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Epoxy Polymer Based Nano-Composite, Highly Anticorrosive Coatings for Corrosion Protection

Neetu Singh

Department of Chemistry, PSIT.College of Engineering, Bhauti, Kanpur, UP. India

Abstract : The successful use of polymeric coatings for corrosion prevention or mitigation is often hindered by their inherently porous microstructure that fails to resist the ingress of detrimental species and/or by their vulnerability to damage by surface abrasion, wear, or scratches. This study discusses the utilization of nanotechnology to greatly enhance the properties of polymer-based coatings for anticorrosion applications, by modifying the microstructure of the coating bulk or endowing it with additional functionality. It also provides a review of technological advances in the use of nanotechnology to produce high-performance polymeric coatings with outstanding corrosion resistance and other relevant properties.
Keywords : corrosion-resistant, grapheme nano sheet, coating.

Introduction

Corrosion is the surface disintegration of metals/alloys within specific environment. Some metals basically exhibit high corrosion resistance than others and this can be attributed to several factors like their chemical constituents, the nature of electrochemical reactions itself and others. The degradation of metal surfaces due to atmospheric corrosion is a major problem for many exposed metallic structures, such as bridges, pipelines and storage tanks. If seawater is present, there is a remarkable increase in the degree of corrosion since the environment becomes even more aggressive.[1]

The corrosive action of the atmosphere depends primarily on factors such as relative humidity, pollutants, temperature and residence time of electrolyte solutions on the metal surface. The physicochemical characteristics that may interfere with the corrosive action of the environment are the presence of water, salts, gases, differences in pH and electrical conductivity.[2] On the other hand, the corrosion process in metal exposed to soil is mainly due to the natural soil conditions, and not to small variations that may exist in the environment.

Epoxy has been widely used as a coating material to protect the steel structures , because of its outstanding process ability, excellent chemical resistance, good electrical insulating properties and strong adhesion to heterogeneous materials.[3,4,5]Many researchers have worked on the mechanical andmorphological properties of epoxy composite.[6]

Tang et al**.** studied the mechanical properties of treated halloysite reinforced epoxy Nano composites. It was described that the fracture toughness of epoxy considerably improved by78.3% due to the existence of 10 wt. % of added halloysite nanotubes (HNTs). Some of the researchers did surface modification of Nano particles by treating it with aminopropyl trimethoxy silane (APS) coupling agents before addition to the epoxy matrix .[7,8]

Anti-Corrosion Coatings: Mechanism

There are so many mechanisms of anti – corrosion coatings but generally, mechanism of coating can be differentiated into three, namely; barrier creation between substrate materials and environments, inhibition of the corrosion processes, and coating acting as sacrificial materials. However, recently one of the newest approaches is what is called "*active-passive"*. This involved the coating acting as barrier layers which will not aloe permeation of corrosive agents to the metal surface (passive). While the active approach allows the formation of effective passive layer and this will impedes the corrosion half reactions leading to Schottky barrier at the interface resulting in depletion of electrons.[9]

Material Preparation Methods

Powder Coatings-

Manufacturing of powder coatings was different from other kinds of coatings. Resin, pigment, filler, curing agent and other additives were mixed in certain proportion. Then the compositions was extruded, crushed and screened to gain powder of coating. The powder always was stored at room temperature. The powder coatings often operated by two kinds that electrostatic spraying method applied for thermoset powder coatings and fluidized bed dipping method used for thermoplastic powder coatings. After that, the powder was heated to melt and cure. Finally, a smooth bright permanent film on articles was formed to achieve the purpose of decoration andcorrosion.[10]

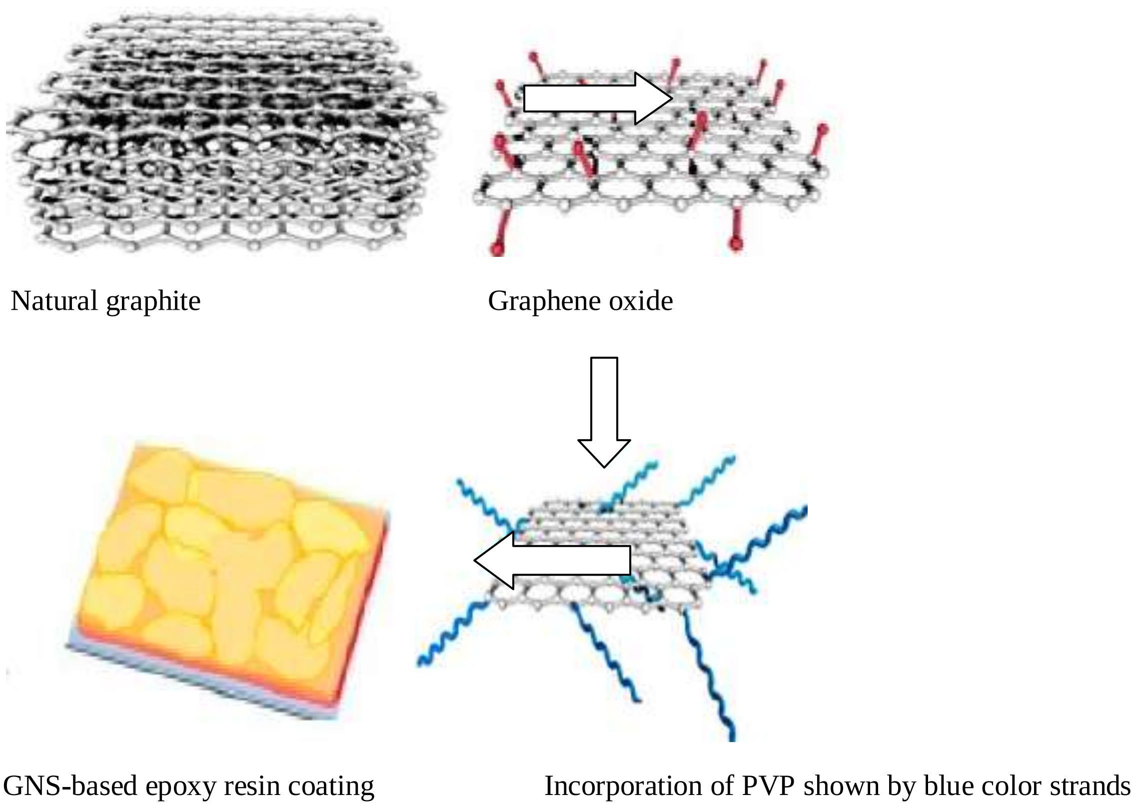
Polymer Nanocomposites Coatings

Epoxy resin was diluted by adding Acetone and stirred at about 500 RPM for 5 minutes. ZnO Nano powder was directly added to the resin acetone solution and stirred at a speed of 2500 rpm for at least 1 hr, using mechanical stirring.[11]

After mechanical stirring the solution was sonicated for 90 minutes at 50 ºC. Acetone was used as a solvent because the study of Fourier transform infrared spectroscopy (FTIR) and FT-Raman [13]revealed that mixing and sonication in acetone did not induce any chemical change in epoxy network.[12]

Nanosheet Based Epoxy Resin

Epoxy resin is the most common polymeric coating that inhibited the process of metal corrosion due to high tensile strength and modulus, low shrinkage in cure, good chemical and corrosion resistance, high adhesion and dimensional stability.[13]On the other hand, it has been experimentally demonstrated that the graphene coating effectively suppresses metal oxidation by oxygen reduction and metal salt solution. Most importantly, graphene sheets can protect the polymer underneath from atomic oxygen (AO) erosion because they pose a high energy barrier to AO diffusing from the top ofthe graphene sheets to the reactive polymer surface underneath. These results indicate the functional capabilities of graphene as effective corrosion-inhibiting materials.[14,15]So, graphene nanosheets(GNS)-based epoxy resin coating is expected to be a good kind of anticorrosive material. Althoughepoxy resin/graphene nanocomposites have attracted a tremendous amount of attention because graphene fillers with very low loading have the potential to match or exceed the performance of large quantities of traditional composite fillers, most works have mainly emphasized enhancing mechanical, electrical or flame retardancy properties of epoxy resin by adding graphene fillers [4–11].[16,17,18]These nanocomposites contained either expanded graphite or functionalized[19] graphene sheets with the smallest measured thickness of about 0.8 (nm) by the atomic force microscopy (AFM). The nanoscale graphene sheets had a wrinkled topology which could be attributed to their extremely small thickness. The fracture surface featured an extensive plastic deformation around the graphene sheets, which suggests strong interfaces between polymer matrix and grapheme sheets.GNS-based epoxy resin coating was prepared as shown in Scheme 1.



Scheme 1.Synthetic process of GNS-based epoxy resin coating.

In the present research, the nanoindentation test was used to measuring the elastic modulus (*E*) and the hardness (*H*) of GNS-based epoxy resin coating.[20].. It showed that the hardness and the elasticmodulus could be measured by analyzing the unloading part of the load displacement curve. The indentation hardness is given by:

$$H = \frac{Pmax}{A} \qquad (1)$$

where, *P*max is the maximum normal load and *A* is the projected contact area at the maximum load. The elastic modulus (*E*) can be calculated from the following equations:

$$\frac{1}{E_r} = \frac{(1 - v^2)}{E} + \frac{(1 - v_i^2}{E_i} \qquad (2)$$

where, *Er* is the reduced modulus of indentation contact, *Ei* (1140 GPa) and νi (0.07) are the elastic modulus and Poisson's ratio of the indenter, and ν = 0.40 is the Poisson's ratio of the test sample.[21]

Anticorrosive Nature

The nanocomposite microstructure can be categorized according to the interaction between the polymer matrix and the added nanomaterial (i.e., phase separated, hybrid phase, intercalated and exfoliated composites). The cost-effective use of nanomaterials to enhance the anti-corrosion performance of polymeric coatings hinges on their dispersion in the host polymer. Incorporation of nanomaterials into polymer matrix offers environmentally benign solutions for enhancing the integrity and durability of coating systems. Powder coating is a 100% solids coating applied as a dry powder and subsequently formed into a film with heat.

Its application method is that utilizes solid binder and pigment. The solid binder melts upon heating, binds the pigment and results in a pigment coating upon cooling. polymer coatings containing a small amount of nanomaterials (typically no more than 4% by weight of polymer) offer significant barrier properties for corrosion protection and reduce the tendency for the coating to blister or delaminate. Due to their high surface activity, nanomaterials may serve as a template to guide the curing of monomers and oligomers near them and lead to formation of better cured polymeric networks in the interfacial region.

Conclusion

Nanoscale materials may have unique physical, chemical and physicochemical properties to allow for improvements in corrosion protection compared with bulk size objects made of the same materials. It has also been well-known that such nanoparticles create high surface area to allow their uniform dispersion into matrix materials with a low dosage so that the efficiency of nanocomposites could be significantly enhanced in terms of materials properties. Epoxy paint was used as a binder for the nanocomposites so as to obtain more uniform coatings.Nanocomposites to the epoxy paint allows a greater anticorrosive efficiency, when compared to pure epoxy paint without any corrosion inhibitor. This behavior might be further exploited for the development of innovative hybrid nanopigments for corrosion protection.

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