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Recycling of plastic waste as green corrosion inhibitors for steel in different corrosive media

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ABSTRACT

The present article is intended to report a series of works aimed to alleviate of the environmental pollution by converting plastic waste into useful products, and to evaluate the inhibition action of plastic waste on the corrosion of steel alloys, in different aqueous media. Poly (ethylenterphthalate),PET plastic waste was used as cheap and safe corrosion inhibitors for steel in hydrochloric acid, sulfuric acid, acetic acid,formic acid, nitric acidcorrosive media, and in aqueous NaCl corrosive medium.The present article reports the evaluation of Poly (ethylenterphthalate),PETwaste and their modified products as corrosion inhibitors for steel in different media by chemical and electrochemical measurements. © 2016 Trade Science Inc. - INDIA

KEYWORDS

Waste;
Steel;
Corrosion;
Weight loss;
Plastics waste;
PET;
Green inhibitors.

INTRODUCTION

In the 1980s, polyethylene terephthalate, (PET) began to be used popularly for the production of disposable soft drink bottles and in 1987, more than 700 million pounds of PET were consumed in their production[1]. As a resultof the diversity of its applications in a high volume of consumer products, large amount of PET waste is also generated, which includes polymer manufacturing waste as well as the products after the end of their useful life. (PET) is a worldwide used polymer, and packaging is one of its most important applications. Due to its high resistance to the atmospheric and biological agents, this polymer is not considered as biodegradable. PET is not a hazardous product, but its waste quantity increasesdrastically. With the increasing pressure of keeping, the environmental clean. Recycling of PET waste is an ecofriendly manner is the only solution. PET waste can be recycled by different methods likephysical recycling and chemical recycling. Chemical recycling is the reaction of PET with various reagents to obtain products that are used in the chemical industry[2],the chemical recycling of PET has been the subject of keen interest as a valuable feedstock for different chemical processes. During chemical recycling, PET waste can be depolymerised to base monomers or oligomers. With the use of solvent of depolymerization, generally called solvolysis of polymer,methanolysis[3-5] and glycolysis[6,7] are the main possible routes. Hydrolysis[8-12]of PET is also possible using water under

pressure. Aminolysis is another method of chemical degradation of PET, which has been little explored as compared to other techniques.

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 ofsteel is its dissolution in acidic 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 corrodedeasily[42-46]. Corrosion is an afflicting problem associated with every use of metals. The damage by corrosion results in highly cost for maintenance and protection of materials used. Metals generally tend to move to its original state by corrosion process because Corrosion is a thermodynamically feasible process as it is associated with decrease in Gibb's free energy. Development of methods to control corrosion is a challenge to scientists working in this area[42-46]. Amongst various methods developed for corrosion protection, use of inhibitor is an attractive and most practical method for the protection of metals in contact with corrosion medium. Inhibitors reduce the corrosion of metallic materials by controlling the metal dissolution and consumption[42-46]. Acid solutions are used for pickling, chemical, and electrochemical etching of metals, acidization of oil wells and in cleaning of scales because it is more economical, efficient and trouble-free, compared to other mineral acids[13, 14]. It is very important to add corrosion inhibitors to prevent metal dissolution and minimize acid consumption[15-17]. 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. This process is considered as interface inhibition, according to Fischer's classification[18, 19]. The surfactant inhibitor obtained from waste has many advantages such as high inhibition efficiency, low price, low toxicity, Available, renewable and easy production[20-25]. The adsorption of the surfactant on the metal surface can markedly change the corrosion resisting property of the metal[26, 27], and so the study of the relationship between the adsorption and corrosion inhibition is of great importance. The present review article report and highlight the intensive efforts underway to develop new corrosion inhibitors starting from PET waste and their modified products and oligomeric surfactants was used as a cheap and save corrosion inhibitors for steel in aqueous medium.

Modified plastic waste as corrosion inhibitors for steel

In this part, it is intended to report a series of works aimed to alleviate of the environmental pollution by converting plastic waste into useful products, and to evaluate the inhibition action of plastic waste on the corrosion of some steel alloys, in different aqueous media.[28-36],PET plastic waste was used as cheap and safe corrosion inhibitors for steel in hydrochloric acid, sulfuric acid,acetic acid and nitric acid corrosive media, and also in aqueous NaCl corrosive medium[37].

The recycling of plastic waste and use of their modified products as corrosion inhibitors for steel are limited. The use of plastic waste and their modified derivatives as corrosion inhibitors can be traced back to 2006's when Reda. S. Abdel Hameed and coworkers prepare some water soluble surfactant derived from plastic waste, this surfactants were evaluated as corrosion inhibitors for C- Steel in 1M hydrochloric acid corrosive media,[28]. The application of plastic waste as corrosion inhibitors include the synthesis of new compounds with new structural properties from PET in an effort to improve their efficiencies in field of protection of steel from corrosion. In this respect:H. Shehata,H. Abdelbary,SamerAbdelsalam,Ahmedsalem, A.M.Atta,andReda.S.AbdelHameed. try to modify PET waste as the following:

i) The PET waste converted into glycolysed products via glycolysis reaction by using TEA and

DEA. With molar ratio 1:1 (wt. % of PET to wt.% of the used amines) These glycols used to convert PET into water soluble oligomers and act as the solvent of PET.

ii) These glycolysed products are utilizing in synthesis of polymeric surfactants having different hydrophile - lipophile balances HLB.

iii) Surfactants are produced from reaction of produced oligomers with polyethylene glycol, PEG, and stearic acid (SA).

iv) These surfactants used as corrosion inhibitors for carbon steel alloy in presence of 1M HCl in aqueous solution. Using weight loss, and electrochemical measurements.

v) Evaluation of the prepared surfactants from waste as corrosion inhibitors at different temperatures.

In 2012 H.Shehata, H.Abdelbary, SamerAbdelsalam, Ahmedsalem, A.M.Atta, and R.S.AbdelHameed. Were able to concluded that[34].

1. Nonionic surfactants are produced from reaction of the produced oligomers from PET waste with PEG, having M.Wt. 400, 1000 and 4000, in presence of β-β‘ dichloro diethyl ether as a linking agent and NaOH as a catalyst.
2. Inhibition efficiencies increase by an increase in inhibitor concentration and an increase in temperature up to 50°C.
3. The uniform increasing inhibition efficiency as the function of concentration are dealing with adsorption phenomenon and the adsorption of all additives obeys the Langmuir adsorption isotherm. The negative values of enthalpies identifies that the adsorption is a physic -chemical adsorption type.
4. All entropy parameters for adsorption of inhibitors molecules on steel are positive and increase by increasing the temperature which indicate that the inhibitors more oriented and more ordered on the surface of the metal.
5. Activation energy increases with addition of inhibitors. It is shown that physical adsorption occurs in the first stage.
6. GT -EO90-SA shows an inhibiting effect on the corrosion of carbon steel in 1M HCl which increases with inhibitor concentration.
7. The activation parameters of the dissolution (*E*°, *ΔH*° and *ΔS*°) were calculated and showed that the used inhibitors decrease the rate of corrosion.

In 2008's, R.S.AbdelHameed, MetwallySh.Metwally,S.Abdelsalam,and Al Shafy H.[29] were able to prepare and modify (PET), with Diethanolamine and Triethanolamine having 1:2 wt% of PET: wt% of DEA or wt% TEA, in presence of manganese acetate as a catalyst. The prepared inhibitors from waste were purified and characterization by FT-IR and 1HNMR. The inhibition action of the prepared compounds (D_2& T_2) on the corrosion of carbon-steel which used in the manufacture of petroleum pipelines in nitric acid was evaluated, at different concentrations of inhibitors from (50-250 ppm) and different temperatures, ranged from (303-333 K). The polarization curves indicate that these compounds may act as mixed-type inhibitors. The adsorption isotherm of the prepared compounds on C-steel was found to follow the Langmuir adsorption isotherm and they obey El-Awady isotherm. The values of activation energies, (E_a*), and all thermodynamic activation parameters which determined and indicating that the type of adsorption of D2,T2 derived from PET waste on the steel surface was chemical adsorption.

In 2009's, R.S.AbdelHameed,et al.[30] report the use ofethoxylated poly(ethylene terephthalate) derived from plastic waste as corrosion inhibitors for C-Steel in 1 M acetic acid solutions, the inhibition efficiency of ethoxylated derivatives (derived from waste) was determined using weight loss measurements as well as potentiodynamic polarization technique. It was concluded that:

1- All studied ethoxylated oligomers are excellent inhibitors and act as a mixed type inhibitors for carbon steel corrosion in acetic acid solution.

2- Inhibition efficiencies increased by increasing inhibitor concentration (from 84% to 92%) and by \increasing temperatures up to 333 K.

3- All entropy parameters for adsorption of inhibitors molecules on steel are positive and increase by increasing the temperature which indicates that the inhibitors being more oriented and more ordered on the surface of the metal.

4- The activation parameters of the adsorption (E*,

ΔH* and ΔS*) were calculated and showed that the used inhibitors decrease the rate of corrosion.

5- The adsorption of these inhibitors on steel surface obeys Langmuir's adsorption isotherm.
6- The increase in the ethylene oxide unites in the molecular structure leads to more inhibition efficiency. And the corrosion inhibition efficiency reach to 92%.

In 2010's, Atta, Migahed, et al, synthesized a new water soluble corrosion inhibitor from recycled poly(ethylene terphethalate). Polyethylene terephthalate waste (PET) was depolymerized by triethanolamine into glycolyzed prod-uct (GT), followed by esteriûcation with bromoacetic acid in the presence of manganese acetate as a catalyst to give (GT-Br). The obtained ester was reacted with thiourea to give thiol derivative (GT-SH). The effectiveness of the synthesized compound as corrosion inhibitor for API XL65 carbon steel, in 2 M hydrochloric acid solution was investigated by various electrochemical techniques such as open circuit potential, potentiodynamic polarization and electrochemical impedance spectroscopy (EIS). The results of these investigations showed enhancement in inhibition efûciencies with the increasing of inhibitor concentration. The protective ûlm formed on carbon steel surface was analyzed using an energy disper-sive X-ray analysis (EDX) technique. Also, scanning electron microscope (SEM) was used to study the surface morphology of steel surface in the absence and presence of 400 ppm of the additive[41].

In 2011's, R.S.AbdelHameed introduce new water soluble amide derived from PET waste,[36] in this respect: Soft drink bottles was subjected to depolymerization through aminolysis using mono ethanol amine, (MEA) in the presence of sodium acetate as a catalyst the product of pol(bis(2-hydroxyethylene)terephthalamide. (PHETA) was evaluated as corrosion inhibitors for C-Steel in 1 M HCl by using weight loss, open circuit potential and potentiodynamic polarization measurements. The polarization curves indicate that these compound (amide) act as mixed type inhibitors. The inhibition efficiency increase with increasing the concentration of the inhibitors and decreases with increasing the temperature, the values of activation energy (E_a) and free energy of adsorption ("G_{ads}) indicated that the type of adsorption was chemical adsorption. The inhibition occurs through adsorption of the inhibitor molecules on the metal surface without modifying the mechanism of corrosion process. The adsorption of the inhibitor on C-Steel surface was found to follow the Langmuir adsorption isotherm. Scanning electron microscope (SEM) was used to study the surface morphology of steel surface in absence and presence of 200 ppm of the used inhibitor derived from waste.

In 2012's, Abdel Hameed, et,al. was studied the corrosion of Mild Steel in NaCl solutions and effect of recycled plastic waste inhibitors[37]. in this respect:recycled poly ethyleneterphthalate (PET) with both of Diethanolamine (DEA) and Triethanolamine (TEA) (ratios of 1:2 wt %) followed by esterification with stearic acid, to give (D_2S and T_2S). the corrosion inhibition effect of (D_2S and T_2S) was determined using weight loss, potentiodynamic polarization techniques and open circuit potential measurements. The results showed that the inhibition of the prepared recycled compounds (D_2 S& T_2S) occurs through adsorption of the inhibitor molecules on the metal surface and the inhibition efficiency was found to increase with increasing the inhibitor concentrations and temperature as well as these inhibitors act as mixed–type.The adsorption of these compounds on the metal surface is found to obey Langmuir adsorption isotherm. Thermodynamic functions for both dissolution and adsorption processes were calculated. The obtained results from weight loss and potentio-dynamic polarization techniques are in a good agreement.

In 2013's, R. S. Abdel Hameed, et,al was study the corrosion inhibition of carbon steel in 1 M formic acid by Poly(oxyethylene)terphthylaminederived from plastic waste. In this respect: polyethylene terphthalate waste depolymerized with diethanolamine to gives the corresponding amine, etherfication of the produced hydroxyle amine with different molecular weight of poly ethylene glycol,(PEG1000, PEG4000) to gives the corresponding poly(oxyethylene) terphthalamine) which were separated, identified and evaluated as corro-

sion inhibitors for Carbon steel in 1 M methanoic acid[47]. the corrosion inhibition efficiency were determined at different concentrations of the used inhibitors by chemical techniques(weight loss) and electrochemical techniques (potentiodynamic Polarization and open circuits potential). The corrosion inhibition efficiency depends on the inhibitor concentration and type, The protection efficiency increase with increasing the concentration and the number of ethylene oxide units in order of (Dn_{22} and Dn_{90}), The inhibition was assumed to occur via the adsorption of the inhibitors on the metal surface. And obey Langmuir adsorption isotherm. The polarization curves indicate that these compounds at as mixed-type inhibitors. Addition of inhibitors molecules to the corrosive medium produces a negative shift in the open circuit potential. Effects of temperatures on the inhibition efficiency were studied, thermodynamic parameters were computed and discussed, it was found that the obtained data from different techniques are in good agreement, and the increase in the numbers of ethylene oxide units in the molecular structure of the modified plastic waste leads to increase inhibition efficiency. Finally in 2016, R. S. Abdel Hameed, et,al was study the corrosion inhibition of carbon steel in phosphoric acid corrosive medium by tow compounds derived from PET, waste[48], viathe reaction of waste with Ethylene glycol(EG) and ethylene di amine (EA) in the presence of catalysts. The tow compounds were evaluated as inhibitors for steel at different concentrations and temperature by chemical and electrochemical methods, the experimental results indicate that the inhibition efficiency in case of di amine based EA, more than glycol based compound.

CONCLUSIONS

Recycling of plastic waste as corrosion inhibitors for steel in different media are limited and traced back to 2006's by R.S. AbdelHameed and coworkers.

All the reported materials showed good inhibition efficiency for corrosion of steel in different aqueous media.

Modified Plastic waste show real promise as greencorrosion inhibitors for steel alloys in aqueous corrosive media.

All water soluble polymeric surfactants obtained from PET are of great advantages for corrosion inhibition of steel in different media, which are biodegradable; do not contain heavy metals or other toxic compounds, inexpensive, readily available and renewable. As in addition to being environmentally friendly and ecologically acceptable, also give higher inhibition efficiency.All obtained results from Electrochemical and weight loss measurements are in good agreement with each other and indicate the possibility of using modified plastic waste as green corrosion inhibitors for steel in different corrosive media.

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