polarization resistance scan shows that the Silcolloy® coating reduces corrosion by 3 orders of magnitude in 5% HCl. Corrosion current was estimated from the slope in the linear polarization scan (not shown here).

The second set of samples to be investigated are 304 stainless steel samples that are mechanically polished to a mirror-like finish. As can be expected, the substrate difference caused significant difference in the magnitude of the corrosion current in comparison to the first set of samples, as seen in Figure 3 below. Three coatings, Silcolloy®, Dursan® and Dursox™, were evaluated here. All coatings were found to improve the corrosion performance of the 304 SS by 2~3 orders of magnitude in 5% HCl. The pictures taken after the scan showed that while the uncoated 304 SS was visibly corroded in the exposed area, all coated samples exhibited no sign of corrosion, as was suggested from the scan results. The tests were repeated and the results were reproducible.

Conclusion

SilcoTek's CVD coatings are effective barriers against corrosion on stainless steel substrate. This Technical Insight used potentiodynamic polarization scan as a quick and accurate method to evaluate the benefits of coatings in comparison to the uncoated counterparts. The results confirmed that SilcoTek's CVD coatings provide complete coverage to the metal surface and reduce corrosion current in 5% HCl by 2~3 orders of magnitude.



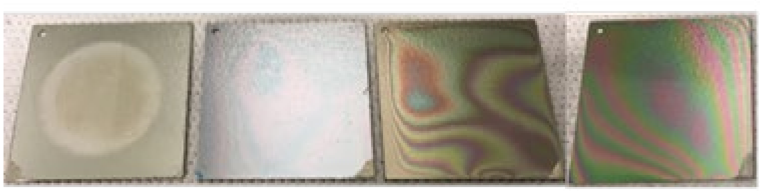


***Figure 3:* Polarization resistance scan shows that Silcolloy®, Dursan®, and Dursox™ coatings are all effective in reducing corrosion in 5% HCl. Corrosion current was estimated from the slope in the linear polarization scan (not shown here).**

References

1. Gamry "Polarization Resistance Tutorial – Getting Started"
2. ASTM G59-97 "Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements"

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