Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 5 Issue 2, February - 2019

Investigation of Eco-Friendly Plant Nanoparticles Inhibitor on The Corrosion Behaviour of Duplex Stainless Steel 2101 And 2205 In 0.5M H_2SO_4

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***Abstract*— The inhibitive efficiency of extracts from some plants parts against corrosion in metals has been well proved. Moreover, it's been established that nanometer scaled materials exhibit more distinct properties compared to the bulk materials, and nanoparticles has high inhibition efficiency due to their large surface to volume ratio. We therefore investigated the corrosion protection potentials of copper nanoparticles derived from potato leaf, stem and roots on duplex stainless steels (2101 and 2205) in 0.5M H_2SO_4 solution using Autolab PGSTAT 204 potentiostat. Atomic Absorption Spectroscopy, Ultraviolet Visible Spectroscopy and Fourier Transformed Infrared Spectroscopy were used to characterised the extracts. The results indicated that the corrosion rate decreases with an increase in inhibitor concentration. The studies showed that the inhibition efficiency of the nanoparticles increases with the concentration. It was also observed that the nanoparticles from root offered the highest resistance to the dissolution of the metal in acidic environment when compared with nanoparticles from the leaves and the stems. The copper nanoparticles inhibited 2101 and 2205 duplex stainless steel in 0.5M H_2SO_4.**

***Keywords*— Nanoparticles, Corrosion, Inhibitors, Acidic Environment, Stainless Steel**

I. INTRODUCTION

Nanoscaled materials are increasingly being used in scientific and technological applications [1], thereby deepening interest in nanotechnology, particularly their application in the metal industry. Nanoparticles have higher tendency to interact with each other to form agglomerate [2], which are useful fundamentals in surface coating of metals. The unique properties of nano-scaled particles are mainly due to their high surface area and large surface area to volume ratio [3]. The application of nanotechnology in inhibiting corrosion in metal is evolving and are increasingly relevance in the push to reduce the large amount of synthetic chemicals used as corrosion inhibitors which are expensive and very hazardous to environments. The known synthetic inorganic inhibitors are hazardous and hence the need to develop cheap, non-toxic, less bulky and environmentally friendly have now made researchers to focus on the use of natural products [4].

Studies showed that green corrosion inhibitors are natural compounds that constitute (nitrogen, sulphur or oxygen atoms) are biodegradable and do not contain toxic compounds Several research work shows that green corrosion inhibitors effectively inhibit corrosion [5-14]. In corrosion studies stated that green corrosion inhibitors function through adsorption of the molecules at the metal surface by growing a barrier to corrosion attack [15]. The use of plant extracts as corrosion inhibitor has become important because of their environmental acceptability, availability and renewable source for a wide range of green inhibitors.

Solanum tuberosum is of the *solanaceae* family which is popularly known as potato, it contains glycoalkaloids. Pandian *et al.,* (2009) [11] investigated the use of acid extracts from *solanum tuberosum* on mild steel in 1M H_2SO_4 and 1M HCL using different techniques such as weight loss in different temperatures, potentiodynamic test, EIS (Electrochemical Impedance Spectroscopy) and SEM. It was concluded that the plant extract behaves as mixed mode inhibitor. This study aims at investigating the corrosion protection potentials of copper nanoparticles synthesised from potato roots, stem and leaf on 2101 and 2205 grade duplex stainless steel in 0.5M H_2SO_4 solution.

2.2 Methods

2.3 Preparation of plant extracts

The potato plant (leaves, stems and roots) were collected from agricultural field in Akure, Ondo State, Nigeria. The plant parts were washed with distilled water to remove sand and dirt, and sun dried to remove residual moisture. Solution of each plant part samples were made with distilled water in the ratio 1:20 and were heated for 8 minutes in a microwave oven. On cooling, the solution was filtered and the filtrate was kept below room temperature for further use.

2.4 Characterization of Plant extracts

The plant part extracts were characterized using IR-prestige-21 Shimadzu Fourier Transform Infrared Spectroscopy (FTIR) spectrophotometer, to identify different types of active functional groups in the extract using KBR pellet method. The spectral pattern was analysed and matched according to IR absorption table to identify the functional group contained in the extracts. Atomic Absorption Spectroscopy (AAS buck scientific 210 VGP) was used to determine the metal present. These tests were carried out at the laboratories of the Afe Babalola University, Ado-Ekiti, Ekiti State and Redeemers University, Ede, Osun State, Nigeria. The UV/VIS absorption spectra of the nanoparticles were measured using Cecil 7500 spectrophotometer at Sheda Science and Technology Complex (SHETSCO), Abuja, Nigeria.

2.5 Synthesis of copper Nanoparticles

Aqueous solution of 10,000 ppm mol/L of copper sulphate pentahydrate ($CuSO_4.5H_2O$) was prepared. Each potato plant part extracts were added to different flasks containing copper sulphate pentahydrate ($CuSO_4.5H_2O$) for bio-reduction. The volume ratio of plant extracts to aqueous copper sulphate pentahydrate ($CuSO_4.5H_2O$) was 1:4 to facilitate the precipitation of copper nanoparticles. Addition of the plant extracts to aqueous $CuSO_4.5H_2O$ resulted in change of colour within minutes resulting in the formation of CuNPs showing its signatory colour. The bio-reduction of Cu^{2+} ions was monitored by periodic sampling by the UV spectrophotometer. Copper nanoparticles were prepared using the stem, leaves and root of the potato plant. Prepared extracts from each plant parts, were added to copper sulphate pentahydrate ($CuSO_4.5H_2O$) in ratio 1:4 to facilitate the precipitation of copper nanoparticles.

2.6 Polarization Measurement

An electrochemical cell, with three-electrode set up containing a counter electrode which is platinum electrode, reference (Ag/AgCl) electrode and a working electrode (2101 and 2205 duplex stainless steel) were set up with a computer controlled potentiostat instrument, Autolab PGSTAT 204 equipped with Nova 2.0 software at the Advanced Materials and Electrochemical Research Group laboratory, Department of Metallurgical and Materials Engineering, FUTA, Ondo state was used for polarization measurement. The test was conducted with a scan rate of 2mV/s.

The percentage inhibition efficiency (I.E %) from the polarization measurement was calculated using the following equation

$$IE\ (\%) = CR_1 \quad \frac{CR_0 - X\ 100}{CR_0}$$

Where IE = inhibition efficiency, CR_0 = corrosion rate without inhibitor, $C.R_1$ = corrosion rate with inhibitor

3. Results and Discussion

3.1 Elemental constituents of the Extracts

Spectroscopic screening of the plant extracts shows that the heavy metals present in the extracts are in minute concentration, hence making the plant extract suitable for use as corrosion inhibitor.

3.2 Functional Groups of the Different Parts of *Solanum tuberosum*

The FTIR spectrum of potato leaves, stem, and root (Figures 1-3) indicates the presence of some chemical functionality groups. For potato leaves (Figure 1), the strong band at 3441.2 cm^{-1} indicate the presence of O-H stretching vibrations which was also seen in *Malus domestica* vinegar extract [16]. C = C stretching bond was noticed at 1649.19 cm^{-1}, same as in [17] *Hunteria umbellate* extract, while a strong C- O bond was equally noticed at 1128.39 cm^{-1}.

Potato stem (Figure 2), show strong absorption band at 3423.76 cm^{-1} and this was attributed to O-H stretching vibration. At 1604.83cm^{-1}, the activity of C=C stretch appears while at 1400.37cm^{-1}.

Table 1: Elemental composition of the Different Parts of *Solanum Tuberosum* showing the Concentration of some Metals.

	Ca	Fe	Mg	Cu	Mn	Pb	Ni	Cr	Cd	Zn
	Ppm									
Leaf	15.870	0.206	11.459	0.103	0.468	0.050	0.012	0.002	ND	0.618
Stem	12.700	5.017	4.060	0.110	0.961	0.072	0.007	0.009	ND	1.089
Root	9.767	0.687	4.981	0.189	0.268	0.079	0.015	0.002	0.001	0.317

Table 1: Elemental composition of the Different Parts of *Solanum Tuberosum* showing the Concentration of some Metals.

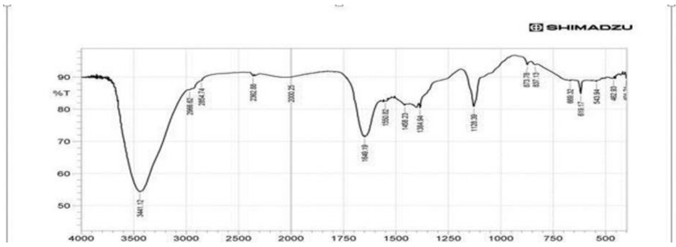

Figure 1: FTIR Spectrum for *Solanum Tuberosum* leaf Extract

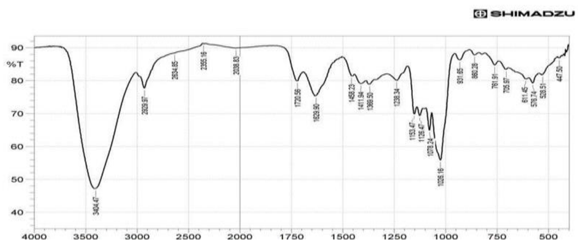

Figure 2: FTIR Spectrum for *Solanum Tuberosum* Stem Extract

The potato root (Figure 3), show strong band at 3404.47 cm^{-1} of O-H stretching vibration which reduces to 2929.97cm^{-1} of C-H stretching band which was reported for spearmint extract and *Morinda citrifolia* extract [18]. At 1720.56cm^{-1} C- O stretching vibration appears while at 1629.90cm-1 C=C stretching frequency occurs. A sharp adsorption band was observed at 1026.16cm^{-1} and this was attributed to C- O stretching vibration. This shows that the extract contains (O-H), (C=C), (C-H), (C-O) functional groups.

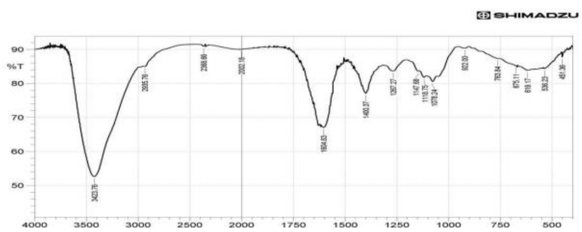

Figure 3: FTIR Spectrum for *Solanum Tuberosum* Root Extract

3.3 Corrosion behaviour

The corrosion behaviour of 2101 and 2205 duplex stainless steel in 0.5M H_2SO_4 at various concentrations of copper nanoparticles synthesized by potato leaf, stem and root extracts are shown in Figures 4-9.

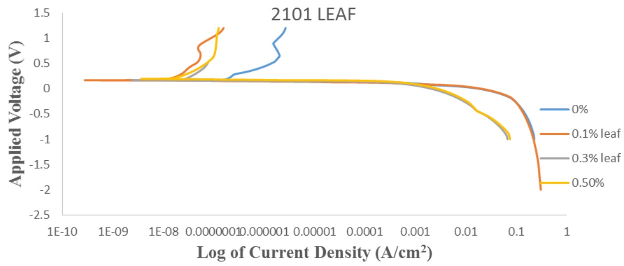

Figure 4: Potentiodynamic polarization curves for 2101 duplex stainless steel immersed in 0.5M H2SO4 with and without potato leaf extract as inhibitor.

On addition of nanoparticles from leaf (Figure 4), the polarization curve shifted to the left, this shows that the steel on addition of nanoparticles serves as inhibitors against corrosion in the environment. the corrosion current (icorr) values reduces with increased in the concentration of inhibitors from 1.17×10-7 A/cm2 for 0% inhibitors to 1.54 ×10-8 0.5% inhibitors (Table 2). Thereby showing a corresponding reduction in the corrosion rates. The Ecorr shifted to a more positive side. The corrosion potential values increased with increased concentration of the inhibitor. The inhibitors deactivate the anodic sites on the metal surface by causing the local current density to exceed the amount needed for passivation therefore establishing the corrosion inhibition at higher concentration of corrosion inhibitors.

Table 2: Electrochemical polarization parameters for 2101 duplex stainless steel immersed in 0.5M H_2SO_4 solution at different concentrations of potato leaf extract.

Samples	E_{corr} (V)	I_{corr} (A/cm2)	Corrosion rate (mm/yr)	Inhibitor Effiecency (%)
0%	0.16822	1.7717E-07	0.00205870	-
0.1% leaf NP	0.16827	2.2948E-08	0.00150460	26.915
0.3% leaf NP	0.16881	1.6790E-08	0.00024029	88.328
0.5% leaf NP	0.19325	1.5436E-08	0.00017937	91.287

In Table 2, at 0.5%, the inhibitor efficiency was not very high as compared to 0.3% leaf. Inhibition efficiency was observed to increase with increase of inhibitor concentration. The lowest inhibition efficiency of 26.91% was recorded with 0.1% inhibitor concentration while maximum inhibition efficiency of 91.28% was attained with maximum inhibitor concentration of 0.5%. For the nanoparticles synthesised by potato leaf extracts the corrosion rates decreases with increased concentration of inhibitors. The corrosion rate was observed to decrease from ratio of 11:1

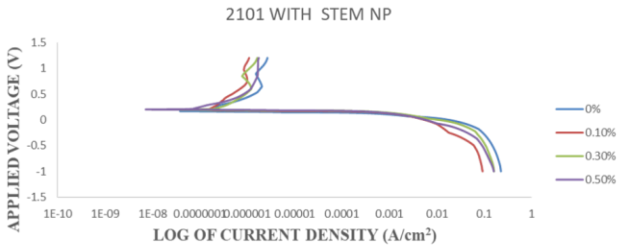

Figure 5: Potentiodynamic polarization curves for 2101 duplex stainless steel immersed in 0.5M H_2SO_4 with and without potato stem extract as inhibitor.

From Figure 5, it was observed that the addition of nanoparticles synthesised from the stem extract reduces the corrosion current, indicating resistance to corrosion offered by the steel due to the inclusion of the nanoparticles to serve as inhibitors against corrosion in that environment. The corrosion potential (E_{corr}) values increases to more positive values as the concentration increases. The Inhibition efficiency was observed to increase with increase of inhibitor concentration.

The inhibition efficiency of 87.89% was least exhibited by 0.1% inhibitor concentration while maximum inhibition efficiency of 91.88% was attained at concentration of 0.5%. Corrosion rate was observed to decrease with the ratio of 12: 1

Table 3: Electrochemical polarization parameters for 2101 duplex stainless steel immersed in 0.5M H_2SO_4 solution at different concentrations of potato stem extract.

Samples	E_{corr} (V)	I_{corr} (A/cm2)	Corrosion rate (mm/yr)	Inhibitor Efficiency (%)
0%	0.16822	1.7717E-07	0.00205870	-
0.1% leaf NP	0.183070	1.1448E-07	0.00024922	87.894
0.3% leaf NP	0.193080	1.0584E-07	0.00018414	91.056
0.5% leaf NP	0.201920	5.7879E-08	0.00016725	91,876

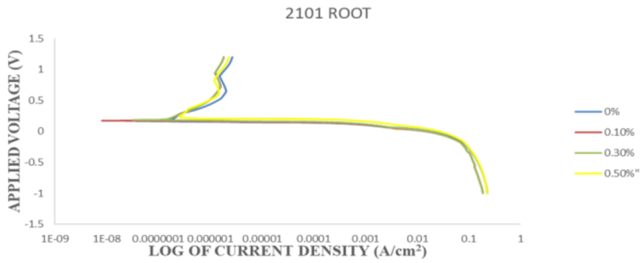

Figure 6: Potentiodynamic polarization curves for 2101 duplex stainless steel immersed in 0.5M H_2SO_4 with and without potato root extract as inhibitor

Fig 6. showed that the electrolyte with 0.5% of nanoparticles from root offered the highest resistance to corrosion. On addition of nanoparticles from leaf, it was observed that the E_{corr} was shifted to the positive side of the anodic arm and was in increasing order with increase in the concentration of the inhibitor. The corrosion potential shift to more positive value showed the tendency for the inhibitors to inhibit corrosion. The i_{corr} shifted to the left, thus indicating that there was resistance offered by the steel due to the inclusion of the nanoparticles to serve as inhibitors against corrosion in that environment. Inhibition efficiency was observed to increase with increase of inhibitor concentration.

Table 4: Electrochemical polarization parameters for 2101 duplex stainless steel immersed in 0.5M H_2SO_4 solution at different concentrations of potato root extract

Samples	Ecorr (V)	Icorr (A/cm^2)	CORROSION RATE (mm/yr)	INHIBITOR EFFICIENCY (%)
0%	0.16822	1.7717E-07	0.00205870	-
0.1% Root NP	0.17407	1.2986E-07	0.00150900	26.701%
0.3% Root NP	0.18565	8.6704E-08	0.00100750	51.061%
0.5% Root NP	225520	2.79048E-07	8.0687E-05	96.081%

Table 4 show the inhibition efficiency of the root sample. The maximum inhibition efficiency was

96.08% with 0 .5 % inhibitor while the least inhibition efficiency of 26.70% was observed at 0.1% inhibitor concentration. Corrosion rate decrease from 2.05870 ×10^{-3}mm/yr to 8.0687×10^{-5}mm/yr.
The optimum corrosion resistance for 2101 duplex stainless steel was observed at 0.5% copper nanoparticles synthesized with root extracts. The least corrosion resistance was observed with sample without inhibitors.
Generally the corrosion rates decreases with increasing concentration for all the nanoparticles. Addition of nanoparticles reduces the corrosion rate of 2101 in 0.5M H_2SO_4.

Corrosion behaviour of 2205 duplex stainless steel in different concentration of inhibitors in 0.5M of H_2SO_4
Figure 7 show the effect of addition of nanoparticles synthesized from leaf on the corrosion behaviour of 2205 samples immersed in 0.5M H_2SO_4. The curves showed a reduction on the corrosion cuurent density with the addition of copper nanoparticles, thus indicating that there was resistance by the steel due to the inclusion of the nanoparticles, to serve as inhibitors against corrosion in that environment. The E_{corr} also shifted to more positive side of the anodic part of the curves, and these was in an increasing order with increase in the concentration of the inhibitor.

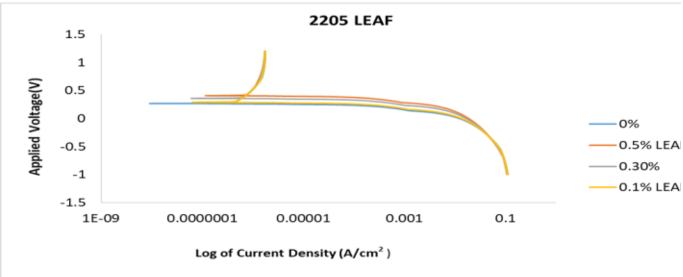

Figure 7: Potentiodynamic curves showing the corrosion behaviour of Duplex stainless steel 2205 in H_2SO_4 containing Nanoparticles from leaf of *Solanum tuberosum* at different concentration.

Least inhibition efficiency of 25.003% was exhibited by 0.1% inhibitor concentration while maximum inhibition efficiency of 36.937% was attained with maximum inhibitor concentration of 0.5%. Corrosion rate was also observed to reduce from 1.6 : 1.

From Figure 8, it is seen that on addition of nanoparticles from stem, the I_{CORR} shifted to the left, thus indicating that there was resistance offered by the steel due to the inclusion of the nanoparticles to serve as inhibitors against corrosion in that environment. The E_{corr} was shifted to the positive side of the anodic arm and was in increasing order with increase in the concentration of the inhibitor. Inhibition efficiency was observed to increase with increase of inhibitor concentration. The maximum inhibition was 36.94%.

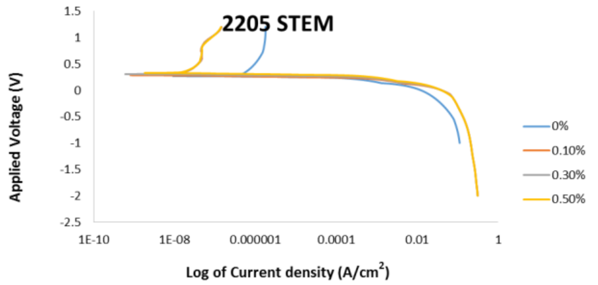

Figure 8: Potentiodynamic curves showing the corrosion behaviour of Duplex stainless steel 2205 in H_2SO_4 containing Nanoparticles from Stem of *Solanum tuberosum* at different concentration.

Table 5: A Table Showing the Ecorr, icorr, corrosion rate and the inhibitioin efficiency of 2205 duplex stainless steel with different concentratioin of copper nanoparticles from leaf of *Solanum Tuberosum*

	E_{CORR} (V)	i_{corr} (A/cm^2)	CORROSION RATE(mm/yr)	INHIBITOR EFFICIENCY
0%	0.21109	6.3056E-08	0.00073271	-
0.1% LEAF NP	0.29101	3.5602E-07	0.00071439	25.003%
0.3% LEAF NP	0.36122	6.0733E-07	0.00056571	29.520%
0.5% LEAF NP	0.40931	3.961E-07	0.00046207	36.937%

Least inhibition efficiency of 38.892% was exhibited by 0.1% inhibitor concentration while maximum inhibition efficiency of 59.614% was attained with maximum inhibitor concentration of 0.5%. Corrosion rate was observed to decrease from 0.00073271mm/yr to 0.00029591mm/yr.

Addition of nanoparticles from root as shown in Figure 9 indicated that the I_{CORR} shifted to the left, thus there was resistance by the steel due to the addition of the nanoparticles to serve as inhibitors against corrosion in acidic environment. Also the E_{CORR} shifted to the positive side of the anodic arm, and this was in an increasing order with increase in the concentration of the inhibitor.

Table 6: A Table Showing the Ecorr, Icorr, Corrosion Rate and the Efficiency of the Inhibitor in Solution Containing DSS 2205 and Nanoparticles from Stem of *Solanum Tuberosum*

	Ecorr (V)	icorr (A/cm2)	CORROSION RATE (mm/yr)	INHIBITOR EFFICIENCY
0%	0.21109	6.3056E-08	0.00073271	-
0.1% ROOT NP	0.30771	1.5857E-08	0.00018426	74.853%
0.3% ROOT NP	0.43299	9.6709E-05	1.1238E-05	98.466%
0.5% ROOT NP	0.46871	7.0357E-05	8.1754E-06	98.884%

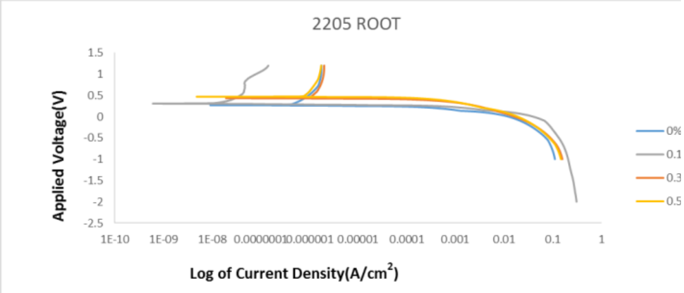

Figure 9: Potentiodynamic curves showing the corrosion behavior of Duplex stainless steel 2205 in H_2SO_4 containing Nanoparticles from Root of *Solanum tuberosum* at different concentration.

Table 7: A Table Showing the Ecorr, Icorr, Corrosion Rate and the Efficiency of the Inhibitor inSolution Containing DSS 2205 and Nanoparticles from Root of *Solanum tuberosum*

samples	E_{corr} (V)	I_{corr} (A/cm^2)	CORROSION RATE (mm/yr)	INHIBITOR EFFICIENCY
0%	0.21109	6.3056E-08	0.00073271	-
0.1% STEM NP	0.21144	2.5468E-07	0.00044773	38.892%
0.3% STEM NP	0.23317	3.309E-07	0.0003845	47.524%
0.5% STEM NP	0.25576	3.8531E-07	0.00029591	59.614%

Least inhibition efficiency of 74.853% was exhibited by 0.1% inhibitor concentration while maximum inhibition efficiency of 98.884% was attained with maximum inhibitor concentration of 0.5%. Corrosion rate was observed to decrease from 0.00073271mm/yr to 8.1754E-06mm/yr (Table 7).

The results from the potentiodynamic polarization curves showed that the corrosion rate decreases with an increase in inhibitor concentration. This was in agreement with some works on inhibition such as Starch [19], *Tridax procumbens L* leaves [20], Rice Husk [21], Cinnamon [22], Ginger [23], *Spirula plantesis* [11], Potato peel [24], Musa paradisiaca [25] and Potato leaf

which were said to have reduced corrosion rate. The electrochemical polarization parameter tables, show that 0.5% nanoparticles synthesized from root had the best inhibition efficiency on both 2101 and 2205 duplex stainless steel in 0.5M H_2SO_4. The inhibition efficiency of nanoparticles synthesized by leaf and stem of 2101 duplex stainless steel are higher than 2205 duplex stainless steel in 0.5 M H_2SO_4. The highest inhibition efficiency was observed for 2205 duplex stainless steel with copper nanoparticles synthesized by potato root extracts.

3.4 Absorbance of Nanoparticles

From the spectra obtained from the Ultraviolet Visible Spectrophotometer, it was observed that at a wavelength of 200 Nanometers, the nanoparticles had absorbance of the following values in the table below.

Table 8: The Absorbance of the Nanoparticles at 200nm

SAMPLE	ABSORBANCE
LEAF N.P	1.44
STEM N.P	0.812
ROOT N.P	0.528

It was observed that the values obtained from the optical interference spectrophotometer agreed with the value obtained from the Ultraviolet Visible Spectrophotometer. The optical interference spectrophotometer produced values for the wavelength and percentage transmittance (% Transmittance).
The % transmittance was converted to absorbance by the beer lambert relation:

$$A = 2 - \text{Log } \% \, T$$

Where,
A=Absorbance
%T= percentage transmittance

Figures 9-12 shows the plot of absorbance against the wavelength of the synthesis NPs.

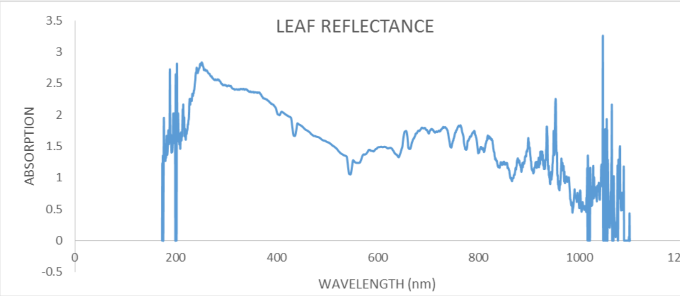

Figure 10: Spectrum of leaf nanoparticles Reflectance

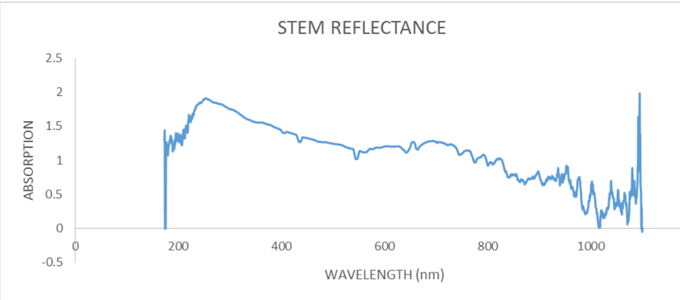

Figure 11: Spectrum of stem nanoparticles Reflectance

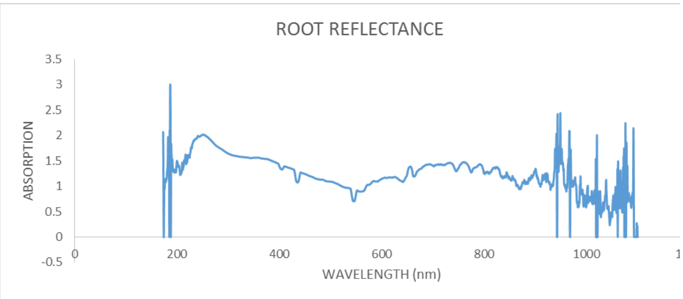

Figure 12: Spectrum of stem nanoparticles Reflectance

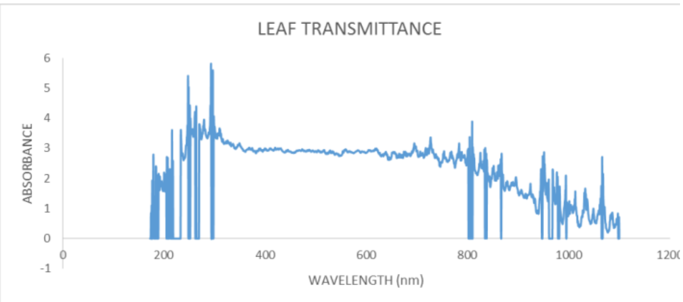

Figure 13: Spectrum of leaf nanoparticles Transmittance

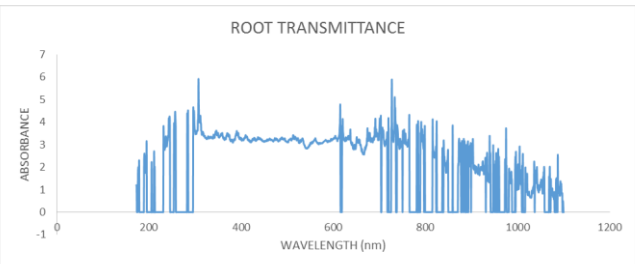

Figure 14: Spectrum of Root nanoparticles Transmittance

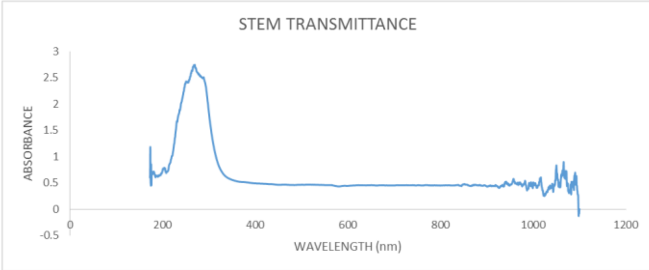

Figure 15: Spectrum of Stem nanoparticles Transmittance

In figures 10-15, a peak ranging from 260nm-280nm was common to the spectra of the potato plant parts nanoparticles which suggest the presence of phenolic group in the extracts. The phenolic compounds present in the extracts are mainly responsible for the inhibition behaviour or mechanism of the Nanoparticles as they contain oxygen and double bonds which have the ability to inhibit corrosion on the surface of the metal [26]. This result agrees with the Fourier Transform Infra-red (FTIR) characterization.

3.5 Resistivity of the Nanoparticles

Table 9: Nanoparticles obtained from potato leaf
Current Source: 4.996632E-04 A
Resistivity: 22.6764 Ωcm

X	Y	Rs (Ohm)	Res (Ohmcm)	V/I (Ohm)	Thickness (um)
0.000	0.000	6.58E+03	23.039	1.45E+03	35
2.500	0.000	6.51E+03	22.800	1.43E+03	35
0.000	2.500	6.47E+03	22.649	1.42E+03	35
-2.500	0.000	6.43E+03	22.521	1.42E+03	35
0.000	-2.500	6.39E+03	22.373	1.41E+03	35

Table 10: Nanoparticles obtained from potato stem
Current Source: 4.997536E-07A

Resistivity: 25760 Ωcm

X	Y	Rs (Ohm)	Res (Ohmcm)	V/I (Ohm)	Thickness (um)
0.000	0.000	7.665E+06	2.68E+04	1.691E+06	35
2.500	0.000	7.757E+06	2.71E+04	1.712E+06	35
0.000	2.500	6.750E+06	2.36E+04	1.489E+06	35
-2.500	0.000	7.683E+06	2.68E+04	1.695E+06	35
0.000	-2.500	7.001E+06	2.45E+04	1.545E+06	35

Table 11: Nanoparticles obtained from potato root Current Source: 4.997444E-06
Res
istivity: 1036 Ωcm

X	Y	Rs(Ohm)	Res(Ohmcm)	V/I (Ohm)	Thickness (um)
0.000	0.000	2.92E+05	1.02E+03	6.45E+04	35
2.500	0.000	2.94E+05	1.03E+03	6.50E+04	35
0.000	2.500	2.97E+05	1.04E+03	6.56E+04	35
-2.500	0.000	2.99E+05	1.04E+03	6.60E+04	35
0.000	-2.500	3.007E+05	1.05E+03	6.63E+04	35

Table 9-11 shows the resistivity of the Nanoparticles obtained from the parts of potato plant. Where, Rs= Sheet Resistance, Res= Resistivity

It was observed from table 9-11 that stem and root nanoparticle have a higher resistivity which in turn helps to protect the steels from localized corrosion. High resistivity is reported to favour low corrosion rate [27] (Lim *et al*., 2017) and this corroborates the results gotten from the potentiodynamic test where the stem and root were observed to have a lower corrosion rate than the leaf nanoparticle.

3.6. Inhibition mechanism

The inhibition of metal corrosion depends on the nature of the metal structure, the metal surface, and electronic characteristics of the nanoparticles, as well as the aggressive media. In acidic solution, Cu_2O nanoparticles are reduced to Cu^{2+} according to the following equation;

$$Cu_2O + 2H^+ + 2e^- \rightleftharpoons 2\,Cu^+ + H_2O$$

Therefore, the metal protection could be attributed to the adsorption or electrodeposition reaction of metallic cations, copper ions, on the mild steel surface. The adsorbed cations act as a protective layer, reducing the interaction between the aggressive ions and the steel surface.

Conclusion

The results shows that nanoparticles from different parts of the potato plant can serve as corrosion inhibitor. It was revealed that the nanoparticles obtained from these different parts of plant inhibited duplex stainless steel 2101 and 2205. The inhibition efficiency of these inhibitors were in increasing order of the concentration of the inhibitors. Inhibition mechanisms of these extracts was adsorption on the surfaces of the steels which is as a result of the phenolic compounds present in the inhibitors. The sizes of these phenolic compounds made the extracts to form a covering on the steels thereby preventing the dissociation of the steels in the acidic environment. Moreover, the efficiency of the inhibitors is also attributed to the fact that heavy metals were not present in the extracts obtained from the plants. The roots offered the highest resistance to corrosion than the stem and leaf for the steel. The inhibitors were able to offer resistance to the flow of current hence protecting against localized corrosion.

Acknowledgment

I acknowledge the supports of Advanced Materials and Electrochemical Research group (AMERG) laboratory Federal University of Technology Akure, Nigeria and Sheda Science and Technology Complex (SHETSCO), Abuja, Nigeria.

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