Special Issue of the 8th International Advances in Applied Physics and Materials Science Congress (APMAS 2018)

Investigation of the Effects of MoS_2 Doped (PANI and PPy) Coatings on Mild Steel Corrosion in Alkaline Medium

A. Asan[a], G. Asan[b,*] and H. Çelikkan[c]

[a]Hitit University, Faculty of Engineering, Department of Chemical Engineering, Çorum, Turkey,

[b]Hitit University, Vocational School of Technical Science, Çorum, Turkey

[c]Gazi University, Faculty of Science, Department of Chemistry, Ankara, Turkey

One of the common ways of protecting the metal from corrosion is to form a film on the metal surface or coating it with a suitable material. Unfortunately, as long as there is a needle-like gap in the coating, water and oxygen will reach the metal surface and start corrosion. In this study polypyrrole (PPy), polyaniline (PANI), PPy + MoS_2 and PANI + MoS_2 coatings were obtained on steel in 0.1 M $H_2C_2O_4$ by cyclic voltammetry method. The electro polymerization was carried out between 0.0 V and 1.0 V. The effect of these coatings on corrosion of steel was determined by the Tafel polarization method. As a result of experiments, it is determined that these obtained homogenous and adherent coatings are effective against corrosion. The best protection against corrosion is provided by PPy + MoS_2, PPy, PANI + MoS_2 and PANI coatings, respectively. Better protection efficiency of PPy than PANI can be explained by the fact that the pyrrole oxidation potential is lower than the oxidation potential of aniline. The reason MoS_2 added coatings are more effective than others is that the gaps formed in the coating may be filled by MoS_2.

DOI: 10.12693/APhysPolA.135.987

PACS/topics: corrosion, polypyrrole, polyaniline, electro polymerization, MoS_2

1. Introduction

Conductive polymers (CPs) are considered as key components for next generation active coatings with self-healing properties for metal corrosion control. The most widely used CPs in corrosion protection are polypyrrole and polyaniline [1–3]. Their synthesis is relatively easy with various chemical and electrochemical methods. In order to make the CPs more resistant to corrosion, coatings are made by adding some aniline and pyrrole additives and testing different coating conditions [4, 5]. The most important properties required in these coatings are machinability, stability, easy preparation, adhesion to metal and long-term mechanical integrity. CPs have been the subject of many investigators in recent times due to their resistance to corrosion. According to the results of many researches in the literature, CP can provide protection from corrosion by creating an electronic active barrier or a physical barrier, anodic protection or cathodic protection and passivation [6, 7].

In this study, MoS_2 was added to the coating solution after separating it into layers as in our previous work [8]. Pyrrole, aniline, pyrrole with MoS_2 and aniline with MoS_2 have been electro polymerized on mild steel in oxalic acid by cyclic voltammetry method. The effect of these coatings against corrosion was investigated in a 0.1 M NaOH.

*corresponding author; e-mail: guldenasan19@gmail.com

2. Experimental procedure

In the study, a 3-neck 100 ml balloon was used as a corrosion cell. The working electrode is immersed in the middle. One of the electrodes has a saturated calomel electrode (SCE) as a reference electrode and a platinum plate with a counter electrode. The exposed surface area was polished under water with 2000 number sandpaper before each experiment. It was treated with water and acetone to remove dirt and organic oils. Corrosion tests were carried out in 0.1 M NaOH solution. The electropolymerization process was carried out on mild steel by cyclic voltammetry method. The voltammetric measurements were made with Ivium CompactStat Instruments system. All cyclic voltammetry curves were obtained at a scan rate of 100 mV/s, and Tafel polarization curves were obtained at a scan rate of 2 mV/s.

3. Results and Discussion

PPy and PANI are electro polymerized on mild steel by cyclic voltammetry method in 0.1 M oxalic acid. Figure 1 shows that this electro polymerization has obtained with 15 scan number. It is seen that electro polymerization of pyrrole starts about 0.6 V potential.

The corrosion rate was determined by the Tafel polarization method. The protection efficiency was calculated using the following expression, where CR_{uncoated} and CR_{coated} corrosion rate without and with coating, respectively.

$$\eta = \frac{CR_{\mathrm{uncoated}} - CR_{\mathrm{coated}}}{CR_{\mathrm{uncoated}}} \times 100\%. \quad (1)$$

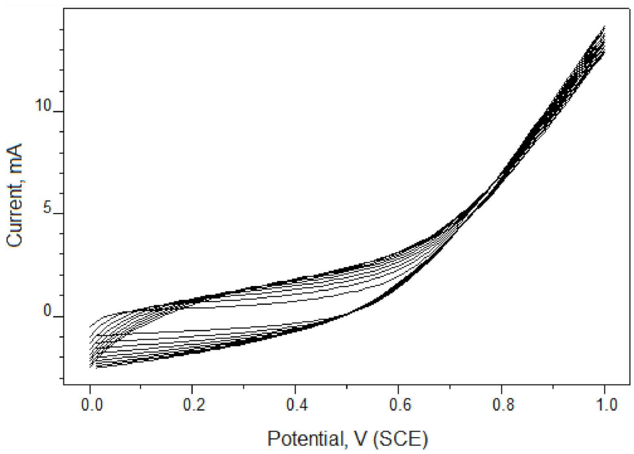

Fig. 1. Electro polymerization of pyrrole on mild steel in 0.1 M oxalic acid.

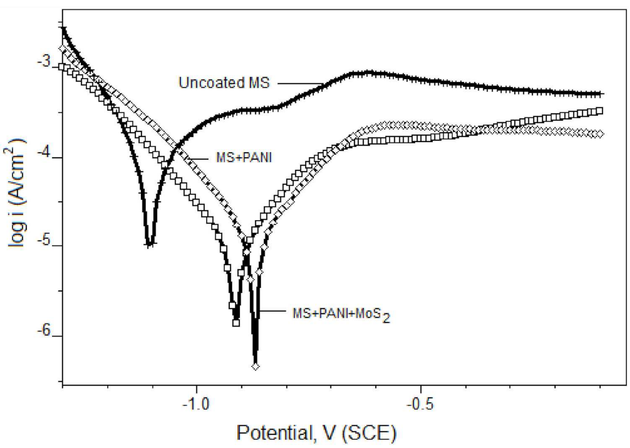

Fig. 2. The Tafel polarization curves of uncoated mild steel, coated with PANI and coated with PANI + MoS_2.

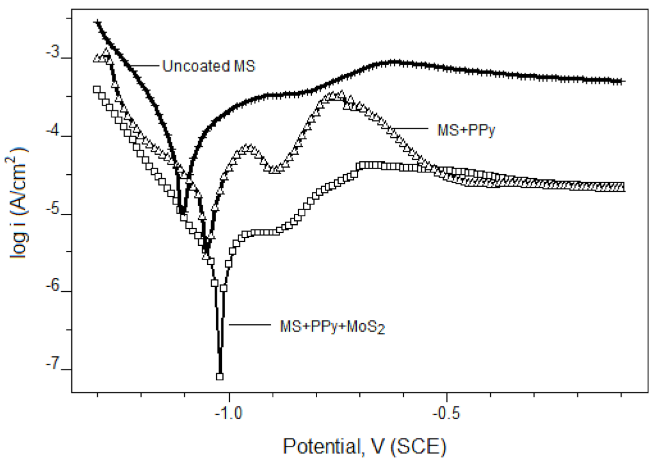

Fig. 3. The Tafel polarization curves of uncoated mild steel, coated with PPy and coated with PPy + MoS_2.

Figure 2 shows that the coatings on mild steel shift the open circuit potential to more positive values and reduce the corrosion current. The MoS_2-doped PANI coating performed better than the PANI coating.

Figure 3 shows PPy coating and MoS_2 doped PPy coating curves. Corrosion current decreased as the potential of the open circuit increased. It is understood that MoS_2 doped PPy coating is more effective than PPy coating.

It is understood that PPy coatings provide more effective protection against corrosion than PANI coatings.

The corrosion performance of PANI, PPy, PANI doped with MoS_2 and PPy doped with MoS_2 coatings were summarized in Table I.

TABLE I

Tafel polarization parameters and coating efficiency for the corrosion of mild steel in 0.1 M NaOH.

	$-E_{cor}$ [mV]	R_p [Ωcm^{-2}]	β_a [V/dec]	β_c [V/dec]	CR [mm/y]	CE [%]
uncoated, MS	1118	424.2	0.352	0.124	1.102	–
MS + PANI	1059	1991	0.189	0.209	0.254	77.0
MS + PPy	869	2927	0.206	0.198	0.176	84.0
MS + PANI + MoS_2	916	3842	0.185	0.174	0.119	89.2
MS + PPy + MoS_2	1066	9540	0.825	0.122	0.057	94.8

4. Conclusion

PPy coatings provide more effective protection against corrosion than PANI coatings. The MoS_2 additive made a significant contribution to both PPy and PANI coatings. The fact that PPy is more effective than PANI can be explained by the fact that pyrrole is oxidized at lower potentials than aniline. The protective effect of MoS_2 can be explained by MoS_2 forming an impermeable layer by filling the gaps in the coatings.

References

[1] P. Zarras, N. Anderson, C. Webber, D.J. Irvin, J.A. Irvin, A. Guenthner, J.D. Stenger-Smith, *Radiat. Phys. Chem.* **68**, 387 (2003).

[2] J.O. Iroh, W. Su, *Electrochim. Acta* **46**, 15 (2000).

[3] L. Jiang, J.A. Syed, Y.Z. Gao, Q.X. Zhang, J.F. Zhao, H.B. Lu, X.K. Meng, *Appl. Surf. Sci.* **426**, 87 (2017).

[4] Q. Yu, J. Xu, J. Liu, B. Li, Y. Liu, Y. Han, *Appl. Surf. Sci.* **263**, 532 (2012).

[5] E. Akbarinezhad, M. Ebrahimi, F. Sharif, A. Ghanbarzadeh, *Prog. Org. Coat.* **77**, 1299 (2014).

[6] S.A. Umoren, U.M. Eduok, *Carbohydr. Polym.* **140**, 314 (2016).

[7] T.J. Pan, X.W. Zuo, T. Wang, J. Hu, Z.D. Chen, Y.J. Ren, *J. Power Sourc.* **302**, 180 (2016).

[8] G. Asan, H. Çelikkan, *J. Fac. Engin. Architect. Gazi Univ.* **32**, 617 (2017).