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Synthesis of Polyaniline Coatings on Low Carbon Steel by Galvanostatic Deposition Method

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Abstract- The Polyaniline coatings (PANI) have been synthesized on low carbon steel (LCS) substrates by galvanostatic method. An aqueous solution of oxalic acid used as supporting electrolyte. These galvanostatic coatings were synthesized by keeping constant current density at 0.66 mA/cm^2. The potential - time behavior recorded during synthesis reveals that in PANI coating formation the passivation is essential step through the formation of iron oxalate interphase. This interphase acts as a barrier against the further dissolution and facilitate the deposition of PANI. The coatings are uniform, and strongly dark green colored which enhances the electrochemical performance and stability of the LCS substrate for various applications. The PANI coatings characterized by FTIR and SEM, its results shows successful synthesis of PANI also indicates that the oxalic acid is a suitable medium for the ECP of PANI on the LCS substrate.

Keywords: Galvanostatic, Electrochemical Polymerization (ECP), polypyrrole (PPY), Low carbon steel (LCS)

1. INTRODUCTION

Conducting polymers (CPs) have been received a great interest in academia and industry by providing the opportunity of combining the electrical properties of a semiconductor and metals with the traditional advantages of conventional polymers such as easy and low-cost preparation and fabrication [1]. Most extensively studied conducting polymers (CPs) are polyaniline [2-4], polypyrrole [5-8] some substituted derivatives of polyaniline like polytoluidine [9,10], polyanisidine [11]. Formation of copolymers with tailored functionality, variable molecular weight and desired chemical composition also has potential applications [12-16].

2. EXPERIMENTAL

In present work, the Polyaniline coatings were synthesized by electrochemical polymerization of Aniline under galvanostatic conditions at room temperature. The LCS substrates used as working electrode, saturated calomel electrode as reference electrode and platinum electrode as counter electrode in three electrode geometry for ECP.

The aqueous oxalic acid solution was used as the supporting electrolyte. The concentrations of oxalic acid and aniline in the electropolymerization were kept constant at 0.3 M and 0.1 M, respectively.

3. RESULT AND DISCUSSION

3.1 Synthesis of PANI coatings

Polyaniline coatings were synthesized by galvanostatic method by applying constant current density 0.66 mA/cm^2. The galvanostatic conditions were controlled using a SI 1280B Solartron Electrochemical Measurement System (U.K.). The potential Vs time (E-t) curves recorded during the synthesis of coatings. After deposition, the working electrode was removed from the electrolyte and rinsed with double distilled water and dried in air.

E-t curves of Polyaniline (PANI)

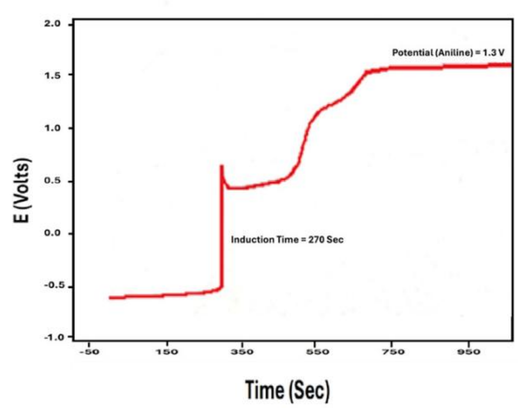

Fig.1: -The E-t curve recorded during the synthesis of PANI coatings on LCS with an applied current density of ~ 0.66 mA/cm^2.

The E-t curve recorded during the synthesis of PANI coatings on LCS at room temperature with an applied current density of ~ 0.66 mA/cm^2 are shown in Fig.1. Initially the electrode potential is negative and it remains fairly constant for a particular time known as an induction time. This is followed by sudden increase of potential to a positive value and then it decreases sharply and eventually reached to a steady state value. The induction time is known to depend on the deposition parameters such as applied current density, pH of electrolyte, supporting electrolyte and monomer concentration, while the applied current density significantly affects the rate of dissolution rate of LCS electrode. The E-t curve recorded under these experimental conditions the induction time is found to be 270 sec. It is observed from Fig.1, that the ECP of PANI occurs in three successive steps i) initially the potential is negative and it remains fairly constant for certain time known as induction time. This induction time for PANI in aqueous solution of oxalic acid is 270 sec. The electrochemical polymerization of Aniline do not occurs at this negative potential. During this negative potential two reactions occur a) the LCS electrode undergoes the dissolution at the negative potentials, which generates Fe^{2+} ions and ii) The generated Fe^{2+} ions interact with the oxalate electrolyte to form insoluble FeC_2O_4, $2H_2O$ which adheres to the electrode surface, thereby forming an iron oxalate interphase at the electrode surface [10]. ii)This is followed by sudden increase of potential to positive value which indicates complete passivation of LCS surface iii) Then it deceases sharply and eventually reached to a steady state value represents decomposition of iron oxalate interphase followed by successful ECP of polyaniline.

3.2 Characterization of PANI Coatings

The resulting Polyaniline coatings were characterized by E-t curves, Fourier Transform Infrared (FTIR) spectroscopy and scanning electron microscopy (SEM). The FTIR transmission spectrum of PANI coatings were recorded in the spectral range 4000-400 cm^{-1} using a Perkin Elmer spectrometer (1600 Series II, U.S.A.). SEM was employed to characterize the surface morphology with a Leica Cambridge 440 Microscope (U.K.) and Cambridge Instruments Stereoscan S-120 Scanning Electron Microscope.

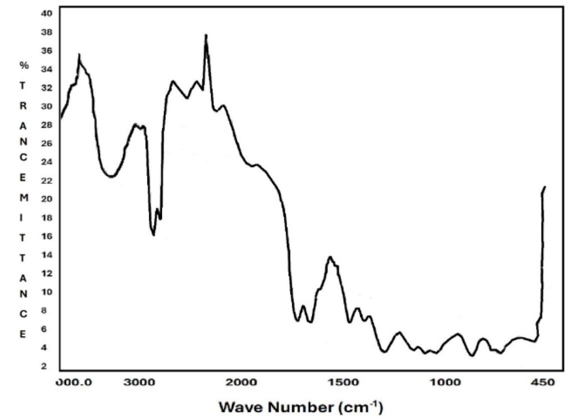

Fig.2: -The FTIR spectrum of PANI coatings on LCS synthesized under galvanostatic conditions at an applied current density of ~ 0.66 mA/cm^2.

The FTIR spectrum of PANI coatings on LCS synthesized under galvanostatic conditions at an applied current density of ~ 0.66 mA/cm2 is shown in figure 2. This FTIR spectrum is characterized by 3380 cm-1 due to the stretching frequencies of OH and NH groups, The peaks at 1456 cm-1 are due to the C=C of quinone and benzene ring in polyaniline. 1652 cm^{-1} attributes to the stretching frequency of carboxyl carbonyl group present in the dopant, 1278 cm^{-1}, may be due to the stretching frequency of C-O The C–N stretching vibration appeared at 1313cm^{-1} [11].

The SEM of PANI coatings on LCS synthesized under galvanostatic conditions at an applied current density of ~ 0.66 mA/cm^2 shown in Fig.3. The visual observation shows that the electrode surface is covered with dark green PANI coating on LCS substrate and its SEM shows non-uniform and fibrous surface morphology.

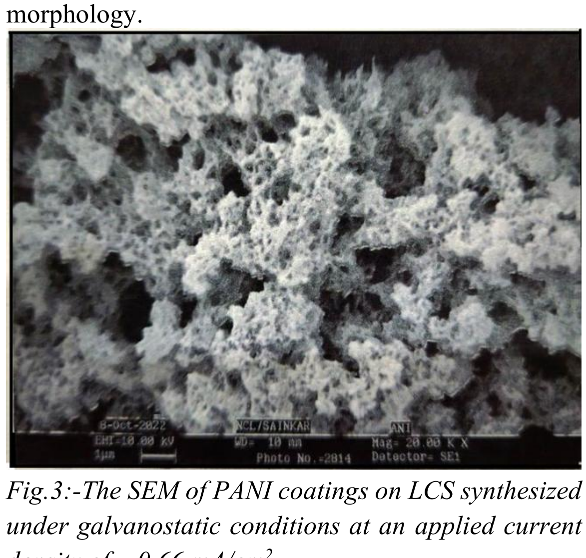

Fig.3:-The SEM of PANI coatings on LCS synthesized under galvanostatic conditions at an applied current density of ~ 0.66 mA/cm^2.

4. CONCLUSION

- Polyaniline coatings on LCS were synthesized by ECP of aniline under galvanostatic condition.
- The characterization of coating shows oxalic acid is suitable for ECP of PANI.
- ECP of aniline takes place in three stages induction time, complete passivation and decomposition of interphase followed by ECP of PANI.
- FTIR and SEM results shows successful synthesis of PANI coatings on LCS.

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