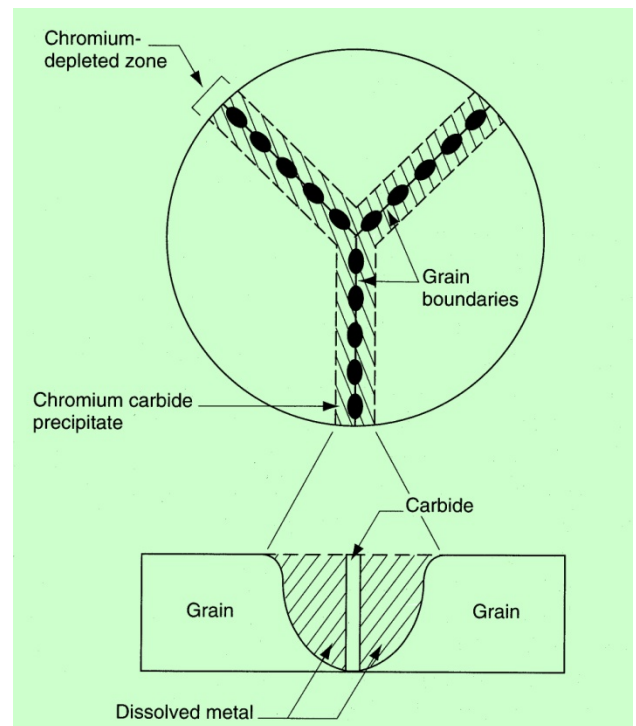
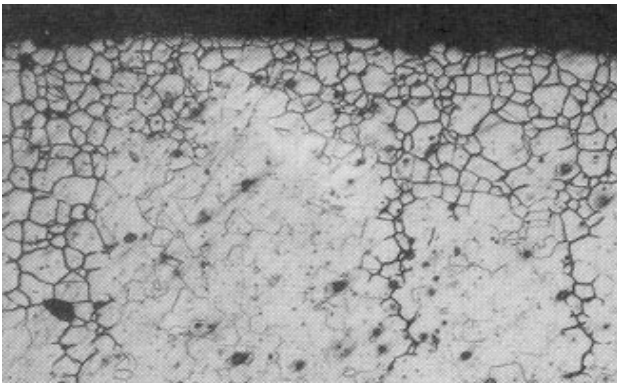


Intergranular Corrosion

It is a form of localized attack on the grain boundaries of a metal or alloy in corrosive media, which results in the loss of strength and ductility. The localized attack may lead to dislodgment of the grain. Localized attack at and adjacent to grain boundaries, with relatively little corrosion of the grains. The alloy, sensitive to IGC, disintegrates and/or loses its strength when exposed to environments. the loss of strength and ductility and may lead to dislodgment of grain. The attack is distributed over all the grain boundaries cutting the surface.



Causes of intergranular corrosion

- Segregation of impurities at the grain boundary i.e. Fe in Al alloys.
- Enrichment of one of the alloying elements or depletion of one of these elements in the grain boundary areas.

Some technical terms

(A) Sensitization. When steels, such as austenitic type, are slowly cooled through the range 550-850°C, they frequently become susceptible to intergranular attack in a corrosive medium.

(B) Stabilized steel. Steels containing stabilizers, such as titanium and niobium, which form carbides that are more stable than chromium carbides, are called stabilized stainless steels.

(C) Chromium depletion. When the concentration of chromium adjacent to the grain boundaries becomes less compared to its concentration away from the grain boundaries, the phenomenon is termed chromium depletion.

What happen when the steel is sensitized

When stainless steel, for example 18-8 steel, is cooled slowly through 550-850°C, it becomes susceptible to intergranular corrosion when exposed to a corrosion medium. The following observations characterize the intergranular attack:

- (1) Sensitization occur only in the temperature range 550-850°C because of the diffusion of the carbon to the grain boundaries.
- (2) Fast cooling rate through the sensitizing temperature range does not provide adequate time for the process of sensitizing to occur.
- (3) The degree of sensitization increases with increasing carbon contents and decreasing chromium contents.
- (4) Chromium carbide precipitate at the grain boundary. The precipitation of carbide is a time-temperature dependent phenomenon. The carbide precipitated is mainly Cr_{23}C_6 , so that a single atom ties up almost four chromium atoms. Carbides play a very important role in intergranular attack. Intergranular attack does not occur without the formation of chromium carbides.

Factors effected on sensitization of steel

1-Effect of carbon : Carbon plays a very crucial role in the precipitation of carbides and a decrease of carbon content of steels restricts the formation of harmful carbides, such as chromium carbide, which is primarily responsible for the depletion of chromium adjacent to the grain boundaries.

2-Effect of alloying element

- (1) Nickel. The susceptibility to sensitization decreases with increased nickel content because the carbon solubility decreases with increased nickel content.
- (2) Molybdenum. The susceptibility of steels to intergranular attack decreases with increased Mo content. The Mo also increases the resistance to pitting and crevice corrosion.
- (3) Chromium. It generally increases the resistance to sensitization.
- (4) Nitrogen. The effect of nitrogen depends upon the amount contained in a steel. Nitrogen is an austenite stabilizer Steels containing 18% chromium, 9-12% Ni and 0.02-0.03% C which are sensitized at 500° C for 100 h showed a maximum resistance sensitization at 0.04% nitrogen.
- (5) Titanium and Niobium. These are added to give stabilization against the harmful precipitates, such as chromium carbides. These elements combine with carbon and nitrogen and do not allow carbon and nitrogen to precipitate

as carbides and nitrides which lead to intergranular corrosion. The optimum temperature for formation of TiC (titanium carbide) is 900-950° C.

simplified mechanism of intergranular corrosion

Various theories and models have been proposed to account for the intergranular corrosion of steels. These are summarized below. For in-depth understanding of the theories, references are cited at the end of the chapter. The theories are reviewed here to provide a basic understanding of the mechanism of intergranular corrosion to engineers. The following three steps lead to the intergranular corrosion of austenitic steels:

- (1) Sensitization in the temperature range 550-900° C.
- (2) Diffusion of carbon to a grain boundary and formation of carbide. This leads to depletion of chromium content along the grain boundary.
- (3) Weakening of the grain boundary and disintegration of the grains.

Control of IGC

- 1) Metallurgical measures :
 - a) Solution annealing : heating the alloy to 1050 C where all Cr-carbides are dissolved, followed by rapid cooling.
 - b) Low-carbon alloy modifications : lower the carbon content to below 0.03% for austenitic stainless steels(304L, 316L) or to below 50ppm for ferritic stainless steels.
 - c) Stabilization treatment : add strong carbide former(Ti, Nb) in melt: Types 347 and 321 stainless steels.
- 2) Environmental measures : lower acidity and less oxidizing conditions will generally reduce the susceptibility to IGC.