Corrosion Behavior of Common Metals in Eutectic Ionic Liquids

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The corrosion behavior of six choline chloride-based eutectic solvents namely, ChCl-Ur, ChCl-EG, ChCl-Gl, ChCl-MA, ChCl-Ph and ChCl-TG towards copper, mild steel and stainless steel 316 have been investigated. The effect of temperature and moisture content was evaluated. The corrosion rates of the three materials increased with an increase in the temperature and moisture content. Stainless steel was found to be the most resistant under all experimental conditions. The experimental results demonstrated ChCl-Ph and ChCl-Gl to have high inhibition efficiency suggesting these to be a suitable candidate as green corrosion inhibitors for metal and alloys under extreme environments.

Keywords: Molten salts, Mild steel, Copper, Stainless steel, EIS, Cyclic voltammetry

1. INTRODUCTION

Ionic Liquids (IL) are under considerable industrial attention due to their intrinsic properties of thermal stability, negligible vapor pressure at room temperature, high decomposition temperature, solvation characteristics, non-flammability, and low melting points [1-4]. Ionic liquids have been referred in literature as fused salts, molten salts, ionic fluids, liquid electrolytes, ionic glasses, ionic melts, ambient temperature molten salts, liquid organic salts and designer chemicals [5]. These salts are referred as designer solvents as their physiochemical properties can be easily modified by changing the relevant anions and cations [6-8]. Ionic liquid mixtures, thus, offer enhanced possibilities for fine-tuning of mixture properties according to the desired applications [6-8].

Deep eutectic solvents (DES), a promising subgroup of IL, are eutectic mixtures of Lewis and Bronsted acids and bases. DES generally refers to mixture of salt and hydrogen bond donor to form liquid having melting point lower than its parent components [9, 10]. DES are regarded as alternatives...
to conventional IL and organic solvents due to their cost effectiveness, simple synthesis and flexibility in choice of constituent component [11, 12]. These are frequently being employed for applications in fields such as electrochemistry, solvent extraction, nanotechnology, shape controlled nanosized catalyst synthesis, lubricants and zeolite analogues synthesis [13-18].

Corrosion of metal and alloys is a major concern for industries that leads to financial burden in terms of maintenance and replacement costs. Organic polymeric corrosion inhibitors have conventionally been employed extensively to reduce corrosion of metal and alloys in aggressive media. The use of such corrosion inhibitors is particularly limited due to their low solubility in polar electrolytes, toxicity, non-biodegradability and high volatility. Due to increased environmental concerns associated with conventional corrosion inhibitors, recent studies are focused towards the search for environment benign corrosion inhibitors. IL are being recognized as potential green corrosion inhibitors for metals and alloys on account of their relative non-toxicity, biodegradability and high solubility in polar electrolytes [19-21]. The metal-inhibition bonding and electron rich centers acting as adsorption centers in case of IL is analogous as in case of corrosion inhibition mechanism by traditional organic polymeric inhibitors [5, 21]. The corrosion inhibition efficiency and adsorption behavior of few IL, such as azomethine and indazole derivatives, have been reported in literature [21-23]. Corrosion inhibition efficiency of imidazolium based IL in corrosive media have been reported to increase with an increase in the size and number of alkyl chains [19-22]. However, a longer chain molecule reduces the effective movement of inhibitor molecules in polar media. Thus, a moderate size and chain length is more reasonable in enhancing the corrosion inhibition as it favors the movement of inhibitor molecules from solution to the metallic surface as compared to a longer chain molecule [5, 24, 25]. Verma et al. suggested choline based IL to be the best example of moderate chain length and size molecule offering optimum conditions (hydrophilic or hydrophobic) for metal-inhibition interactions [5].

Choline chloride based DES (CDES), such as ChCl-Ur, represent an important class of IL as they are biodegradable, non-toxic, inexpensive and water soluble [26]. In spite of these environment friendly properties, the use of CDES as corrosion inhibitors is quite limited. Very few reports explaining the corrosion inhibition behavior of CDES have been reported in literature. An investigation of the corrosion rates of metal electrodes in ChCl-EG and proline-lactic acid showed increased stability and decreased corrosion rates of titanium, nickel and iron [27]. Kityk et al. studied the kinetics and corrosion mechanism of mild steel in ChCl-Ur and ChCl-EG [28]. They concluded that the corrosion in these media can lead to accelerated corrosion of mild steel due to the presence of chloride ions [28]. Understanding the corrosion rates of DES, proposed as potential lubricants, is an important factor to be researched for their commercial applicability. Abbott et al. evaluated the corrosion rates of aluminum, nickel and steel in CDES and reported to have significantly reduced corrosion rates in such media [18].

Research on the synthesis and applications of CDES is a relatively new subject, with first reference to its preparation appearing in literature in 2001. With the potential industrial applications of these materials, one of the properties that are crucial to design and selection for materials of construction for the equipment, is the corrosion properties [29, 30]. The present research is an attempt to report the inhibition behavior and characteristics of mild steel, copper and stainless steel 316 in six CDES (ChCl-Ur, ChCl-EG, ChCl-Gl, ChCl-MA, ChCl-Ph and ChCl-TG) and their aqueous solutions at room and elevated temperatures.
2. EXPERIMENTAL PROCEDURES

2.1. Materials

Malonic acid (assay 99% min.), urea (99% min.), glycerol, ethylene glycol and phenol were purchased from LabChem Inc. Triethylene glycol (extra pure) was supplied by SchartauChemie S.A., Spain, respectively. Potentiostat (ACM Instruments - Gill AC), double distilled water (Water Still Aquatron A4000D, UK), precise vacuum oven (Model WOV-30, DAIHAN Scientific Co. Ltd, Korea) fitted with a vacuum pump (Model G-50DA, UlvacKiko, Japan) and hot plate stirrer (MSH-20D, Korea) were used.

2.2. Metal and alloys Composition

Table 1 summarizes the composition of mild and stainless steel. All elements are mentioned other than iron in these alloys.

<table>
<thead>
<tr>
<th>Composition of mild and stainless steel.</th>
</tr>
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<tr>
<td>Mild Steel</td>
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<tr>
<td>Stainless Steel</td>
</tr>
</tbody>
</table>

2.3. CDES Preparation:

21.00 g of the salt, Choline Chloride, was mixed with hydrogen bond donors (HBD) i.e. 18.07g urea, 18.67g ethylene glycol, 27.70g glycerol, 15.65g malonic acid, 42.47g phenol and 67.76g triethylene glycol, respectively according to their respective molar ratios mentioned in literature, as given in Table 2. In each case, the mixture was shaken at 400 rpm and 343 K for one to two hours for the formation of stable DES with no apparent precipitation. All chemicals were subjected to vacuum oven for 24 hours at 343 - 353 K to remove moisture. The prepared DES were put in desiccators to avoid any moisture influence before the measurements.

<table>
<thead>
<tr>
<th>Table 2. Molar ratio for CDES synthesis</th>
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</thead>
<tbody>
<tr>
<td>CDES (Salt+HBD)</td>
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<tr>
<td>ChCl-Ur</td>
</tr>
<tr>
<td>ChCl-EG</td>
</tr>
<tr>
<td>ChCl-Gl</td>
</tr>
<tr>
<td>ChCl-MA</td>
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<tr>
<td>ChCl-Ph</td>
</tr>
<tr>
<td>ChCl-TG</td>
</tr>
</tbody>
</table>
2.4. Corrosion Tests

A typical 3 electrode cell was used to carry out the electrochemical measurements. A saturated calomel electrode containing potassium chloride was used as reference electrode (RE). The potential of working electrode (WE) was measured with respect to the RE. A platinum wire was used to act as the auxiliary electrode (AE). The platinum wire transmits current through the DES, either to or from the WE. A Gill AC potentiostat was used to connect the three electrodes. Data was recorded from the software coupled with Gill AC potentiostat. The electrodes, with exposed surface area of approximately $7.5 \text{ cm}^2$, were immersed in a 17 mL of CDES aqueous solution. Before the start of the experiment, the electrodes were immersed in solution for 5 minutes to ensure the thermal equilibrium of the system. Electrochemical measurements were performed and recorded using A GILL AC potentiostat. The three metals were tested with six DESs and their aqueous mixture (water wt%: 5% and 10%) at 298 K, 323 K and 348 K, respectively. EIS and potentiodynamic polarization curves were performed and reported.

The electrochemical impedance spectroscopy was carried out between a frequency range of 1000 Hz to 0.1 Hz with a peak to peak amplitude of 20 mV. The potentiodynamic polarization was conduction within the potential range of -150 mV to +150 mV with a sweep rate of 20 mV/min. The cathodic and anodic regions of the generated Tafel plot were scanned from -150 mV to 0 mV and from 0 mV to +150 mV, respectively.

3. RESULTS AND DISCUSSION

Electrochemical tests, like linear polarization resistance (LPR), potentiodynamic polarization curves, and Electrochemical Impedance Spectroscopy (EIS) provide a convenient, easy and quick measurements for corrosion rates. Since the corrosion phenomena is time dependent the aforementioned tests may not provide an accurate interpretation of the corrosion rate. Gravimetric method, where the metal is put in the media to be tested then actual change in mass is measured, is more accurate in predicting corrosion rate. Nevertheless, the results obtained from electrochemical tests, besides being quick and convenient can be correlated to the actual corrosion rates, and will give a valid comparison between different metals or different mediums.

The three electrochemical tests mentioned above were performed, and their results show good agreements in describing the corrosion rate trend with respect to the investigated parameters. The full results obtained for the effect of six choline chloride based ionic liquids on acidic corrosion of mild steel, copper and stainless steel has been reported in table 1-18 of the Appendix.

3.1 Potentiodynamic Polarization Studies

The potentiodynamic polarization curves (PPC) for cathodic and anodic PPC for copper, mild steel and stainless steel samples recorded in order to determine the electrochemical nature of the inhibitor CDES molecules [31]. The PPC curves for copper at different temperature and water content (wt%)
using ChCl-Ur are presented in figure 1 – 5 while the complete data for other metals and CDES are presented in table 1-18 of the Appendix

**Figure 1.** Potentiodynamic polarization curves of copper immersed in pure ChCl-Ur DES (0% water content) at different temperatures

**Figure 2.** Potentiodynamic polarization curves of copper immersed in ChCl-Ur DES with 5% water content at different temperatures
The data for Copper in ChCl-Ur can be taken as a representative example of the results, the same trend with regards to temperature and water content is observed in the other metals and mediums tested. Figure 1, Figure 2, and Figure 3 show the potentiodynamic polarization curves results for copper in ChCl-Ur at 0% 5% and 10% water content respectively, each figure shows three curves corresponding to different temperatures, namely 25 °C, 50 °C and 75 °C.

The rest potential decreases as temperature increases, this decrease in corrosion potential is caused by a shift in the anodic dissolution of copper, hence the corrosion rate is higher at higher temperatures. A similar trend on the cathodic part of the curve is observed, where the corrosion potential increases as the water content increases, and the increase in potential is accompanied by a shift in the cathodic part of the curve as shown in Figure 4.
Figure 5. Potentiodynamic polarization curves copper in ChCl-Ur DES at different temperatures and water contents

The values of Tafel parameters from the PPC curves such as slopes (cathodic and anodic), corrosion current density and corrosion potential were determined through extrapolation of linear segments of Tafel cathodic and anodic linear segments. The values of such parameters are presented in table 1-18 of the Appendix.

From the results provided in table 1-18 of the Appendix, it is clear that CDES significantly retards the cathodic and anodic reactions. The significant reduction in the current density in the presence of CDES can be attributed to the adsorption of CDES molecules on the metal surface preventing cathodic or anodic reactions [32, 33].

The corrosion current density increases as the water content in the system increases. It can be seen that increasing the water content at a fixed temperature or increasing the temperature at a fixed water content caused a decrease in the charge transfer resistance $R_p$ and an increase in the double layer capacitance $C_{dl}$. This indicates that the electrochemical process intermediates from the dissolution of copper have low retention time in this case. The increase in double layer capacitance can be due to a thinner protective film being formed on the copper surface. This can also be attributed to a passive layer formation on the material surface [28]. The displacement of corrosion potential ($E_{corr}$) in the presence or absence of CDES in the corrosive environment determines the inhibitor type (cathodic, anodic or mixed) [32, 34, 35]. In our present study, both the $\beta_c$ and $\beta_a$ values are affected representing that both metal dissolution (anodic) and hydrogen evolution (cathodic) were inhibited. The inhibition type can be recognized to be cathodic type inhibition as the $\beta_c$ values were more affected compared to $\beta_a$ values [32, 34-37].

3.2 Electrochemical Impedance Spectroscopy (EIS)

The electrochemical impedance spectroscopy is an imperative method to understand the physical processes and electrochemical changes occurring during corrosion of metal at the metal/electrolyte interface [36, 38]. The corrosion characteristics of copper, mild steel and stainless steel in 1 M HCl solution was investigated in six eutectic ionic liquids (pure as well as with 5 – 10 wt% water) at three
different temperatures (25°C, 50°C and 75°C). Figure 6 shows the corrosion rates for copper immersed in 1 M HCl solution with eutectic ionic liquids at various water concentrations (5 – 10 wt%). The results depict that the eutectic ionic liquids act as inhibitor molecules and inhibit corrosion of copper by adsorbing on the material-electrolyte interfaces [31, 39]. Figure 6 show that the presence of water in the solution increases the corrosion rate. The CDES molecules tend to adsorb on the metal/electrolyte surface thus inhibiting corrosion [40]. This suggests that the presence of water in the solution decreases the concentration of the inhibitor in the system and decreases the adsorption of CDES molecules on the metal/electrolyte interface. The decrease in the inhibitor concentration at the metal/electrolyte interface tend to decrease the inhibitive film on the metal surface thus increasing the corrosion rates of copper and other metals.

![Figure 6. Corrosion rate of copper in CDES with different water contents and at A) 25°C and B) 75°C](image)

The analysis of the electrochemical impedance spectra for 1 M HCl medium with pure eutectic ionic liquids and in the presence of water (5-10 wt%) was carried out with the use of suitable equivalent circuit (as shown in figure 6). The values for the solution resistance $R_s$, the Double layer capacitor $C_{dl}$, and the polarization resistance $R_p$, can be obtained and used to interpret the behavior of the system [40, 41]. A Randles circuit with solution resistance $R_s$, a polarization resistance $R_p$, and a capacitor $C_{dl}$ as shown in Figure 6, was found to best fit the experimental data from the EIS test [40].

![Figure 7. Randles circuit](image)
The main parameters along with the corrosion rates and inhibition efficiencies are provided in table 1-18 of the Appendix.

An attempt was made to replace the double layer capacitance by a Constant phase element CPE, in order to compensate for any non-homogeneity in the system which can be caused for instance by roughness in the surface, as opposed to the ideal response from single electrochemical reactions where the capacitor having a phase equal to 1 [42]. The fitting gave less error but the results didn’t predict the actual behavior of the system which can be confirmed by the results from potentiodynamic polarization curves. This make it clear that upon fitting a data to a circuit, the best model is not necessary the one with the least error but rather the one that best describes the actual system. Results from the fit to the circuit in Figure 6 are in good accord with the results from the potentiodynamic polarization curves.

Figure 6 presents the corrosion of copper with pure CDES as electrolytes at different temperatures. Inspection of the figure shows that the corrosion of copper increases as the temperature is increased. The maximum inhibition is offered by ChCl-Ur and ChCl-Gl even at elevated temperatures. Similar trends are obvious in case of corrosion of mild steel, copper and stainless steel where the metal corrosion increases with increasing temperature. Similarly, the corrosion rates of mild steel, copper and stainless steel increases with increasing the water content in the solution.

**Figure 8.** Corrosion rate of copper in pure CDES at different Temperature

The effect of temperature on the corrosion properties of CDES towards copper, mild steel and stainless steel has been shown in Figure 1 to 5 and table 1-18. It is apparent from these tables that the corrosion rates of these materials in CDES increases with increasing the solution temperature. This can be attributed to the high kinetic energies of the CEDS molecules and molecular decomposition of the CDES. The higher kinetic energies of the CDES molecules at high temperatures result in rapid movements that result in decreased attractive forces between CDES molecules and material surface. This increases the desorption probability of the molecules from the material surface resulting in higher corrosion rates of these materials. Furthermore, rapid etching of the material and molecular decomposition of the CDES at elevated temperatures might be attributed to affect the corrosion properties and inhibition efficiency of these CDES resulting in enhanced corrosion rates of mild steel, copper and stainless steel. Similar results have been reported by Verma et al. who used CDES as
corrosion inhibitors on mild steel in acidic media. Additionally, Verma et al. explained in detail the temperature effects on inhibition efficiencies of CDES through Arrhenius equation comparing the activation energies of non-inhibited and inhibited mild steel [5].

It has been established that these CDES are hygroscopic and changes in water contents of the CDES solvents can lead to physicochemical characteristics of these CDES. An increase in the water content in CDES results in decreased viscosity, decreased density and increased conductivity of the CDES-water solution. Thus, an increase in the water content of these CDES effects the physiochemical properties and corrosion activities of CDES on copper, stainless steel and mild steel. Increase in the water content of the CDES results in increased corrosion rates of mild steel, stainless steel and copper. This can be attributed to the reduced viscosity resulting in enhanced diffusion rates. These enhanced diffusion rates can adversely affect the adsorbed CDES protective layer on the material surface. Similar trends were reported by Kityk et al. who reported the mechanism and kinetics of mild steel corrosion in ChCl-EG and ChCl-Ur [28]. Similar studies showing results on the corrosion activities and mechanism of several CDES in acidic environment has been reported in literature [31].

The above results for the corrosion activities of six CDES (ChCl-Ur, ChCl-EG, ChCl-Gl, ChCl-MA, ChCl-Ph and ChCl-TG) on mild steel, stainless steel and copper dictates that two CDES namely ChCl-Ur and ChCl-Gl have lowest corrosion rates for these materials even at elevated temperatures and with moisture content upto 10 wt% percent. This point out towards the fact that these CDES (ChCl-Ur and ChCl-Gl) can be used as corrosion inhibitors in harsh acidic and moist environment for structures and machines related to mild steel, stainless steel and copper.

4. CONCLUSION

In the present study, inhibition effects of six choline based deep eutectic solutions (CDES) has been demonstrated to be effective corrosion inhibitors for copper, mild steel and stainless steel 316. The study reveals that the corrosion rate of these materials increases as the temperature and moisture content increases. The corrosion rate of steel in urea and ethylene glycol based CDES was found to be minimum as compared to other materials and CDES. The corrosion inhibition of stainless steel 316 was found to be maximum in case of pure ChCl-Ur at 25°C. Moreover, the corrosion rate of stainless steel was found to be the lowest at all conditions for urea based CDES materials suggesting it to be suitable for a number of industrial applications. The results suggest that these CDES, urea and glycol based CDES, can be suitable alternatives to traditional organic polymeric corrosion inhibitors.

ACKNOWLEDGEMENT
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References

Appendix

EIS and CS parameters obtained using Glycine on copper. obtained for mild steel in 1 M HCl in absence and presence of different concentrations of GPHs.

Copper:

Table 1. EIS and PPC parameters obtained for Copper in ChCl-EG (in absence and presence of different water content)

<table>
<thead>
<tr>
<th>T</th>
<th>Water %</th>
<th>Rs Ω cm²</th>
<th>CPE-T Ω cm²</th>
<th>Rp mV</th>
<th>E_cor</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current mA/cm²</th>
<th>CR-Tafel mm/yr</th>
<th>CR-EIS mm/yr</th>
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<tbody>
<tr>
<td>25</td>
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<td>45.3</td>
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<td>0.01744</td>
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Table 2. EIS and PPC parameters obtained for Copper in ChCl-GI (in absence and presence of different water content)

<table>
<thead>
<tr>
<th>T</th>
<th>Water</th>
<th>Rs</th>
<th>CPE-T</th>
<th>Rp</th>
<th>E_corr</th>
<th>ba</th>
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<th>Corrosion Current</th>
<th>CR-Tafel</th>
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<tr>
<td>°C</td>
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<td>Ω.cm²</td>
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Table 3. EIS and PPC parameters obtained for Copper in ChCl-MA (in absence and presence of different water content)

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<th>Rs</th>
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Table 4. EIS and PPC parameters obtained for Copper in ChCl-Ph (in absence and presence of different water content)

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<th>Rp</th>
<th>E_corr</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current</th>
<th>CR-Tafel</th>
<th>CR-EIS</th>
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<td>°C</td>
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<td>Ω.cm²</td>
<td>mV</td>
<td>mV/dec</td>
<td>mV/dec</td>
<td>mA/cm²</td>
<td>mm/yr</td>
<td>mm/yr</td>
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Table 5. EIS and PPC parameters obtained for Copper in ChCl-Ur (in absence and presence of different water content)

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<th>T (°C)</th>
<th>Water %</th>
<th>Rs (Ω cm²)</th>
<th>CPE-T (Ω cm²)</th>
<th>Rp (mV)</th>
<th>Ecorr (mV)</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current (mA/cm²)</th>
<th>CR-Tafel (mm/yr)</th>
<th>CR-EIS (mm/yr)</th>
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Table 6. EIS and PPC parameters obtained for Copper in ChCl-TG (in absence and presence of different water content)

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<th>CPE-T (Ω cm²)</th>
<th>Rp (mV)</th>
<th>Ecorr (mV)</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current (mA/cm²)</th>
<th>CR-Tafel (mm/yr)</th>
<th>CR-EIS (mm/yr)</th>
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<tbody>
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Mild steel:

**Table 7.** EIS and PPC parameters obtained for mild steel in ChCl-EG (in absence and presence of different water content)

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<th>Rp (Ω.cm²)</th>
<th>E_cor (mV)</th>
<th>ba (mV/dec)</th>
<th>bc (mV/dec)</th>
<th>Corrosion Current (mA/cm²)</th>
<th>CR-Tafel (mm/yr)</th>
<th>CR-EIS (mm/yr)</th>
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**Table 8.** EIS and PPC parameters obtained for mild steel in ChCl-GI (in absence and presence of different water content)

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<th>CPE-T</th>
<th>Rp (Ω.cm²)</th>
<th>E_cor (mV)</th>
<th>ba (mV/dec)</th>
<th>bc (mV/dec)</th>
<th>Corrosion Current (mA/cm²)</th>
<th>CR-Tafel (mm/yr)</th>
<th>CR-EIS (mm/yr)</th>
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Table 9. EIS and PPC parameters obtained for mild steel in ChCl-MA (in absence and presence of different water content)

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<th>Rp</th>
<th>$E_{corr}$</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current</th>
<th>CR-Tafel</th>
<th>CR-EIS</th>
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<td>Ω.cm$^2$</td>
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<td>mV/dec</td>
<td>mV/dec</td>
<td>mA/cm$^2$</td>
<td>mm/yr</td>
<td>mm/yr</td>
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Table 10. EIS and PPC parameters obtained for mild steel in ChCl-Ph (in absence and presence of different water content)

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<th>Rs</th>
<th>CPE-T</th>
<th>Rp</th>
<th>$E_{corr}$</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current</th>
<th>CR-Tafel</th>
<th>CR-EIS</th>
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<td>%</td>
<td>Ω.cm$^2$</td>
<td>Ω.cm$^2$</td>
<td>mV</td>
<td>mV/dec</td>
<td>mV/dec</td>
<td>mA/cm$^2$</td>
<td>mm/yr</td>
<td>mm/yr</td>
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### Table 11. EIS and PPC parameters obtained for mild steel in ChCl-Ur (in absence and presence of different water content)

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<th>Rs (Ω.cm²)</th>
<th>CPE-T (Ω.cm²)</th>
<th>Rp (Ω.cm²)</th>
<th>Ecorr (mV)</th>
<th>ba (mV/dec)</th>
<th>bc (mV/dec)</th>
<th>Corrosion Current (mA/cm²)</th>
<th>CR-Tafel (mm/yr)</th>
<th>CR-EIS (mm/yr)</th>
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<td>1.5*10⁻⁵</td>
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### Table 12. EIS and PPC parameters obtained for mild steel in ChCl-TG (in absence and presence of different water content)

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<th>Rp (Ω.cm²)</th>
<th>Ecorr (mV)</th>
<th>ba (mV/dec)</th>
<th>bc (mV/dec)</th>
<th>Corrosion Current (mA/cm²)</th>
<th>CR-Tafel (mm/yr)</th>
<th>CR-EIS (mm/yr)</th>
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Table 13. EIS and PPC parameters obtained for stainless steel 316 in ChCl-EG (in absence and presence of different water content)

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<th>E_corr</th>
<th>ba</th>
<th>bc</th>
<th>Corrosion Current</th>
<th>CR-Tafel</th>
<th>CR-EIS</th>
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<td>mV</td>
<td>mV/dec</td>
<td>mV/dec</td>
<td>mA/cm²</td>
<td>mm/yr</td>
<td>mm/yr</td>
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Table 14. EIS and PPC parameters obtained for stainless steel 316 in ChCl-GI (in absence and presence of different water content)

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<th>Rp</th>
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<th>ba</th>
<th>bc</th>
<th>Corrosion Current</th>
<th>CR-Tafel</th>
<th>CR-EIS</th>
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<tr>
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Table 15. EIS and PPC parameters obtained for stainless steel 316 in ChCl-MA (in absence and presence of different water content)

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Table 16. EIS and PPC parameters obtained for stainless steel 316 in ChCl-Ph (in absence and presence of different water content)

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Table 17. EIS and PPC parameters obtained for stainless steel 316 in ChCl-Ur (in absence and presence of different water content)

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Table 18. EIS and PPC parameters obtained for stainless steel 316 in ChCl-TG (in absence and presence of different water content)

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