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Use of *Butea monosperma* Extract as Green Corrosion Inhibitor for Mild Steel in 0.5 M H_2SO_4

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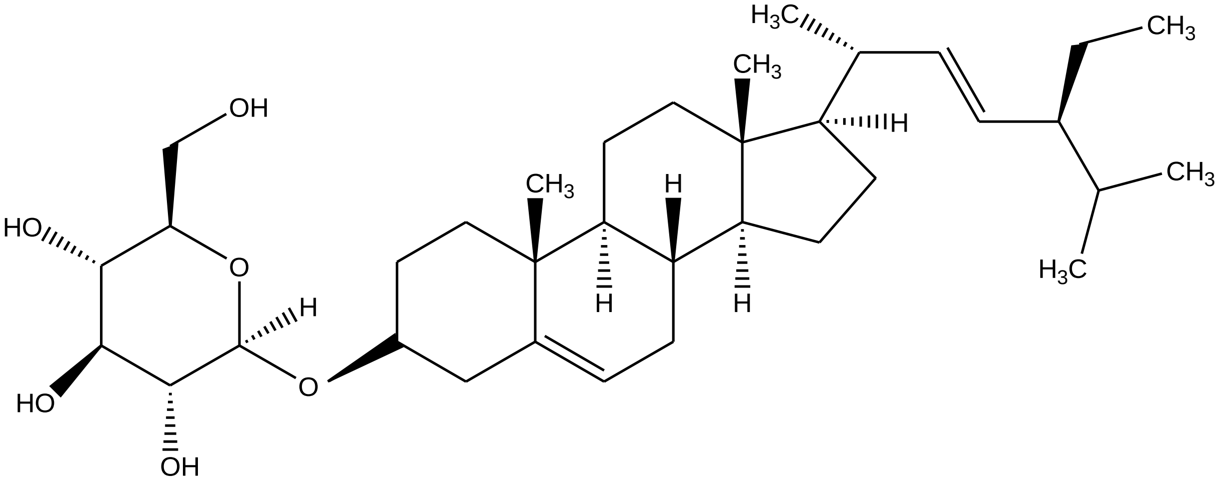
The extract of *Butea monosperma* has been examined to check the inhibitory effectiveness of mild steel corrosion in 0.5 M H_2SO_4 by using polarization measurements and EIS technique. The adsorption of *Butea monosperma* extract on the surface of mild steel has been investigated by using AFM study, SEM study and absorption spectroscopic techniques. This investigation clearly tells us that the extract of *Butea monosperma* shows very high corrosion inhibition efficiency so it can be used in the form of an excellent inhibitor to protect the metal from corrosion.

Keywords: *Butea monosperma*, Electrochemical Impedance Spectroscopy, Polarization Measurements, SEM, AFM, weight loss measurements.

1. INTRODUCTION

Corrosion is as old as the earth itself. Referred to world as rust, corrosion is an undesirable wonder which obliterates the shine and excellence of the materials and reduces their life. It is a consistent and constant issue, frequently can’t be discarded completely. Corrosion is an irreversible interfacial response of a material with its environment which brings about the utilization of the material or its disintegration into the material of a segment of nature. With mild steel we can make a wide variety of hardware and metallic structures because it is easily available and enormous mechanical excellence. A significant part of the mild steel that is produced is presented to open air conditions, regularly in exceedingly dirtied environments where corrosion is significantly more serious than in clean situations. The compound we use to remove the impurities and unwanted surface deposits from the metal surface consists of strong acids. [1].

Natural and inorganic compounds constitute a substantial class of corrosion inhibitors, which influence the whole surface of a corroding metal when present in adequate mass. The vast majority of the natural/inorganic compounds containing elements of groups functional groups of the sort NH_2, C=O and CHO is known to be viable inhibitors [2]. Previous researchers have been reported a number of organic inhibitors [3-7]. But they are highly toxic. Abundant work has been done utilizing natural compounds for restraint of corrosion, however next to being exceptionally costly, they have a few negative consequences for the environment. One of the techniques to counteract corrosion is to utilize eco-friendly and benign inhibitors. Compounds (normally natural) containing heteroatom like sulfur, N or phosphorous are known to demonstrate amazing corrosion hindrance productivity. These compounds get adsorbed on the metal surface to stimulate the improvement of a defensive layer. This happens as a consequence of connection between the lone pair or the π-orbital of the metals [8-11]. The *Butea monosperma* extract consists of Stigmasterol β-D-glucopyranoside [12]. *Punica granatum* [13], *Sida acuta* [14], *Osmanthus fragran* [15], *Salvia officinalis* [16], *Euphorbia falcata* [17], *Atropa belladonna* [18], *Nicotiana tabacum* [19], *Pimenta dioica* [20] have been investigated by other researchers as better corrosion inhibitors. Figure 1 shows the chemical constituent of *Butea monosperma* extract.



Stigmasterol β -D-glucopyranoside

Figure 1. Chemical constituent of *Butea monosperma.*

2. EXPERIMENTAL

2.1. Preparation of plant extract

The raw product of *Butea monosperma* was purchased from the market and it was validated by a botanist in the Department of Biotechnology Lovely Professional University Punjab, India. First, the raw product was grinded and converted to powder form. Then the powdered *Butea monosperma* was dissolved in 500 ml distilled water. Then the extract was taken out with the help of soxhlet apparatus. The extract obtained by this method was filtered. Finally the extract was concentrated by a rotator evaporator.

2.2. Weight loss measurements

The composition of mild steel which has been used in the experiment is given here- Fe 97.60%, C, 0.083%, is 0.39%, men 0.43%, P 0.12%, Cr 0.45%, Ni 0.27% and Cu 0.43%. From weight loss measurement, we made this measure that how much was then lost in weight of mild steel strip when it was dissolved in 0.5 M H_2SO_4 solution. The rectangular specimens of mild steel were taken. They were cleaned with different grades of emery paper. Then the specimens were rinsed with double distilled water and dried out. These specimens were poured into the acid solution with different inhibitor concentration. Here we noted down the initial weight of mild steel specimens when they were poured into the solution and final weight of the specimens, i.e. when they were extracted from the solution after a time period of three hours. In this way we got to know how much was the total loss in weight of steel specimens. 0.5 M H_2SO_4 was used for the presented investigation. By using the weight loss values we calculated the inhibition efficiency and surface coverage, i.e. the total surface covered by inhibitor with the help of following formulas-

$$\theta = \frac{w_0 - w_\mathrm{i}}{w_0} \tag{1}$$

$$\eta(\%) = \frac{w_0 - w_i}{w_0} \times 100 \tag{2}$$

Where w_i and w_0 are the weight loss values in the presence and absence of inhibitor, respectively

2.3. Electrochemical measurements

The impedance techniques are utilized to estimate the corrosion rate, because the two fold layer capacitance and charge exchange resistance (Rct) can be resolved. CH Instrument Electrochemical Workstation was used to carry out such studies. The instrument was connected with a three cell assembly which already contained the working electrode i.e. specimen of mild steel, a calomel electrode as a reference electrode and a platinum electrode as a counter electrode. Here we studied the Tafel extrapolation and EIS techniques. Both these techniques are helpful to calculate the inhibition efficiency. The Tafel plots were recorded with a scan rate of 1 mVs^{-1} and The EIS spectra was recorded with 5 mV AC amplitude over a frequency range of 0.1 Hz-100 KHz. By applying both these techniques the inhibition efficiency has been determined with the help of following formula-

$$\eta(\%) = \frac{I_{0corr} - I_{icorr}}{I_{0corr}} \times 100 \tag{3}$$

Where I_{0corr} and I_{icorr} represent the corrosion current density values without and with inhibitor, respectively.

Impedance measurements can also be carried out with the help of such studies. Here we get the Nyquist curves. The inhibition efficiency on the basis of impedance study can be calculated by using the following formula-

$$\eta\% = \frac{R_{ct} - R^0_{ct}}{R_{ct}} * 100 \qquad (4)$$

Where Rct and R^0_{ct} are the charge transfer resistance with inhibitor and without inhibitor respectively.

2.4. UV- Visible Spectroscopy

With the help of UV-Visible absorption spectrophotometer the UV spectra of 0.5 M H_2SO_4 in which the mild steel specimens were poured, taken out. The spectra were taken out in two different situations i.e. the acidic solution of inhibitor in which the mild steel specimens were not poured and the other for that solution in which the steel specimens were poured. Both these spectra were compared to explain the mechanism of inhibition.

2.5. IR Spectroscopy

For a better understanding of inhibition mechanism the IR spectra of *Butea monosperma* extract was taken out. From IR spectra we found out what heteroatoms are present in the extract which is responsible for adsorption of inhibitor on the surface of metal.

2.6. Surface Analysis

SEM and AFM techniques were carried out to study the adsorption of *Butea monosperma* extract on the steel specimens. For this the steel specimens were poured into 0.5 M H_2SO_4 without and with *Butea monosperma* extract for a time period of three hours and then the SEM and AFM images of mild steel specimens were taken.

3. RESULTS AND DISCUSSION

3.1. IR study

In IR spectra of *Butea monosperma* the peak at 3412cm^{-1} is due to O-H stretching of alcohol, the peak at 1024 cm^{-1} shows C-O stretching and the peak at 1641 cm^{-1} shows C=C stretching. IR spectra of Butea monosperma extract is shown in figure 2.

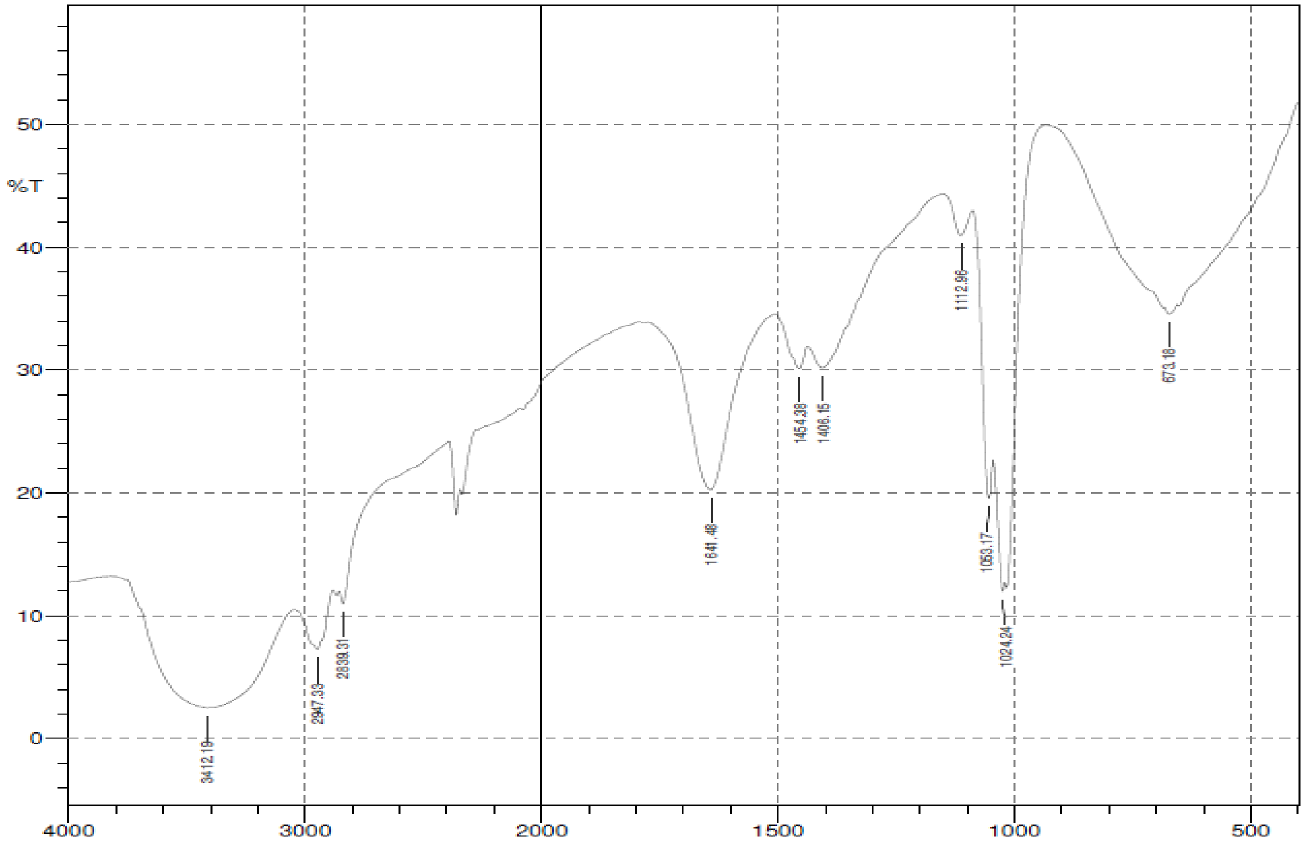


Figure 2. IR Spectra of *Butea monosperma* extract.

3.2 UV Visible spectroscopy:

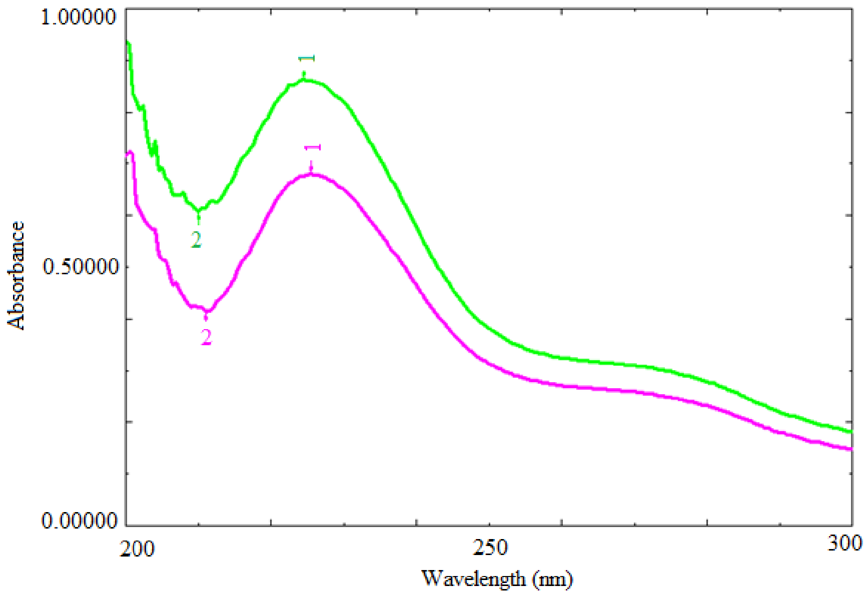


Figure 3. UV Spectra of Butea monosperma extract before and after immersion of mild steel strips.

The UV spectra of *Butea monosperma* extract saturated with 0.5 M H_2SO_4 before and after immersing from the solution were compared and they have been shown in figure 3. From the absorption spectra it is clear that the absorbance of solution in which steel specimen was not poured is higher compared to the solution in which mild steel specimen was poured into for a period of three hours. It clearly indicates that when the mild steel specimen was poured into the acidic solution of *Butea monosperma* extract, then some molecules from the solution have been adsorbed on the metal surface.

3.3. Weight loss study

Table 1. Corrosion parameters for mild steel in 0.5 M H_2SO_4 without and with various concentrations of *Butea monosperma.*

Acid solution	**Inhibitor Concentration (ppm)**	**Weight loss (g)**	**Efficiency (η %)**	**Surface coverage (θ)**
0.5 M H_2SO_4	0	0.23	00	00
	100	0.055	76.086	0.76086
	200	0.04	82.60	0.8260
	300	0.04	82.60	0.8260
	400	0.03	86.95	0.8695
	500	0.034	87.45	0.8745

The results obtained by weight loss study for steel specimens in 0.5 M H_2SO_4 without and with *Butea monosperma* extract have been shown in table 1. The weight loss study clearly points out that the inhibition efficiency increases with increasing the concentration of *Butea monosperma* inhibitor.

3.4. Polarization Measurements

Table 2. Potentiodynamic polarization parameters for the corrosion of mild steel in 0.5 M H_2SO_4 without and with different concentrations of extract.

Inhibitor concentration (ppm)	**E_{corr} (V)**	**I_{corr} (A)**	**$β_a$ (V/decade)**	**Bc (V/decade)**	**Efficiency (η %)**
0	-0.465	0.008909	141.663	164.257	0
100	-0.445	0.0003677	55.276	117.79	95.87
200	-0.451	0.0003328	49.298	113.71	96.26
300	-0.453	0.0002230	50.387	115.300	97.49
400	-0.574	0.0001977	50.95	111.64	97.78
500	-0.464	0.0001836	49.43	117.43	97.94

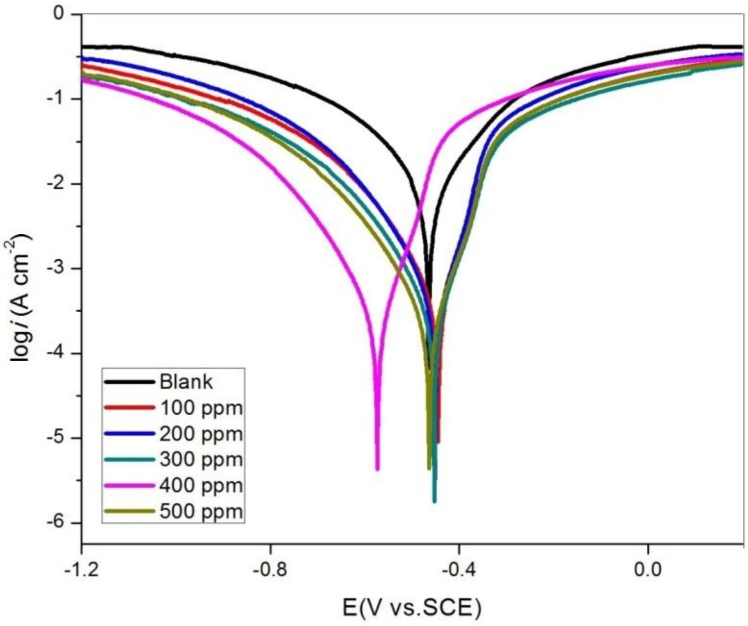


Figure 4. Tafel polarization curves for mild steel in 0.5 M H_2SO_4 with various concentrations of *Butea monosperma* extract.

Concentration effect of the *Butea monosperma* extract on the polarization behaviour of mild steel in 0.5 M H_2SO_4 was analyzed and the Tafel plots were recorded for different inhibitor concentrations which are shown in figure 4. From Tafel plots we got the values of corrosion potential (E_{corr}), anodic Tafel slope (β_a), cathodic Tafel slope (βc), corrosion current density (I_{corr}) and inhibition efficiency which are given in table 2. With the increase in inhibitor concentration surface coverage also increases.

3.5. EIS Measurements

Table 3. EIS parameters for the corrosion of mild steel in 0.5 M H_2SO_4 without and with different concentrations of *Butea monosperma* extract.

Acid Solution	**Inhibitor concentration (ppm)**	**Rct (Ω cm^2)**	**CPE (ΩF cm^{-2})**	**Efficiency (η %)**
0.5 M H_2SO_4	0	1.535	0.010622	0
	100	44.005	0.000303	96.51
	200	48.138	0.000338	96.81
	300	80.553	0.000297	98.09
	400	91.641	0.000316	98.32
	500	96.597	0.000204	98.41

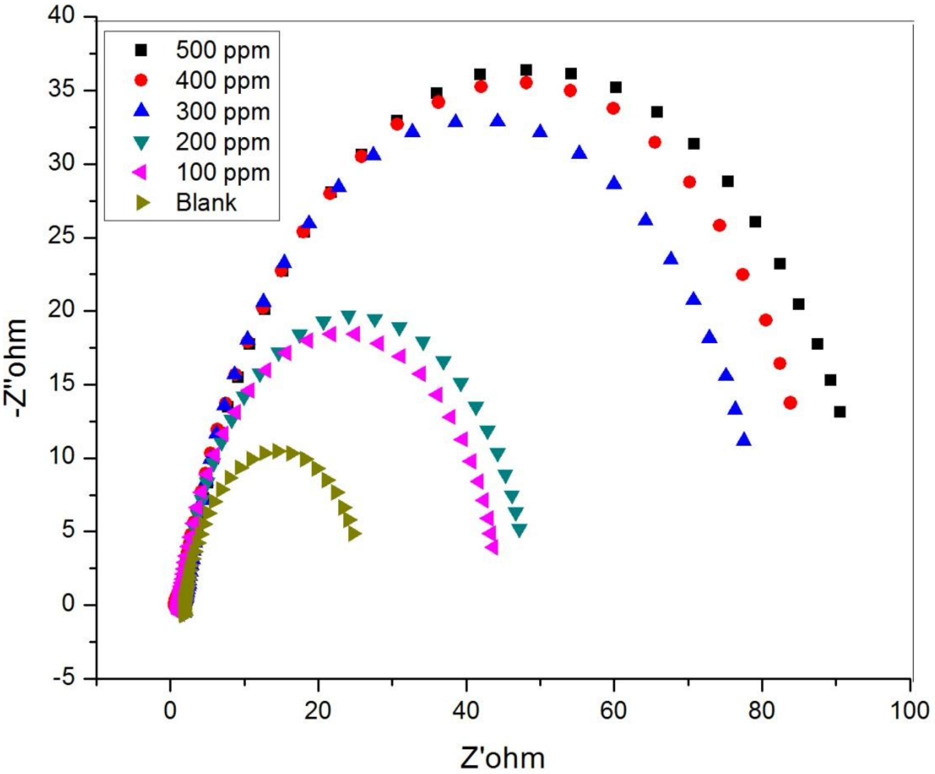
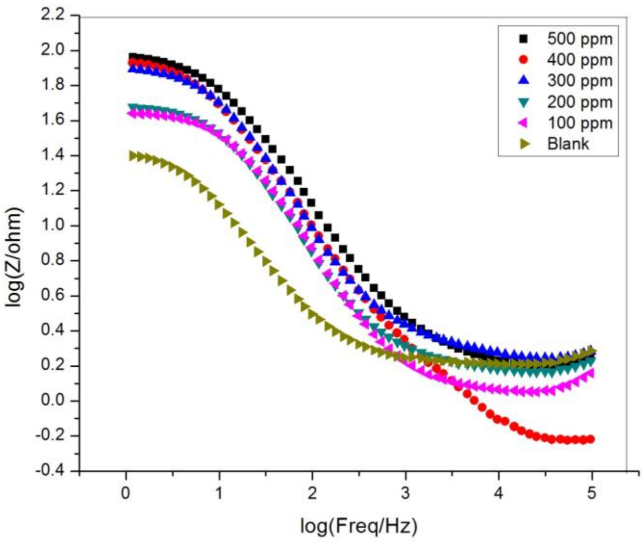
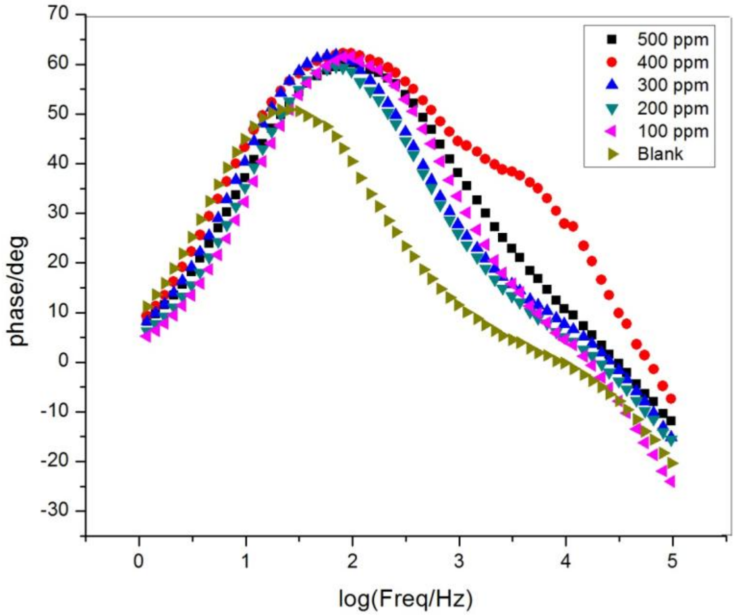


Figure 5. Nyquist plots for mild steel in 0.5 M H_2SO_4 with various concentrations of *Butea monosperma* extract.

For studying the impedance parameters of mild steel specimens in 0.5 M H_2SO_4 with different concentrations of *Butea monosperma* inhibitor EIS measurements were carried out. The results are shown in table 3.



A



B

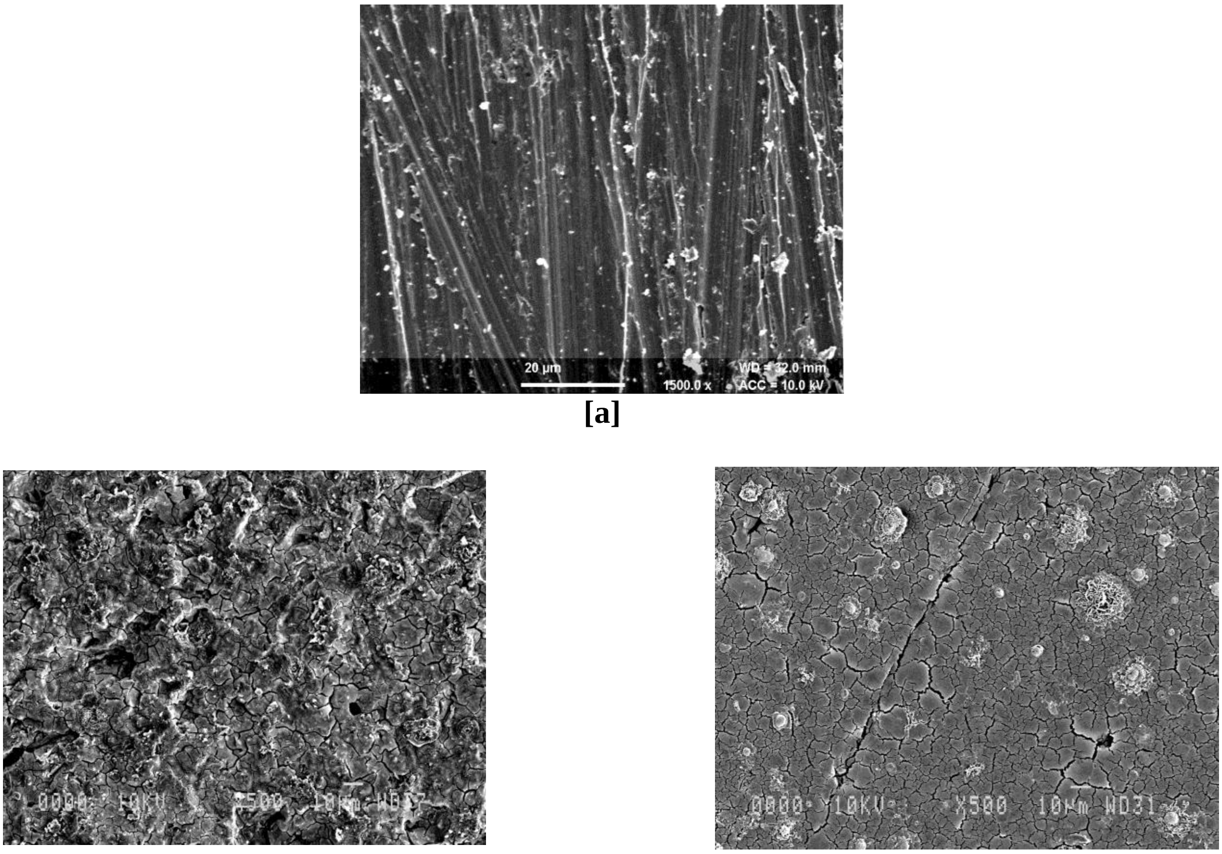
Figure 6. Bode plots for mild steel in 0.5 M H_2SO_4 in the absence and presence of *Butea monosperma* extract.

Nyquist plots for mild steel in 0.5 M H_2SO_4 in the absence and presence of inhibitor is shown in figure 5. The impedance spectra illustrate that by increasing the concentration of inhibitor the diameter of the semicircle increases. The result clearly indicates that *Butea monosperma* inhibitor inhibits the corrosion of mild steel at any concentration used and on increasing the inhibitor concentration, inhibition efficiency increases [21]. Bode plots for mild steel in 0.5 M H_2SO_4 in the absence and presence of different concentrations of inhibitor are shown in figure 6 [a] and 6 [b]. The increase in phase angle shift shows the progress of surface coverage by *Butea monosperma* extract.

3.6. Surface Analysis

3.6.1. Scanning Electron Microscope

The surface morphology of mild steel in 0.5 M H_2SO_4 solution without and with *Butea monosperma* inhibitor has been shown in figure 7. Figure 7 [a] is the SEM of polished mild steel, 7 [b] is the SEM of mild steel sample after 3 hour immersion in 0.5 M H_2SO_4 and a badly damaged surface is observed. When we used the *Butea monosperma* inhibitor then the surface of mild steel is comparatively improved as shown in figure 7 [c].



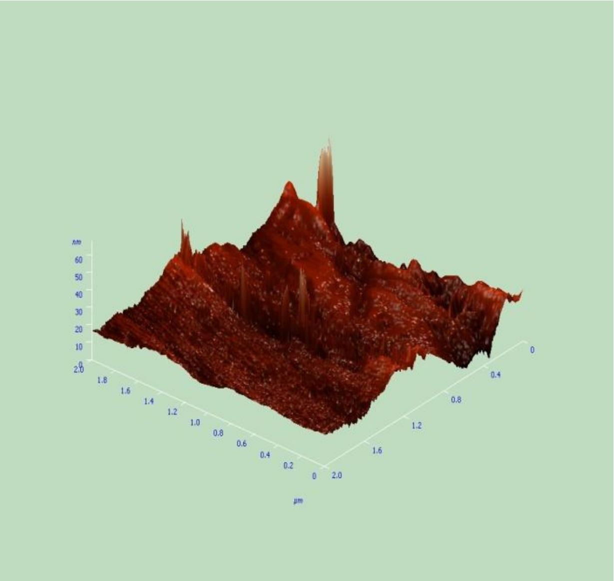
[a]

[b]

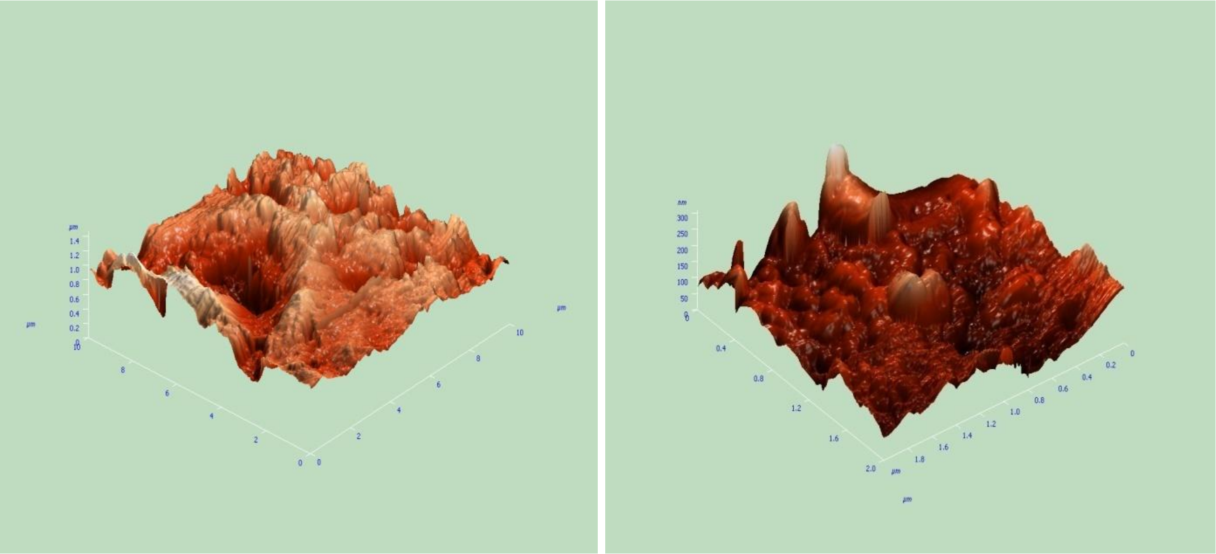
[c]

Figure 7. SEM images of polished mild steel [a], mild steel immersed in 0.5 M H_2SO_4 without inhibitor [b] and mild steel immersed in 0.5 M H_2SO_4 saturated with *Butea monosperma* inhibitor [c].

3.6.2. Atomic Force Microscope



[a]



[b] **[c]**

Figure 8. AFM images of polished mild steel [a], mild steel immersed in 0.5 M H_2SO_4 without inhibitor [b] and mild steel immersed in 0.5 M H_2SO_4 saturated with *Butea monosperma* inhibitor [c].

The three dimensional AFM images of polished mild steel, uninhibited mild steel and inhibited mild steel in 0.5 M H_2SO_4 with *Butea monosperma* extract have been shown in figure 8 [a], 8 [b] and 8 [c] respectively. The average surface roughness for polished mild steel is 2.099 nm. In the absence of *Butea monosperma* extract the surface of mild steel is strongly damaged due to the dissolution of metal in the acid solution. The average surface roughness in this case is 138.807 nm. While in the presence of *Butea monosperma* extract the value of average surface roughness is 27.90 nm. The decrease in average surface roughness of the mild steel specimen is due to the adsorption of *Butea monosperma* inhibitor on the metal surface. It can be said that a protective layer is formed on the surface of metal.

3.7. Mechanism of action

The adsorption of *Butea monosperma* inhibitor on the surface of mild steel can occur in following two ways-

(a) Because of the interaction between the p-electrons of aromatic ring and vacant d-orbital of metal.

(b) Because of the interaction between lone pair of hetero atoms and vacant d-orbital of metal.

The mechanism of corrosion inhibition is shown in figure 9.

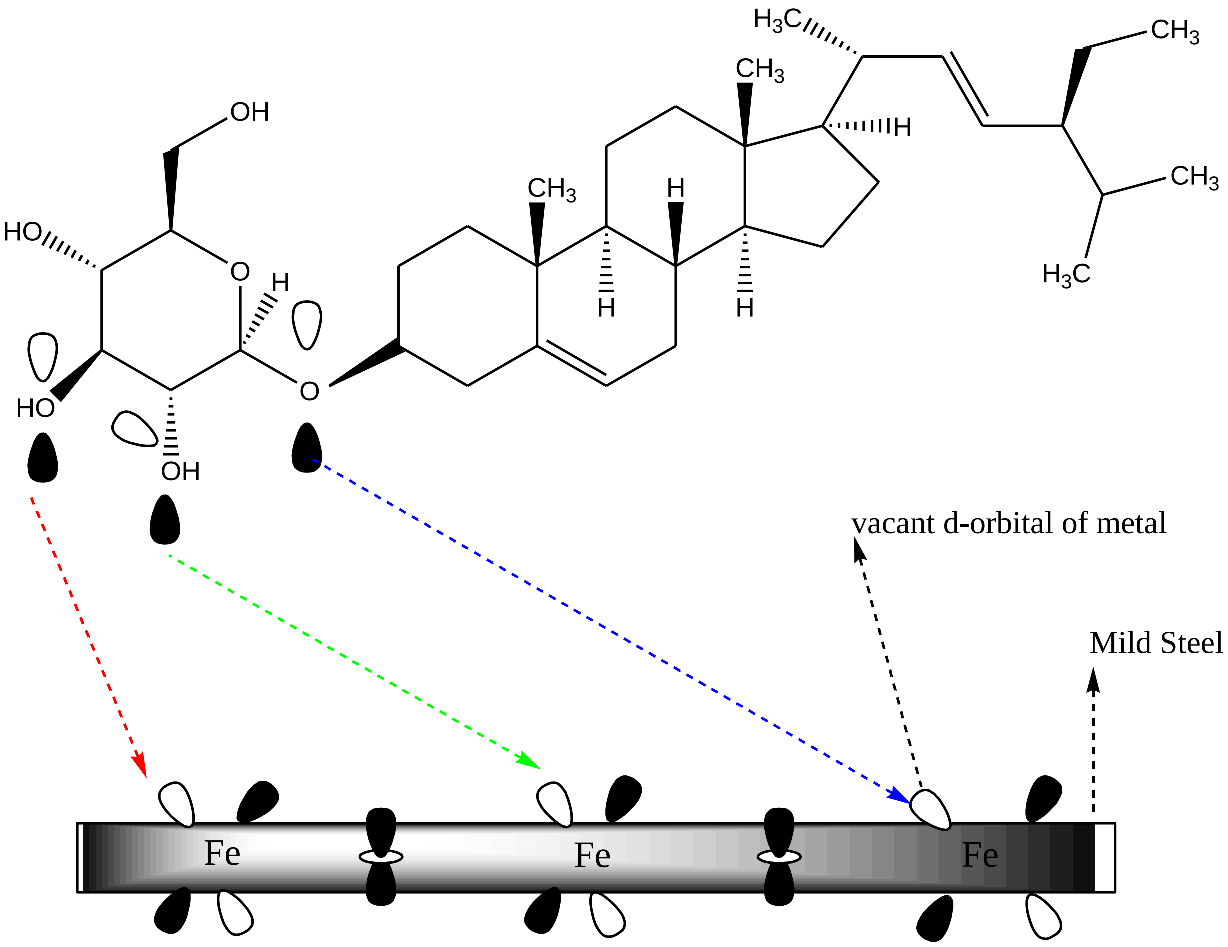


Figure 9. Mechanism of corrosion inhibition.

4. CONCLUSION

On the basis of the presented experiment we got the following conclusions-

1. Maximum 98% inhibition efficiency was observed for *Butea monosperma* plant extract at 500 ppm inhibitor concentration.
2. The surface analysis tells that on using the *Butea monosperma* extract on mild steel surface decreases the corrosion rate and improves the surface damage.
3. *Butea monosperma* plant extract can be a better corrosion inhibitor for mild steel.
4. The increase in inhibition efficiency on increasing the inhibitor concentration has been verified by different electrochemical processes.
5. Compared to our previous study for the plant extract of *Withania somnifera* for which we obtained 91% inhibition efficiency at 300 ppm concentration [22], the plant extract of *Butea monosperma* shows 96% efficiency at just 100 ppm inhibitor concentration.

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References

1. M. Quraishi, A. Singh and V. Singh, *Mater. Chem. Phys.*, 122 (2010) 114.
2. A. Fouda and A. Ellithy, *Corros. Sci.*, 51 (2009) 868.
3. M. Quraishi and R. Sardar, *Corros.*, 58 (2002) 103.
4. H. Lateef, L. Aliyeva and V. Abbasov, *Adv. Appl. Sci. Res.*, 3 (2012) 1185.
5. M. Lebrini, M. Lagrenee, H.Vezin, L.Gengembre and F. Bentiss, *Corros. Sci.*, 47 (2005) 485.
6. F. Bentiss, M. Bovanis, B. Mernari, M.Traisnel and M.Legrenee, *Appl. Surf. Sci.*, 253 (2007) 3696.
7. G. Husnu and S. Ibrahim, *Ind. Eng. Chem. Res.*, 51 (2012) 785.
8. D. Yadav, D. Chauhan, I. Ahamad and M. Quraishi, *RSC Adv.*, 3 (2013) 632.
9. G. Dwivedi, S. Sundaram and R. Prakash, *Ind. Eng. Chem. Res.*, 52 (2013) 10673.
10. J. Aljourani, K. Raeissi and M. Golozar, *Corros. Sci.*, 51 (2009) 1836.
11. H. Sorkhabi, D. Seifzadeh and M. Hosseini, *Corros. Sci.*, 50 (2008) 3363.
12. M. Mishra, Y. Shukla and S. Kumar, *Phytochem.*, 54 (2000) 835.
13. M. Behpour, S. Ghoreishi, M. Khayatkashani and N. Soltani, *Mater. Chem. Phys.*, 131 (2012) 621.
14. U. Eduok, S. Umoren and A. Udoh, *Arabian J. chem.*, 5 (2012) 325.
15. L. Li, X. Zhang, J. Lei, J. He, S. Zhang and F. Pan, *Corros. Sci*, 63 (2012) 82.
16. N. Soltani, N. Tavakkoli, M. Khayatkashani, M. Jalali and A. Mosavizade, *Corros. Sci.*, 62 (2012) 122.
17. A. Bribri, M. Tabyaoui, B. Tabyaoui, H. Attari and F. Bentiss, *Mater. Chem. Phys.*, 141 (2013) 240.
18. K. Shalabi, Y. Abdallah, H. Hassan and A. Fouda, *Int. J. Electrochem. Sci.*, 9 (2014) 1468.
19. J. Bhawsar and P. Jain, *Alexandria Eng. J.*, 54 (2015) 769.
20. K. Anupama, K. Ramya, K. Shainy and A. Joseph, *Mater. Chem. Phys.*, 167 (2015) 28.
21. E. Noor, *Mater. Chem. Phys.*, 131 (2011) 160.
22. A. Saxena, D. Prasad and R. Haldhar, *Asian J. Chem.*, 28 (2016) 2471.

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