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Carbohydrate polymers protecting metals in aggressive environments

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Abstract

The biopolymers and polysaccharides which are naturally present or are a product of some biochemical process are abundant in nature. With proper planning and management, they are non- toxic as well as inexhaustible natural source of incredibly interesting compounds. Using carbohydrate polymers is not a novel phenomenon for the industries; they have already been employed as binders, coatings, drug carriers and most interestingly as corrosion inhibitors in various media. Innumerable researches have been carried out and reviewed in the past two decades on their use. What makes these incredible substances so sought after as corrosion inhibitors, what is the mode of their action and how efficient they are? This discussion describes the application of carbohydrate biopolymers and their more efficient derivatives for inhibition of corrosion of metals. The modes and mechanisms of how they fit in a corrosion reaction to protect the metal would also be described. Their efficiency which is directly related to their macromolecular weights, chemical structures and their interesting molecular and electronic orientations would be discussed.

Naturally occurring polysaccharides are biopolymers existing as products of biochemical processes in living systems. A wide variety of them have been employed for various material applications, as binders, coatings, drug delivery, corrosion inhibitors etc. This review describes the application of some green and benign carbohydrate biopolymers and their derivatives for inhibition of metal corrosion. Their modes and mechanisms of protection have also been described as directly related to their macromolecular weights, chemical composition and their unique molecular and electronic structures. For instance, cellulose and chitosan possess free amine and hydroxyl groups capable of metal ion chelation and their lone pairs of electrons are readily utilized for coordinate bonding at the metal/solution interface. Some of the carbohydrate polymers reviewed in this work are either pure or modified forms; their grafted systems and nanoparticle composites with multitude potentials for metal protection applications have also been highlighted. Few inhibitors grafted to introduce more compact structures with polar groups capable of increasing the total energy of the surface have also been mentioned. Exudate gums, carboxymethyl and hydroxyethyl cellulose, starch, pectin and pectates, substituted/modified chitosans, carrageenan, dextrin/cyclodextrins and alginates have been elaborately reviewed, including the effects of halide additives on their anticorrosion performances. Aspects of computational/theoretical approach to corrosion monitoring have been recommended for future studies. This non-experimental approach to corrosion could foster a better understanding of the corrosion inhibition processes by correlating actual inhibition mechanisms with molecular structures of these carbohydrate polymers.

Corrosion is a hazardous phenomenon having a devastating impact on technological and industrial applications, particularly in the oil and gas industries. Therefore, controlling the corrosion of metals is an important activity of technical, economic, environmental, and aesthetical importance in order to save huge expenses in materials, equipment, and structure. The use of corrosion inhibitors is one of the best options for controlling the metallic corrosion in various corrosive media. Numerous problems aroused with the use of inorganic and small molecule organic corrosion inhibitors, and the use of polymeric corrosion inhibitors came into limelight. This review article provides an overview of the recent development of different classes of corrosion inhibitors with special emphasis on different functional motifs of natural, synthetically modified natural, and synthetic polymeric materials.

Corrosion is referred to as the deterioration of the materials by the chemical reactions between materials and their reactive ambiance. It is a hazardous phenomenon having a devastating impact on gas and oil manufacture and their subsequent transportation, triggered more or less by almost any aqueous environment and happens by means of redox reactions in gas and oil production, handling, and pipeline systems. Technically, corrosion is considered a bounded electrochemical reduction-oxidation (redox) reaction taking place on the surface of materials, typically metals, prompting the release of electrons by the dissolution of metal and their successive transfer to another position on the surface causing the oxygenated water or hydrogen ions to be reduced and resulting in gradual deterioration and consequent failure of the host material. This corrosion process consists of a cathode, an anode, and an electrolyte. The anode is the location where the corrosion of metals takes place to generate free electrons, which travel through the corrosive electrolytic medium to the cathode, where hydrogen ions (from an acidic corrodant) are reduced to hydrogen gas. Natural gas and crude oil usually contain several highly contaminated products, which are innately corrosive. Free water, carbon dioxide (CO2), and hydrogen sulfide (H2S) are well-established examples of extremely corrosive media in case of oil and gas wells and pipelines. Furthermore, oxygen contaminations in basic or neutral conditions lead to the production of hydroxyl ions through the reduction of oxygenated water by the current produced at the anodic site due to the oxidation process. In general, upon exposure to metals, the chemical species, such as moisture/water (H2O), acids (HNO3, HCl, and H2SO4), bases (NaHCO3, CaCO3, and NaOH), table salts (NaCl), aggressive metal polishes, and gases (ammonia, formaldehyde, and sulfur-containing gases and liquid chemicals), perpetuate the degradation of the metals.