

STRATEGIES TO PREVENT CORROSION

Dr. Shamsheera K O

*Assistant Professor, Department of Chemistry, KAHM Unity Women's College,
Manjeri. Kerala-676122, India*

e-mail id: shamsimanu@gmail.com

Corrosion has been the subject of scientific study for more than 150 years. Humans have been trying to understand, control, and prevent corrosion for as long as they have been using metal objects. Corrosion never stops but its severity can be controlled by various methods either by isolating the metal from the aggressive environment or elimination of any one of the components of electrochemical cells which accelerates the corrosion process. The general classification of various corrosion prevention methods is summarized in Figure 1

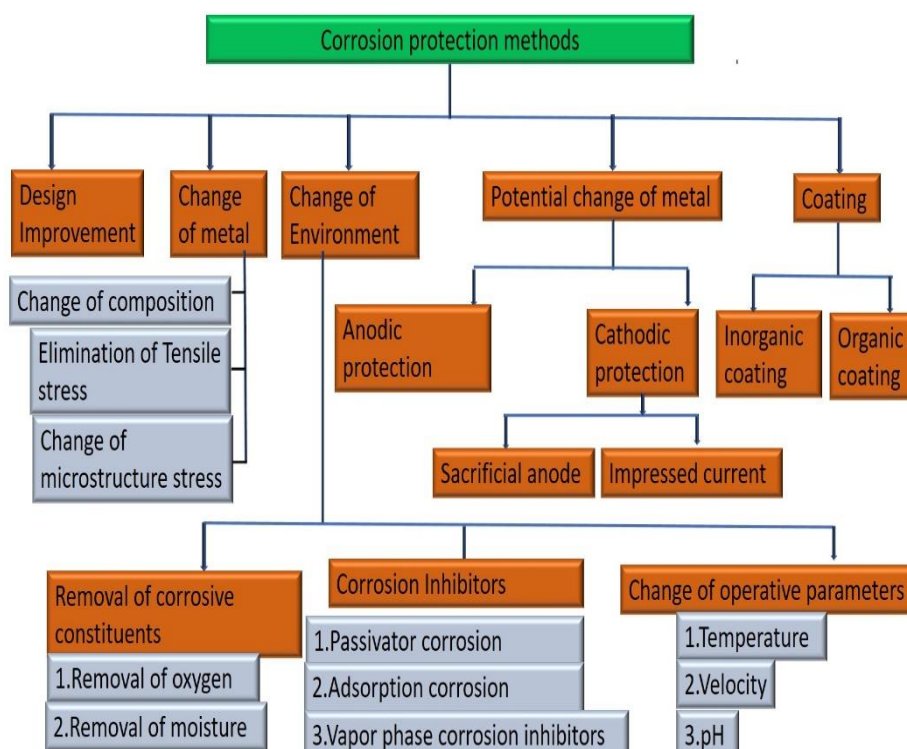


Figure 1. Corrosion prevention methods

1. CORROSION INHIBITORS

Changing the environment by adding corrosion inhibitors (CI) is considered as an efficient corrosion management method^[1]. A corrosion inhibitor is a chemical substance which when added in a small concentration to the corrosive environment results in a significant reduction in the corrosion rate either by reducing the rate of attack or by reducing the probability of its occurrence or by both^[2]. An efficient inhibitor should be economical, environment friendly, and inhibit the corrosion process when present in a small concentration. Corrosion prevention using inhibitors has some noticeable advantages such as low cost, simple control and operation, and non-requirement of special instruments^[3]. Corrosion inhibition is achieved in two ways. In some cases, the inhibitor interacts with the metal surface and forms an inhibitive surface film at the metal/electrolyte interface (Figure. 2).

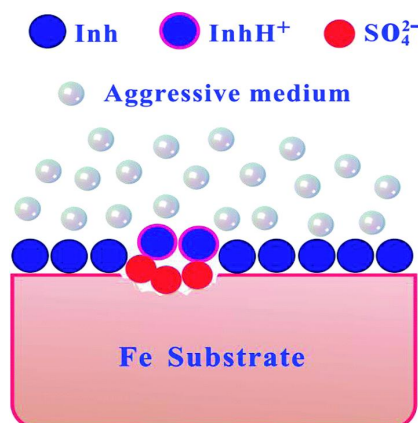


Figure. 2. Mechanism of Inhibition

In other cases, the inhibitor can alter the corrosive environment into a less corrosive or noncorrosive environment, e.g. by chemically neutralizing dissolved acidic gases, chemically scavenging dissolved oxygen, etc. Thus, based on the mode of interaction a qualitative classification of CI is presented in Figure.3^[4].

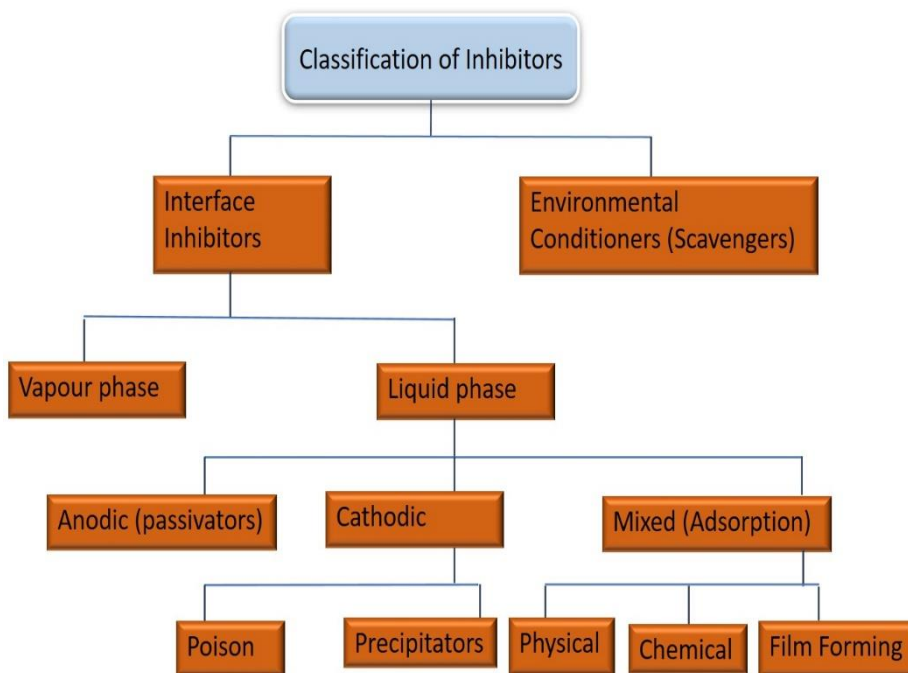


Figure 3. Classification of corrosion inhibitors

Environmental conditioners or scavengers control the corrosion process by decreasing the corrosivity of the medium through scavenging the aggressive substances. In near neutral and alkaline solutions, the cathodic oxygen reduction can be controlled by decreasing the oxygen content using scavengers ^[5]. In a boiler system, hydrazine is used as a scavenger to remove traces of oxygen ^[6]. Interphase inhibitors prevent the corrosion process by forming a film at metal/environment interphase. Substances having low vapour pressure with corrosion inhibiting capacity are used as vapour phase inhibitors (VPI) against atmospheric corrosion, especially in a closed environment. In boilers, VPIs prevent corrosion in condenser tubes by neutralising the acidic CO₂. Volatile inhibitors of this type transported to the corrosion site and inhibit the corrosion process by maintaining the atmosphere alkaline ^[7].

LPIs are classified as cathodic, anodic, or mixed type inhibitors, based on whether they inhibit the anodic, cathodic, or both the electrochemical corrosion process. Anodic inhibitors develop a protective oxide film on the surface of the metal and causing a large anodic corrosion potential shift and thereby force the metal surface into the passivation region and hence commonly referred to as passivators. If the concentration of anodic inhibitors is not enough to block off all the anodic sites, the oxidising nature of the inhibitor encourages the anodic reaction and results in pitting corrosion. So, they are

classified as dangerous inhibitors and chromates, tungstate, molybdates, nitrates, etc are belonging to this category.

Cathodic inhibitors inhibit the corrosion process by either decreasing the cathodic reduction rate or by selectively precipitating an insoluble species onto the cathodic sites to limit the diffusion of reducing species to the metal surface. They are belonging to safe inhibitors because they do not cause localised corrosion. Zinc ions are used as a cathodic inhibitor by precipitating $Zn(OH)_2$ at the cathodic site in the cathodic oxygen reduction process.

Mixed (adsorption) inhibitors work by reducing the anodic and cathodic corrosion reactions. Many inhibitors work by adsorption on the metal surface. Adsorption depends on the surface charge of the metal atom, structure of the inhibitor, and type of the electrolyte. Adsorption inhibitors offer corrosion inhibition via physisorption, chemisorption, and film formation. Physisorption by the electrostatic interaction between the metal atom and the inhibitor is removed from the surface of the metal on increasing the temperature. Chemisorption due to charge sharing or charge transfer between the metal and inhibitor molecules is more effective and not completely reversible [8]. The adsorption can be represented as



The extent of adsorption depends on the nature of the metal, the chemical structure of the inhibitor, the mode of adsorption, and the type of corrosive medium. The exact nature of adsorption can be verified from adsorption isotherms which describe the surface coverage (θ) by the inhibitor on the metal surface and the concentration of the inhibitor.

2. SYNERGISM AND CORROSION INHIBITION

Synergism is an adequate method for enhancing the corrosion inhibition performance of an inhibitor especially at elevated temperatures. It can be defined as the marked augmentation of the corrosion inhibition performance of one inhibitor by adding a small amount of another inhibitor, even though the second inhibitor is less effective when used separately. Co-adsorption of two or more molecules onto the metal surface provide better inhibition than either of the individual components. Speller et al reported that the corrosion inhibition performance by phosphate-chromate mixtures is found to be more effective than their individual performance. The method of using two or more inhibitors

together via synergistic interaction, is an effective method of enhancing the corrosion inhibition. Here the quantity of the inhibitors can be considerably reduced without compromising efficiency of inhibition.

3. CORROSION RESISTANT COATINGS

Corrosion protection by coating has attracted much attention due to its high efficiency and durability in various aggressive environments^[9]. The durability and performance of corrosion resistant coatings depend on many factors such as type of metallic substrate, pre-treatment of metal, curing, adhesion between the metal and the coating, the thickness of the coating, etc^[10]. An effective coating must have intrinsic durability, adhesion with the metal substrate, toughness to survive cracking and keep its appearance when subjected to stress, swell, or weathering^[11]. An anti-corrosive system for a highly corrosive environment usually consists of a primer, one or several intermediate coats, and a topcoat^[12]. The primer ensures good adhesion to the metallic substrate and protects the metal from corrosion. The function of the intermediate coat is to build up the thickness of the coating system, resist transport of aggressive ions from electrolyte to the metal substrate, and ensure good adhesion between the primer and the topcoat. The topcoat is exposed to the environment and must offer the metallic surface with the required colour, gloss, and resistance to ultraviolet radiation^[13]. Coatings can be classified into noble coatings and sacrificial coatings. Noble coatings provide barrier protection. Whereas in addition to barrier protection sacrificial coatings also provide cathodic protection. Coatings can be further classified into metallic, inorganic, and organic coatings.

- Metallic coating: metals or their alloys are applied to other metals via electroplating, hot dipping, thermal spraying, vapor deposition, etc can function as either noble coating or sacrificial coating.
- Inorganic coating: Non-metallic inorganic coating includes ceramic coating, cement, silicate, ceramics, conversion coating, and sol-gel coatings. The inorganic material in the sol- gel coating act as a good barrier against the diffusion of corrosive ions. Phosphate coating and chromate conversion coating are two usually used inorganic conversion coatings. Chromate conversion coatings (CCCs) are produced on the metal surface by chemical or electrochemical treatment of the metal or metallic coating in solutions containing Cr(VI) and other components. The porosity and stress-induced

cracking developed in inorganic coatings limit their use as efficient coatings as the corrosive species diffuse through the coating to the underlying metal^[14]

- Organic coating: Such as epoxy, plastics, enamel, oils, greases, and paints. In organic coatings, many different types of fillers and corrosive pigments are used, but the lack of thermal resistance, flexibility, and relatively less adhesion to metallic surfaces of organic coatings limit their long-term stability.
- Organic-inorganic hybrids (OIHs): OIHs offer an effective coating on the metal substrate by linking both inorganic and organic phases covalently on the molecular scale. In OIHs the capacity of inorganic phase to bond covalently with the metal increases leading to highly adherent coatings, which impedes the diffusion of aggressive ions from the electrolyte. The inorganic compound offer scratch resistance, durability, and adhesion to the metallic substrate. The organic part improves the flexibility and functional compatibility with the polymer system ^[15]. OIHs coating developed via the sol-gel process is considered as an effective alternative to CCCs for the metallic substrate.

References

- [1] A. Goyal, E. Ganjian, H. S. Pouya and M. Tyrer, *Construction and Building Materials* **2021**, *303*, 124461.
- [2] P. B. Raja and M. G. Sethuraman, *Materials letters* **2008**, *62*, 113-116.
- [3] J. M. Gaidis, *Cement and Concrete Composites* **2004**, *26*, 181-189.
- [4] a) V. S. Sastri, *Green corrosion inhibitors: theory and practice*, John Wiley & Sons, **2012**, p; b) A. Rostami, *SPE International Symposium on Oilfield Chemistry* **2009**.
- [5] E. Lyublinski, P. Lynch, I. Roytman and T. Yakubovskaya, *International Journal of Corrosion and Scale Inhibition* **2015**, *4*, 176-192.
- [6] S. T. M. TAKADA, H. GOTOU, K. MAWATARI, N. ISHIHARA and R. KAI, *Mitsubishi Heavy Industries Technical Review* **2009**, *46*, 43.
- [7] A. Leng and M. Stratmann, *Corrosion science* **1993**, *34*, 1657-1683.
- [8] E. Gutiérrez, J. A. Rodríguez, J. Cruz-Borbolla, J. G. Alvarado-Rodríguez and P. Thangarasu, *Corrosion Science* **2016**, *108*, 23-35.

- [9] a) Y. Qian, Y. Li, S. Jungwirth, N. Seely, Y. Fang and X. Shi, *Int. J. Electrochem. Sci* **2015**, *10*, 10756-10780; b) F. Presuel-Moreno, M. Jakab, N. Tailleart, M. Goldman and J. Scully, *Materials today* **2008**, *11*, 14-23.
- [10] a) M. Dabral, L. Francis and L. Scriven, *AIChE journal* **2002**, *48*, 25-37; b) E. Almeida, *Industrial & engineering chemistry research* **2001**, *40*, 3-14.
- [11] P. A. Sørensen, S. Kiil, K. Dam-Johansen and C. E. Weinell, *Journal of Coatings Technology and Research* **2009**, *6*, 135-176.
- [12] D. Kjærsmo, K. Kleven and J. Scheie, *Bording A/S, Copenhagen* **2003**.
- [13] a) R. Zhang, H. Chen, H. Cao, C. M. Huang, P. Mallon, Y. Li, Y. He, T. Sandreczki, Y. Jean and R. Suzuki, *Journal of Polymer Science Part B: Polymer Physics* **2001**, *39*, 2035-2047; b) J. Pospíšil and S. Nešpurek, *Progress in Polymer Science* **2000**, *25*, 1261-1335.
- [14] a) M. Norouzi and A. A. Garekani, *Ceramics International* **2014**, *40*, 2857-2861; b) J. Quinson, C. Chino, A. De Becdelievre, C. Guizard and M. Brunel, *Journal of materials science* **1996**, *31*, 5179-5184.
- [15] a) C. Jackson, B. Bauer, A. Nakatani and J. Barnes, *Chemistry of materials* **1996**, *8*, 727-733; b) T. L. Metroke, R. L. Parkhill and E. T. Knobbe, *Progress in Organic Coatings* **2001**, *41*, 233-238.
- [16] N. S. Sangaj and V. Malshe, *Progress in Organic coatings* **2004**, *50*, 28-39.