ELECTRICAL PROPERTIES OF NATURAL INHIBITORS ON CORROSION INHIBITION IN SEAWATER

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Introduction

Aluminum is an important subject of research because it is abundant in nature, easy to handle and represents an important category of materials due to their high technological value and wide range of industrial applications, especially in aerospace and household industries. In addition, aluminum is justified by low price, high electrical capacity and high energy density [1]. The most important feature of aluminum is its corrosion resistance due to the presence of a thin, adherent and protective surface oxide film. Aluminum and its alloy, however, are reactive materials and are prone to corrosion [2].

The corrosion process in deep seawater occurs under very specific conditions and is characterized mainly by low temperature, high chloride contents, low oxygen content, the presence of CO_2 and H_2S, microorganisms and high contents of dissolved salts [3−5]. Seawater systems are used by many industries such as shipping, offshore oil and gas production, power plants and coastal industrial plants. The main use of seawater is for cooling purposes but it is also used for fire fighting, oil field water injection and for desalination plants.

Aluminum alloy is commonly used in marine applications as well. It has the additional advantage of superior resistance to corrosion, since it corrodes over 100 times more slowly than conventional structural carbon steel used to build ships. Technological advances have allowed aluminum to meet or exceed the minimum strength requirements for normal strength steels currently used in the shipbuilding industry. Aluminum alloys are also applied as the materials for body panels of the automobile and the hydrogen gas vessels with high temperature applications [6].

The use of inhibitors is one of the most practical methods for protection against corrosion. Natural inhibitors offer interesting possibilities for corrosion inhibition and are of particular interest because of their safe use and high solubility in water [7]. In this study potentiodynamic polarization (PP) and electrochemical impedance spectroscopy (EIS) measurements are applied to investigate the properties of natural inhibitors on corrosion inhibition of aluminum alloys in seawater.

Materials and Methods

The experiments were performed with Al-Mg-Si alloy (25 × 25 × 3 mm coupons) specimens with the following chemical composition (wt): Si (0.40%), Fe (0.7%), Cu (0.15%), Mn (0.15%), Mg (0.80%), Cr (0.04%), Zn (0.25%), Ti (0.15%) and Al (remainder). The samples were mechanically polished using 400, 500 and 600 emery papers and lubricated using distilled water. The polished samples were cleaned with acetone, washed using distilled water, dried in air and stored in moisture-free desiccators prior to use. The test solution used for the investigation was seawater collected from Pantai Teluk Kalong, Kemaman, Terengganu (port area). The natural inhibitors used were natural honey collected freshly from the nest of bees, vanillin and tapioca starch obtained from local market, with the concentration range from 200−1000 ppm. All the experiments were conducted at room temperature (25ºC).

Al-Mg-Si alloy specimens for each inhibitor concentration were immersed in a 100-mL beaker containing the respective solution for 30 minutes. All the electrochemical measurements were obtained using Autolab frequency response analyzer (FRA) coupled to an Autolab potentiostat connected to a computer. The cell used comprised the conventional three electrodes with a platinum-wire counter electrode (CE) and a saturated calomel electrode (SCE) as reference, to which all the potentials were referred.

The working electrode (WE) was in the form of a square cut so that the flat surface was the only surface in the electrode. The exposed area to the test solution was 3.75 cm^2. The WE was first immersed in the test solution and after establishing a steady state open circuit potential, the electrochemical measurements were performed.

The potentiodynamic current-potential curves were recorded by changing the electrode potential automatically from −250 mV to +250 mV, related to the open circuit potential, with the scanning rate of 5 mV s^{-1}. The impedance measurements were conducted over a frequency range of 5 × 10^5 Hz down to 5 × 10^{-3} Hz. The results were analyzed using the fit program FRA.

Results and Discussion

The values for the corrosion current densities, i_{corr} and polarization resistance, R_p from PP, the values of polarization or charge transfer resistance, R_{ct} and the double layer capacitance, C_{dl} from EIS are listed in Table 1. From results obtained, it can be concluded that:

- The values of i_{corr} corrosion current decreases obviously after natural inhibitors are added in all test solution at all concentrations. It is clear that the presence of these inhibitors causes markedly decrease in the corrosion rate.
- The values of R_p and R_{ct} for samples with inhibitors increase as compared to that of without the inhibitors. It indicates that the resistance of metal against corrosion was improved with the presence of natural inhibitors.
- The C_{dl} values diminish when the inhibitors are added to the system indicating the formation of a surface film [6].

Table 1 The values of i_{corr}, R_p, R_{ct} and C_{dl} at various concentrations of natural inhibitors.

Inhibitor	c (ppm)	PP		EIS	
		i_{corr} (μA cm^{-2})	R_p kΩ cm^2)	R_{ct} (kΩ cm^2)	C_{dl} (μF cm^{-2})
Blank		1.622	11.71	11.76	23.98
Honey	200	0.593	34.78	33.10	8.11
	600	0.434	55.06	57.12	5.16
	1000	0.137	112.72	119.84	2.31
Vanillin	200	0.538	35.28	39.04	7.06
	600	0.330	57.13	60.27	4.39
	1000	0.122	145.05	155.84	1.95
Starch	200	0.483	41.29	40.73	7.30
	600	0.199	81.67	79.23	3.37
	1000	0.103	177.00	166.09	0.99

The values of the inhibition efficiency, IE (%) from the PP and EIS tests were calculated using the following equations [7]:

$$IE_{PP}\ (\%) = 100\ (1 - i'_{corr}/i_{corr}) \quad (1)$$

$$IE_{EIS}\ (\%) = 100\ (1 - R_{ct}/R'_{ct}) \quad (2)$$

The values of IE (%) for all natural inhibitors at various concentrations are given in Figure 1. The data reveal that IE (%) of natural inhibitors increases with the inhibitors concentrations ranging from 200 to 1000 ppm. The tapioca starch shows the excellent corrosion inhibitors followed by vanillin and natural honey.

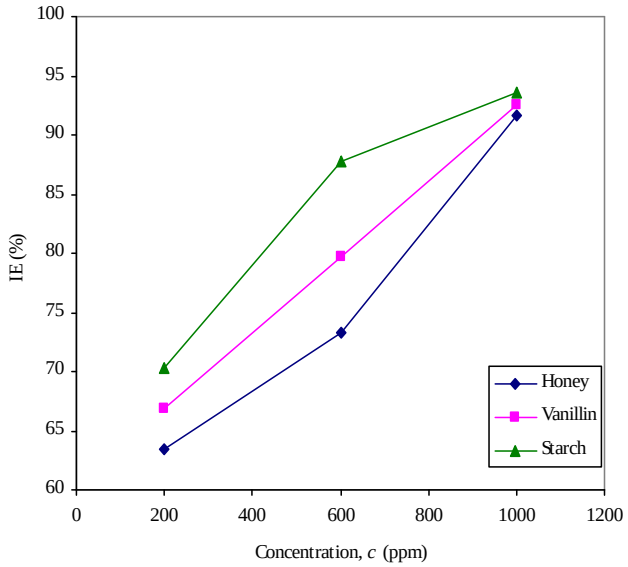

Fig. 1 IE (%) of natural inhibitors at various concentrations.

Conclusions

The natural inhibitors improve the electrical resistance of aluminum alloy by increasing the values of R_p and R_{ct} and decreasing the values i_{corr} and C_{dl}. Effective corrosion resistance is associated with high R_p and R_{ct}, and low i_{corr} and C_{dl} values. We consider that these natural products can be used as an excellent corrosion inhibitor of aluminum alloy in seawater.

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