INHIBITION CORROSION OF EUGENOL ON THE CORROSION OF TITANIUM-NICKEL IN PHYSIOLOGICAL MEDIA

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Abstract: The effect of addition of (2-methoxy 4- allyl phenol), eugenol, on the corrosion of Titanium-Nickel (TiNi) in physiological media was investigated through electrochemical impedance spectroscopy (EIS), free potential, potentiodynamic polarization curves and gravimetric measurements. The obtained results showed that eugenol revealed a good corrosion inhibitor. The inhibition efficiency depends on both the nature of treatment and concentrations of eugenol. Scanning electron microscopy (SEM) of the TiNi revealed that eugenol is adsorbed on the surface of TiNi.

Keywords: *eugenol, corrosion, inhibitor, electrochemical method, physiological media*.

INTRODUCTION

An important method of protecting materials against deterioration from corrosion is by using inhibitors [1-3]. Review including extensive listing of various types of organic inhibitors has been published [4]. Compounds with functional group containing heteroatoms which can donate lone pair of electrons are found to be particularly useful as inhibitors for corrosion of metals [5]. Generally, the tendency to form a stronger coordination bond and, hence, to cause a higher efficiency increases in the order P > S > N >O [6]. Much interest has also been devoted to organic inhibitors such as triazole type compounds in various media [7, 8].

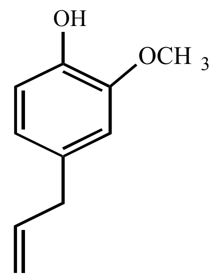

Figure 1. *Chemical structure of eugenol*

Eugenol (Figure 1) occurs widely as a component of essential oils and is a major constituent of clove oil. It has been used since at least the nineteenth century, primarily as a flavouring agent, in a variety of foods and pharmaceutical products, and as an analgesic in dental materials. Recently it has been used as inhibitor on the corrosion of stainless steel in phosphoric acid solution [9].
The aim of the present investigation is to study the effect of eugenol on the corrosion of TiNi alloys in physiological media.

MATERIALS AND METHODS

Eugenol was prepared in the laboratory following the usual extraction procedure.
The specimens used were equiatomic TiNi (1 x 1 cm^2). The electrochemical cell was constituted of three electrodes: platinum was used as the counter electrode, saturated calomel electrode (SCE) as reference electrode, and the working electrode with a surface of about 1 cm^2. The electrolyte was prepared from NaCl and distilled water (9 g/L). Before starting each experiment, strips were mechanically polished on wet SIC paper (grade 600), washed with ethanol, rinsed with distilled water and dried at room temperature. The potentiodynamic control of the working electrode was provided by a potentiostat (Voltalab 10 PGZ 100), and assisted by Master 4 software. The experiments were carried out at 37°C by circulating the water bath through the double wall of the cell. The weight loss measurements were carried out after 24 h of immersion time. The surface of specimens was observed using a scanning electron microscope (SEM).

RESULTS AND DISCUSSION

Gravimetric measurements

Weight loss in mg/cm^2 of the surface area for TiNi alloys was determined in the absence and in the presence of eugenol with various concentrations. The inhibition efficiency (E %) was calculated from the equation (1):

$$E\% = \left(1 - \frac{W'}{W}\right) \cdot 100 \qquad (1)$$

were W and W’ are respectively, the corrosion rate of TiNi alloys without and with inhibitor. Table 1 shows the corrosion rate and the inhibition efficiency percentages of different concentrations of eugenol.

Table 1. *The corrosion rate (W) of TiNi alloys and inhibition efficiency of eugenol*

Eugenol concentration (M)	W ($mg/cm^2.h$)	E %
0	0.3005	-
1.10^{-6}	0.1010	66.39
5.10^{-6}	0.0520	82.70
1.10^{-5}	0.0511	83.00

It is clear that the weight loss decreases in the presence of inhibitor and with increasing of its concentration. The inhibition efficiency increases when the concentrations increase.

Free potential

Figure 2 shows the curves of free potential with and without eugenol in the biological environment. The value of free potential was obtained when the potential remained constant. In the absence of eugenol, the potential was stabilised at 0.23 V, in his presence the potential was stabilised between 0.4 and 0.5 V.

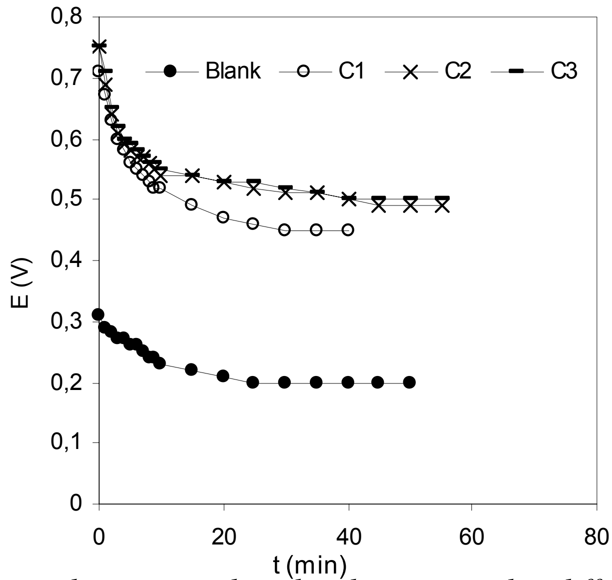

Figure 2. *Free potentials curves with and without eugenol at different concentrations ($c_1=10^{-6}$, $c_2=5.10^{-6}$, $c_3=10^{-5}$)*

Polarisation curves

The polarisation curves and the parameters obtained from the curves of Tafel were presented in Figure 3 and Table 2 respectively. Table 2 shows that the current density decreases in increasing the concentration of eugenol, whereas the resistance of polarisation increases in the presence of eugenol. The efficiency inhibition was calculated as following:

$$E\% = \left(1 - \frac{i_{corr(inh)}}{i_{corr}}\right) \cdot 100 \qquad (2)$$

where $i_{corr(inh)}$ and i_{corr} are the corrosion current density values without and with inhibitor, respectively. They are determined by extrapolation of cathodic Tafel lines to the corrosion potential. In the presence of eugenol, the corrosion potential (E_{corr}) and cathodic Tafel slope (β_c) decrease.

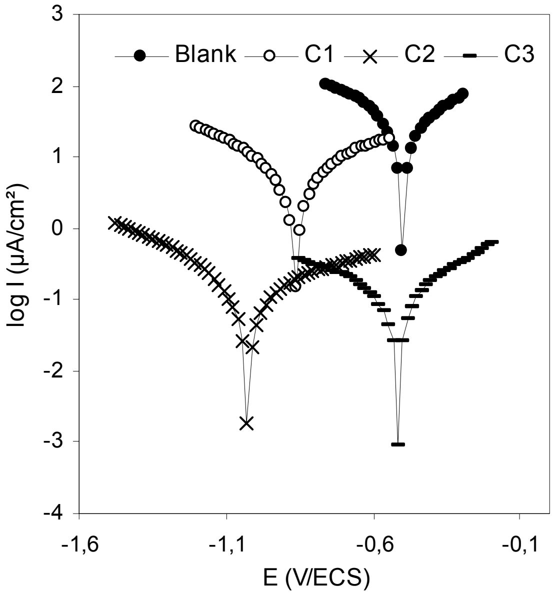

Figure 3. *Curves of global polarisation of TiNi in physiological media with and without eugenol at different concentrations ($c_1=10^{-6}$, $c_2=5.10^{-6}$, $c_3=10^{-5}$).*

Table 2. *Electrochemical parameters obtained from Tafel curves in the absence and in the presence of eugenol*

Concentration of eugenol (M)	0	1.10^{-6}	5.10^{-6}	1.10^{-5}
E (i = 0)	-494.1	-861.7	-1026	-521.7
R_p (kohm.cm^2)	2.67	15.02	717.85	741.66
I_{corr} (µA/cm^2)	19.46	4.16	0.19	0.15
β_c (mV)	342.1	351.0	1225	598.5
β_a (mV)	-292.1	-383.9	-551.8	-838.1
E %	-	78.63	99.02	99.23

The electrochemical impedance spectroscopy

Impedance measurements were made under open circuit conditions after 1h of immersion with and without eugenol. The Nyquist plots obtained showed a semicircle at high frequencies in absence of eugenol, in his presence the shape of Nyquist plots changed from a semicircle to a widely arc (Figure 4).

The charge transfer resistance R_t values are calculated from the difference in impedance at lower and higher frequencies.

The efficiency inhibition of TiNi was calculated by change transfer resistance as equation (3):

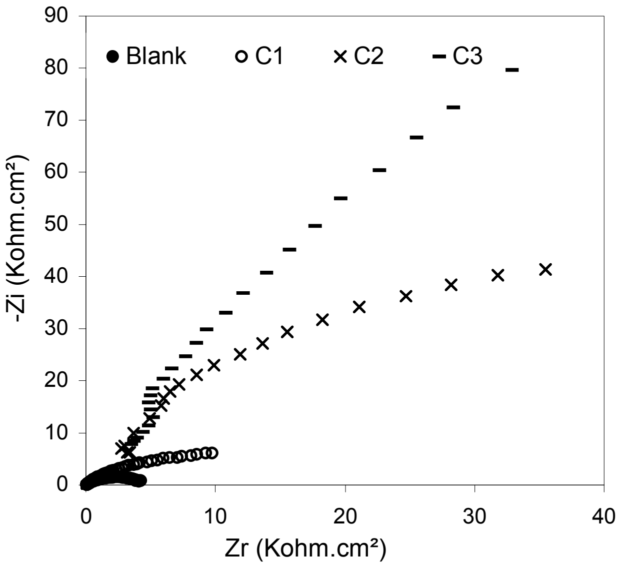

***Figure 4.** EIS curves of TiNi in physiological media with and eugenol at different concentrations ($c_1=10^{-6}$, $c_2=5.10^{-6}$, $c_3=10^{-5}$)*

$$E\% = \left(1 - \frac{R_{t\,corr(inh)}^{-1}}{R_{t\,corr}^{-1}}\right)\cdot 100 \qquad (3)$$

where $R_t^{-1}{}_{corr(inh)}$ and $R_t^{-1}{}_{corr}$ are the transfer resistance respectively with and without inhibitor. The impedance parameters obtained from this investigation are presented in Table 3. As can seen that the R_t increase in the increasing of concentration of eugenol, but the C_{dt} value decrease. That can be explained by adsorption of inhibitor on the surface.

***Table 3.** Electrochemical parameters obtained from impedances curves in the absence and in the presence of eugenol*

Concentration of eugenol (M)	R_t (kohm.cm^2)	C_{dt} (μA/cm^2)	E %
0	4.64	76.88	-
10^{-6}	9.74	51.61	47.63
5.10^{-6}	111.27	0.25	95.83
10^{-5}	342.63	0.21	98.65

Scanning electron microscopy

The surface of specimens was observed by SEM (Figure 5). The examination of the surface confirmed the results obtained by methods used.

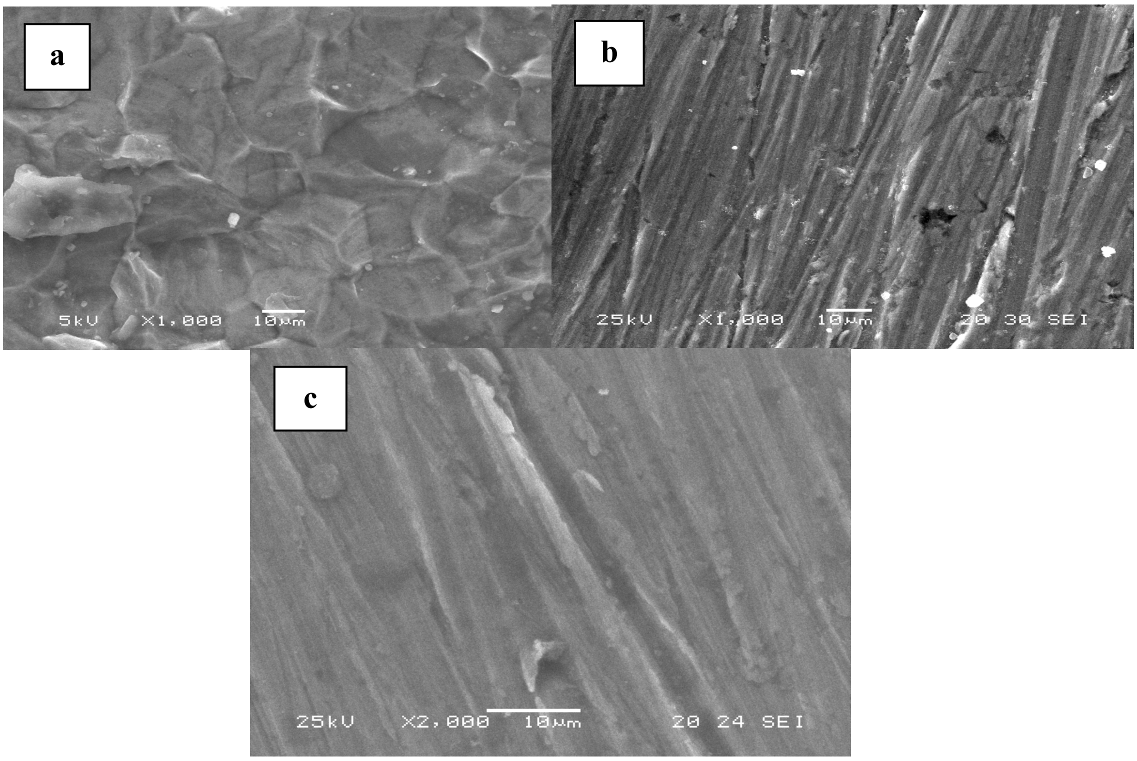

Figure 5. *SEM photograph of the surface of TiNi: (a) before corrosion, (b) after corrosion without eugenol, (c) aftere corrosion with eugenol*

CONCLUSION

The results obtained in this work showed clearly that the eugenol react as inhibitor of corrosion of TiNi in physiological environments.

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