

CORROSION AND ELECTROPLATING

CORROSION

Corrosion is the disintegration of materials by chemical interaction with their environment. Most metals corrode on link to water, acids, salts, oils, and solid and liquid chemicals. Metals will also corrode when exposed to gaseous substances like acid vapours, formaldehyde gas, ammonia gas and sulphur containing gases.

The term corrosion is also applied to the degradation of plastics, concrete and wood, but generally refers to metals

EXAMPLES

Some of the most common examples of corrosion are:

- Tarnishing of the silver
- Iron being covered with a brittle brown coloured layer
- Brass and copper is enclosed in a green coloured deposit
- The surface of the aluminium becoming dull and losing its shine.

CAUSES OF CORROSION

Metal corrodes on reacting with another substance such like oxygen, hydrogen, an electric current or even dirt and bacteria. Corrosion also takes place when metals like steel are placed under too much stress causing the material to crack.

MECHANISM OF CORROSION

Numerous theories have been made to explain it over the period of time. but the modern view which is known as the electrochemical theory seems more practical. Let's understand this theory with the assist of an example of rusting of iron.

Water containing oxygen and carbon dioxide acts as an electrolyte and assist in the flow of electron. The formation of rust on the surface of iron takes place through the following steps.

At the anodic region

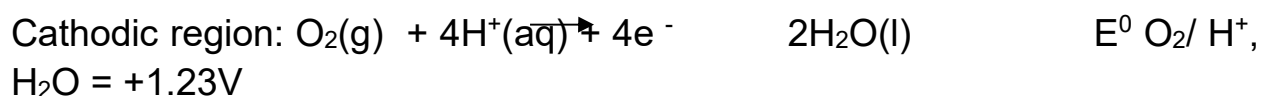
Iron in dealing with water act as an anode and gets oxidized to Fe^{2+} Anodic region:



The released electrons move to another part of the iron sheet. This part of the iron sheet serves as a cathode.

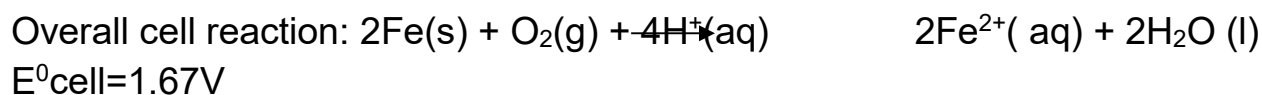
At the cathodic region

At this cathodic part of the surface, oxygen in the presence of H^+ ions gets reduced to form H_2O .

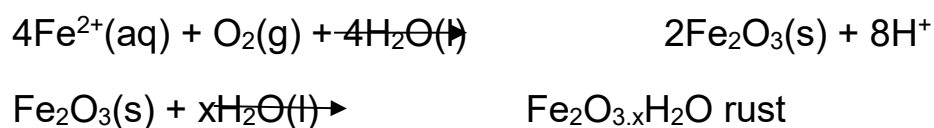


Overall cell reaction

The overall reaction of the local cell is the add up of the cathodic and anodic reactions.



Fe^{2+} ions shuffle across the water on the surface of the iron sheet. Existence of electrolytes in water assist in carrying more current through the local cell on the surface of the iron. The increased flow of the current enhances the rate of corrosion. The Fe^{2+} ions are again oxidized by atmospheric oxygen to Fe^{3+} and form hydrated iron (III) oxide, expressed as $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$. The hydrated ferric oxide is called as rust.



H⁺ ions produced in the above reaction help further in the rusting of iron. Impurities exist in iron also increase rusting by setting a number of localized cells.

Factors influencing corrosion

There are several factors influencing the rate of corrosion :

Diffusion

In the majority of cases, the corrosion rates of metals are checked by the diffusion of reactants to and from the metal surface. Freshly exposed bare steel surfaces will corrode at a greater rate than those enclosed with a compact layer of rust. The corrosion rate is also greatly controlled by the diffusion of oxygen through the water to steel surface. In areas where oxygen diffusion is prevalent, corrosion seems to take place at faster rates.

Temperature

As corrosion rates are dictated by diffusion, diffusion rates are also controlled by temperature. Steel and other metals corrode at faster rates at high temperature than at low temperatures. As a result, under-deck areas and regions adjacent to the engine rooms or to heated cargo tanks, will tend to corrode faster or preferentially.

Conductivity

For corrosion to take place there must be a conductive medium between two parts of the corrosion reaction. Corrosion will not take place in distilled water and the rate of corrosion will increase as the conductivity increase due to the presence of more ions to the solution.

Acidity and Alkalinity (pH)

The pH affect the rate of corrosion of metals by one of the three general methods.

- ✚ Metals such as iron dissolve fastly in acidic solution. In the middle pH range (4 to 10), the concentration of H⁺ ion is less. Nevertheless the corrosion rate is controlled by the rate of transport of oxidizer.
- ✚ Certain atmospheric metals dissolve readily in either acidic or basic solution. Example are aluminium and zinc. Corrosion proceeds.

- ✚ Noble metals are affected by pH. Examples are gold and platinum. The H^+ ions have a capacity to take up electrons to form H_2 gas. Therefore H^+ ions capture electrons and proceeds anodic corrosion.

Electrochemical Potential

Every metal takes up a special electrochemical potential when immersed in a conducting liquid. The potential that a metal take up in a solution can determine if and how rapid it will corrode.

TYPES OF CORROSION

There are following types of corrosion

- Uniform corrosion
- Pitting corrosion
- Crevice corrosion
- Galvanic corrosion
- Interangular corrosion
- Stress corrosion cracking
- High temperature corrosion

UNIFORM CORROSION

- Uniform corrosion is the type of corrosion that proceeds at approximately the same rate over the exposed metal surface.
- It is the most common form of corrosion.
- Cast irons and steels corrode uniformly when exposed to open atmosphere, soils and natural waters following to the rusty appearance.

PITTING CORROSION

- One of the most aggressive form of corrosion, pitting can be hard to predict, detect or characterize.
- This localized type of corrosion takes place when a local anodic or cathodic point forms a corrosion cell with the surrounding surface.
- This pit can make a hole or cavity which typically penetrates the material in a vertical direction down from the surface.

- Pitting corrosion can be caused by damage or break in the oxide film or a protective coating and can also be caused through non uniformities in the structure of the metal.
- This dangerous form of corrosion can cause a structure to fail rather than a relatively low loss of metal.

CREVICE CORROSION

- This form of corrosion takes place in areas where oxygen is restricted such as under washers or bolt heads.
- This localized corrosion mostly result from a difference in the ion concentration between two areas of metal.
- The stagnant micro environment prevents circulation of oxygen, which inhibit passivation and causes a build- up of stagnant solution moving the pH balance away from neutral.
- The imbalance between the crevice and the rest of the material results to the high rates of corrosion.
- Crevice corrosion can happens at lower temperatures than pitting corrosion.

GALVANIC CORROSION

- This form of corrosion takes place when two different metals with physical or electrical contact are immersed in a common electrolyte or when a metal is exposed to different concentrations of electrolyte.
- Where two metals are immersed together, known as galvanic couple the more active metal corrodes readily than the more noble metal.
- The galvanic series determines which metal corrode rapid, which is useful when using a sacrificial anode to protect a structure from corrosion.

INTERANGULAR CORROSION

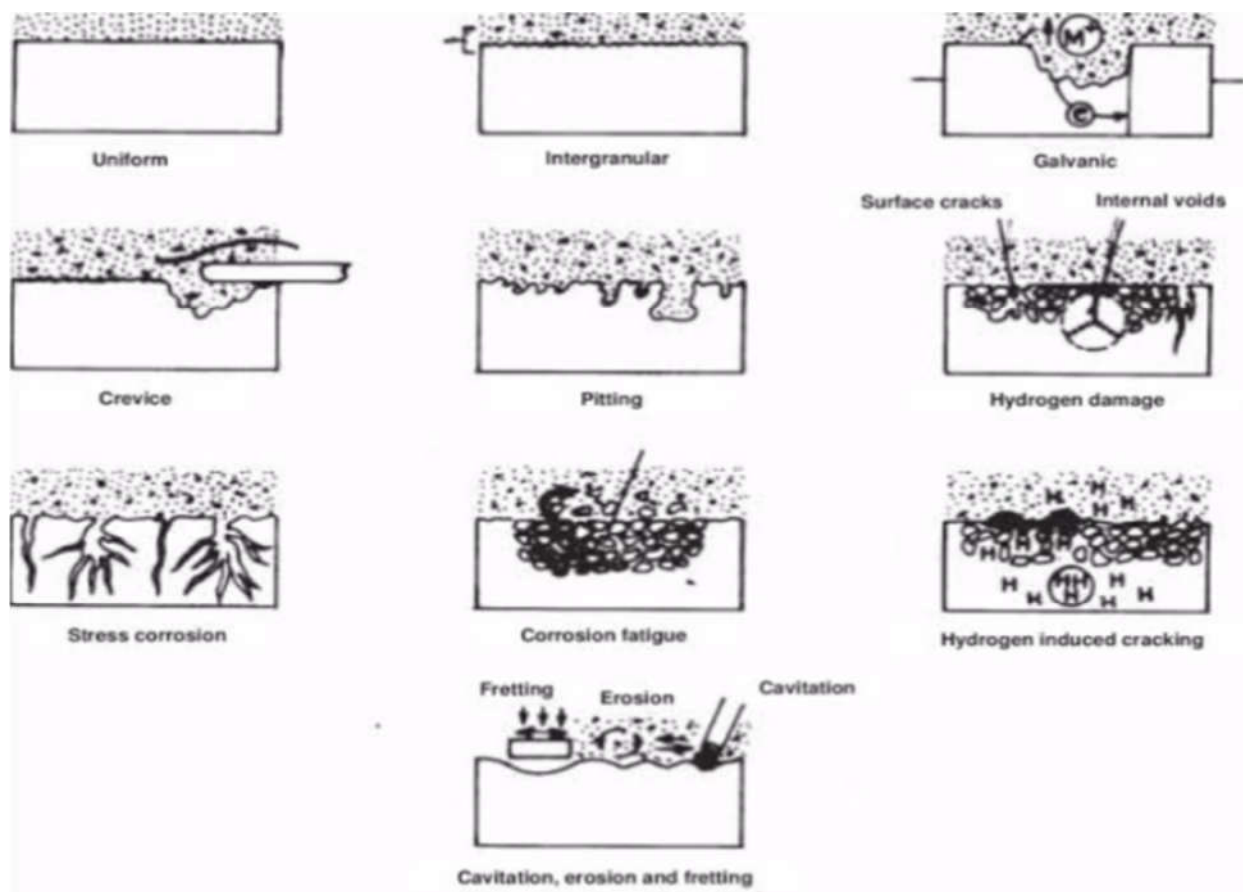
- ❖ Interangular corrosion takes place when impurities are present at grain boundaries which form during solidification of an alloy.
- ❖ It can also be caused by the enrichment or depletion of an alloying element at the grain boundaries.
- ❖ This type of corrosion occurs along or adjacent to the grains, affecting the mechanical properties of the metal rather than the bulk of the material being unaffected.

STRESS CORROSION CRACKING

- Stress corrosion cracking leads to the growth of cracks due to a corrosive environment which can lead to the failure of ductile metals when subjected to a tensile stress, particularly at high temperatures.
- This type of corrosion is more common between alloys than with pure metals
- It is dependent on specific chemical environment whereby only small concentrations of active chemicals are needed for catastrophic cracking.

HIGH TEMPERATURE CORROSION

- ✚ It is chemical disintegration of a material as a result of heating.
- ✚ This non-galvanic form of corrosion can happen when a metal is subjected to a hot atmosphere containing oxygen, sulphur, or other compounds capable of oxidizing the material concerned.
- ✚ For example, materials used in aerospace, power generation and even in car engines have to resist sustained periods at high temperature in which they may be exposed to an atmosphere containing potentially high corrosive products of combustion.
- ✚ The products of high temperature corrosion can potentially be turned to the advantage of the engineer.
- ✚ The formation of oxides on stainless steels, for example, can give a protecting layer preventing further atmospheric attack.



ECONOMIC IMPACTS

In 2002, the US Federal Highway Administration published a study titled “Corrosion Costs and Preventive Strategies in the United States” on the direct costs associated with metallic corrosion in the US industry. In 1998, the total annual direct cost of corrosion in the US was ca. 276 billion dollars (ca. 3.2% of the US gross domestic product). Broken down into five specific industries, the economic losses are 22.6 billion dollars in infrastructure; 17.6 billion dollar in production and manufacturing; 29.7 billion dollar in transportation; 20.1 billion dollar in government and 47.9 billion dollar in utilities.

Rust is the most common causes of bridge accidents. As rust has a much higher volume than the original mass of iron, its build up can also cause failure by forcing apart adjacent parts. It was the reason of the collapse of the Mianus River Bridge in 1983, when the bearing rusted internally and

pushed one corner of the road slab off its support. Three drivers on the road way at the time died as the slab fell in to the river below.

Similarly, corrosion of concrete-covered steel and iron can cause the concrete to spall, causing severe structural problems. It is one of the most common failure modes of reinforced concrete bridges. Measuring instruments based on the half cell potential can determine the potential corrosion spots before total failure of the concrete structure is reached.

PREVENTION FROM CORROSION

There are a variety of measures we can take to minimize corrosion.

BARRIER COATINGS

One of the easiest and cheapest ways to prevent corrosion is to use barrier coatings like paint, plastic or powder. Powders containing epoxy, nylon and urethane are heated to the metal surface to create a thin film. Plastic and waxes are sometimes sprayed on to metal surfaces. Paint acts as a coating to protect the metal surface from the electrochemical charge that arise from corrosive compounds. Today's paint systems are mostly a combination of different paint layers that serve different functions. The primer coat act as an inhibitor, the intermediate coat adds to the paint's overall thickness and the finish coat provides resistance to environmental factors.

HOT-DIP GALVANIZATION

This corrosion prevention method involves dipping steel in to molten zinc. The iron in the steel reacts to zinc to make a tightly- bounded alloy coating which serves as protection. The process has been around for more than 250 years and has been helpful for corrosion protection of things like artistic sculptures and play ground equipment.

ALLOYED STEEL

Alloyed steel is one of the most best corrosion prevention method around, combining the properties of various metals to provide added strength and resistance to the resulting product. Corrosion resistant nickel, for example, join with oxidation- resistant chromium results in an alloy that can be used

in oxidized and reduced chemical environments. Different alloys give resistant to different conditions, giving companies greater flexibility.

CATHODIC PROTECTION

Cathodic protection protects against galvanic corrosion, which takes place when two different metals are put together and exposed to a corrosive electrolyte. To prevent this, the active sites on the metal surface need to be changed to passive sites by providing electrons from another source, typically with galvanic anodes attached on or near the surface. Metals used for anodes include aluminium, magnesium or zinc.

ELECTROPLATING

Electroplating is a process of plating one metal onto another by hydrolysis most commonly for decorative purposes or to prevent corrosion of a metal. Electroplating allows manufacturers to use cheaper metals such as steel or zinc for the majority of the product and then apply different metals on the outside to account for appearance, protection and other properties desired for the product. The surface can be a metal or even plastic.

INTRODUCTION

Many times finishes are solely decorative such as the products we use indoors or in a dry environment where they are unlikely to suffer from corrosion. These types of products usually have a thin layer of gold or silver applied so that it has an attractive appeal to the consumer. Electroplating is heavily used in industries such as automobiles, airplanes, electronics, jewelry and toys. The overall process of electroplating contains an electrolytic cell, which consist of putting a negative charge on the metal and dipping it in to a solution that contain a metal salt which contain positively charged metal ions. Then because of positive and negative charges, the two metals are attracted to each other.

The purposes of electroplating:

-  Appearance
-  Protection

- ✚ Special surface properties
- ✚ Engineering or mechanical properties

BACKGROUND

The cathode would be the piece to be plated and the anode would be either a sacrificial anode or an inert anode, generally either platinum or carbon. In the figure below, the Ag^+ ions are being drawn to the surface of the spoon and it eventually becomes plated. The process takes place using silver as anode and screw as the cathode. The electrons are transferred from the anode to the cathode and is underwent in a solution containing silver.

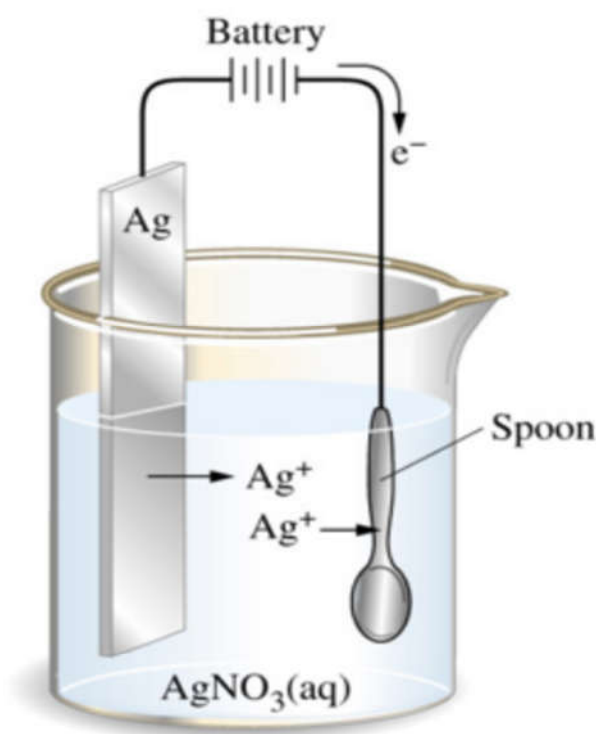


Figure 1: Electroplating silver onto a spoon.

HISTORY OF ELECTROPLATING

Electroplating was first discovered by Luigi Brugnatelli in 1805 through using the electrodeposition for the electroplating of gold. However, his discovery was not noted as he was disregarded by French academy of science as well as Napoleon Bonaparte. But a couple of decades later, John Wright managed to use potassium cyanide as an electrolyte for gold and silver. He discovered that potassium cyanide was infact an efficient electrolyte. The Elkington cousins later in 1840 used potassium cyanide as their electrolyte and managed to create a feasible electroplating method for gold and silver. They attained a patent for electroplating and this method became widely spread through out the world from England. Electroplating method has gradually become more efficient and advanced through the use of eco-friendly formulas and by using direct current power supplies.

CHOOSING THE ELECTROLYTES

There are many different metals that can be used in electroplating , so determining the right electrolyte is important for the quality of plating. Some electrolytes are acids, bases, metal salts or molten salts. When choosing the electrolyte some things to keep in mind are corrosion, resistance, brightness or reflectivity, hardness, mechanical strength, ductility and wear resistance.

PREPARING THE SURFACE

The purpose of preparing the surface before beginning to plate another metal on to it is it ensure that it is clean and free of contaminants, which may interfere with bonding. Contamination often prevents deposition and lack of adhesion, .normally this is done through following steps: cleaning, treatment and rising. Cleaning usually consist of using certain solvents such as alkaline cleaners, water or acid cleaners in order to remove layer of oil on the surface. Treatment include surface modification which is the hardening of the parts and applying metal layers. Rinsing leads to the final product and is the final touch to electroplating. Two certain methods of preparing the surface are physical cleaning and chemical cleaning.chemical cleaning consist of using solvents that are either surface active chemicals or chemicals which react with the metal/surface. In

physical cleaning there is mechanical energy being applied in order to remove contaminants. Physical cleaning includes brush abrasion and ultrasonic agitation.

ELECTROPLATING METHODS

Electroplating can be done by following methods:

MASS PLATING

- Mass plating is an electroplating process that is used to plate a huge number of components very quickly.
- To do mass plating, a barrel is loaded with parts and then placed in to a container filled with the coating material.
- It is not ideal for items that are detailed as it is not effective for preventing scratches and entanglement.

RACK PLATING

- Rack plating is a method used to electroplate brittle, large and complex parts that are difficult to plate using other processes.
- The parts are mounted to a fixture known as a rack and then immersed in a plating solution bath.
- It is more expensive than mass plating.

CONTINUOUS PLATING

- Continuous plating is a process in which items such as wires, tubes and strips are plated by running them continuously through a plating assembly, one after the other.
- The process gives a uniform distribution of the coating of a ductile metal like aluminium, zinc or tin on to a metal substrate such as steel.
- This process is a bit cheaper.

LINE COATING

- ✚ Line plating is a technique used to electroplate a thin layer of a protective corrosion- resistance metal on to a metallic surface in an efficient manner through the use of repetitive automated machinery.
- ✚ Cheaper, as a fewer chemicals are needed and a production line is used to plate parts.

TYPES OF ELECTROPLATING

There are different types of electroplating.

- Chromium plating
- Gold and silver plating
- Tin plating
- Zinc plating

CHROMIUM PLATING

- It is performed on different objects car parts, bath taps, kitchen burners and bicycle handles.
- In this case, layer of chromium metal is deposited over other metal like iron / steel.
- Chromium assists in keeping material shiny and scratch free.
- Also there is no corrosion (metal is not damaged or gets rust due to rain)
- It is highly expensive metal that's why only a layer is used of chromium.

GOLD AND SILVER PLATING

- It is used in case of jewellery.
- Coating of gold and silver is done so that it provides the appearance of gold and silver jewellery.
- It is much cheaper than making whole product of gold and silver.

TIN PLATING

- Cans are formed of iron, coating is done of tin.
- It is because if food reacts with iron directly it gets spoiled.

ZINC PLATING

- ✚ It is used in bridges and automobiles.
- ✚ They are made of iron.
- ✚ Coating of zinc is done to prevent it from getting rust.

THE PLATING METALS

Electroplating comes with several metals. Here are some important metals.

- Nickel

- Chromium
- Palladium or palladium nickel alloy
- Gold
- Silver
- Copper
- Tin
- Platinum
- Ruthenium
- Cadmium
- Brass
- Zinc

APPLICATIONS OF ELECTROPLATING

There are many reasons to electroplate items. Here are just a few of them.

PREVENT CORROSION

- Electroplating is one way to ward off corrosion, especially when the metals being plated are naturally corrosive.
- Enclosing the corrosive metal with a thin layer of non-corrosive metal will prevent corrosion of the surface.
- One example of this is when cheaper metal jewelry is coated in 10k gold, keeping it from turning green after being worn for an extended period of time.

IMPROVE THE AESTHETICS

- Electroplating is commonly used in jewelry where cheaper metals are coated with gold and other high value metals to make them look pristine and expensive.

INCREASE ELECTRICAL CONDUCTIVITY

- Gold and silver are good conductors of electricity but they are too expensive to fill electronics with.
- Integrated circuits in computers and other devices are made up of inexpensive metals that do not conduct electricity effectively.
- To improve their conductivity, the parts are coated with thin layer of gold and silver.

COMMERCIAL APPLICATIONS

- ✚ Various car parts are form of non-smooth metals
- ✚ These parts are plated with a thin coat of chromium or other shiny metals in order to make them look smooth and polished.
- ✚ When buffed, this plating gives off a high shine that is appealing to car fans.

PROTECT AGAINST RADIATIONS

- ❖ Many metals do not have an inherent protection from radiation, abrasion and other natural occurrences.
- ❖ To make up for this, these metals are coated with thin layer of protected metals as additional defense against these natural phenomena.
- ❖ The extra coating protect the metal inside and prevents damage.

REDUCE FRICTION

- Some metals are prone to too much friction when they come in contact with other metals.
- To reduce the amount of resistance, a thin layer of different metals is added to one or both of the parts.
- The coating acts as a buffer and prevents metal from rubbing against one another.
- This is essential in machine work or factories where metals are widely used in production.

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