
SUMMARY AND CONCLUSION

The salient features pertaining to the present study entitled “Corrosion monitoring of metal (Mild steel, AA1100) /1M HCl interface in the presence of *Spathodea campanulata*, *Tecoma capensis* leaf and flower extracts –Chemical, Electrochemical and Theoretical studies” are summarized below

Module I

- ❖ Characterisation of the inhibitors using various techniques namely FT-IR, UV-Vis and GC-MS revealed the presence of N and O atoms that act as a prerequisite for the extracts to act as corrosion inhibitors. Preliminary phytochemical screening tests also confirmed the above observations.

Module II

- ❖ The investigated inhibitors, performed in an effective manner to minimize the corrosion of **MS / AA1100** in 1M HCl medium.
- ❖ The potentiodynamic polarisation curves reflect that the anodic (b_a) and cathodic (b_c) curves shifted towards low corrosion current density values in the presence of the inhibitors. This supported the view that the inhibitors were able to suppress both the anodic dissolution and cathodic hydrogen evolution.
- ❖ The results indicated a considerable reduction in the I_{corr} values in the presence of the inhibitors. The IE was found to increase with increase in concentration of the inhibitors.
- ❖ Perusal of the available literature indicated that an inhibitor may be classified as anodic or cathodic when the change in E_{corr} values is larger than 85 mV. Since the potential displacements for the inhibitors were less than 85 mV in cathodic or anodic direction, it may be said that the inhibitors acted as mixed type inhibitors.
- ❖ The impedance spectra obtained for **MS** in the presence and absence of the inhibitors at room temperature exhibited single capacitance loop indicating that the corrosion is controlled by charge transfer process. The diameter of the semi circle increased with increase in concentration of the studied inhibitors and the shape of the semi circle was similar in the presence of the inhibitors implying that there was no change in the mechanism of MS dissolution in the presence of the investigated inhibitors.

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- ❖ In the case of **AA1100**, at room temperature, a capacitance loop at high frequency range and an inductive loop at the low frequency range were observed. The appearance of the inductive loop might be due to the relaxation of adsorbed species $H_{ads}^+ / Cl^- / O^{2-}$ ions /adsorbed phyto constituents or redissolution of the oxide layer surface or Al dissolution. Nevertheless the shape of the capacitive and inductive loops increase with increasing concentration of the inhibitors, thereby indicating the inhibitive properties of the inhibitors.
 - ❖ The data obtained by impedance spectroscopy was analysed by proposing an equivalent circuit .Excellent fit for the results were obtained. The results reflected the increase of charge transfer resistance (R_{ct}) with increase in concentration of inhibitor .This might be due to the adsorption of the phytochemical constituents adsorbed onto **the MS / AA1100** surface. The value of C_{dl} decreased with inhibitor concentration which might be due to decreased value of dielectric constant and/or due to the adsorbed film formed at acid/metal interface. Higher value of C_{dl} and lower values of R_{ct} were noted with elevated temperatures due to the fact that increase in temperature increased the activation energy of the metal surface leading to increased corrosion..
 - ❖ Analysis of the results of the mass loss measurements of **MS / AA 1100** infer that the inhibition efficiencies increased with increasing concentration of the inhibitors. Immersion studies reveal that as the time of immersion increases from ½ hr to 12h/ 6h the inhibition efficiency increases. After 12 h / 6h there is a slight decline in the inhibition efficiency at 24 hrs. In the case of AA1100, the IE increases upto 1h and after that a slight decline is observed. The decrease in inhibition efficiency at longer immersion time might be due to the desorption of the protective layer formed in the presence of the inhibitors on the metal surface. All the investigated inhibitors could furnish an efficiency of 90-98 percentage at a maximum concentration of 0.7%.
 - ❖ The kinetic and mechanistic aspects of corrosion may be gained by studying the effect of temperature on the corrosion of **MS / AA1100** in the presence and absence of the inhibitors. It can be noted that the maximum IE obtained was in the range of 90- 94 percentage (323 K/333 K) in 1M HCl and then a slight decrease was observed after that and at 353K it was found to be at 80-85 percentage for the investigated inhibitors for MS. In the case of AA1100, the IE increased upto 313 K and then decreased. A maximum efficiency of 70 – 82 percentage was afforded by
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all the investigated inhibitors at 353 K. This may be due to the adsorption of the inhibitor upto a particular temperature and then desorption of the inhibitor at higher temperature.

- ❖ Analysis of the mass loss data obtained from the investigated inhibitors using SPSS statistical package reflected the applicability of Langmuir and Temkin adsorption isotherm.
- ❖ In the present investigation E_a values were found to be greater or smaller than those calculated in the absence of the inhibitors. This can be explained by the fact that at higher degree of coverage, the dissolution process is not only determined by the reaction of the metal from the bare surface but also involves the adsorbed inhibitor.
- ❖ The positive value of the enthalpy of activation (ΔH_a°) reflected the endothermic nature of the metal dissolution process. The negative values of entropy of activation (ΔS_a°) in the presence of the inhibitors in 1 M HCl imply that the inhibitor molecules, freely moving in the bulk solution are adsorbed in an orderly fashion onto the metal surface.
- ❖ The negative values of ΔG_{ads}° demonstrate that the inhibitors are spontaneously adsorbed onto the MS / AA1100 surface. In the present study, the calculated values of ΔG_{ads}° obtained for the investigated systems range between -13 kJ / mole to -22 kJ / mole indicating that the adsorption of the inhibitors on the surface of the metal was through physical means of adsorption but chemisorption cannot be excluded .
- ❖ The negative sign of ΔH_{ads}° indicated that the adsorption of the inhibitors on metal surface was exothermic in nature. The positive sign of ΔS_{ads}° arised from substitutional process, which can be attributed to the increase in the solvent entropy and more positive water desorption entropy. This lead to an increase in disorder due to the fact that more water molecules can be desorbed from the metal surface by one inhibitor molecule. The negative values of entropy (ΔS_{ads}°) in the presence of the inhibitors in 1 M HCl implied the inhibitor molecules, freely moving in the bulk solution are adsorbed in an orderly fashion onto the metal surface.
- ❖ Surface morphology of the metal indicated that the surface of the metal was found to be rough after subjecting the **MS / AA 1100** specimens in the acid medium and this reflected the aggressive nature of the inhibitors under study. The inhibited

surface was found to be smooth and this revealed that the surface of the metal was protected by the adsorption of the active constituents of the plant species. The EDX patterns corroborated the results of SEM analysis.

- ❖ FT IR spectrum implied the presence of O and N atom containing functional groups, that act as a prerequisite for a molecule to function as a corrosion inhibitor.
- ❖ UV spectral data confirmed the formation of protective layer of metal-inhibitor complex on the metal surface.
- ❖ The morphology of the specimens using XRD and 3D Optical Profiler ascertained the inhibitive nature of the inhibitors under study.
- ❖ The results of quantum chemical studies carried out using semi empirical approach -- PM3 and AM1 (Hyperchem 7.5) for the selected phytochemical constituents present in *Spathodea campanulata* namely Kaempferol, spathodol, phytol and in *Tecoma capensis* caffeic acid, tecomoside, luteolin – confirmed the probable adsorption centers through which the metal atom is linked to form metal – inhibitor complex.

SCOPE FOR FURTHER STUDY

- ❖ Corrosion inhibition studies may also be carried out using the investigated inhibitors in phosphoric acid medium, nitric acid medium, in alkaline and neutral medium.
- ❖ Further utilisation of Impedance spectroscopy to analyse the influence of exposure time on the corrosion of MS and AA1100 and the pitting potential statistics
- ❖ Isolation of specific phytochemicals from the crude plant extracts to exactly pinpoint the components responsible for corrosion inhibition
- ❖ The effectiveness of the investigated inhibitors on various concentration of HCl may be studied
- ❖ Theoretical analysis involving Fukui indices and molecular simulation may be carried out.
- ❖ Theoretical calculation may be carried out for other phyto components present in the investigated plants
- ❖ The investigated inhibitors may be tested as corrosion inhibitor in other metals – carbon steel, copper, brass and zinc etc.,
- ❖ Apply mathematical equations to find out the theoretical investigation of corrosion inhibition studies.
- ❖ The investigated inhibitors may be tried as corrosion inhibitors in electroplating industries.