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Corrosion inhibition property of polyester–groundnut shell biodegradable composite

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ABSTRACT

The use of natural fibers as reinforcing materials in thermoplastics and thermoset matrix composites provide optimistic environmental profits with regard to ultimate disposability and better use of raw materials. The present work is focused on the corrosion inhibition property of a polymer matrix composite produced by the use of groundnut shell (GNS) waste. Polyester (PE) was synthesized by condensation polymerization of symmetrical 1,3,4-oxadiazole and pimelic acid using sodium lauryl sulfate as surfactant. The polyester–groundnut shell composite (PEGNS) was prepared by ultrasonication method. The synthesized polyester–groundnut shell composite was characterized by FT-IR, TGA and XRD analysis. The corrosion inhibitory effect of PEGNS on mild steel in 1 M H_2SO_4 was investigated using gravimetric method, electrochemical impedance spectroscopy, potentiodynamic polarization, atomic absorption spectroscopy and scanning electron microscopy. The results showed that PEGNS inhibited mild steel corrosion in acid solution and indicated that the inhibition efficiency increased with increasing inhibitor concentration and decrease with increasing temperature. The composite inhibited the corrosion of mild steel through adsorption following the Langmuir adsorption isotherm. Changes in the impedance parameters R_t, C_{dl}, I_{corr}, E_{corr}, b_a and b_c suggested the adsorption of PEGNS onto the mild steel surface, leading to the formation of protective film.

1. Introduction

In spite of much advancement in the field of corrosion science and technology, the phenomenon of corrosion remains a major concern to industries around the world. Though the serious consequences of corrosion can be controlled to a great extent by selection of highly corrosion resistant materials, the cost factor associated with the same, favors the use of cheap metallic materials along with efficient corrosion prevention methods in many industrial applications. Mild steel is the most commonly used engineering material. Often mild steel is exposed to the attack of acid solutions during industrial processes such as acid cleaning, pickling and descaling. This results in easy corrosion of the mild steel, thereby necessitating the use of inhibitor. There are numerous methods for controlling the corrosion of metals but the use of inhibitors is still one of the best methods of protecting metals against corrosion (Viswanathan and Saji, 2010). Many organic compounds are used as corrosion inhibitors for mild steel in acidic environments. Such compounds usually contain nitrogen, oxygen or sulfur in a conjugated system and function via adsorption of the molecules on the metal surface, creating a barrier to the corrodant attack (Hari Kumar and Karthikeyan, 2013; Udhayakala et al., 2012). In recent years, polymers have drawn considerable attention as corrosion inhibitors because of their large surface area, inherent stability and cost effectiveness. Polymers exhibit excellent inhibition even at very low concentration when added to the aggressive medium (Banerjee et al., 2011). Several researches have indicated that polymers can be used as corrosion inhibitors because through their functional groups they form complexes with metal ions and on metal surfaces. These complexes occupy a large surface area, thereby blanketing the surface and protect the metal from corrosive agents present in solution (Arthur et al., 2013). The inhibitive power of these polymers is related structurally to the cyclic rings and heteroatoms that are the major active centers of adsorption.

The main advantages of polymeric inhibitors are (i) a single polymeric chain displaces many water molecules from the metal surface thus making the process entropically favorable (ii) the presence of multiple bonding sites makes the desorption of polymers a slower process (Amin et al., 2009). Most polymers are not easily biodegradable which allow for their long time storage and usage on corrosion protection of metals and alloys. Mechanism of inhibition is mainly attributed to adsorption and depends on the metal, physicochemical properties of the molecule such as

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functional groups, steric factors, aromaticity at the donor atom and p orbital character of donating electrons, as well as the electronic structure of the molecules.

The development in science and technology requires a variety of polymers with good properties and low cost. To improve the inhibition efficiency and to minimize the consumption of polymers, an attempt has been made to incorporate natural filler materials in the polymer matrix. Therefore, polymer composites were considered to be among the more promising approaches to yield new materials and have been investigated extensively. In recent years, many studies have been dedicated to utilize lignocellulosic fillers such as coconut shell, wood, pineapple leaf, palm kernel shell, groundnut shell etc., as fillers in order to replace synthetic fillers through utilization of natural fillers or reinforcement in polymer composites in an attempt to minimize the cost, increase productivity and enhance mechanical properties of product. Due to the toxic nature, high cost and increasing awareness and strict environmental regulations of some of these compounds, the use of natural product as corrosion inhibitor is receiving attention.

In the light of the above, the present study is channeled towards producing a composite material using polyester (PE) as the matrix and a groundnut shell (GNS) as the reinforcing filler so as to further reestablish the use of agricultural wastes as reinforcements in polymer matrices. The groundnut shell was collected from local suppliers in and around Coimbatore district. Groundnut botanically known as Arachis hypogeal belongs to Leguminosae family. India is the second largest producer of groundnut after China. Groundnut shell (*Arachis hypogea* L) is an important oil seed crop of India. The pod or dry pericarp contains about 25–40% shell. Chemical composition of groundnut shell is as follows: 65.7% cellulose, 21.2% carbohydrates, 7.3% protein, 4.5% minerals and 1.2% lipids (Shehu et al., 2014). Inhibitive effects of the polyester composite has been investigated using gravimetric method, electrochemical impedance spectroscopy (EIS), potentiodynamic polarization, atomic absorption spectroscopy and scanning electron microscopy.

2. Materials and method

2.1. Electrodes and solutions

The mild steel with chemical composition by weight 0.084% C, 0.369% Mn, 0.129% Si, 0.025% P, 0.027% S, 0.022% Cr, 0.011% Mo, 0.013% Ni and balance iron was used for the experiment. Mild steel coupons of size $1 \times 3 \times 0.1$ cm^3 for weight loss measurements and mild steel rod with an exposed area 0.785 cm^2 (cylindrical rod embedded in Teflon with a diameter of 1 cm and area exposed to corrosive medium is 0.785 cm^2) for electrochemical measurements were used in the study. Before testing, to remove impurities from the surface, the coupons were abraded with emery sheets (1/0, 2/0, 3/0 and 4/0) washed with distilled water followed by degreasing with trichloroethylene.

The test solution 1 M H_2SO_4 was prepared from 36 M H_2SO_4 analytical grade and double distilled water. The inhibitors concentrations were taken in ppm for all investigation.

2.2. Synthesis of polyester composite

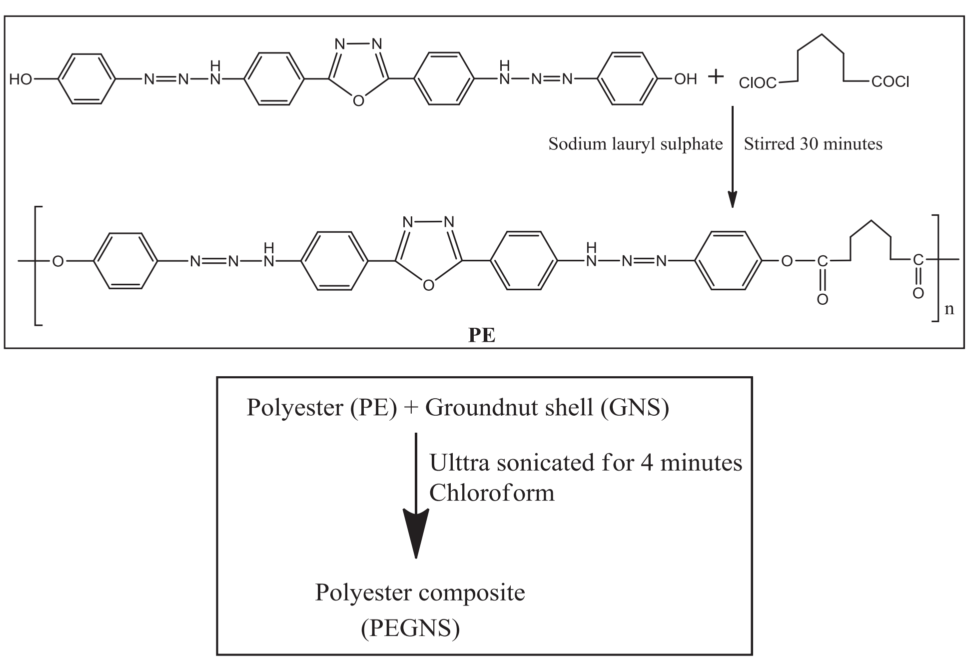
The polyester composite (Scheme 1) was prepared as reported earlier (Sava et al., 2003; Sivadhayanithy et al., 2007; Guilbert-Garcia et al., 2012).

The structure of the synthesized polyester and polyester composite was confirmed by IR spectra using Shimadzu IR Affinity 1. In order to determine the thermal stability of the polymers and its composite, TGA was carried out. The thermo grams were recorded in dynamic nitrogen atmosphere with a heating rate of 10 °C using a Perkin-Elmer (TGS-2 model) thermal analyzer. The crystalline nature of the polyester and polyester composite was confirmed by XRD using Brucker XRD at STIC, CUSAT, Cochin.

2.3. Non-electrochemical techniques

2.3.1. Weight loss measurements

The weight loss experiments were carried out by standard procedure (Guilbert-Garcia et al., 2012). The mild steel was immersed in 1 M H_2SO_4 in presence and absence of various concentrations (500 ppm of PE+100 ppm/1000 ppm/2000 ppm of



Scheme 1. Synthesis of Polyester composite.

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