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Nano-composite as corrosion inhibitors for steel alloys in different corrosive media

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ABSTRACT

The application of nanotechnology in the corrosion protection of metals has recently gained momentum; Environmental impact can improved by utilizing nanostructure particulates in corrosion inhibition, Nano composites have also proven to be an effective alternative to other hazardous and toxic compounds, the present article reports some of the preliminary investigations on the corrosion-resistance performance of Nano-composite.

Key words*:* *Corrosion; Steel; Nanotechnology; Nanocomposite, polymer nano clay .*

INTRODUCTION

Nanostructures materials (1–100 nm) are known for their outstanding mechanical and physical properties due to their extremely fine grain size and high grain boundary volume fraction [1]. Significant progress has been made in various aspects of synthesis of nano-scale materials. The focus is now shifting from synthesis to manufacture of useful structures and coatings having greater wear and Corrosion resistance.

Steel is widely used as the constructional material in most of the major industries particularly in food , petroleum, power production, chemical and electrochemical industries, especially due to its excellent mechanical properties and low cost. The major problem of steel is its dissolution in acidic and alkaline medium. Corrosion of iron and steel in acidic aqueous solutions is one of the major areas of concern in many industries where in acids are widely used for applications such as acid pickling, acid cleaning, acid descaling, and oil well acidizing. Because of general aggressiveness of acid solution, the materials of construction are being corroded easily.

It is very important to add corrosion inhibitors to prevent metal dissolution and minimize acid consumption [1-14]. Most well known acid inhibitors are organic compounds containing nitrogen, sulfur and oxygen atoms. The inhibiting action exercised by organic compounds on the dissolution of metallic species is normally related to interactions by adsorption between the inhibitors and the metal surface [38-41]. The good inhibitor has many advantages such as high inhibition efficiency, low price, low toxicity and easy production [13,14]. Nanocomposite exhibit such advantages with addition of improvement of the environmental impact, In the last two decades, nanotechnology has been playing an increasing important role in supporting innovative technological advances to manage the corrosion of steel [15-35].

Nano-composite as Corrosion Inhibitors for Steel Alloys

The application of nanotechnology in the corrosion protection of metals has recently gained momentum [15-21]. A polymer Nano composite coating can effectively combine the benefits of organic polymers, such as elasticity and water resistance, to that of advanced inorganic materials, such as hardness and permeability [18].

Environmental impact can also be improved by utilizing nanostructure particulates in corrosion inhibition, coating, and eliminating the requirement of toxic solvents. Nano composites have also proven to be an effective alternative to phosphate-chromate pretreatment of metallic substrate, which is hazardous due to the presence of toxic hexavalent chromium [18-24].

The present article reports some of the preliminary investigations on the corrosion-resistance performance of Nano-composite. The corrosion-protective performance of Nano-composite was evaluated in terms of physico-mechanical properties, corrosion rate, and SEM studies [19-25].

In the last two decades, nanotechnology has been playing an increasing important role in supporting innovative technological advances to manage the corrosion of steel [16-36]. Significant advancements have been made to improve the management of steel corrosion through research, development, and implementation; and nanotechnology has been playing an increasing important role in supporting innovative technological advances.

First of all, improved understanding of corrosion and inhibition mechanisms has been continually achieved through characterization and modeling of the steel surface and corrosion products at various length scales down to the nanometer scale [15,18].

Secondly, nanotechnology has been employed to enhance the inherent corrosion resistance and performance of the steel itself, by achieving the desirable finely crystalline microstructure of steel (e.g., Nano-crystallization) or by modifying its chemical composition at the nanometer scale (e.g., formation of copper nanoparticles at the steel grain boundaries). Metallurgy approaches to the production of high-performance steel with a fine-grain structure and/or self-organization of strengthening Nano phases (carbides, nitrides, carbonitrides, intermetallides) have been burgeoning under the guide of Nano technological principles, including Nano processes for steel smelting and micro alloying, mechanical pressure treatment (e.g., intense plastic deformation), and heat treatment (e.g., superfast quenching of melts) [19-23]. One such technology commercialized in the U.S. produces high-performance carbon steels that feature a "three-phase microstructure consisting of grains of ferrite fused with grains that contain dislocated lath structures in which laths of marten site alternate with thin films of austenite" [18-23].

Thirdly, nanotechnology has been employed to reduce the impact of corrosive environments through the alternation of the steel/electrolyte interface (e.g., formation of Nano-composite thin film coatings on steel). Significant improvements in the corrosion protection of steel have been reported through the co-deposition of Ni-SiC or Ni-Al_2O_3 Nano composite coatings on mild steel [22-25] and the application of TiO_2-naoparticle sol-gel coatings or multilayer polyelectrolyte Nano films on 316L stainless steel [31,32].

The incorporation of Nano-sized particles (e.g., polyaniline/ ferrite, ZnO, Fe_2O_3, hallo site clay, and other nanoparticles) into conventional polymer coatings also significantly enhanced the anti-corrosive performance of such coatings on steel substrates [112-36].

Recent progress in the use of nanomaterial's for corrosion control is summarized in a 2007 review article [23], which discussed the incorporation of nanoparticles in ceramic coatings, polymer coatings, and hybrid sol-gel systems, for improved properties (e.g., resistance to corrosion and high-temperature oxidation, self-cleaning, and anti-fouling).

A novel PANI/ferrite/alkyd coating material based on a Nano technological approach that was able to effectively protect steel from corrosion in acid, alkaline, and saline media was developed [21-36].

PANI/ferrite/alkyd coatings were found to act as inhibitors, maintaining high resistance to corrosive ions due to the presence of a dense, nonporous, continuous network-like structure. This uniformly dispersed Nano composite coating provides space for a variety of modifications to its physical structure, making it more malleable and adaptable for many application processes, including spraying, dipping, or spin coating [33].

Intrinsically conducting polymer metal Nano composites were synthesized by polymerizing anthranilic acid (PANA) with metal salts like ferric chloride, Zinc oxide and Magnesium oxide by chemical oxidation method. Polyanthranilic acid iron Nano composite (PANA-Fe), Polyanthranilic acid-Zinc Nano composite (PANA-Zn) and Polyanthranilic acid-magnesium Nanocomposite (PANA-Mg) ware synthesized BY Sophia et.al, [26] Cyclic voltammetric studies revealed the presence of an adherent polymer film on the glassy carbon electrode and showed redox behavior of the polymer metal Nano composites. The XRD (X Ray Diffraction) studies showed a rather more crystalline behavior of the Nano composites and the grain size was calculated using Scherrer's formula and it was found to be in Nano range. SEM (Scanning Electron Microscope) analysis showed a rather mixed crystalline and amorphous behavior. EDAX (Energy Dispersive X Ray Spectroscopy) confirms the incorporation of the metals iron, Zinc and Magnesium in the polymer metal Nano composites. The inhibition efficiency of the polymer metal Nano composites were calculated for stainless steel in acidic environment using electrochemical impedance spectroscopy (EIS) and polarization (Tafel) studies and the prepared PANA-Fe and PANA-Zn Nano composites showed effective anti-corrosive behavior on stainless steel in acid medium [26,33].

Polymer –Clay Nano composite materials as corrosion inhibitors for steel: A series of polymer-Clay Nano composite materials that consisted of emeraldine base of poly(O-ethoxyaniline) and layered montmorillonite clay were prepared and tested as corrosion inhibitors for steel in acidic, alkaline, and NaCl aqueous electrolytes, poly-clay nanocomposite at low clay loading up to 3wt.% in the form of coating on steel, were found to exhibit much superior corrosion inhibition effect as compared to poly(o-ethoxyaniline) itself. The polymer-clay nano materials were evaluated in 5% (wt %) aqueous NaCl electrolyte, by electrochemical measurements. Corrosion potential, polarization resistance, corrosion current, and impedance spectroscopy show that the increasing Clay loading up to 3% enhance corrosion inhibition efficiency. The corrosion inhibition efficiency increases in case of polymer-Clay Nano composite and its greater than using polymer without clay, so its preferred to use poly-clay Nano composite than polymer itself to enhance the corrosion inhibition efficiency of steel in aqueous corrosive media [27, 36]. Sulfonated polyurethanes (SPU) were used as corrosion inhibitor for mild steel in acidic solution[37]. The sulfonation of the >N-H groups of the urethane linkages was confirmed from Nuclear Magnetic Resonance (NMR) and Fourier Transform Infra Red (FTIR) spectroscopic techniques. The inhibition efficiency of sulfonated polyurethanes, prepared from two different routes, was investigated using different techniques. The effects of microstructure of polyurethane (PU), degree of sulfonation, time of immersion and temperature on the inhibition of corrosion were discussed. The *disc-like* nanoparticles, so-called *nanoclay*, either suspended or chemically attached to SPU chains (nanocomposites) dramatically enhanced the inhibition efficiency for mild steel in acidic medium. All the inhibitors retard the corrosion rate by getting themselves adsorbed on the corroding surface by following the *Langmuir* adsorption isotherm. The surface analysis of inhibited and uninhibited samples was performed using Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). Among the various inhibitors used, the nanocomposite of polyurethane was the most effective. Molecular modeling helped in determining the extent of packing of the SPU chains leading to better inhibition efficiency[37].

CONCLUSION

- The application of nanotechnology in the corrosion protection of metals has recently gained momentum and of real promise.
- Environmental impact can be improved by utilizing nanostructure particulates in corrosion inhibition, coating, and eliminating the requirement of toxic solvents.
- Nano-composite was evaluated in terms of physico-mechanical properties, corrosion rate, and SEM studies.
- Nano technological approach that was able to effectively protect steel from corrosion in acid, alkaline, and saline media was developed.
- Nanotechnology has been playing an increasing important role in supporting innovative technological advances.

First of all, improved understanding of corrosion and inhibition mechanisms. **Secondly**, nanotechnology has been employed to enhance the inherent corrosion resistance and performance of the steel itself, by achieving the desirable finely crystalline microstructure of steel (e.g., Nano-crystallization) or by modifying its chemical composition at the nanometer scale. **Thirdly,** nanotechnology has been employed to reduce the impact of corrosive environments through the alternation of the steel/electrolyte interface (e.g., formation of Nano-composite thin film coatings on steel).

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