Synthetic Metals 161 (2011) 153–157

Contents lists available at ScienceDirect

Synthetic Metals

journal homepage: www.elsevier.com/locate/synmet

Electrochemical deposition of a carbon nanotube-poly(o-phenylenediamine) composite on a stainless steel surface

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ARTICLE INFO

Article history:
Received 4 May 2010
Received in revised form 24 October 2010
Accepted 12 November 2010
Available online 15 December 2010

Keywords:
Carbon nanotubes
Composite
Electrodeposition
Passivation
Poly(o-phenylenediamine)

ABSTRACT

Electrodeposition of a nano-composite made of oxidized carbon nanotubes (CNTs) and a conductive polymer such as poly(o-phenylenediamine) (PoPD) on a stainless steel surface from aqueous solution was carried out by cyclic voltammetry. The presence of the CNTs enhanced the deposition of the PoPD and this enhancement was more significant in the presence of single walled carbon nanotubes (sCNT) by comparison to multi-walled carbon nanotubes (mCNT). Scanning electron microscope images indicated the incorporation of the CNTs in the PoPD layer. The nano-composite layer as well as the pure PoPD layer keeps the stainless steel in a passive state in acidic solution. The oxide film underneath the nano-composite layer is unique and showed high corrosion resistance in concentrated chloride solutions, which was confirmed by the presence of high contents of iron and chromium components. These findings suggest that the CNTs indirectly assist the passivation of the stainless steel by catalyic oxygen reduction and polymer oxidation process.

1. Introduction

Stainless steels belong to a class of metals and alloys that protect themselves from corrosion by forming a passive film on their surfaces. The properties of the passive film provide the key to the high resistance of stainless steels to corrosive attack [1]. The passivation of stainless steels was achieved by coating with conductive polymers (CPs) [2–10]. The protection afforded by conducting polymer coatings is not simply due to barrier protection or inhibition alone, but rather is due to modification of the interface to produce passivating oxide layers. Such layers suggest that charge transfer reactions occur between the metal and the polymer [11]. The polymer significantly changes the composition and the structure of the lower layers of the passive film on the stainless steel. The process of oxygen reduction is coupled to the oxidation of the conductive polymer and indirectly to the formation of the passive oxide layer [12]. Improving the efficiency of oxygen reduction by incorporating a catalyst in the polymer matrix is significant. Recently, Hermas [4,13,14] found that the passive film of SS under CP layers has different characteristics than that formed by an applied positive potential. The porosity and anion exchange properties of CPs, however could be disadvantageous, particularly for pitting corrosion caused by small aggressive anions such as chlorides. By CPs blending with polymer binders (composite systems), the protective properties of the conductive polymers are increased.

Since the discovery of carbon nanotubes (CNTs) in 1991 by Iijima [15], CNTs have captured the attention of researchers worldwide. CNTs show characteristics of unique size distributions, novel hollow-tube structures, high specific surface areas as well as properties such as electrical semi-conductivity and conductivity. These characteristics allow CNTs to be used in a broad range of applications [16–22]. The unusual interest in carbon nanotubes (CNTs) resides in their possible technological applications in various fields of science. The incorporation of the modified mCNT enhanced the mechanical properties of the polyimide due to the presence of strong interfacial interaction between the polymer matrix and the nanotubes in polymer composites. The resultant polyimide/mCNT composites were electrically conductive with a significant conductivity enhancement at 3 wt% mCNTs [23]. Pt-mCNT/PANI composite films showed excellent electrocatalytic activity for formic acid oxidation and also exhibited good stability [24]. Nanometer carbon black (CB) grafted with polyvinyl alcohol composite was prepared by mechanical agitation, and it was used as a coating for mild steel. The composites coatings with 1 wt% CB nanoparticles reduced the corrosion rate of steel [25]. According to this literature survey, the application of the nano-composite polymer layer for the protection of metals is in its infancy. In a recent study, we succeeded in reinforcing of mCNT into PANI via an in situ electropolymerization on the surface of stainless steel. The formed layer showed promising protection action against corrosion [26].

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doi:10.1016/j.synthmet.2010.11.014