

PASSIVATION

Corrosion is always an electrochemical process. Corrosion occurs when the difference in electric potential between two adjacent materials reaches and exceeds a critical value. This value is measurable and is expressed as the electrochemical pitting potential. Any surface condition that inhibits the flow of electric current in response to that difference in potential creates a passive layer. That passive layer can be a layer of paint, a non-conductive insulating layer, or, as in the case of stainless steels, an oxide layer. More specifically a chromium oxide layer. This is the origin of the requirement for a material to contain at least 11 wt% chromium to be considered a stainless steel. A similar oxide layer forms on aluminum surfaces and the aluminum oxide may be recognizable as “chalking” or whitening of the surface, as on aluminum house siding. The difference is that the passive chromium oxide layer on stainless steel is thinner and colorless.

The formation of the chromium oxide passive layer is an electrochemical process. This oxide, like rust on carbon steels, forms spontaneously when a clean metallic surface is exposed to oxygen. This action occurs continuously causing the oxide layer to thicken until either the chromium or oxygen, or both, are consumed. This is also responsible for the “self-healing” property of the oxide layer.

In the formation of the oxide layer the chromium and oxygen form a strong chemical bond that is not easily broken by corrosive media. There are, however, various environments that initiate a chemically reducing action that is strong enough to break the bond between chromium and oxygen. The oxygen present is then free to bond with iron in the metal forming iron oxide, or rust. Halogenated solutions (chlorine, fluorine, bromine, or iodine) with acidic pH are particularly prone to accelerating the breakdown of passive oxide layers, as are elevated temperatures.

Contaminants on the surface of the metal, such as free iron, oils, dust, paint, or rust inhibitors prevent or inhibit exposure of chromium in the metal to oxygen and thereby the formation of the passive layer. Such contaminants come from lubricants used in machining or forming of components; from fingerprints; from mis-used “protective coatings”; from abrasive or machining debris; from contact with metal chains, slings; or from contact surfaces on forming equipment. Contaminating surfaces may include those made of steel, copper, bronze, brass, lead, zinc, or other soft metals. When embedded in the surface of stainless steel, these particles create crevices that prevent oxygen from reaching and combining with chromium and preventing local formation of a passive layer. Scratches or voids in protective coatings (paint, oils, plastic wraps, etc.) or on the stainless steel itself create crevices that are quickly depleted of oxygen inhibiting the formation of the passive oxide layer.

Any contaminants need to be removed to allow the formation of a passive layer. This is generally achieved by either exposure to a chemical solution, or by mechanical removal by abrasive polishing.



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*"Confusion exists regarding the meaning of the term passivation. It is not necessary to chemically treat a stainless steel to obtain the passive film; the film forms spontaneously in the presence of oxygen. Most frequently, the function of passivation is to remove free iron, oxides, and other surface contamination. For example, in the steel mill, the **stainless** steel may be pickled in an acid solution, often a mixture of nitric and hydrofluoric."*

In the hygienic and high purity applications, the chemical solution cleaning of process systems generally involves exposure to nitric acid, or citric acid, followed by a clean de-ionized water rinse. Individual components might alternatively be cleaned by electropolishing, usually followed by a nitric acid rinse, followed by a clean de-ionized water rinse. When generally soiled surfaces are involved, it is a good practice to first clean the components with a detergent solution and clean water rinse to avoid degradation of the passivating solution. Ultrasonic cleaning is generally effective in loosening and removing deposited debris but is not effective in removal of existing oxide layers.

Abrasive polishing removes existing surface oxides and other contaminants, exposing clean "virgin" metal ready for the formation of a passive layer on exposure to oxygen. There is, however, a potential contamination issue if contaminants are ground into the surface during polishing. A nitric or citric acid cleaning after polishing would be recommended to remove ground in contaminants.

We can conclude that the process commonly referred to as "passivation" is not as much a surface improvement by addition of a passive layer, as it is a cleaning operation in preparation for a naturally occurring phenomenon. And that there are other options to create a passive layer to prevent corrosive attack, many of which are suitable for use on materials other than stainless steel that has been adequately cleaned.