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RESEARCH ARTICLE

STUDY THE EFFECT OF SCHIFF BASE NICKEL NANOCOMPOSITE COMPOUNDS AS STAINLESS STEEL CORROSION INHIBITION IN BACTERIAL PROBLEM MEDIA

***[1,2]Omnia A.A. El-Shamy, [1]Abdullah S. Al-Ayed and [2,3]Hala M. Abo-Dief**

[1]College of Science and arts- Ar-Rass, Qassim Univesity, P.O. Box 53, KSA
[2]Egyptian Petroleum Research Institute, Nasr City, 11727 Cairo, Egypt
[3]College of Science, Taif University, KSA

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ABSTRACT

The inhibition efficiency of Schiff base namely 2-[(2-Hydroxyphenyl)methylene] hydrazine carbothioamide, (ShB), on corrosion behavior of 304 stainless steel induced by sulfate reducing bacteria (SBR) in formation water was studied using weight loss measurements. The temperature effect on the corrosion behavior was studied at 30, 45, 65 ºC. Adsorption of ShB onto stainless steel surface was found to obey Langmuir adsorption isotherm. Schiff base- nano nickel nanocomposites were prepared with different weight ratio and used for coating the stainless steel surface. The electrochemical impedance measurements were used to identify the corrosion attitude of the coated stainless steel surfaces. The morphology of the coated stainless steel surfaces after immersion were investigated using scan electron microscope (SEM).

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INTRODUCTION

Corrosion is the impairment of a metal due to chemical or electrochemical reactions between its surface and environment resulting in several undesirable effects as pitting, wear, cracking etc (Fang *et al*., 2002). According to US Minerals Management services, most damaged metal are due to internal corrosion (Maruthamuthu *et al*., 2005). Anaerobic corrosion is considered as one of the most serious problem affect the metal surface, about 20% of all metal damage caused by microorganisms (Shi *et al*., 2011 and Beech *et al*., 2005). Many groups of anaerobic bacteria are implicated in the bio-corrosion process as acid producing bacteria, metal precipitating bacteria, sulfate reducing bacteria, etc (Black *et al*., 2002). Sulfate Reducing Bacteria (SRB) is considered as the most popular kind of anaerobic bacteria, it is acquired energy for growth by reducing sulfate to hydrogen sulfide. The producing H_2S increases the corrosion rate of the metal causing damage to the metal surfaces. In addition, the dissolved metal ions are reacted with H_2S forming byproduct that can facilitate and accelerate the corrosion reaction (Muyzer *et al*., 2008 and Kauang *et al*., 2007).

****Corresponding author: Omnia A.A. El-Shamy***
College of Science and arts- Ar-Rass, Qassim Univesity, P.O. Box 53, KSA

Stainless steel is widely used as construction materials in the oil gas production as flow line and pipeline. Although the high resistance of stainless steels, they are greatly affected by microbial corrosion (Zhang *et al*., 2012). Bio-corrosion inhibition methods are depending on inhibited the metabolic activity of the effective microorganisms. Among these methods are painting, anodic/cathodic protection, organic or inorganic coating, etc. (Videla *et al*., 2002 and Videla *et al*., 2005).

Schiff bases are widely used as effective inhibitors in several researches, these compounds possess greatest inhibition efficiency comparing with the corresponding amine, aldehyde or ketone this is attributed to the presence of double bond between nitrogen and carbon (Hegazy *et al*., 2009). This work aimed to study the efficiency of Schiff base namely, 2-[(2-Hydroxyphenyl)methylene] hydrazine carbothioamide, as corrosion inhibitors for 304 stainless steel in formation water containing SRB using weight loss measurements. The electrochemical impedance spectroscopy are used to investigate the corrosion resistances of coated stainless steel specimens with nanocomposites in formation water containing SRB.

EXPERIMENTAL

Materials

All the reagents were analytical grade and used as received. The Schiff base, 2-[(2-Hydroxyphenyl) methylene] hydrazinecarbothioamide (ShB) it's m.p > 230 ºC [Fig. 1] and Nickel (II) oxide (nano powder, < 50 nm particle size (TEM) were purchased from Aldrich. Solvents (ethylalcohol, dimethyl formamide DMF, acetone, benzene) were purchased from Acros.

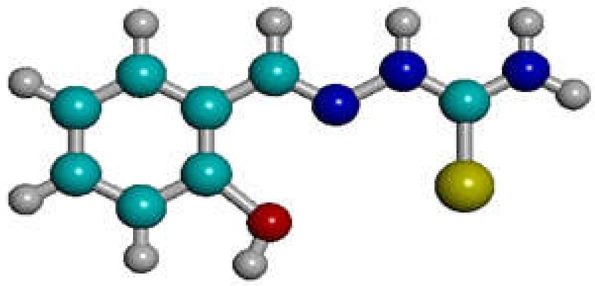


Fig. 1. Molecular structure of ShB. (dark cyan, blue, grey and yellow refer to carbon, nitrogen, hydrogen and sulfur respectively)

Aggressive solution

Formation water samples contaminated by Sulfate Reducing Bacteria (SRB) was supplied from Petroleum Company and used as corrosive media.

Nanocomposite preparation

The nanocomposite was prepared with different weight ratio of Schiff base and nano Nickle II, by dissolving the schiff base: (2-[(2-Hydroxyphenyl) methylene] hydrazinecarbothioamide) in dimethyl formamide with continuous stirring. After complete dissolving of Schiff base add metal nano particle warm and stirring. Let the mixture to evaporate until creamy precipitate of nanocomposites are formed. The nanocomposites were prepared with different weight ratio: 10% nNi/90%ShB (I), 20% nNi/80% ShB (II) 40% nNi/60% ShB (III), 60% nNi/40% ShB (IV).

Nanocomposite coating

The stainless steel sheets were coated by different prepared nanocomposite, according to the same procedure as in (Yan et al., 2011). It was taken at 190 ºC.

Measurements

Weight loss measurements

The stainless steel 304 sheets of (3cm x 2cm x 0.3cm) are abraded carefully, then washed with bi-distilled water and acetone. The accurate weight of the sheets were listed then the sheets are immersed in 100 ml of formation water contaminated with sulfate reducing bacteria with and without different concentrations of ShB molecule. After 6h the sheet are taken out, then washed and dried. The sheets were weighted again and the accurate weight are listed. The measurements were repeated using the most corrosive one at different temperature (30, 45 and 65 ºC) in absence and in presence of different concentration of ShB ($5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$ and $1x10^{-3}$ M).

Electrochemical impedance measurements

The impedance measurements were achieved over high frequency range 100 kHz – 0.1 Hz using an autolab potentiostat / glvanostat (PGSTAT-302).

Scan Electron Microscope (SEM)

The stainless steel samples were analyzed after immersion in the contaminated water with and without optimal concentration of the investigated compounds using SEM Jeol JSM-5400.

RESULTS AND DISCUSSION

Weight loss

Effect of inhibitor concentrations

The surface coverage θ and the percentage of inhibition efficiency are obtained from the following equation (Migahed, 2005):

$$\theta = \frac{W_0 - W}{W_0} \qquad (1)$$

$$\eta\% = \theta \times 100 \qquad (2)$$

The weight loss data of the corrosion of stainless steel induced by SRB in formation water without and with different concentrations of inhibitors are listed in Table 1. The efficiency of ShB as corrosion inhibition increased with increasing its concentrations.

Effect of temperature

Data in Table 1 declared the influence of temperature on inhibition efficiency for corrosion of stainless steel induced by SRB in formation water. The inhibition efficiency increased slightly with increasing temperature indicating both physical and chemical adsorption occurred.

Table 1. Weight loss data of stainless steel without and with ShB at different temperature

Inhibitor	C_i	30 ºC		45 ºC		65 ºC	
		θ	η%	θ	η%	θ	η%
	0	-	-	-	-	-	-
	$5 x10^{-5}$	0.32	32%	0.33	33%	0.34	34%
ShB	$1 x 10^{-4}$	0.45	45%	0.46	46%	0.47	47%
	$5 x10^{-4}$	0.74	74%	0.75	75.5%	0.76	76%
	$1x10^{-3}$	0.86	86%	0.88	88%	0.88	88.5%

Adsorption Isotherm

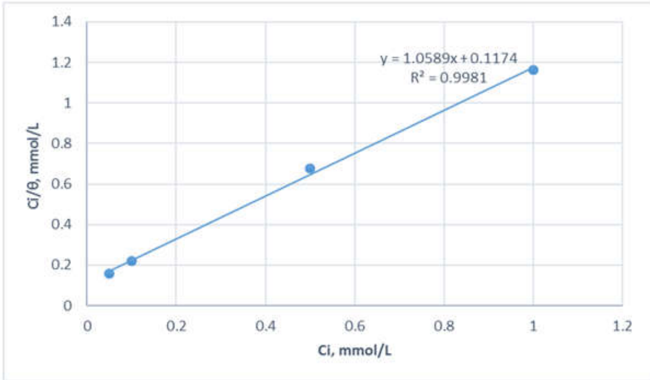
Depending on the structure of the inhibitor and nature of the metal the adsorption may be physical or chemical adsorption of inhibitor molecule on the metal surface. Physical adsorption can occurred between electrically charged metal surfaces and charged species in the bulk solution, while if the process include electron transfer from organic molecule (containing heteroatom as O, N and S) to the d-orbital of the metal chemical adsorption occurred (Amin *et al*., 2006). Adsorption isotherms are considered as one of the most important tools to determine the mechanism of adsorption reaction. Assuming that adsorption of ShB obey Langmuir adsorption isotherm. Fig. 2 Showed linear relation between C_i/θ vs C_i with correlation coefficient near unity, indicating that the adsorption of ShB obey Langmuir adsorption isotherm which is

$$\frac{C_i}{\theta} = \frac{1}{K_{ads}} + C_i \qquad (3)$$

Where, C_i is the inhibitor concentration, θ is the degree of surface coverage at different concentrations of ShB, obtained from weight loss measurements (Eq.1), K_{ads} is the equivalent constant associated to adsorption / desorption process. The equilibrium constant K_{ads} is obtained from the reciprocal of the intercept and it is equal 8.52 x 10^3 M^{-1} which represent the extent of binding efficiency of ShB to the stainless steel. The free energy of adsorption G_{ads} is related to the equilibrium constant of adsorption [15] as given in Eq. 4:

$$G_{ads} = - RT\ln(55.5\ K_{ads}) \qquad (4)$$

The negative value of the calculated free energy of adsorption (G_{ads} = -33.47 kJ/mol) indicated spontaneous adsorption of ShB on the stainless steel. The value of the free energy is closer to -40.kJ/mol, indicated that the adsorption mechanism of ShB on stainless steel surface in SRB media is a mixed from physical and chemical adsorption (Musa *et al*., 2010).



Electrochemical impedance spectroscopy (EIS)

The corrosion attitude of the stainless steel coated with nNi and nanocomposites were investigated using electrochemical impedance technique. Fig. 3 (Nyquist plots) declared that stainless steel sample coating with nNi had the lowest corrosion resistance (Fig. 3 a).

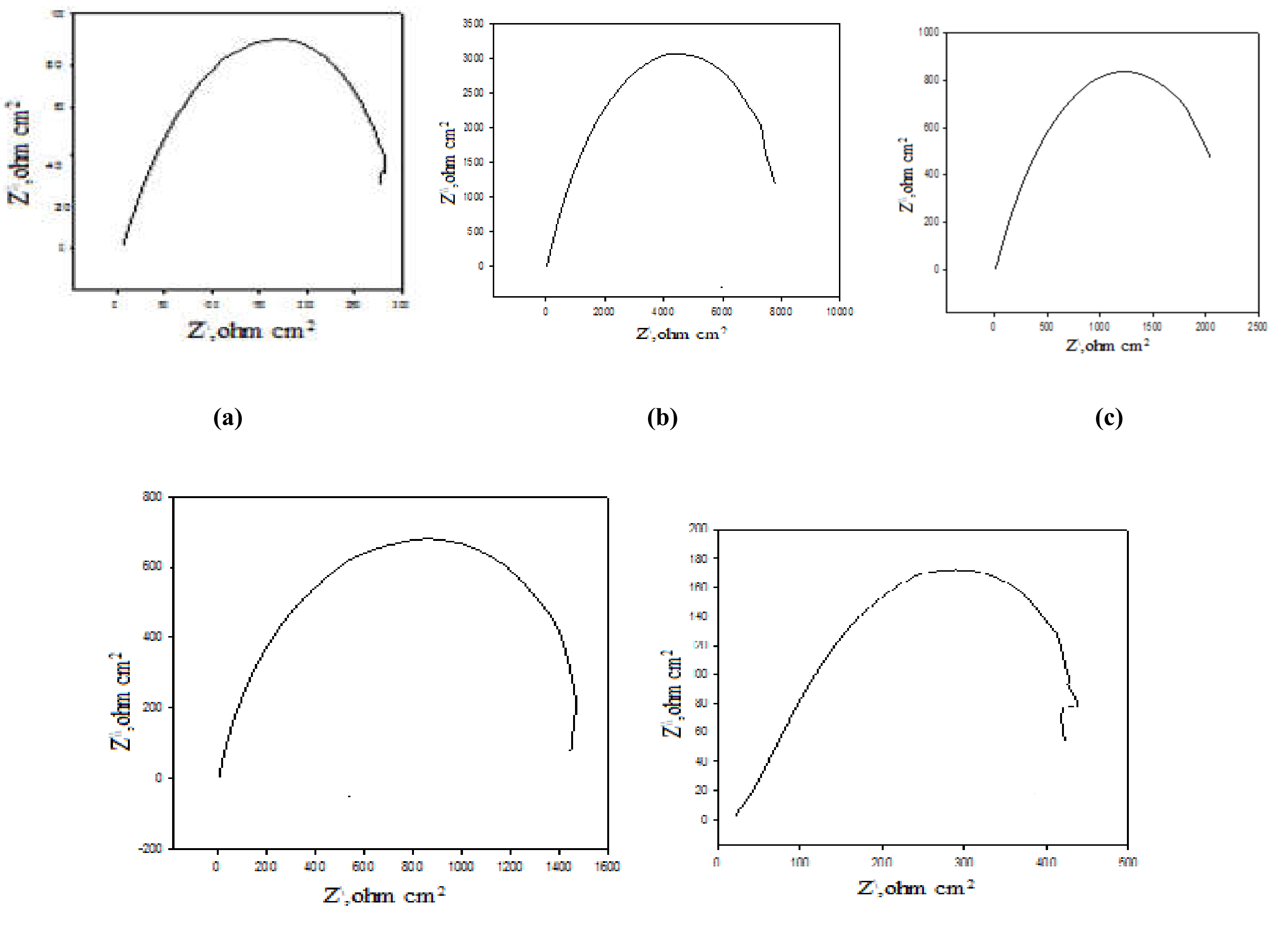
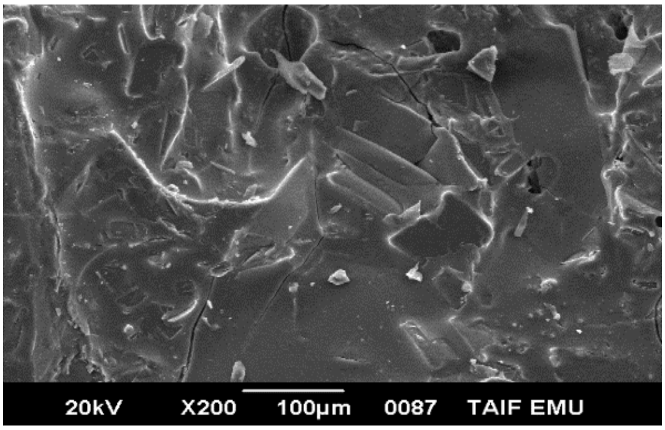


Fig. 3. Nyquist plots for coated stainless steel in formation water containing SRB with: (a) nNi, (b) 10%nNi/90%ShB, (c) 20%nNi/80%ShB, (d) 40%nNi/60%ShB, (e) 60%nNi/40%ShB at 30 °C



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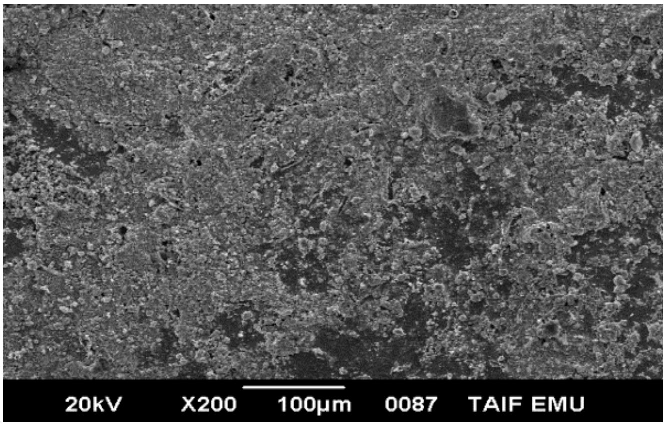

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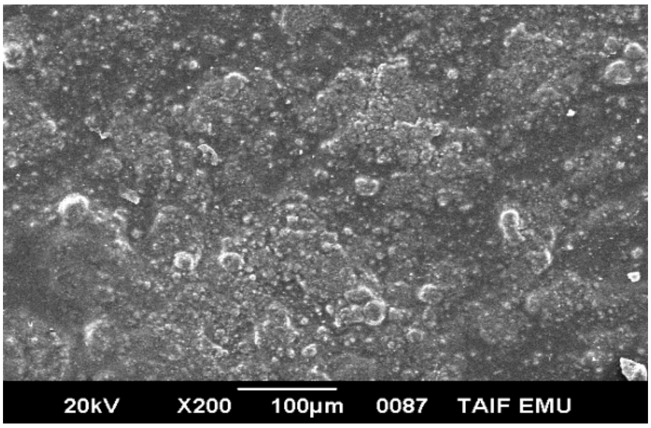

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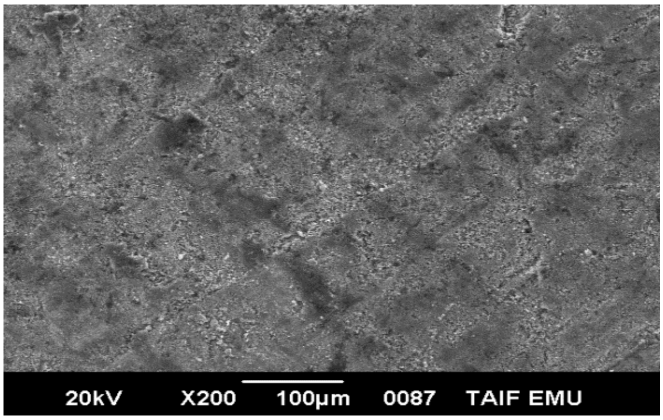

(4)

Fig.4. SEM image of surface of stainless steel after thermal treatment in SRB water with (1) 10%nNi/90%ShB, (2) 20%nNi/80%ShB, (3) 40%nNi/60%ShB and (4) 60%nNi/40%ShB

The increase in the weight percentage of ShB in the coated stainless steel sample, the increase the corrosion resistance value. Maximum surface resistance obtained from specimens coated with 10%nNi/90%ShB. Increase the nNi weight percentage may decrease the active centers of the ShB and hence decrease its inhibition efficiency.

Scan electron Microscope SEM Measurements

The SEM images of the coated stainless steel surface after immersion in contaminated formation water for 24 h were shown in Fig. 4. The micrograph revealed the absence of surface damaged for the coated stainless steel surface. According to impedance measurements and morphology examination, the stainless steel coated with 10%nNi/90%ShB showed the best corrosion inhibition.

Conclusion

ShB showed inhibition characteristics for stainless steel induced by SRB in formation water. The adsorption of ShB on 304 stainless steel surface obeyed Langmuir adsorption isotherm. Coated stainless steel specimens showed high corrosion resistance, the corrosion resistance decrease as the nickel ratio increase. SEM images showed stable protective nanocomposite layer on stainless steel surfaces.

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