

Corrosion Resistance

Oxidation Resistance

As we noted in Unit 1, polymers generally do not oxidize at room temperature, and ceramics are mostly inert to oxidation at all temperatures. With metals, the task is not to prevent oxidation – that is not possible – but rather to see if the oxide films that form are protective. Then, if the oxide layer is broken, then the metal will be self-healing in contrast to when a surface coating such as paint or chrome plating is chipped away. This has been achieved with various alloy systems, perhaps the most familiar being the stainless steels.

Stainless steels are iron-carbon alloys that contain a minimum of about 13% chromium by weight. It is the chromium that forms a thin protective layer of Cr_2O_3 that makes stainless steels passive to further chemical attack. Note that oxygen is required to form the protective film. In a low oxygen environment, stainless steel may no longer be stainless. Similarly, if a situation arises that depletes the chromium content, then the stainless steel will lose its chemical passivity.

It might seem that protective oxide films are always desired, but they do come with some associated problems. Metals with protective oxide skins can be difficult, if not impossible, to join by welding, brazing, or sintering – processes we will explore in Unit 4. Also, oxide films are electrically resistive, making it difficult to obtain good electrical connections – thus, the limited use of aluminum wiring.

Strategies for Controlling Electrochemical Attack – Stopping Wet Corrosion

Since wet corrosion involves a concurrence of conditions, if we can interrupt any one condition, we can stop the process. It is often possible to break the electrical connection between dissimilar metals – by placing electrically insulating material between fasteners and mating materials, for example. We have seen examples of metals, such as aluminum, with protective oxide layers that separate underlying metal from exterior liquids. We note, however, that while aluminum corrodes very slowly in fresh water, it corrodes rapidly in salt water where the chlorine ions tend to break down the Al_2O_3 film. Wet corrosion prediction is very often more experimental than theoretical.

A similar coating situation arises with the use of *corrosion inhibitors*. These are chemical additives to the liquid that react with the metal. Depending on the nature of the liquid (hardly ever the 1 mol/deciliter of the standard electrode potential measurement), the chemical reaction product may be a layer that physically separates the metal and liquid. In other instances, the product may still allow diffusion of metal ions through it, but decrease the rate of corrosion.

Another method of stopping electrochemical attack is cathode polarization, which we will consider at the conclusion of this subunit.

Strategies for Controlling Electrochemical Attack – Living with Wet Corrosion

Many examples can be found in which we do not try to stop wet corrosion, but rather protect a desired part by devising a *sacrificial anode*. Galvanized steel is an example. As long as there are only minor scratches in the zinc coating, the underlying steel is a protected cathode. Only when large areas of steel are exposed to liquid do grain boundaries and other local imperfections cause the steel to be attacked. By the same reasoning, zinc and magnesium bars have been attached to steel ships, and magnesium bars suspended by metal chains into steel water tanks.

Another example of a sacrificial anode is the protection of buried steel pipe. Scrap iron is buried in the same moist earth in proximity to the pipe. A DC (direct current) voltage is imposed between the two to force the scrap iron to be the anode and the pipe to be the cathode.

Strategies for Controlling Electrochemical Attack – Cathode Polarization and Localized Attack

With wet corrosion, the geometry of the anode and cathode are critical. Many of the liquid cathode reactions produce gases. If the cathode area is small, the vapor can adhere to the cathode as a cap, physically separating metal and liquid and stopping the attack. We refer to this as *cathode polarization*. (Note that the label of polarization has other specific identifications in electrochemistry.) With the opposite situation of a small anode area, metal loss is localized and rapid.

Returning to our example of copper sheeting secured with steel nails, we have small anode areas and so expect corrosion to be rapid. Only with the unlikely case of securing steel sheeting with copper nails would we have small cathode areas with the possibility of polarization.

With tinned cans, scratches in the tin coating produce small anode areas of underlying steel. This can be viewed as an advantage in that, if not disposed of properly, it is preferred that the cans corrode relatively quickly.

Finally, we look at an example of how understanding the nature of electrochemical attack can lead to unsuspected conclusions. To protect connected dissimilar metals by painting, it is best to paint the cathode and not to paint the anode. This sounds like it's backwards. Why paint the metal already being protected and leave unpainted the corroding metal? The answer is found above. Small imperfections in a painted anode cause rapid pitting. Small imperfections in a painted cathode can, in the best cases, stop corrosion by cathode polarization.

Localized attack is the norm. Tips of cracks are regions of high stress concentrations and anodic if liquid is present. Impact and fatigue resistances can be greatly reduced in these situations. Extensive experimental results can be found by researching the topics of *stress corrosion cracking* and *corrosion fatigue*.

