Inhibition of Corrosion of Mild Steel in Simulated Concrete Pore Solution in DD water in the presence of self-assembling Nano film of Tri sodium Citrate

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ABSTRACT

Inhibition of corrosion of mild steel in simulated concrete pore solution in DD water in the presence of self-assembling Nano film of Tri sodium citratewith and without the presence of chloride ion has been evaluated by a weight loss method. The formulation consists of 200 ppm of TSC has 98% corrosion inhibition efficiency (IE), in controlling corrosion of mild steel immersed in SCPS. Polarization study reveals that the formulation functions as anodic inhibitor. AC impedance spectra reveal that the formulation of protective film on the metal surface. FTIR spectra reveal that the protective film consists of Fe^{2+} - TSC complex and CaO, $CaCO_3$. The SEM micrographs and EDAX analysis confirm the formation of protective film on the metal surface. AFM images confirm the formation of protective layer on the metal surface.

Keywords: **Simulated concrete pore solution, mild steel, corrosion inhibition, TSC(Tri sodium citrate), fluorescence spectra, SEM,AFM, FTIR, EDAX.**

1. INTRODUCTION

Mild steel, also known as plain-carbon steel, is now the most common form of steel because its price is relatively low, while it provides material properties that are acceptable for many applications. However, the challenge is that it has low corrosion resistance, especially in acidic environments.Corrosion protection of infrastructures such as bridges, steel towers sending electricity and buildings made of steel is very important from the viewpoint of their life expectancy. An extension of their lives is possible by the selection of appropriate corrosion prevention methods. The use of organic inhibitors is one of the most practical methods for protection against corrosion of metals and their alloys. In aqueous solutions, the inhibitory action of organic inhibitors is due to their physical (electrostatic) adsorption onto the metal surface, depending on the charge of the metal surface, the electronic structure of organic inhibitor and the nature of the medium. The present study is carried out to discuss the inhibiting effect of Tri sodium citrate in simulated concrete pore solution in the presence and absence of chloride on the corrosion of mild steel in DD water using weight loss methods, electrochemical studies and surface analysis techniques like Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy (SEM). Polarization study reveals that the inhibitor system controls the cathodic reaction predominantly. AC impedance spectra reveal that a protective film is formed on the metal surface. The above results have been supported by surface morphology study using Scanning electron microscopy carried out on the mild steel samples in the absence and presence of inhibitors.

2. MATERIALS AND METHODS

Metal specimens

The mild steel specimen was used in the present study. (Composition (wt. %): 0.026 S, 0.06 P, 0.4 Mn, 0.1 C and balance iron).
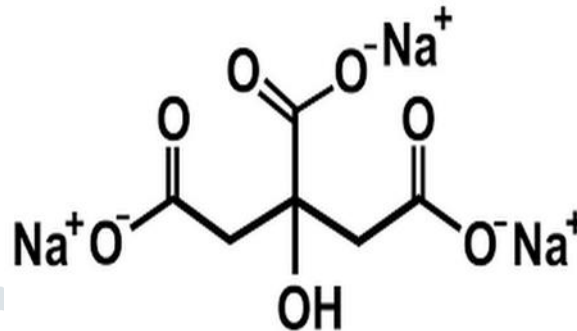
Scheme1. Structure of trisodium citrate

Preparation of the specimens

Carbon steel specimens (0.026%P, 0.4%Mn, 0.1% C and rest iron) of the dimensions 1.0 x 4.0x 0.2 cm was polished to a mirror finish, degreased with trichloroethylene, and used for the weight-loss method.

Simulated Concrete Pore (SCP) Solution

A saturated calcium hydroxide solution is used in the present study, as SCP solution. The electrodes made of mild steel wire were immersed in the SCP solution, polarization study was carried out.

Weight -loss method

Carbon steel specimens were immersed in 100mL of SCPS solution containing various concentrations of the inhibitor in the presence and absence of Cl⁻ for a period of 1 day. The weight of the specimens before and after immersion was determined using a balance, Shimadzu AY62 model. The corrosion products were cleansed with Clark's solution. The inhibition efficiency (IE) was then calculated using the equation:

$$IE=100*[1-(W_2/W_1)] \%$$

Where
W_1 = corrosion rate in absence of the inhibitor,
W_2 = corrosion rate in presence of the inhibitor.

Potentiodynamic polarization study

Polarization study was carried out in an H and CH electrochemical work station impedance analyzer model CHI 660. A three-electrode cell assemble was used. The working electrode was carbon steel with one face of the electrode of constant l cm^2 area exposed and the rest being shielded with red lacquer. A saturated calomel electrode (SCE) was used as reference electrode. Rectangular platinum,

foil was used as the counter electrode. The area of the counter electrode was much larger compared to the area of the working electrode. This can exert a uniform potential field on the working electrode and minimized the polarization effect on the counter electrode. The results such as Tafel slopes, I_{corr} and E_{corr} values were calculated.

The working electrode and platinum electrode were immersed in SCPS solution containing TSC in the absence and presence of Chloride ions.Saturated calomel electrode was connected with the test solution through a salt bridge. Potential (E) vs log current (I) plots were then recorded. Corrosion potential (E_{corr}) and Tafel slopes b_a and b_c were determined from E vs. log I plots. Tangents were drawn on the cathodic and anodic polarization curves. From the point of intersection of the two tangents I_{corr} and E_{corr} were calculated.

AC impedance measurements

A CHI 660A electrochemical impedance analyser model was used to record AC impedance measurements. The cell set up was the same as that used for polarization measurements. The real part (Z') and imaginary (z") of the cell impedance were measured in ohms for various frequencies. The Rt (charge transfer resistance) and Cdl (double layer capacitance values were calculated.

Cyclic Voltammetry

Cyclic voltammograms were recorded in the Versa STAT MC electrochemical system. A three-electrode cell assembly was used. The working electrode was carbon steel. The exposed surface area was 1 cm^2. A saturated calomel electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode. The Cyclic Voltammetry curves were recorded in the scan range of -1.8 to -1.8 V (SCE) with a scan rate of 20 mVs-1.

UV Visible Absorbance Spectra

The instrument UV Spetord S-100 Analytic Jena was used for recording UV-visible absorbance spectra.

Fluorescence Spectra

Fluorescence spectra were recorded in a Glaxo F-6300 Spectro fluorimeter.

Surface analysis by FTIR spectra

FTIR spectra were recorded in a Perkin – Elmer 1600 spectrophotometer. The film was carefully removed, mixed thoroughly with KBr made into pellets and the FTIR spectra were recorded after immersion period of 1 day in various environments, the specimens were taken out of the test solutions and dried. The film formed on the surface was scratched carefully and it was thoroughly mixed so as to make it uniform throughout. The FTIR spectrum of the powder (KBr pellet) was recorded using Perkin – Elmer 1600 FTIR spectrophotometer with are solving power of 4 cm-1.

Scanning Electron Microscopic studies (SEM)

The carbon steel specimen immersed in blank and in the inhibitor solution for a period of one day was removed, rinsed with double distilled water, dried and observed with a scanning electron microscope to examine the surface morphology. The surface morphology measurements of the carbon steel were examined using Hitachi S-3000 H computer controlled scanning electron microscope.

Energy dispersive X-ray analyzer (EDAX)

The elemental analysis of the carbon steel surface at the same condition was carried out using an energy dispersive X-ray analyzer (EDAX).

Atomic force microscopy (AFM)

The mild steel specimens were immersed in blank and in the inhibitor solution for a period of one day. The specimens were removed, rinsed with a double distilled water, dried and subjected to the surface examination. Atomic force microscopy atomic force microscopy (AFM) using Pico SPM 9500-21 with the software version of Pico scan version 5.4.was used to observe the sample's surface in tapping model, using cantilever with linear tips. The scanning area in the images was 50 μm x 50μm and the scan rate was 1 / seconds.

3. RESULTS AND DISCUSSION

Analysis of the weight loss method

The inhibition efficiency of Tri sodium citrate in controlling corrosion of mild steel in SCPS has been evaluated by a weight loss method. The inhibition efficiencies (IE) of SCPS in the absence and presence of chloride ion in controlling corrosion of mild steel are given in Table.1. The influence of Tri sodium citrate on the inhibition efficiency is also given in the table. **[1-3].**

It is observed from the table that when 200 ppm of TSC is added to the SCPS the inhibition efficiency increases to 98%. Howeverwhen 4000 ppm of NaCl is added to the system, the inhibition efficiency decreases from 98% to 91%. This is due to the attack of chloride ion penetrating through the pores of the protective film and attack the metal surface. Thus weight loss study leads to the conclusion that in the presence of chloride ion the inhibition efficiency decreases. In the presence of TSC the inhibition efficiency increases. The corrosion rates of the TSC systems at various concentrations are shown in Fig.1.

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Table.1 Corrosion rate (CR) of mild steel immersed in SCPS prepared in DD water, in the absence and presence of inhibitor and the inhibition efficiency (IE%) obtained by weight loss method.

System	Corrosion rate(CR) (mdd)	IE%
DD Water	20	-
SCPS	7	65
SCPS+ 4000 ppm NaCl	9.6	52
SCPS+ TSC(200 ppm)	0.4	98
SCPS+TSC (200 ppm) + NaCl (4000 ppm)	2	91
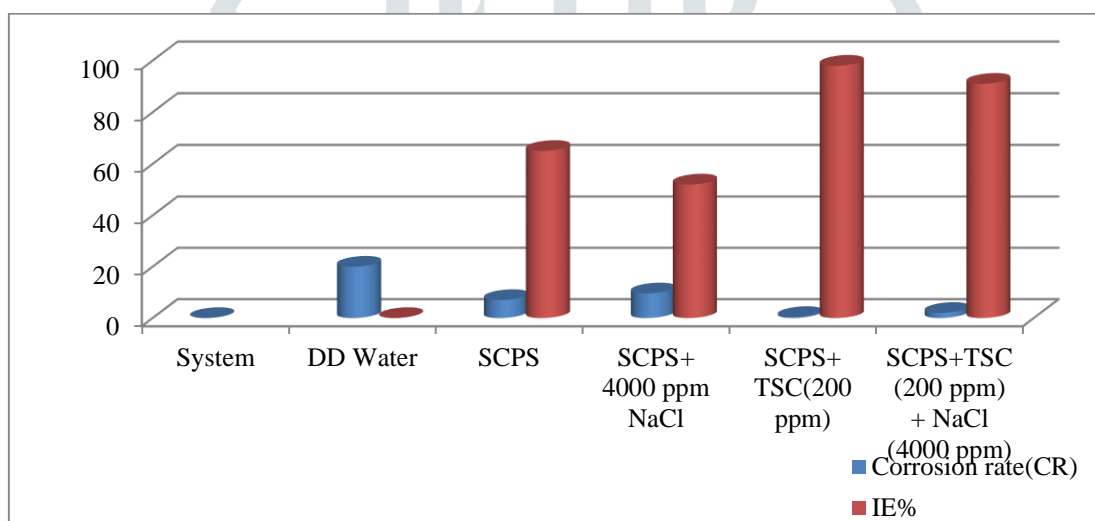
Fig.1 Corrosion rates (CR) of the TSC system in controlling corrosion of mild steel immersed in SCPS prepared in DD water.

Analysis of potentiodynamic polarization study

The Polarization study is useful for confirming the formation of protective film formed on the metal surface **[4-8].** If a protective film is formed, the linear polarization resistance increases and the corrosion current value decrease. The polarization curves of mild steel immersed in various test solutions are shown inFig.2.
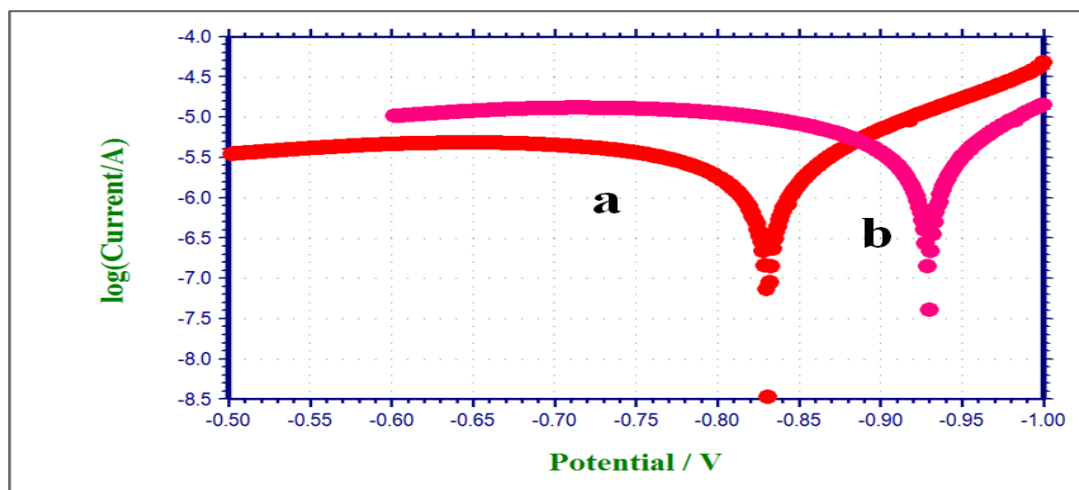
Fig.2 Polarization curves of mild steel immersed in various test solutions.

(a) SCPS (blank); (b) SCPS + TSC (200 ppm)

The corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), linear polarization resistance (LPR), and Tafel slopes (b_c=cathodic; b_a= anodic) are given in table. 2.

Table.2 Corrosion parameters of mild steel immersed in SCPS in the absence and presence of TSC.

System	E_{Corr} mV vs SCE	I_{corr} A/cm^2	LPR ohm cm^2	b_c mV/decade	b_a mV/decade
SCPS (blank)	-930	5.366×10^{-6}	6947.0	122	288
SCPS + TSC (200ppm)	-831	2.924×10^{-6}	14218.1	127	388

It is observed from table 2 that when mild steel is immersed in SCPS, the corrosion potential is -930 mV vs SCE. The corrosion current is 5.366×10^{-6} A/cm^2. The LPR value is 6947.0 ohm cm^2. In the presence of inhibitor, the corrosion potential is shifted from -930 to -831 mV vs SCE. This is an anodic shift. It suggests that the anodic reaction is controlled predominantly. The LPR value increases from 6947.0 to 14218.1 ohm cm^2.The corrosion current decreases from 5.366×10^{-6} to 2.924×10^{-6} ohm/ cm^2.

These observations confirm that a protective film is formed on the metal surface. This controls the corrosion of metal.

Analysis of AC Impedance spectra

AC impedance spectra are useful for confirming the formation of protective film formed on the metal surface **[9-13].** If a protective film is formed on the metal surface, the charge transfer resistance (R_t) value increases; double layer capacitance value (C_{dl}) decreases and the impedance [log (Z/ ohm)] value increases. The AC impedance spectra of mild steel immersed in SCPS, in the absence and presence of inhibitors (TSC 200 ppm) are shown in Fig 3a (Nyquist plots) Fig 3 b&c [Bode plots]. The corrosion parameters, namely R_t, C_{dl} and impedance values are given in table.3.
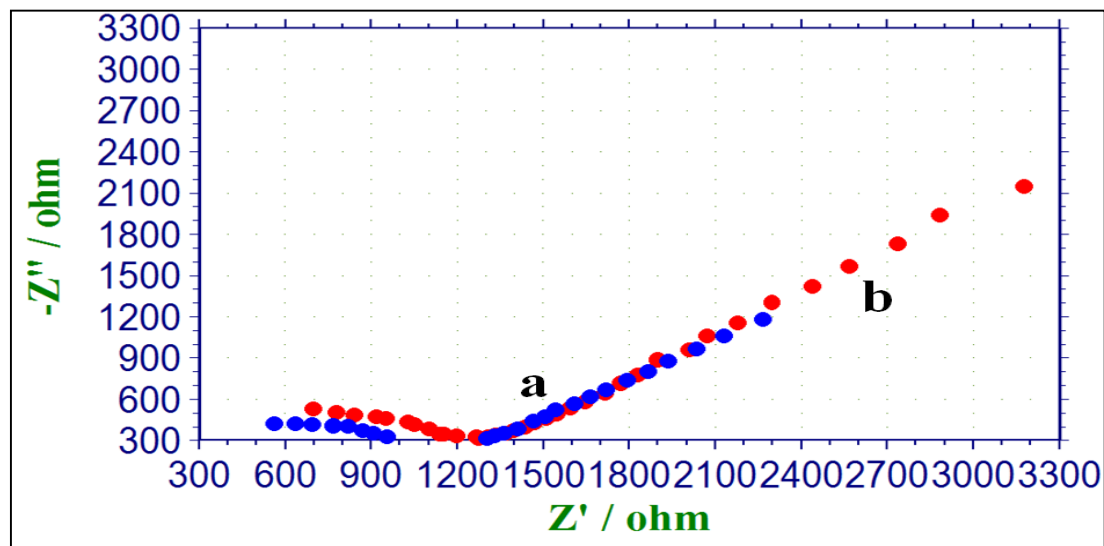
Fig.3a. AC impedance spectra of mild steel immersed in various test solutions (Nyquist Plot); (a) SCPS (blank); (b) SCPS +TSC (200 ppm)
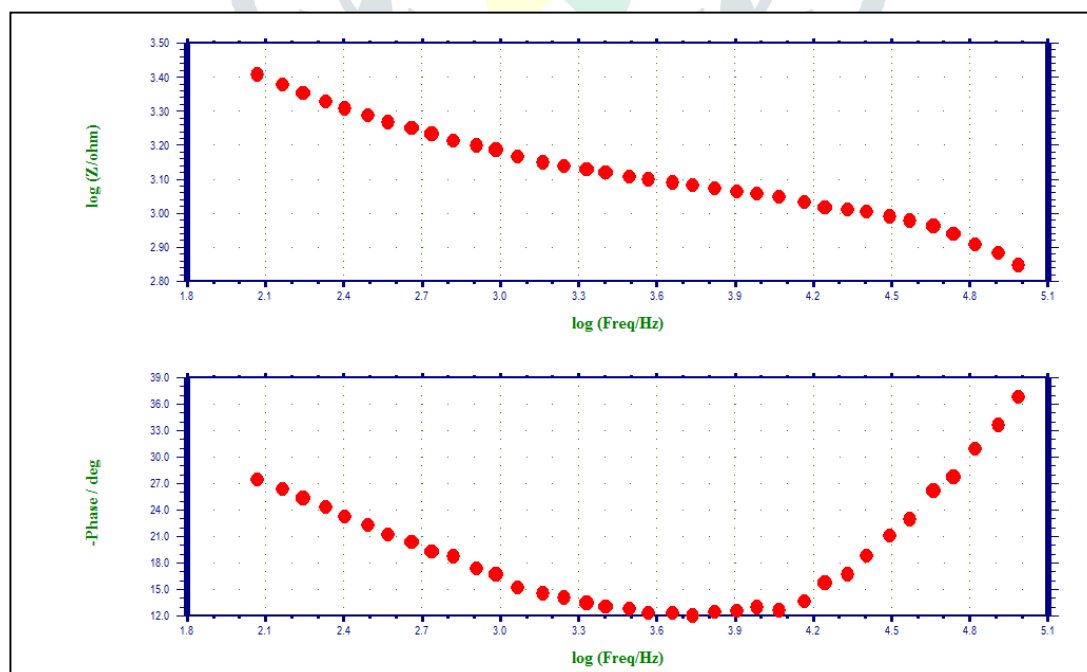

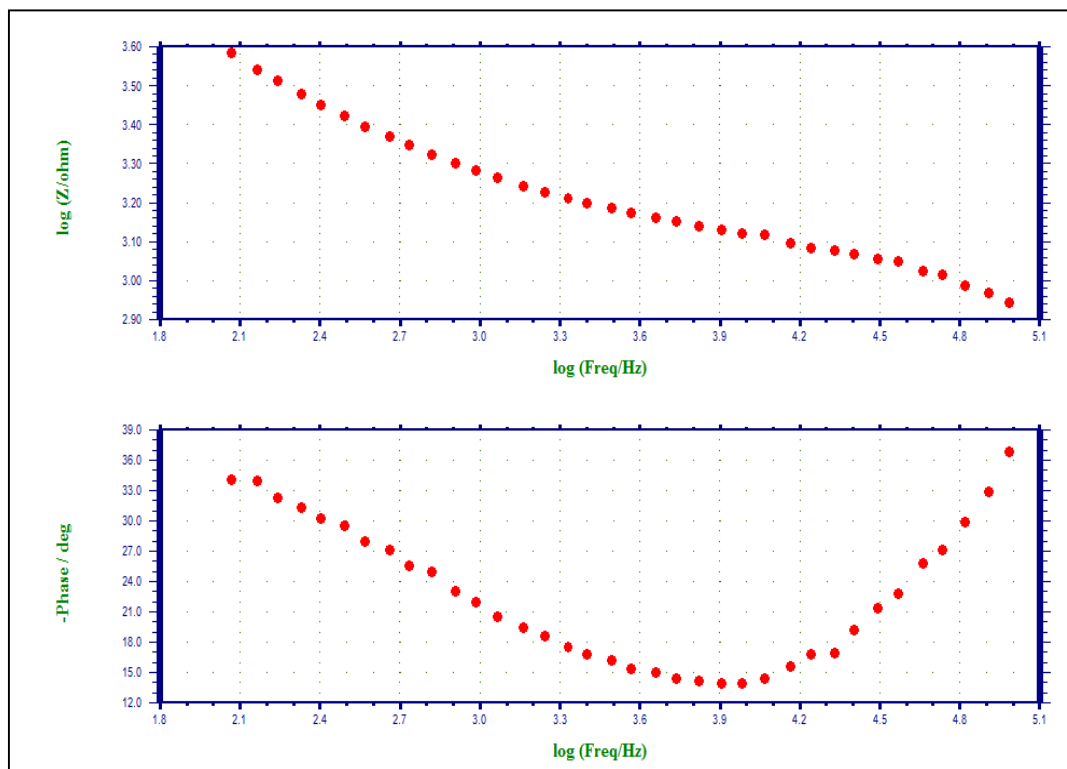**Fig.3b.AC impedance spectra of mild steel immersed in SCPS (Bode Plots)**

Fig.3c AC impedance spectra of mild steel immersed in SCPS+TSC(200 ppm) (Bode plots)

Table.3 Corrosion parameters of mild steel immersed in SCPS in the presence of TSC (200 ppm) obtained from AC impedance spectra.

System	Nyquist plot		Bode plot
	R_t Ohm cm ^{2}	C_{dl} F/cm^2	Impedance log (Z/ohm)
SCPS(blank)	1477.1	3.3850 x10^{-9}	3.35
SCPS+TSC(200 ppm)	2512.6	1.9899 x10^{-9}	3.6

It is observed from the table that when mild steel is immersed in SCPS, the charge transfer resistance is 1477.1 ohm cm^2. The double layer capacitance is 3.3850x 10^{-9} F /cm^2. The impedance value is 3.35. In the presence of inhibitor (200 ppm of TSC), the charge transfer resistance value (R_t) increases from 1477.1ohm cm^2 to 2512.6 ohm cm^2. The double layer capacitance value (C_{dl}) decreases from 3.3850 x 10^{-9} F/cm^2 to 1.9899 x 10^{-9} F/cm^2. The impedance log (Z/ohm) increases from 3.35 to 3.6. These observations confirm that a protective film is formed on the metal surface. This prevents the transfer of electrons from the metal to the solution medium. Thus corrosion of mild steel is prevented. It is observed from the fig 3a that the corrosion prevention process in the presence of inhibitor is a diffusion controlled process.

Cyclic Voltammetry

Cyclic voltammograms have been used to investigate the corrosion behaviour of metals [14-15]. CV study is undertaken to know if the protective film formed on the metal surface is stable in 3.5% NaCl solution. The mild steel electrode was immersed in 3.5% NaCl solution and cyclic voltommogram was recorded.

The anodic peak appears at 500 mv. This is due to dissolution of metal. Fe is converted into Fe^{2+}. There is the formation of ferrous hydroxide. During cathodic sweep very small peaks appears. The peak at – 1v is due to reduction of corrosion product, namely iron oxide to iron. The appearance of cathodic peak around -1.5v is due to reduction of pitting corrosion product precipitate on the metal surface is shown in Fig.4a.

Mild steel electrode was immersed in the solution containing SCPS and (200) ppm of TSC, protective film was formed on the metal surface. The electrode was dried and immersed in 3.5% NaCl solution. Cyclic Voltommogram was recorded is shown in Fig.4b. It is very interesting to note that anodic peak is not seen. Similarly cathodic peaks are not seen. This clearly indicates that the protective film is very stable even in 3.5% NaCl solution. The cyclic voltommogram was run for 5 cycles is shown in Fig.4c. Even then the anodic peak and cathodic peaks do not appear. This means that the protective film is very stable.
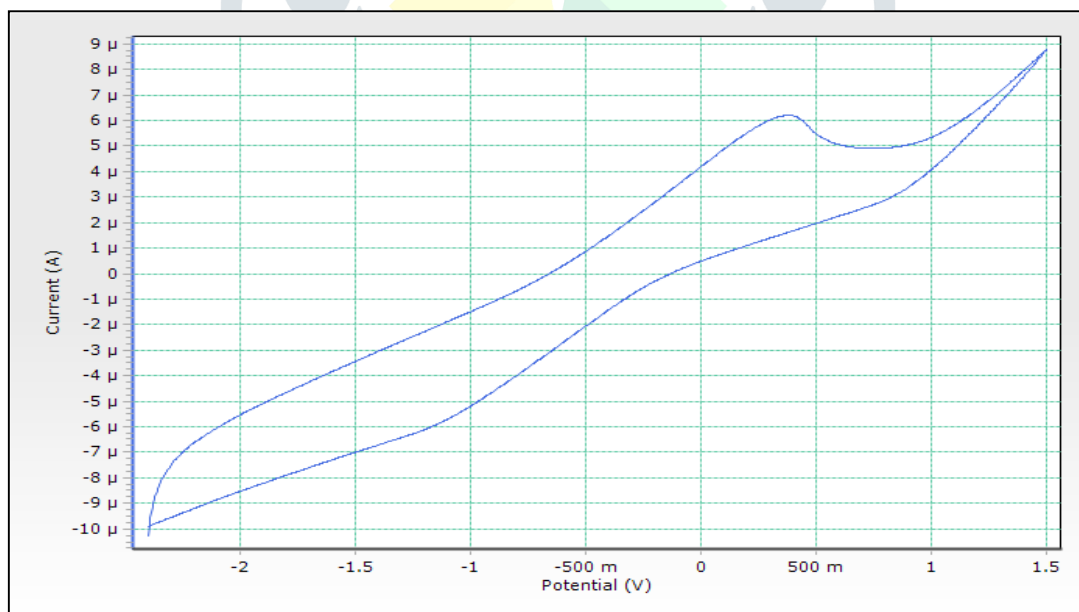

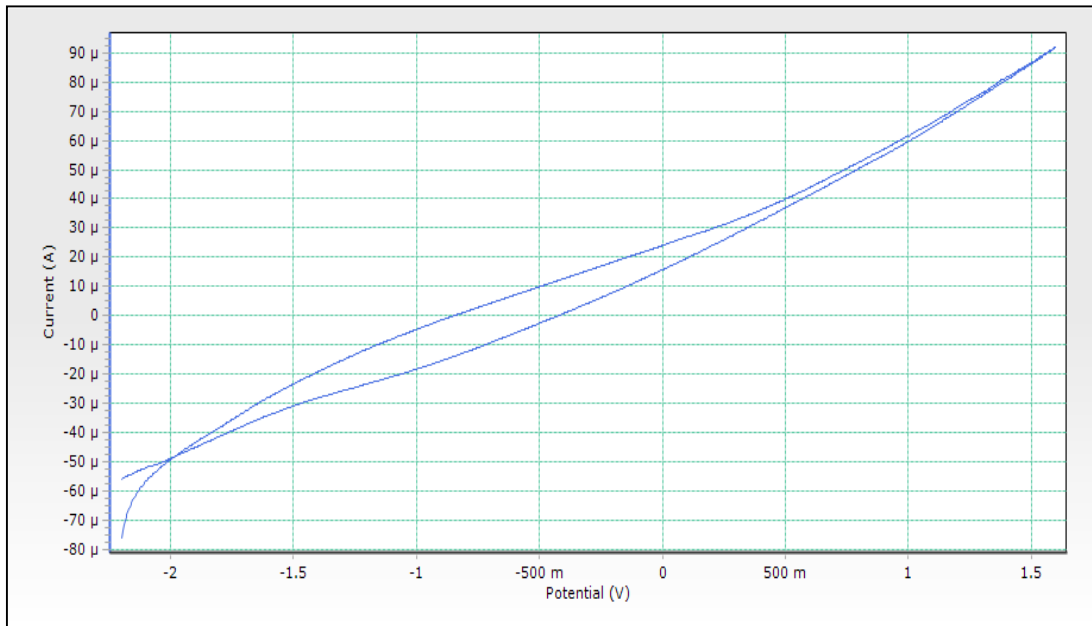**Fig.4a Cyclic voltammogram of mild steel immersed in scp solution.**

Fig.4b Cyclic voltammogram of carbon steel electrode after its immersion in SCPS containing 200ppm of TSC.
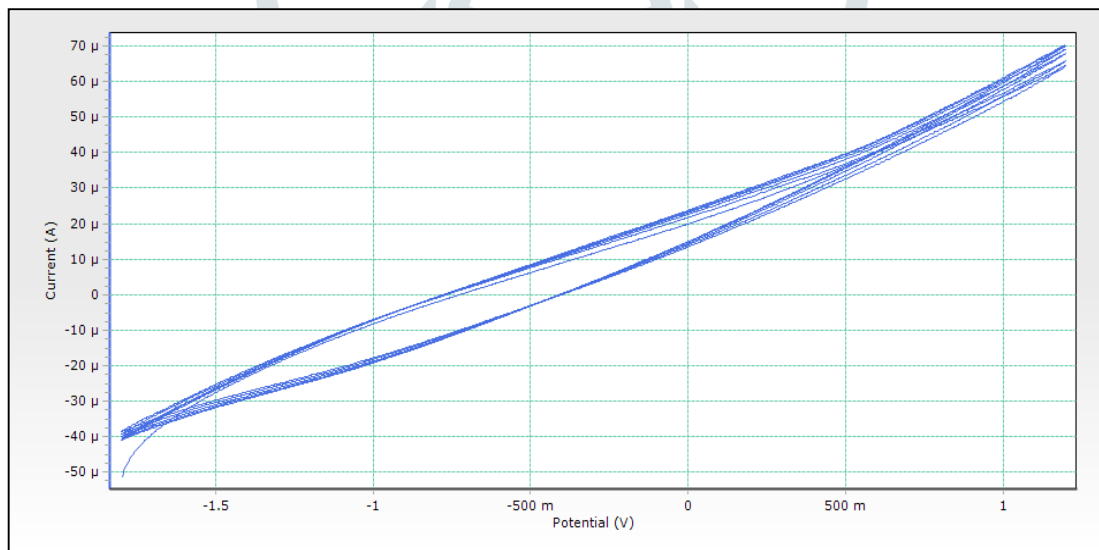

Fig.4c Cyclic voltammogram of carbon steel electrode after its immersion in SCPS containing 200ppm of TSC for five cycles.

Analysis of UV-Visible adsorption spectra

UV-visible absorption study has been widely used in corrosion inhibition studies [19-24].The UV-visible absorption spectrum of a solution containing SCPS +TSC and Fe^{2+} ($FeSO_4.7H_2O$) is shown in Fig 5. A peak appears at 384 nm. This peak is due to TSC- Fe^{2+}-SCPS complex formed in the solution.
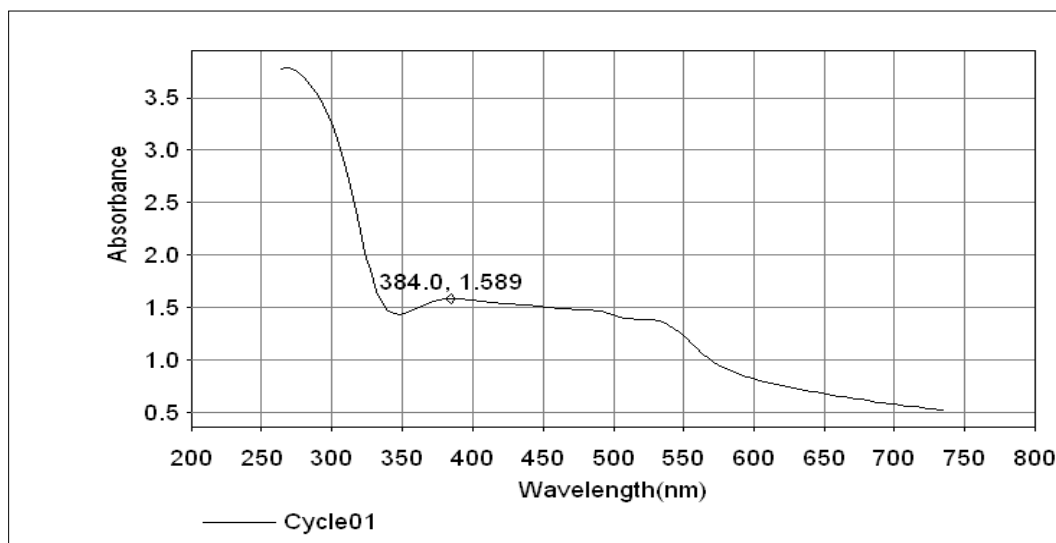
Fig. 5 UV, visible spectrum of a solution containing SCPS, TSC and Fe^{2+}

Analysis of Fluorescence Spectra

Fluorescence spectrometry is a fast, simple and inexpensive method to determine the concentration of an analyte in solution based on its fluorescent properties. It can be used for relatively simple analyses, where the type of compound to be analyzed ('analyte') is known, to do a quantitative analysis to determine the concentration of the analytes. Fluorescence is used mainly for measuring compounds in solution.

If an atom or molecule first absorbs energy - for instance a photon, this is called excitation. Very shortly (in the order of nanoseconds) after excitation it emits a photon of a longer wavelength is referred as fluorescence. A molecule can be excited from its electronic ground state. In the electronic ground state the molecule has the lowest possible electronic energy. Upon excitation (the absorption of a photon) one of the electrons goes into a higher electronic state and the molecule is excited. The molecule will stay in its electronic excited state in the order of Pico or nanoseconds (ns). Then the electron will fall back to its ground state and will emit a photon of a longer wavelength than the photon used for excitation.

Fluorescence spectra have been used in the corrosion inhibition study by many researchers. The fluorescence spectrum ($\lambda_{ex} = 300$ nm) of a solution containing SCPS + Fe^{2+} is shown in Fig 6a. A peak appears at 378.5 nm. This peak is due to SCPS + Fe^{2+} complex formed in solution. The fluorescence spectrum ($\lambda_{ex}=300$ nm) of the film formed on the metal surface after immersion in the solution containing SCPS + TSC + Fe^{2+} is shown in Fig 6b. A peak appears at 390.5 nm. This peak matches with the peak of SCPS + TSC + Fe^{2+} complex. Thus it is confirmed that the protective film consists of SCPS- Fe^{2+}- TSC Complex formed on the metal surface .This film formation on the metal surface is responsible for the protective nature of the SCPS + TSC + Fe^{2+}inhibitor system. It is also observed that, there is a decrease in the intensity of the peak and this may be attributed to the fact that the

complex is in the solid state is present on the metal surface. The presence of a single peak suggested that the complex is homogeneous in nature [**25-32**].
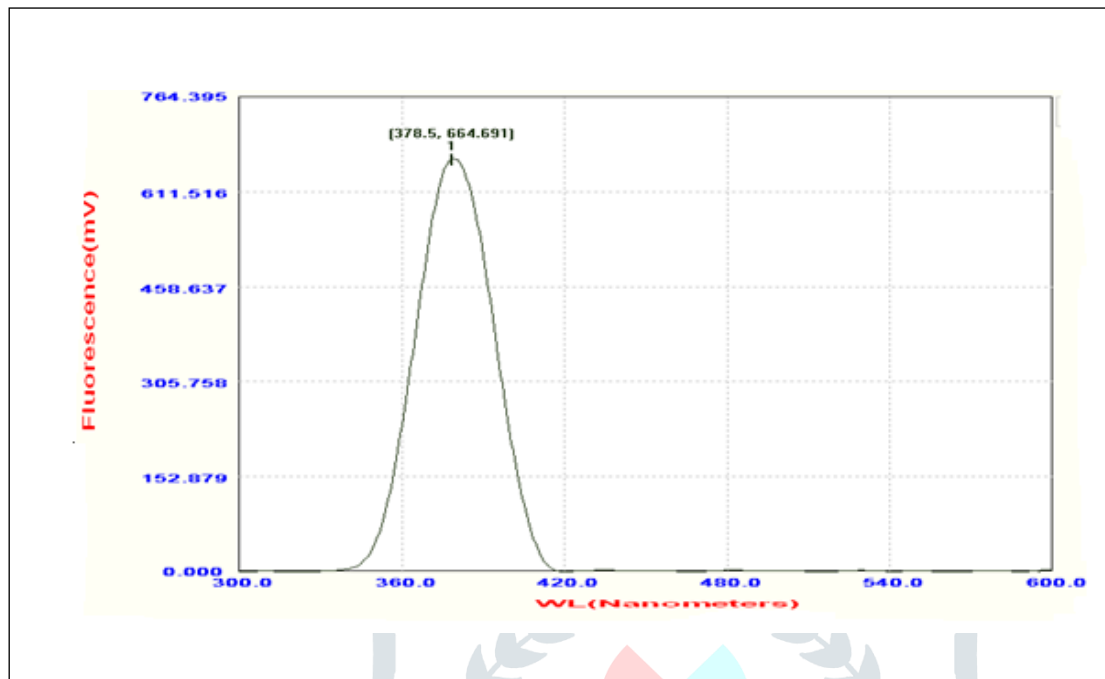

Fig.6a Fluorescence spectrum mild steel immersed in SCPS + Fe $^{2+}$
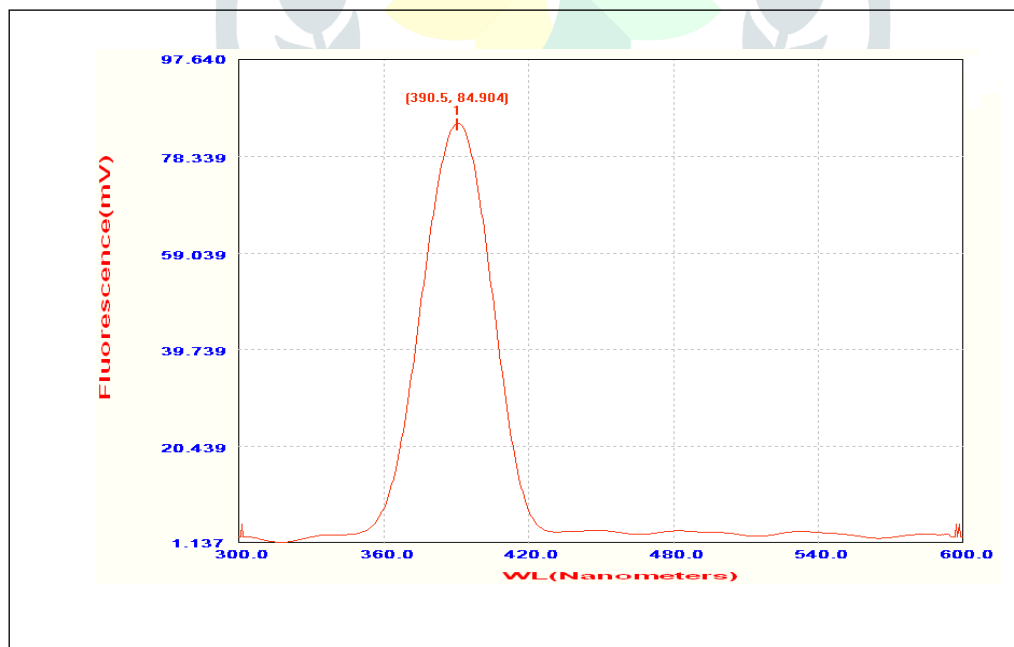

Fig.6b Film formed on the metal surface after immersion in the solution containing 200ppm of TSC.

Analysis of Fourier Transform Infrared Spectroscopy (FTIR) Spectra

FTIR spectra have been used in corrosion inhibition study to analyze the protective film formed on the metal surface **[33-38].**

The FTIR (KBr) spectrum obtained for pure TSC is shown in Fig 7a. The results showed that for pure TSC the C=O stretching frequency of carboxyl group appears at 1593.04 cm^{-1}. The OH-stretching frequency of the carboxyl group appears at 3456.45cm^{-1}. The aliphatic C-H stretching frequency appears at 2925.54 cm^{-1}, 2968.57 cm^{-1}.

The mild steel specimen was immersed in SCPS solution and 200 ppm of TSC system for one day. After one day the metal was taken out and dried. A protective film was found on the metal surface. It was scratched and mixed with KBR pellet. The FTIR (KBr) spectrum obtained by the film formed on the metal surface after immersion in SCPS prepared in DD water containing TSC (200 ppm) is shown in Fig 7b. The C=O stretching frequency has shifted from 1593.04 cm^{-1} to 1635.89cm^{-1}. The O-H stretching frequency has shifted from 3456.45 cm^{-1} to 3435.45 cm^{-1}. This confirms that the oxygen atom of carboxyl group has co-ordinated with Fe^{2+} resulting in Fe^{2+}- TSC complex. The peak at 669.72cm^{-1} is due to metal-oxygen bond. It is inferred that metal hydroxides such as calcium hydroxide is present on the metal surface **[39].** Thus FTIR spectra lead to the conclusion that the protective film consists of Fe^{2+}- TSC complex and calcium hydroxide. The peaks due to calcium oxide, calcium hydroxide and calcium carbonate appears at 1635, 1384, 669 cm^{-1}.
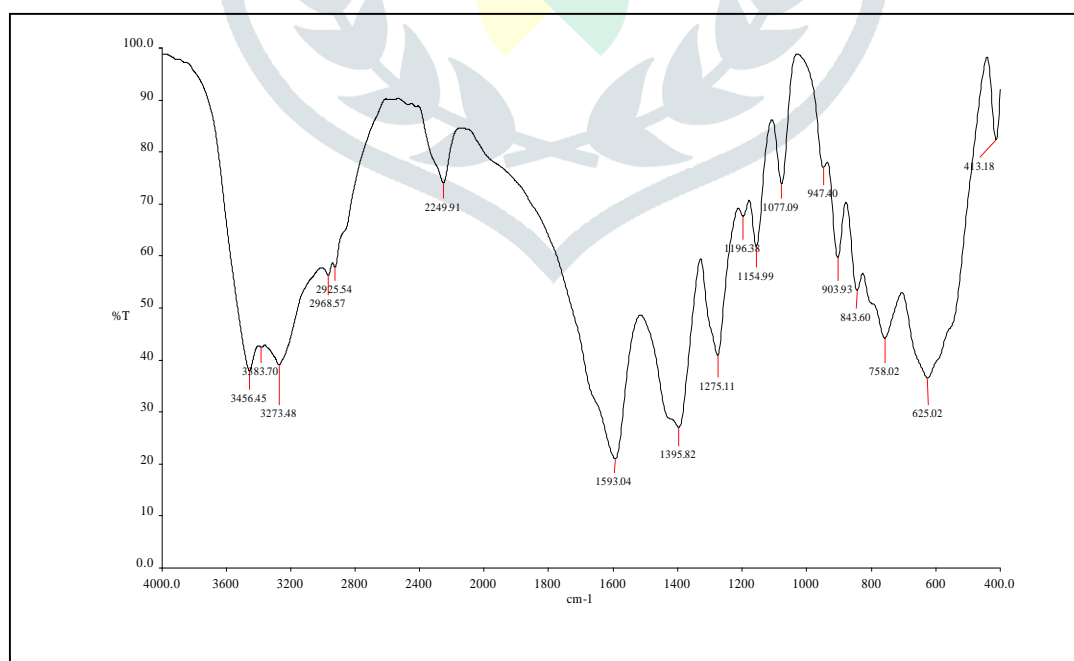

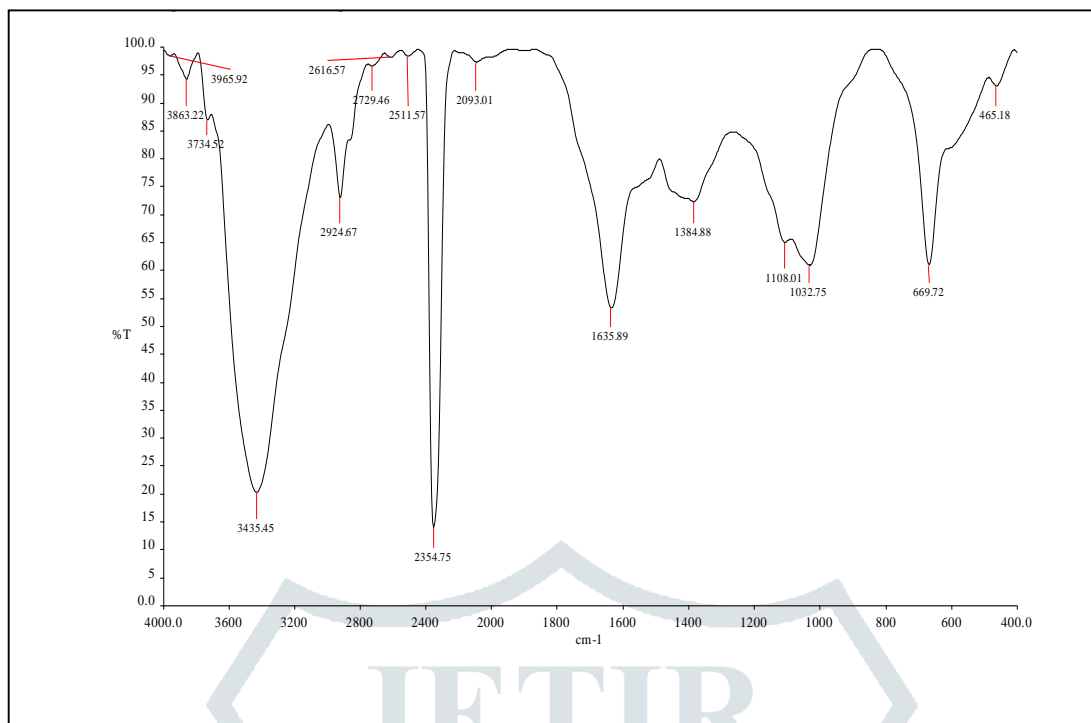
Fig.7a FTIR spectrum of Pure TSC

Fig.7b FTIR spectrum of mild steel immersed in 200 ppm of TSC

Scanning Electron Microscopy (SEM)

SEM provides a pictorial representation of the surface. To understand the nature of the film in the absence and presence of inhibitors and the extent of corrosion of mild steel, the SEM microscopes of the surface are examined.

The surface morphology is studied by scanning electron microscopy after one day immersion in SCPS prepared in DD water before and after addition of inhibitor with the magnification (20µm) are shown in Fig 8 (a, b & c). The SEM image of polished mild steel surface (control) is shown in Fig 8a which represent the smooth metal surface in the absence of any corrosion products or inhibitor complex formed on the metal surface **[40- 45].**

The SEM image of polished metal immersed in SCPS prepared in DD water is shown in Fig 8b shows strongly damaged mild steel surface due to the formation of corrosion product. This reveals that the mild steel immersed in SCPS prepared in DD water shows an aggressive attack of the corroding medium on the mild steel surface.

The SEM image of the metal immersed in SCPS prepared in DD water and inhibitor system is shown in Fig 8c. When mild steel surface immersed in SCPS containing TSC (200 ppm) shows smooth surface and the rate of corrosion is suppressed, this can be seen from the decreases in corroded

area on the metal surface.The metal surface almost free from corrosion due to the formation of insoluble complex on the surface of the metal. In the presence of TSC, the surface is covered by a thin layer of inhibitor which effectively controls the dissolution of mild steel.
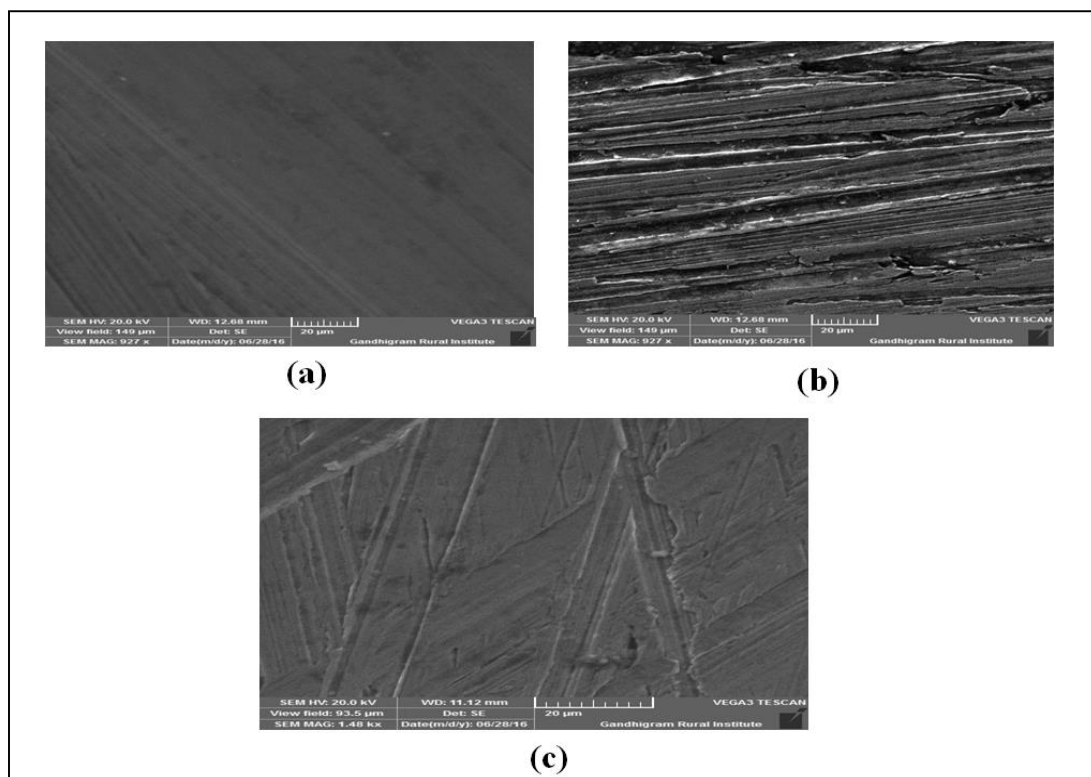

Fig.8 SEM micrographs of

(a) Mild steel (Control); Magnification 20 μm.

(b) Mild steel immersed in SCPS prepared in DD water; (Blank); Magnification 20 μm.

(c) Mild steel immersed in SCPS prepared in DD water containing (TSC 200 ppm); Magnification 20 μm.

Energy Dispersive X-ray Analysis (EDX)

The EDAX analysis, spectra was used to determine the elements present on the metal surface before and after exposure to the inhibitor solution **[46-50].** The objective of this section is to confirm the results obtained from chemical and electrochemical measurements that a protective surface film of inhibitor is formed on the mild surface. To achieve this aim, EDAX examinations of the mild steel surface were performed in the absence and presence of inhibitor system.

The EDAX spectrum of mild steel immersed in SCPS prepared in DD water is shown in Fig.9a.The analysis shows the presence of characteristic peaks of corrosion product elements (Fe, O, C, Ca). The EDAX spectrum of mild steel immersed in SCPS prepared in DD water containing TSC

(200 ppm) is shown in Fig.9b. The analysis shows the presence of characteristic peaks of elements (Fe, O, C, Ca, and Na). The analysis shows the presence of (Na) peak, [where there is no presence of (Na) peak on mild steel surface immersed in SCPS prepared in DD water only] this concludes the presence of Tri sodium citrate-iron complex on the metal surface and a notable decrease in iron peak shows the formation of protective film on the metal surface. The surface of mild steel sample is preserved to a large extent due to formation of the protective film formed of the inhibitor molecules as indicated by the decrease of iron peak in Fig.9b. Then the presence of Ca peak represent there is a possibility of formation of calcium oxide or calcium hydroxide complex on the metal surfaces. The passive film formed on the metal surface becomes stable and corrosion rate falls to a very low value and hence protects the metal against further oxidation.
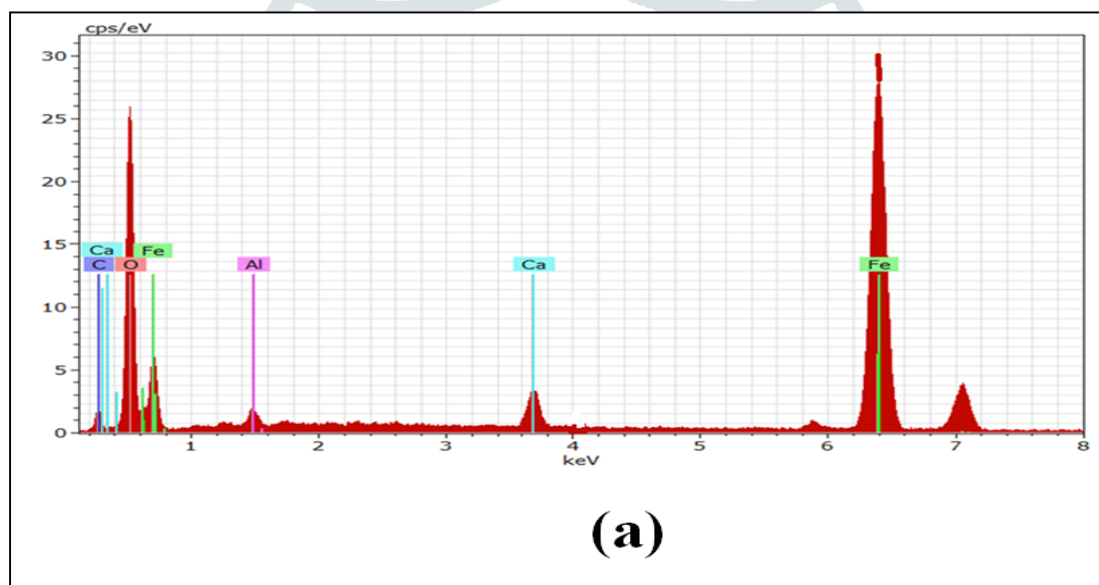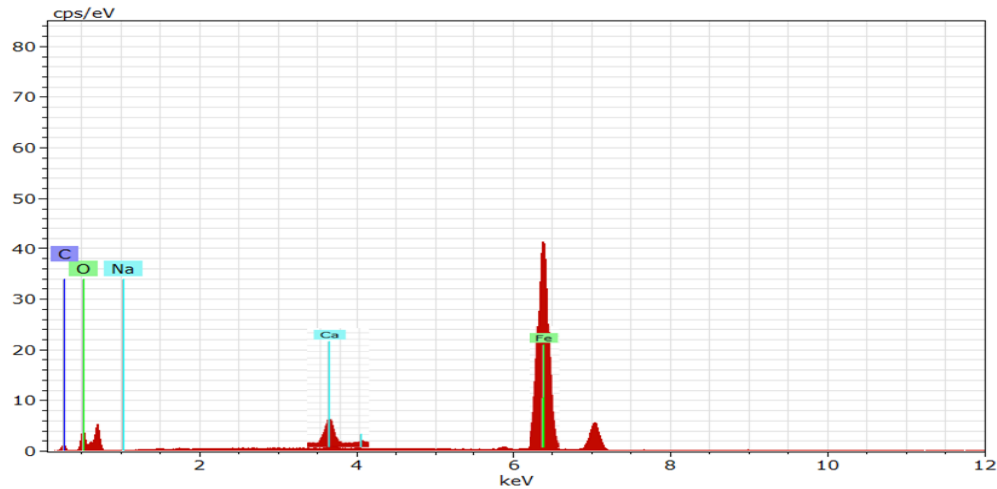

Fig.9a. EDAX spectrum of polished mild steel immersed in SCPS

(b)

Fig.9b.EDAX spectrum of polished mild steel immersed in SCPS containing TSC(200 ppm)

Atomic force microscopy (AFM)

Atomic force microscopy (AFM) is a powerful technique for gathering of roughness statistics from a variety of surfaces.AFM is becoming an accepted method for investigation of roughness **[50-55].**

The two dimensional (2D), three dimensional (3D) AFM morphologies and the AFM cross-sectional profile for polished mild steel surface (reference sample), mild steel surface immersed in SCPS (blank sample) and mild steel surface immersed in SCPS containing TSC (200 ppm) are shown in Figs.10 (a, b, c) and 11 (a, b, c) respectively.

Root- mean-square roughness, average roughness and peak –to-valley height value

AFM image analysis was performed to obtain the average roughness, R_a, (the average deviation of all points roughness profile from a mean line over the evaluation length), root –mean-square roughness, R_q, (the average of the measured height deviations taken within the evaluation length and measured from the mean line) and the maximum peak-to-valley (P-V) height value (largest single peak-to-valley height in five adjoining sampling heights). R_q is much more sensitive than R_a to large and small height deviations from the mean.

The R_q, $R_{a \ and}$ P-V values for mild steel surface immersed in different environments are summarized in Table.4. The value of RMS, Ra and peak to valley height for the polished mild steel surface are 53.324 nm, 43.488 nm and 242.78 nm respectively, which show a more homogeneous surface, with some places in which the height is lower than the average depth. Figs 10a &11a display the uncorroded metal surface. The slight roughness observed on the polished mild steel surface is due to atmospheric corrosion.

The RMS roughness, average roughness and P-V height values for the mild steel surface immersed in SCPS are 396.46 nm, 343.46 nm and1755.3 nm respectively. These data suggest that mild steel surface immersed in SCPS has a greater surface roughness than the polished metal surface. This shows that the unprotected mild steel surface is rougher and is due to the corrosion of the mild steel in SCPS. Figs 10 b &11b displays the corroded metal surface with few pits.

The AFM image of polished mild steel surface immersed in DD water containing TSC (200 ppm) shown in Figs 10c &11c.The RMS roughness, average roughness, P-V height values for the mild steel surface is 63.309 nm, 44.373 nm and 381.72 nm respectively. The Rq, Ra, and P-V height values are considerably less in the inhibited environment compared to the uninhibited environment. These parameters confirm that the surface is smoother and the smoothness of the surface is due to the formation of a compact protective film of Fe^{2+}-TSC complex and calcium oxide or calcium hydroxide complex on the metal surface thereby inhibiting the corrosion of mild steel.

Table.4AFM data for carbon steel surface immersed in inhibited and uninhibited environment.

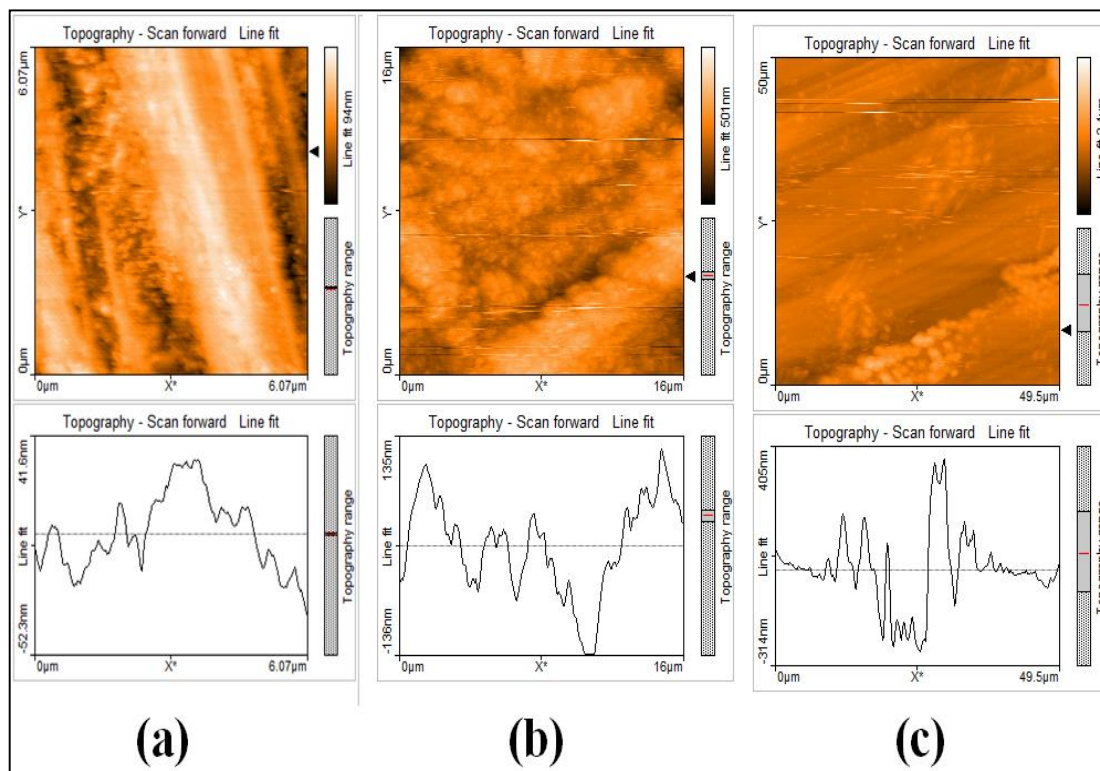| Sample	RMS (R_q) Roughness (nm)	Average (R_a) Roughness (nm)	Maximum peak- to- valley height (nm)
Polished metal	53.324	43.488	242.78
Mild steel immersed in SCPS (Blank)	396.46	343.46	1755.3
Mild steel immersed in SCPS and 200 ppm of TSC	63.309	44.373	381.72

Fig.10 Two dimensional AFM images of the surface of

a) Polished mild steel (control).

b) Mild steel immersed in SCPS (blank).

c) Mild steel immersed in SCPS containing TSC (200 ppm).

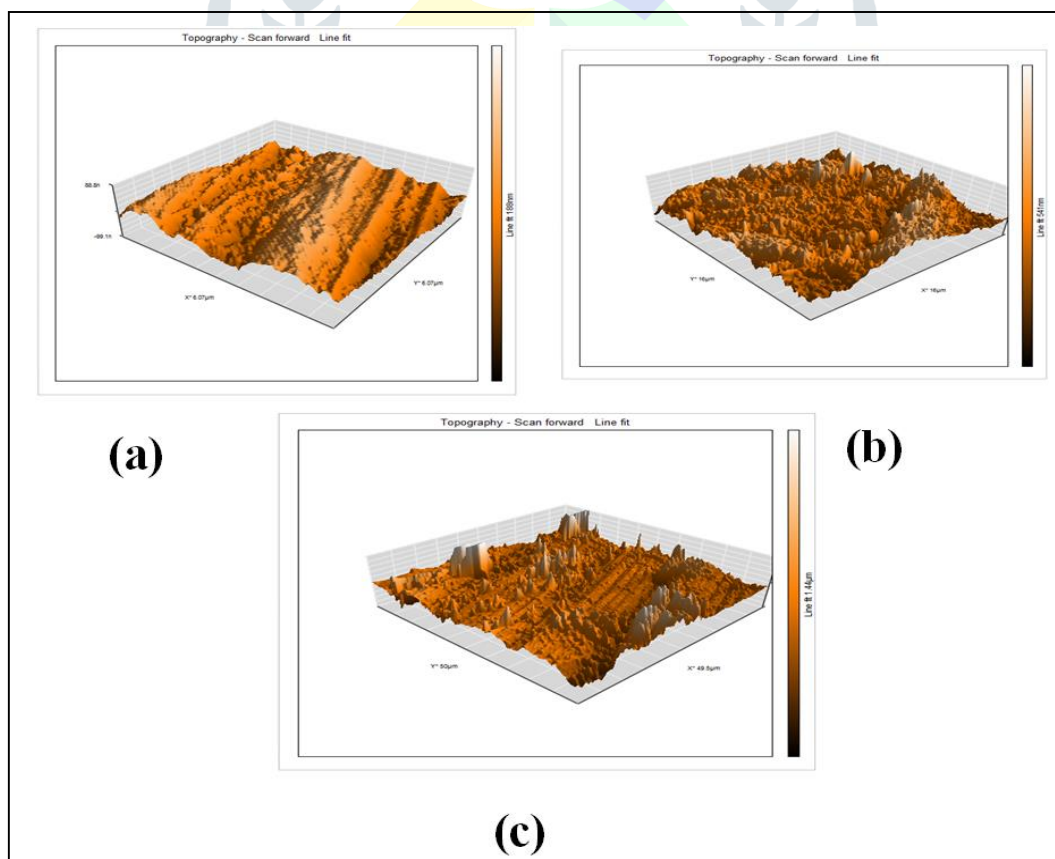**Fig.11 Three dimensional AFM images of**

a) **Polished mild steel (control).**

b) **Mild steel immersed in SCPS water (blank).**

c) **Mild steel immersed in SCPS water containing TSC (200 ppm).**

CONCLUSIONS

The inhibition of corrosion of mild steel in SCPS solution has been evaluated in the absence and presence of chloride.The formulation consisting of 200 ppm of TSC has 98% inhibition efficiency (IE). This suggests that inhibitors controls the corrosion of mild steel immersed in SCPS prepared in the absence of chloride ion.The polarization study reveals that the TSC system controls the anodic reaction predominantly and thus functions as anodic inhibitor .The AC impedance spectra reveal the formation of protective film on the metal surface. The FTIR spectra suggested that the protective film consists of Fe^{2+} - TSC complex and CaO and $CaCO_3$. The CV, SEM, EDX and AFM studies confirmed the formation of protective film on the metal surface.

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