Metrohm Autolab

Application Area: Corrosion

Stepwise dissolution measurement

Keywords

Acceleration Methods, Aluminum, Coating, Corrosion

Introduction

The stepwise dissolution measurement (SDM) is an electrochemical technique used to test the corrosion properties of aluminum-brazing sheets. The SDM is a modification of the anodic accelerated dissolution technique (AAD), developed by Corus Aluminium Walzprodukte (formerly Kaiser Aluminum; Koblenz, Germany). Both techniques have been developed in order to have results relatively quickly, typically hours, compared to days needed to complete the classic salt spray tests. However, in AAD, high over potentials (50 mV to 60 mV) are used, resulting in a too aggressive corrosion acceleration and a poor comparison with the salt spray experiment[1].

Therefore, the SDM technique has been developed as an improvement of the AAD. The scope is to have a non-aggressive technique in which selective dissolution can take place and it is possible to distinguish between good and bad corrosion behavior of different materials.

Experimental Setup

Three sheets of coated aluminum were tested. All of them had a thin coating of aluminum oxide, Al_2O_3. Two of them had an additional coating layer. The exact composition of the coatings was not made available. Therefore, further in the text, they will be referred as “pink” and “gold” coatings. Each sheet was punched to obtain disks of 1.5 cm diameter, to fit the sample holder of the Autolab 1 L corrosion cell, shown in Figure 1. One side of the samples were polished with sandpaper, to remove the coating layers, to assure good electrical contact with the sample holder. All measurements were carried out in artificial seawater, obtained by dissolving 33 g of NaCl in one liter of Millipore water. A stainless steel counter electrode and an Ag/AgCl 3 mol/L KCl reference electrode completed the three-electrode setup. All potentials are referred to this reference electrode. The electrodes were connected to an Autolab PGSTAT204, equipped with a FRA32M impedance module, shown in Figure 1.

Figure 1 - The 1 L corrosion cell and the PGSTAT204 with the FRA32M module

The procedure and the data handling were carried out with NOVA software. The NOVA procedure was in accordance with the SDM technique, which consists of the following steps:

- Record the open circuit potential (OCP) for five minutes.
- Increase the potential 20 mV vs. OCP, and keep the system polarized for 30 minutes.
- Record the OCP for five minutes.

The last two commands were repeated twelve times, for an overall duration of approximately 7 hours. A plot of OCP vs. cycle number was created. The charge was also sampled, as the charge collected per step is an indication of the amount of uncoated aluminum facing the electrolyte, thus an indirect measure of the coating dissolved in that step. From the collected charge for each step, the cumulative charge was then calculated. The cumulative charge is the total charge accumulated up to each step. A plot of the cumulative charge vs. the cycle number was created.

Results and discussion

In Figure 2, the OCP at the end of each cycle is plotted vs. the cycle number.

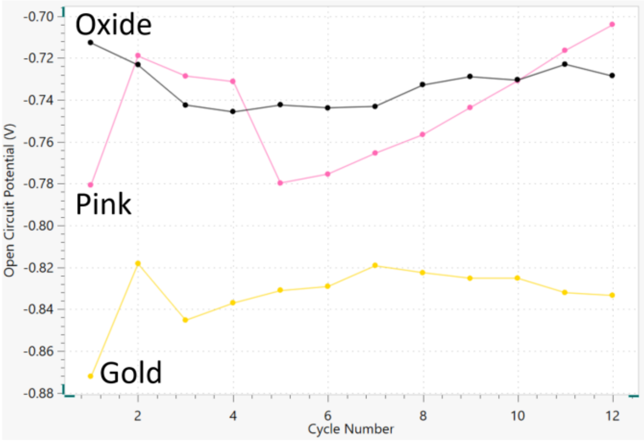

Figure 2 – Open circuit potential vs. cycle number of the three samples.

The oxide-coated sample displayed the most stable OCP during the entire measurement, also with the highest mean OCP value, reported as -0.73 V.

The pink-coated sample had OCP values close to the oxide values, but less stable. After the first cycle, its value increased approximately 40 mV and then it decreased by a similar amount (i.e., 35 mV) after the fourth cycle. The OCP constantly increased after each cycle. The mean value of the OCP was -0.74 V.

The gold-coated sample had an average OCP of -0.83 V. Besides, its value increased after the first cycle, then it changed less dramatically than the pink-coated sample, remaining at approx. -0.83 V.

Usually, a material with a lower OCP has a weaker protection against corrosion. In this example, the gold-coated had the lowest OCP and, therefore, it is the most prone to corrosion, when compared to the other two samples.

The plot in Figure 3 can be of further help. Here, the cumulative charge versus the cycle number has been plotted, for each sample.

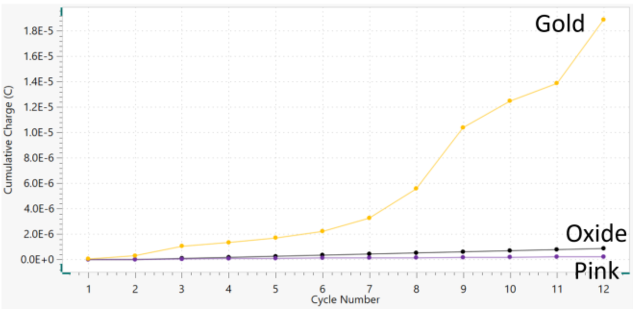

Figure 3 – Cumulative charge vs. cycle number for the three samples

Figure 3 showed that the highest amount of charge was collected by the gold sample. Also the cumulative charge increased drastically after each step. On the other hand, the pink sample delivered the least amount of charge and the oxide-coated sample had close values to the pink-coated one. Both of them had a slight increase of cumulative charge, after each cycle.

The plot in Figure 3 indicated that during the stepwise dissolution measurement, the gold-coated sample corroded more than the two other samples. In this respect, the pink-coated sample seems to give the best protection against corrosion.

Conclusions

The stepwise dissolution measurement is a relatively fast technique, firstly developed to test the aluminum-brazing sheet. In this application note, SDM is applied to aluminum samples coated with different materials, to have insights about the differences in terms of corrosion protection. The combination of Autolab PGSTAT204 with the 1 L Autolab corrosion cell and the NOVA software are the suitable setup to perform SDM and other corrosion experiments.

References

[1] Meijers, S.D., “Corrosion of aluminium brazing sheet”, 2002 Proefschrift, Technische Universiteit Delft, NL; pp 156. © Corus Technology, BV.

Date

November 2018 AN-COR-008

For more information

Additional information about this application note and the associated NOVA software procedure is available from your local Metrohm distributor. Additional instrument specification information can be found at www.metrohm.com/en/products/electrochemistry.