The performance of the Galactomannan as a green inhibitor to protect the carbon steel against corrosion

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Introduction

Natural substances as bio-sourced polymer extracted from plants has been a target in the field of corrosion inhibition to protect iron in different corrosive media. It was found that these substances have a remarkable inhibiting efficiency. Their usefulness is due to the fact that they are ecological and non-toxic compounds [1].

In aim to valorize the galactomannan extract from *Ceratonia Siliqua* L, we used it as a corrosion inhibitor to improve the resistance of the carbon steel, and to minimize the aggressive attack of 1M HCl medium [2].

Materials and Methods

The inhibition performance of the Galactomannan polymer against carbon steel corrosion in a deaerated 1 M HCl solution at 298K are evaluated using the electrochemical measurements (polarization measurements and impedance spectroscopy tests) and theoretical study (DFT and molecular dynamic) [2].

The carbon steel with the following chemical composition: 0.2% of Si, 0.519% of Mn, 0.157% of C, 0.007% of P, 0.009% of S and the rest is iron

The protective effect was confirmed by analyzing the surface morphology of carbon steel with and without inhibitor in 1MHCl solution using scanning electron microscopy SEM coupled with elemental analysis EDS [2].

Results and Discussion

The potentiodynamic polarization plots demonstrated that galactomannan can reduce the corrosion current density as a function of the concentration, indicating the mixed type protection character.

Table. 1: The electrochemical parameters of the polarization curves of an iron electrode in a 1M HCl solution.

Concentration (g/L)	*$-E_{corr}$ (mV/SCE)*	*i_{corr} ($\mu A/cm^2$)*	*$-\beta_c$ (mV/dec)*	*β_a (mV/dec)*	*P (%)*
1M HCl	471.2	242.1	269.7	69.7	…..
0.25	474.6	52.0	228.5	73.3	78.3
0.50	493.0	49.1	152.4	66.8	79.6
0.75	505.8	43.0	150.7	83.3	82.1
1.00	517.9	32.1	114.2	77.3	86.7

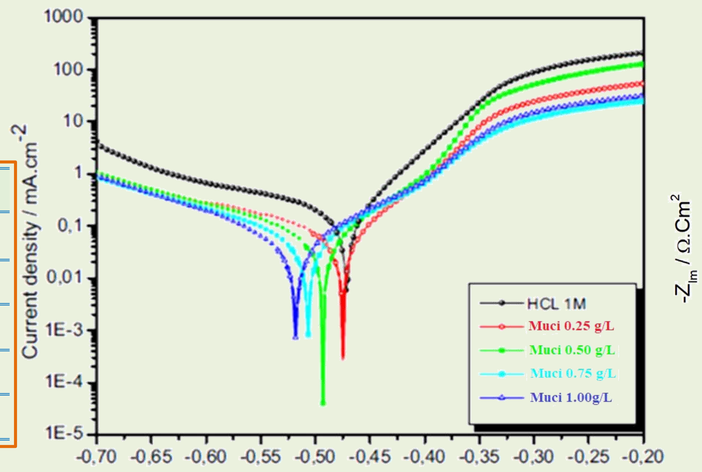

Figure 1. The anodic and cathodic plots of the iron electrode in the 1M HCl solution with and without the various concentration of the Galactomannan

The EIS plots were affected by the two studied variables, the sizes of the loops increased with the increase in the inhibitor concentration and the increase in the immersion time.

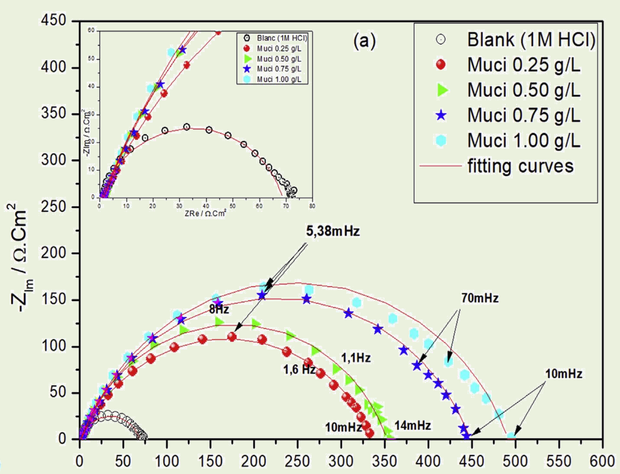

Figure 2. Nyquist diagrams of iron immersed in 1M HCl solution without and with different concentrations of the Galactomannan.

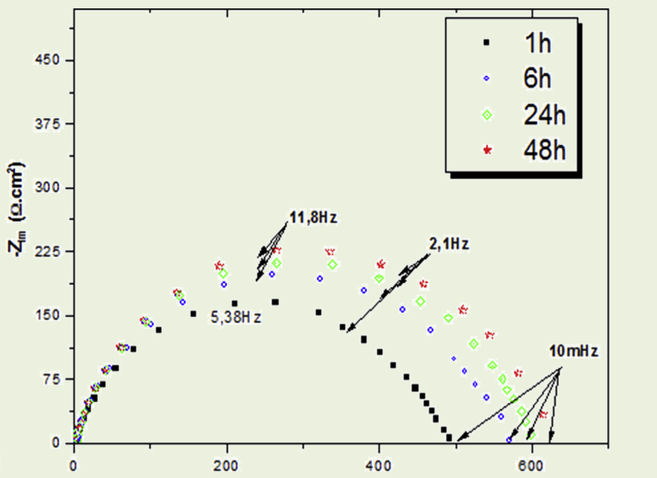

Figure 3. Electrochemical impedance diagrams at different immersion times of an iron electrode in a 1M HCl solution in presence of the inhibitor (1 g/L).

Theoretical calculations imply that oxygen atoms may serve as adsorption sites linking the molecule and the iron. Molecular simulation reveals that the biopolymer can be adsorbed on the carbon steel surface in a closely paralleled way with O–Fe bonds by both physisorption and chemisorption.

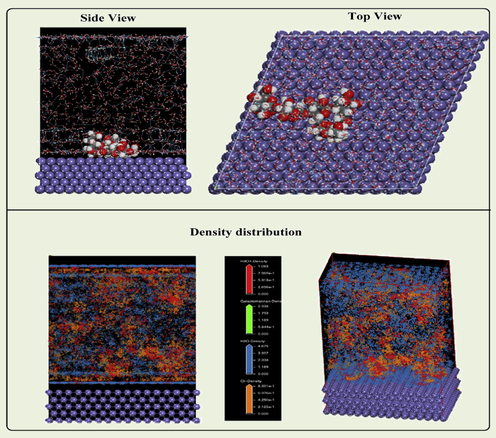

Figure 4. Lateral and Up views of the adsorption (Fe_{110}/Biopolymer/H_2O) and density distribution.

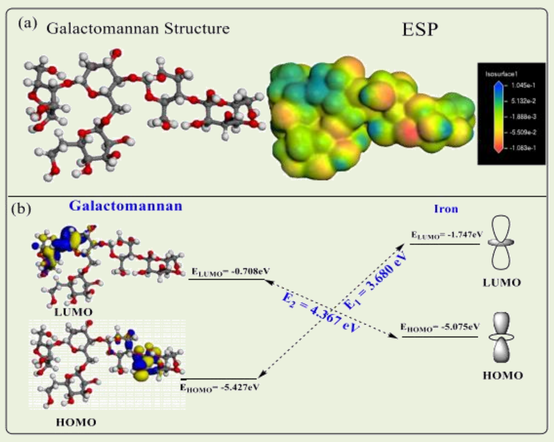

Figure 5. (a) distribution of the frontiers orbitals (HOMO and LUMO) of the inhibitor and ESP and (b) Schematic illustration of the Iron-Galactomannan interactions

The surface morphology study by SEM coupled with EDS confirms the high protective effect of Galactomannan by the formation of an inhibitor film on the metal surface which limits the corrosion rate due to the 1 M HCl solution.

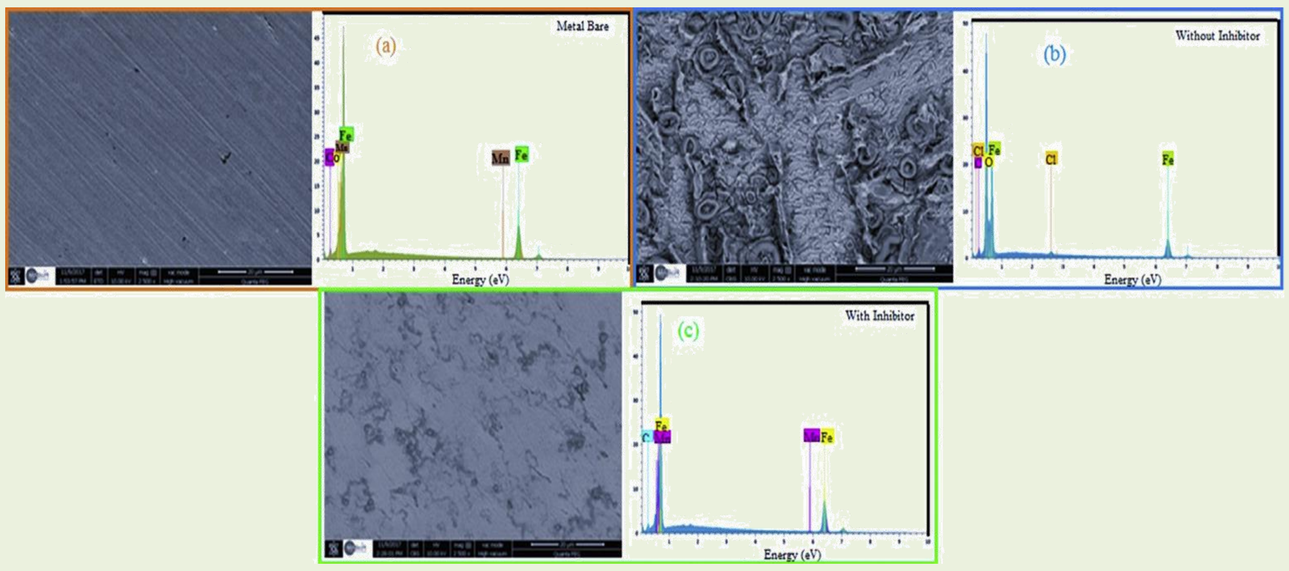

Figure 6. SEM micrograph and EDS spectrum of the iron substrate:
(a): The iron surface**; (b):** The iron surface in case of the blank (1M HCl); **(c):** The iron surface in solution with inhibitor

Conclusion

This research demonstrated the feasibility and the potential of the galactomannan extracted from carob seeds to inhibit carbon steel corrosion in 1M HCl solution.

Obtained results confirmed that this inhibitor behaves as a good mixed corrosion inhibitor. The inhibition efficiency is more important when the concentration of the inhibitor and the immersion time increase, reaching a value of 86.7% at a concentration of 1 g/L.

Surface analysis using SEM/EDS confirms the high inhibition efficiency values that can be attributed to the formation of an inhibitor film on the carbon steel surface.

Theoretical calculations and Molecular simulation confirmed the obtained results.

References

[1] S.A. Umoren, U.M. Eduok, Application of carbohydrate polymers as corrosion inhibitors for metal substrates in different media: a review, Carbohydr. Polym. 140 (2016) 314-341.

[2] S. Abbout , M. Zouarhi , D. Chebabe, M. Damej , A. Berisha , N. Hajjaji, Galactomannan as a new bio-sourced corrosion inhibitor for iron in acidic media, Heliyon 6 (2020) 1-13.

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