

Corrosion protection behavior of graphene added epoxy film coated on mild steel

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ABSTRACT – A series of the graphene-epoxy film has been developed and coated on the mild steel by manual laid-up technique. In this work, the effects of graphene composition on the corrosion behavior of the coated mild steel were investigated. The addition of 0.1 wt.% of graphene is revealed to enhance the corrosion resistance of the epoxy coated mild steel by creating the passive film on the surface of the mild steel owing to its excellent electrical conducting property as confirmed by SEM images. Further additions of graphene however had agglomerated and created pores hence increase the corrosion rate of the coated mild steel.

1. INTRODUCTION

The epoxy paint coating is the common paint coating used in protecting steels because of its high thermal resistance and good adhesion properties. However, it was permeable to aggressive industrial environment which had decomposed the film and exposed the steel to the corrosion. Various fillers have been added to enhance the physical properties and increasing the corrosion protection of the epoxy film include Al₂O₃, ZnO, and conductive nanoparticles [1]. Nazeri et al. revealed that, by adding the battery cathode waste materials as the electrical conducting fillers, the corrosion protection of epoxy coating has been improved through the development of passive film between the coating and substrate [2]. However, the proposed corrosion protection mechanism was not clear because of many factors include the existence of non-conducting particles, impurities, and non-uniform of particles sizes. Thus in this study, graphene will be used as the filler in the epoxy coating film since it has an excellent electrical conductivity enhanced mechanical properties and adhered to the epoxy [3,4].

2. METHODOLOGY

Graphene powder with 99.9 % purity was mixed with the epoxy resin system to obtain a series of graphene-epoxy film with graphene compositions ranged from 0.1 to 1.0 wt. %. The calculated amount of graphene was added into aliphatic amines which act as the hardener and sonicated in the water bath for 30 minutes before it was mixed with epoxy resin. The as-prepared mixture was sonicated for 30 minutes. The sonication is the essential step to break the agglomerated graphene into a mono carbon layer and enhance its distribution in the epoxy resin system. The mixture was carefully hand-layered onto the prepared

mild steel to achieve the coating film with thickness of ≈0.1 mm. The film was self-cured in the ambient environment at the room temperature for 48 hours.

The open circuit voltage (OCV) testing was performed on the coated samples by using 3.5 wt.% of NaCl as the electrolyte for 720 hours. The cross section and surface of the samples were observed by using optical microscope and SEM after completion of 60 days of immersion test.

3. RESULTS AND DISCUSSIONS

The physical appearance of the samples before and after 60 days of immersion in 3.5 wt.% of NaCl electrolyte is shown in Figure 1. It can be clearly seen that the samples with graphene compositions ≥ 0.3 wt.% experiencing corrosion after 60 days of immersion. Compare to the pure epoxy coated sample, the 0.1 wt.% sample was changing its color instead. Which highly attributed from the passive film forming activity by the graphene.

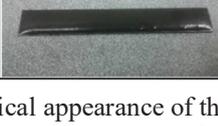
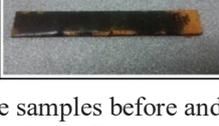
Sample	Before	After 60 days
Pure epoxy coating		
0.1 wt. %		
0.3 wt. %		
0.5 wt. %		
0.7 wt. %		
1.0 wt. %		

Figure 1 Physical appearance of the samples before and after immersion in the 3.5 wt.% NaCl electrolyte for 60 days.

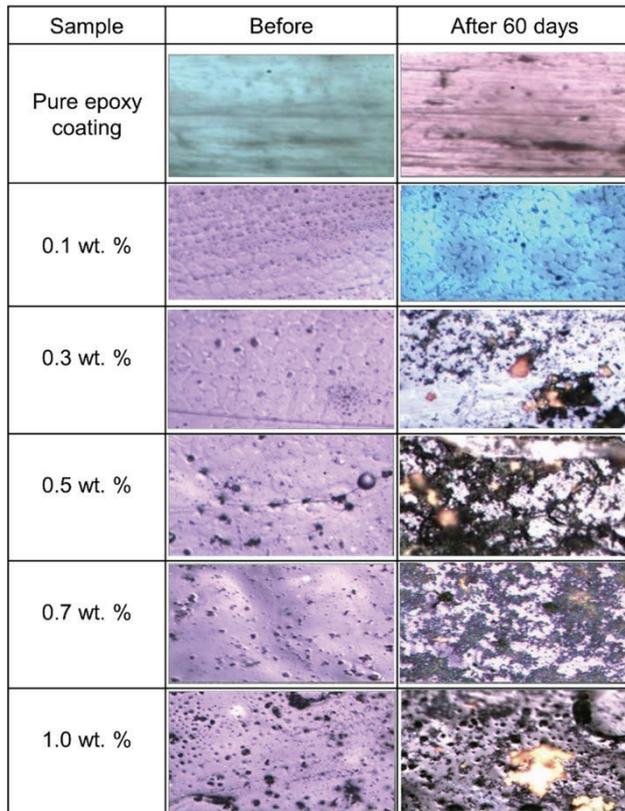


Figure 2 Surface of the samples before and after immersion in the 3.5 wt.% NaCl electrolyte for 60 days. (50x magnifications)

Figure 2 shows the surface evolution of the samples after 60 days of immersion test. It obvious that the film with additions of 0.3 wt.% and above of graphene were unable to provide protection to the mild steel. The agglomeration of graphene and pores have developed weak spots in the epoxy hence allows electrochemical reaction between the electrolyte and mild steel. In the other hands, additions of 0.1 wt.% of graphene has aroused with intriguing phenomenon. The epoxy grain was evolved into larger grains. This could have attributed to the ions movement from electrolyte to the mild steel through the graphene as suggested by Nazeri et al. [2] which prevent the ions from accumulate at a particular spot.

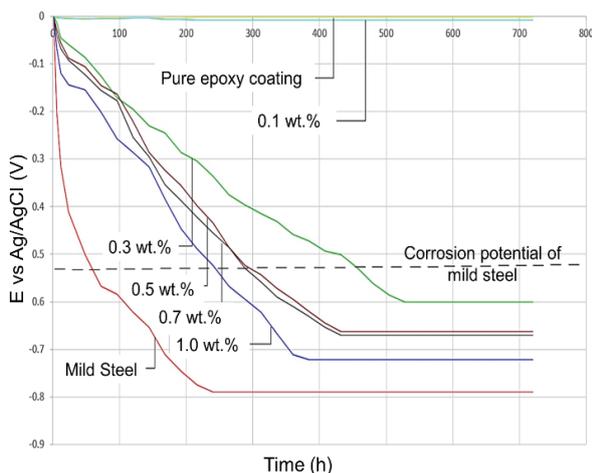


Figure 3 OCV vs time of the samples.

The OCV test shown in Figure 3 had confirmed the corrosion reaction of each samples once the potential exceeded the corrosion potential of mild steel at around -0.55 V. Except for the samples coated with pure epoxy film and 0.1 wt.% added film, their potentials sustained at around 0 and slightly lower respectively.

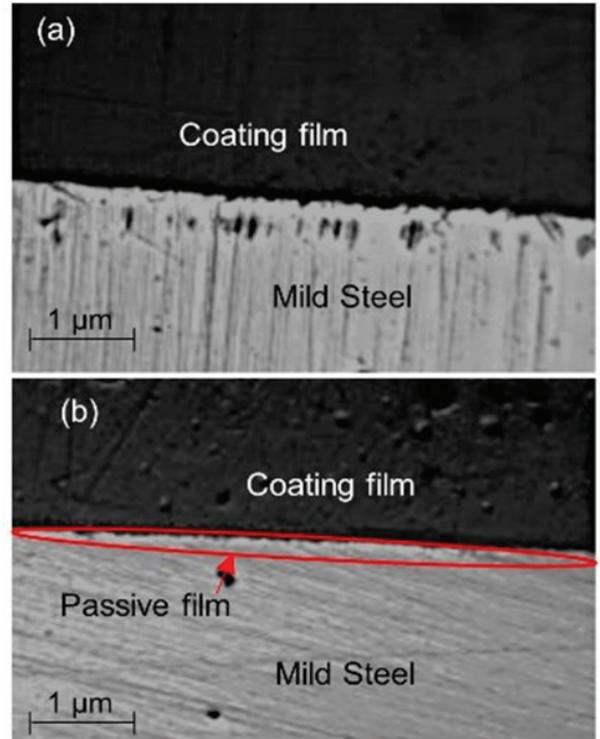


Figure 4 Cross section of the 2 wt.% sample: (a) before immersion, and (b) after 60 days of immersion.

The SEM images in Figure 4 shows the cross section of the 0.1 wt.% sample. From the images, it was revealed that there is a passive layer developed in between the mild steel and the coating after the immersion. The layer prohibited further electrochemical reaction between electrolyte and mild steel hence prevented the corrosion to occur.

4. CONCLUSION

The additions of 0.1 wt.% of graphene in epoxy resin coating has successfully developed a passive films layer on the coated mild steel hence prevent further deterioration the mild steel.

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