Surface Morphology of Protective Film Formed On the Mild Steel Surface Using Contact Angle Measurement

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Abstract

Surface morphology of the metal or alloy is one of the important parameter in corrosion studies. Many methods are available for analysing surface properties. One such method is contact angle measurement. It is used to analyze the hydrophobic nature of the protective film formed on the metal or alloy surface in the presence of inhibitor systems. Contact angle measurement reveals that all the inhibitor systems have good corrosion inhibition efficiency.

Keywords: *contact angle measurement, corrosion, inhibitor, hydrophobic nature*

1. Introduction

Corrosion of mild steel surface in well water medium can be controlled using plant materials as inhibitors by forming protective film. Plant materials are low cost, biodegradable, and readily available. Hence plant materials are used as corrosion inhibitors. The corrosion inhibition properties of plant materials are due to the presence of active principle or active ingredient. The active principle forms protective film on the metal or alloy surface using their polar atoms such as nitrogen, oxygen, sulphur and phosphorus. These atoms enrich with lone pair of electrons. These electrons form bonding with metal ions. The nature of the protective film can be studied using contact angle measurement. It is the important tool in the study of hydrophobic nature of the protective film formed on the metal surface. The ability of a solid surface to be wetted by a liquid can be classified by its wetting contact angle, θ_C: hydrophilic ($\theta_C < 90°$), hydrophobic ($90° \leqslant \theta_C \leqslant 150°$), or super-hydrophobic ($\theta_C > 150°$) [1]-[10].

2. Materials and Methods

2.1. Plant Materials Used

The plant materials used for the present study are given in the *Table 1*.

Table 1. Plant Materials Used

S.No	Name of The Plant Material	Part of the plant
1	Allium sativam(Garlic bulb)	Bulb
2	Justicia adhatoda L(Adhatoda vasica leaves)	Leaves
3	Allium cepa L(Onion bulb)	Bulb
4	Camellia sinensis L (Waste Tea dust)	Leaves
5	Lawsonia inermis L(Henna leaves)	Leaves

2.2. Preparation of Inhibitor Solution

10 g of dried and powdered plant material was boiled with distilled water. It was allowed to cool to attain the room temperature. The solution was filtered and the filtrate was made up to 100 mL using distilled water. It was used as corrosion inhibitor in the present study.

2.3. Preparation of the Environment for Surface Examination Studies

The environment selected for surface examination studies are given in *Table 2*. The proportion consists of 90mL well water and 10 mL of inhibitor was chosen as the effective environment to control corrosion.

Table 2. Preparation of the Environments for Surface Examination Studies

S.No	Inhibitor	Environment
1	Aqueous extract of Allium sativam bulb **(**AEGB)	10 mL of Allium sativam bulb extract + 90 mL of well water
2	Aqueous extract of Justicia adhatoda L leaves **(**AEAL)	10 mL of Justicia adhatoda L leaves extract + 90 mL of well water
3	Aqueous extract of Allium cepa L bulb **(**AEOB)	10 mL of Allium cepa L bulb extract + 90 mL of well water
4	Aqueous extract of Camellia sinensis L leaves **(**AEWT)	10 mL of Camellia sinensis L leaves extract + 90 mL of well water
5	Aqueous extract of Lawsonia inermis L leaves (AEHL**)**	10 mL of Lawsonia inermis L leaves extract + 90 mL of well water

2.4. Contact Angle Measurement Technique

The contact angle is the angle, conventionally measured through the liquid, where a liquid–vapour interface meets a solid surface. It quantifies the wettability of a solid surface by a liquid via the Young equation. A given system of solid, liquid, and vapour at a given temperature and pressure has a unique equilibrium contact angle. However, in practice a dynamic phenomenon of contact angle hysteresis is often observed, ranging from the advancing contact angle to the receding contact angle. The equilibrium contact is within those values, and can be calculated from them. The equilibrium contact angles reflect the relative strength of the liquid, solid and vapour molecular interaction [11], [12].

3. Result and Discussion

3.1. Analysis of Contact Angle Measurement

Contact angle measurement is useful in explaining the hydrophobicity of the surface of the mild steel and surface of the protective film formed. When contact angle increases, hydrophobicity also increases. Because of this, water repellent nature of the surface increases and hence corrosion inhibition efficiency increases. The contact angle images of mild steel surfaces in various environments are shown in *Figure 1*. The contact angle values of polished mild steel, mild steel immersed in corrosive environment (well water) and mild steel immersed in inhibitor systems are in given in the *Table 3*.

Table 3. Contact Angle of Various Surfaces

S.No	System	Contact Angle in Degree
1	Polished mild steel	115.8
2	Mild steel immersed in well water	23.5
3	Mild steel immersed in aqueous extract of Allium sativam bulb	46.7
4	Mild steel immersed in aqueous extract of Justicia adhatoda L leaves	49.8
5	Mild steel immersed in aqueous extract of Allium cepa L bulb	98.5
6	Mild steel immersed in aqueous extract Camellia sinensis L leaves	102.8
7	Mild steel immersed in aqueous extract of Lawsonia inermis L leaves	110.1

It is observed from the *Table 3* that the contact angle for polished metal is very high. For polished metal immersed in corrosive medium, the contact angle is very small. For polished metal immersed in inhibitor systems the contact angle is in between that of the above two systems. Thus contact angle measurement technique is useful in explaining the hydrophobicity of metal surface and corrosion inhibition efficiency of the inhibitor systems.

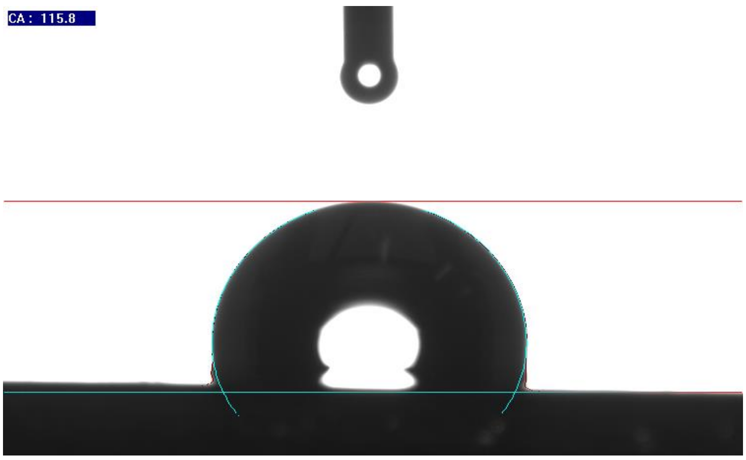

Figure 1a. Polished Mild Steel

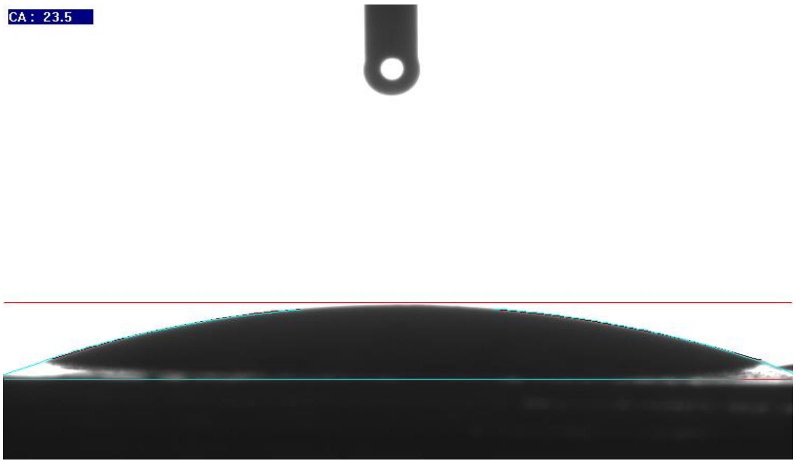

Figure 1b. Mild Steel Immersed In Well Water Medium

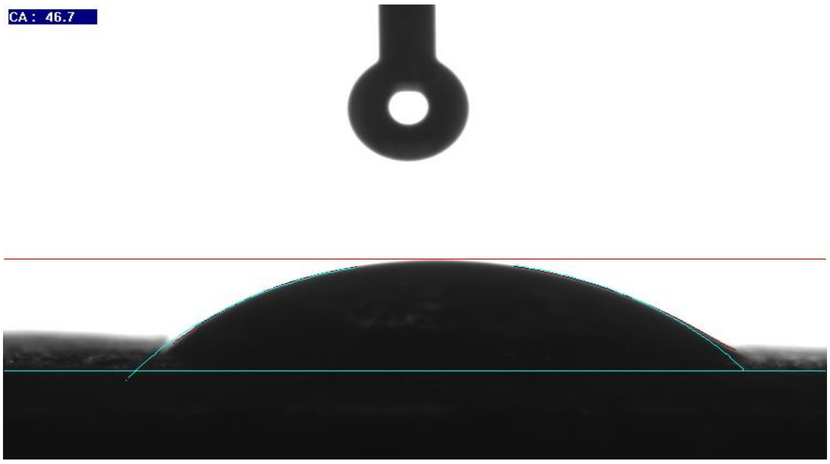

Figure 1c. Mild steel Immersed In Aqueous Extract of Allium Sativam Bulb

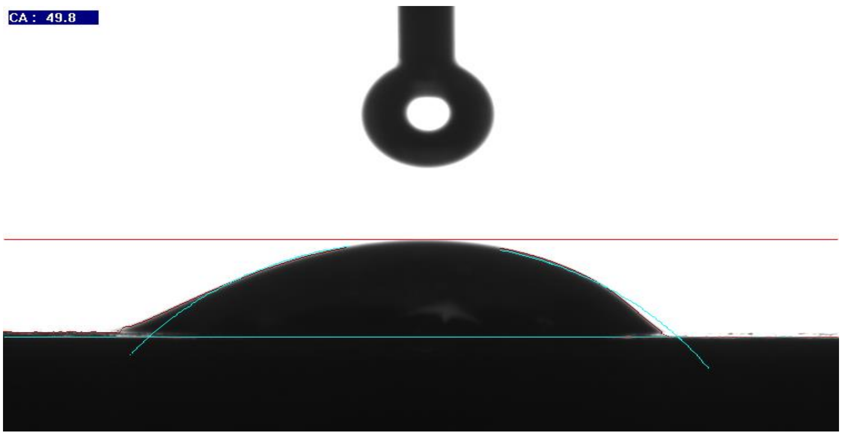

Figure 1d. Mild Steel Immersed In Aqueous Extract of Justicia Adhatoda L Leaves

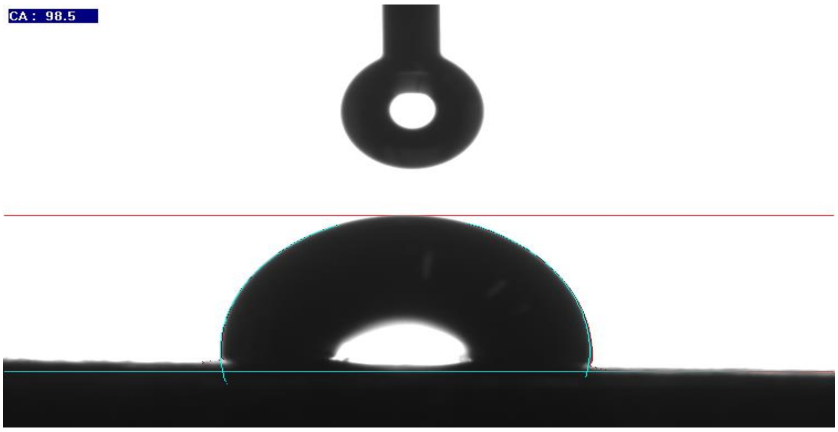

Figure 1e. Mild steel Immersed In Aqueous Extract of Allium Cepa L Bulb

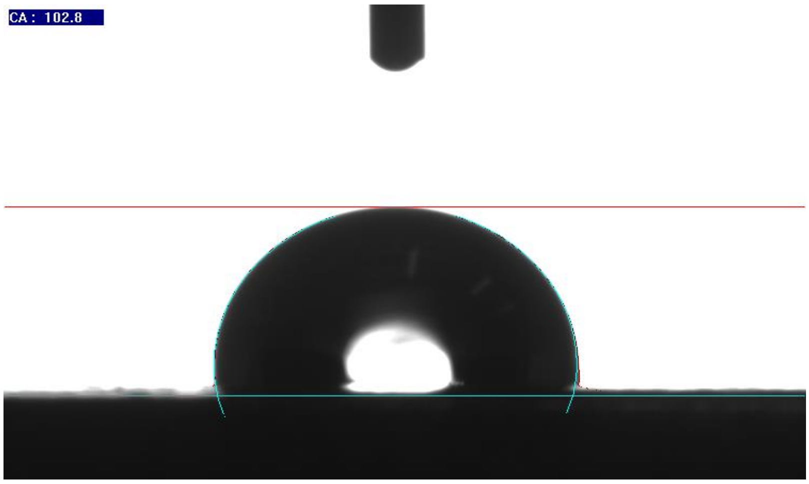

Figure 1f. Mild Steel Immersed In Aqueous Extract Camellia Sinensis L Leaves

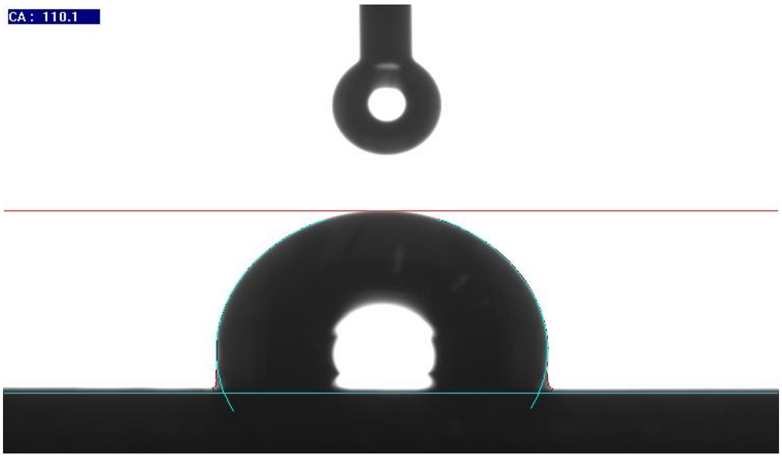

Figure 1g. Mild Steel Immersed In Aqueous Extract of Lawsonia Inermis L Leaves

From the *Figure 1* the contact angle of polished metal surface is 115.8, the corrosive environment is 23.5. In the presence of corrosion inhibitors the contact angle value increase to 46.7, 49.8, 98.5, 102.8, and 110.1.
The contact angle value is in the order of
AEHL (110.1) > AEWT (102.8) > AEOB (98.5) > AEAL (49.8) > AEGB (46.7)

Conclusion

The contact angle value is high in all the inhibitor systems. Contact angle measurement studies reveal that all the inhibitors form protective layer on the mild steel surface in well water environment. All the inhibitors exhibit relatively good corrosion inhibition properties.

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References

[1] *TianyiZhao, LeiJiang, "Contact angle measurement of natural materials", Colloids and Surfaces B: Biointerfaces, Vol. 161, no.1,**(2018)**, pp.324-330.*

[2] *GurramGiridhar, R.K.N.R.Manepalli, GudimamillaApparao, "Chapter 8 - Contact Angle Measurement Techniques for Nanomaterials", Thermal and Rheological Measurement Techniques for Nanomaterials Characterization Micro and Nano Technologies, **(2017)**, pp. 173-195.*

[3] *EmiliaNowak, GaryCombes, E. HughStitt, Andrzej W.Pacek, "A comparison of contact angle measurement techniques applied to highly porous catalyst supports", Powder Technology,Vol.233, **(2013)**, pp.52-64.*

[4] *Douglas J.C.Gomes, Nara C.de Souza, Josmary R.Silva, "Using a monocular optical microscope to assemble a wetting contact angle analyser, Measurement", Vol.46,no.9, **(2013)**, pp.3623-3627.*

[5] *D H Prajitno, A Maulana and D G Syarif, "Effect of Surface Roughness on Contact Angle Measurement of Nanofluid on Surface of Stainless Steel 304 by Sessile Drop Method", Journal of Physics: Conference Series, vol.739 no.1, **(2016)**, 01202.*

[6] *Jackeline B.Brito, Douglas J.C.Gomes, Vanessa D.Justina, Aline M.F.Lima, Clarissa A.Olivati, Josmary R.Silva, Nara C.de Souza, "Nanostructured films from phthalocyanine and carbon nanotubes: Surface morphology and electrical characterization", Journal of Colloid and Interface Science,Vol.367, no.1, **(2012)**, pp.467-471.*

[7] *Hérica Diasda Rocha, Marcosda Silva Sousa, Kevin Figueiredodos Santos , Nara C.de Souza, Josmary R.Silva, "Superhydrophobic films obtained from a spraying technique: Electrowetting dependence on the drying condition and ultraviolet irradiation", Colloids and Surfaces A: Physicochemical and Engineering Aspects,Vol.517, no.20, **(2017)**, pp.12-16.*

[8] *Miklós Mohos, L Románszki, Judit Telegdi, L Nyikos, "Contact Angle Measurement is an Efficient Tool for the Characterization of Corrosion Pro- tection Nanolayers on Copper Alloys and Stainless Steel", Conference: Nanonmaterials: Applications and properties, Vol. 2, no.1,* ***(2013)****, PROC. NAP2 , 01PCSI04.*

[9] *Adel M.A.Mohamed, Aboubakr M.Abdullah, Nathalie A.Younan, "Corrosion behavior of superhydrophobic surfaces: A review", Arabian Journal of Chemistry,Vol.8. no.6,* ***(2015)****, pp.749-765.*

[10] *Judson L. Ihrig, David Y. F. Lai , "Contact angle measurement", Chem. Educ., vol.34(4),* ***(1957)****, pp.196.*

[11] *Loránd Románszki, Miklós Mohos, Judit Telegdi, Zsófia Keresztes, Lajos Nyikos, A comparison of contact angle measurement results obtained on bare, treated, and coated alloy, samples by both dynamic sessile drop and Wilhelmy method, Periodica Polytechnica Chemical Engineering, 58(Sup),* ***(2014)****, pp. 53-59.*

[12] *https://en.wikipedia.org/wiki/Contact_angle.*