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Role of surface functionalization on corrosion resistance and thermal stability of epoxy/glass flake composite coating on cold rolled steel

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ABSTRACT

Composites of epoxy and functionalized glass flake (FGF) with enhanced corrosion protection for cold rolled steel (CRS) are developed. The influence of glass flake (GF) functionalization on their dispersion in the epoxy matrix was examined using TEM and the interface adhesion was evaluated using SEM. The coating corrosion resistance was investigated via Electrochemical Impedance Spectroscopy and Potentiodynamic Polarization measurements and the long-term protection was measured gravimetrically by immersing bare and coated CRS specimens in 3.5 wt.% NaCl for 90 days. The study demonstrates attaching aminosilane groups to the surface of GF leads to substantial enhancement in corrosion protection and thermal stability of the epoxy-FGF (E/FGF) composite coating at small FGF loading.

1. Introduction

Corrosion is a natural phenomenon that takes place in various environments causing metal components to fail at different rates based on the metal composition and environmental factors such as temperature, humidity and salinity. The lack of mitigating of such electrochemical interactions between the metal and the surroundings might raise serious threats to both economy and industry. Therefore, a growing number of studies is dedicated to investigate the corrosion process in various mediums and to examine possible mitigation options. Indeed, total elimination of the corrosion process may not be possible, especially in particular environments such as a Chloride rich medium. Therefore, the wide utilization of metals and in particular cold rolled steel in various fields including construction, pipeline and marine equipment, motivates researchers to investigate various corrosion protection techniques such as Anodic or Cathodic protection, the use of corrosion inhibitors and protective coatings [1–3] in order to extend the life span of the metal in different environments. In particular, the easiness of application, low cost and the remarkable corrosion protection efficiency of protective coatings initiates further investigation and utilization of the coating techniques for corrosion protection purposes. A growing number of research have been devoted to investigate and to further develop the coating techniques including the utilization of nanocomposites, hydrophobic and hybrid materials [4–7].

There are different forms of corrosion; however, in a Chloride rich environment a metal substrate will be more susceptible to pitting corrosion. In pitting corrosion, localize active areas of the metals take part in a galvanic corrosion process and release metal ions to the surroundings, resulting in localized inclusions or breakdown that might be difficult to detect. In a Chloride rich environment, the rate of the localized dissolution and penetration of the metal might be accelerated due to the presence of corrosion agents such as Oxygen, moisture and Chloride. In such form of corrosion, the level of penetration may not be detected until a severe damage has occurred and possibly leading to catastrophic failure. Therefore, pitting corrosion can be considered insidious and unlike other forms of corrosion such as uniform corrosion, pitting corrosion is very difficult not only to detect or predict, but also to evaluate and mitigate.

Polymer composites are perfect examples of corrosion protection coatings that have already been utilized in various fields in order to extend the life span of metals. However, the lack of essential property such as interface adhesion to the metal substrates foils the use of some polymer composites based coatings for corrosion protection purposes [8,9]. Epoxy is an example of polymers that have been widely utilized and investigated as corrosion protective coating on various metal substrates. Moreover, studies have shown that the remarkable corrosion mitigation property of epoxy can be further enhanced by the incorporation of a filler in the polymeric matrix [10–13]. In particular, the advanced barrier properties of Glass flakes encourage researchers to investigate and develop corrosion resistance coatings with advances

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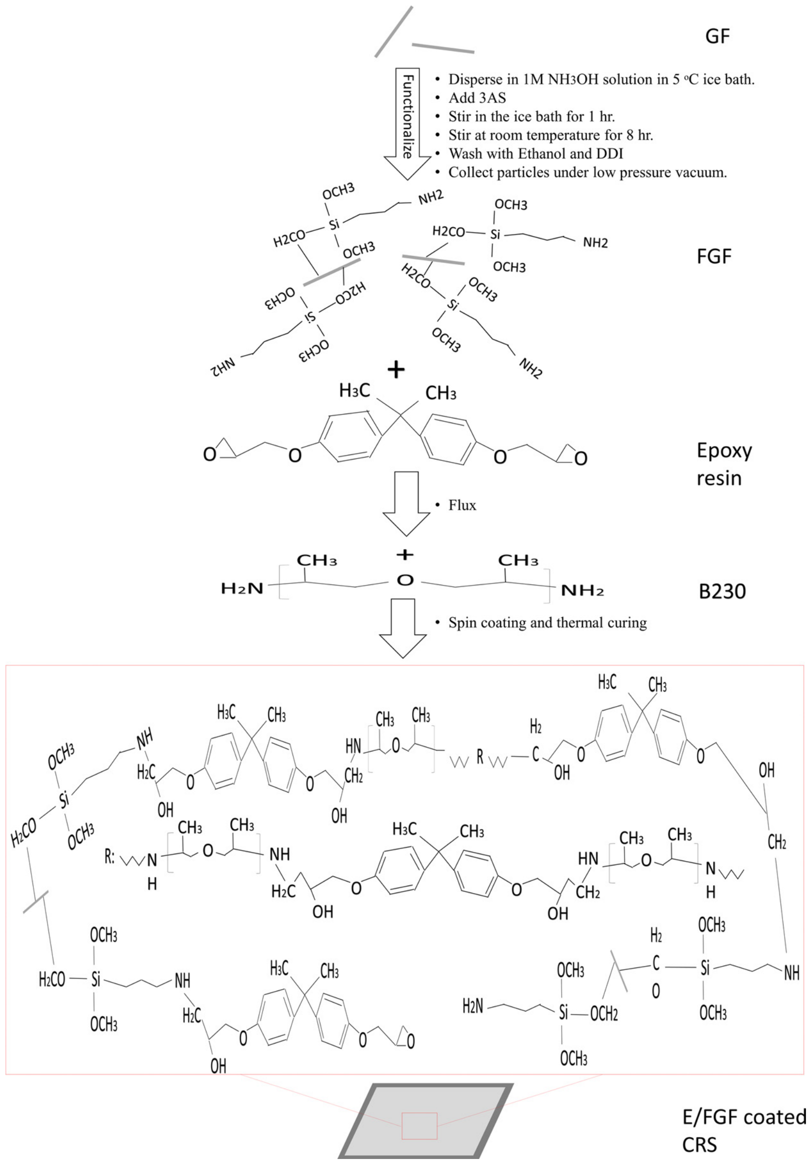

Fig. 1. Schematic description of the preparation of E/GF and E/FGF composites using in situ polymerization.

protection properties based on composites with glass flakes [14–18]. In addition to corrosion protection, some studies have focused on the utilization of Glass flake to enhance various properties such as thermal and viscoelastic properties [19]. However, the prospect of further enhancing the corrosion mitigation performance of Glass flake composites by surface treatment and functionalization of Glass flake, to the better of our knowledge, has not been explored in the literature, which inspires the current study.

In this study, composites of epoxy resin with glass flakes as filler were developed and evaluated as corrosion protective coating for cold rolled steel in a Chloride rich environment. The corrosion protection property of the prepared coating is examined in 3.5 wt.% NaCl solution by conducting electrochemical measurements as well as gravimetric analysis. Furthermore, the interface adhesion between the prepared coating and the Cold rolled steel metal substrate is evaluated according to ASTM standard. Besides corrosion resistance property, the study investigates the influences of the incorporation of Glass flake in the thermal stability of the prepared protective coating. In addition to the synthesis and the evaluation of Epoxy/Glass flake composites as corrosion protective coatings, facile surface modification procedures have been developed to functionalize the surface of Glass flake and the role of the attached functional groups on the corrosion protection efficiency and the thermal stability properties of the Epoxy/Glass flake composites were analyzed.

2. Experimental

2.1. Materials

25 μm-thick Cold Rolled Steel (CRS) sheet (McMaster-Carr) was used as the substrate. CRS substrates were polished with SIC 800 and 1200 grit discs, washed with acetone and DDI water and cleaned with KIMTECH wipes before coating. Bisphenol A diglycidyl ether (BADGE, Sigma Aldrich) and Poly (propylene glycol) bis(2-aminopropyl ether) (B230, Sigma Aldrich) were the Epoxy resin and hardener. (3-Aminopropyl) triethoxysilane (3AS, Sigma Aldrich) was utilized to functionalize the surface of GF, which were supplied by NSG Group as micro-pigment with an average thickness of 1–3 μm.

2.2. Functionalization of GF

To prepare the FGF, the desired amount of GF is added to 10 ml of