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Modified triazine decorated with Fe_3O_4 and Ag/Ag_2O nanoparticles for self-healing of steel epoxy coatings in seawater

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ABSTRACT

New hybrid nanomaterials based on Fe_3O_4 and Ag/Ag_2O nanoparticles (NPs) supported by 2,4-dihydrazino-6-(methoxypolyethyleneglycol)-1,3,5-triazine (mPEGTH) were successfully synthesized without using reducing agents in both solution and solid phases. The mechanism for Fe_3O_4 and Ag/Ag_2O NPs formation in the presence of mPEGTH, their chemical structures, surface morphologies, crystal structures, thermal stabilities and mPEGTH contents were characterized and identified. The effects of seawater salinity and pH of solutions on the Fe_3O_4 and Ag/Ag_2O NPs surface charges and particle sizes distributions were examined to investigate their performances under aggressive conditions. It was found that, the Fe_3O_4/mPEGTH, hybrid nanomaterials obtained good dispersed NPs and exhibit a remarkable superiority in enhancing the anticorrosion performance of epoxy coatings more than Ag/Ag_2O NPs. The Fe_3O_4/mPEGTH nanomaterials achieved significant synergistic effect to improve the anticorrosion and self-healing performances for epoxy composite coatings. They achieved higher salt spray resistance up to 1500 h without rust formation. The new self-healing mechanism of Fe_3O_4/mPEGTH nanomaterials was tentatively discussed.

1. Introduction

Epoxy liquid and powder coatings are favored among several types of organic coatings to protect different metal substrates from aggressive environmental corrosion [1–3]. They possess excellent mechanical and adhesion properties due to the formation of linked networks with metal substrates having a superior crosslink density after curing with polyamine and polyamide curing agents. The excellent crosslink density prevented the electrolytes and corrosive ions to diffuse through the coating matrix. Moreover, the adhesion of the coatings with metal substrate, low number of pores or coating cracks, uniform coatings, and resistances of the organic coatings to corrosive ions diffusion are very important parameters that controlled the coating performances [2,3]. The hydrolytic and microbial degradations of the organic coatings due to the exposure of organic coatings to aggressive marine environmental corrosion affected the barrier performance and the service life of the coatings [4]. The different types of organic and inorganic pigments, based on active (like zinc dust, Al powder and zinc phosphate) and barrier (micaceous iron oxide (MIO) and glass flake) pigments, were used to protect the organic coatings from the chemicals, hydrolytic and bacterial degradations [5–7]. Recently, the organic modified nano-fillers based on different types of the metal and metal oxides nanomaterials were used to improve the epoxy coating performances and to increase the service life and stability against aggressive corrosive environment [8–10]. The nanocomposite materials have great advantages to reduce the coatings cost and enhance the coatings performances at low thickness, low nano-filler contents. Moreover, their ability to self-repair using different self-healing mechanisms was improved in the presence of nano-fillers [11,12]. The aggregations of the nano-fillers into the coating matrixes caused several problems and affected their applications in the coatings. In this respect, the capping or modification of the nanomaterial surfaces with effective organic materials is one of the most useful routes to produce highly dispersed multipurpose nano-fillers which are the main goal of the present work.

The iron oxides nanomaterials as fillers were not widely applied due to their lower dispersion and compatibility with organic coatings although the normal iron oxides were successfully applied as color pigments for several organic paints. The modified iron oxides nanomaterials were applied as fillers to improve the mechanical properties and UV stability and to reduce the water permeability of the epoxy resins [13,14]. Several routes were used to increase the dispersion and the compatibility of the iron oxides NPs with the epoxy matrixes using ball milling device [15]. This technique required high-energy ball milling device and controlled grinding temperature to produce compatible iron

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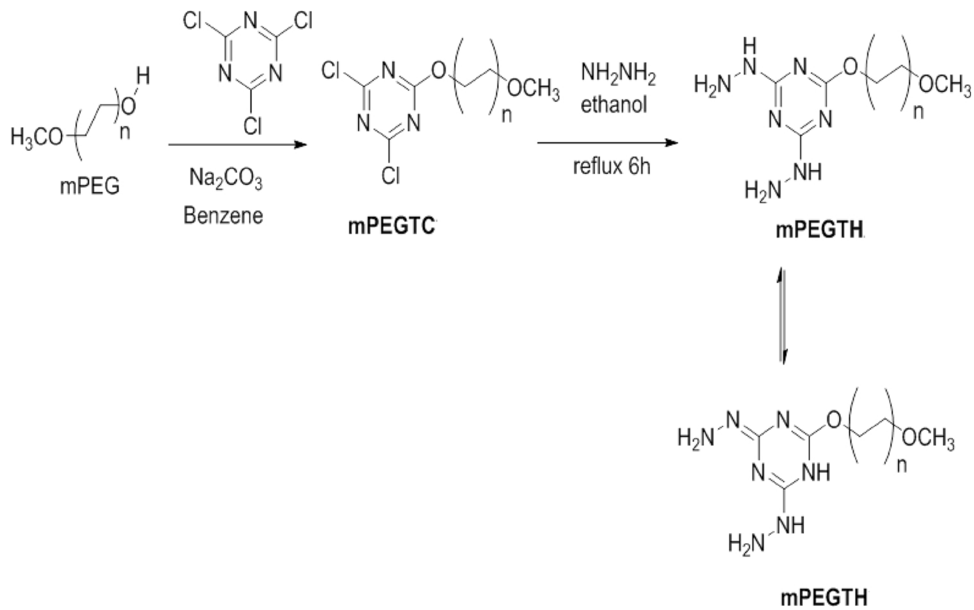
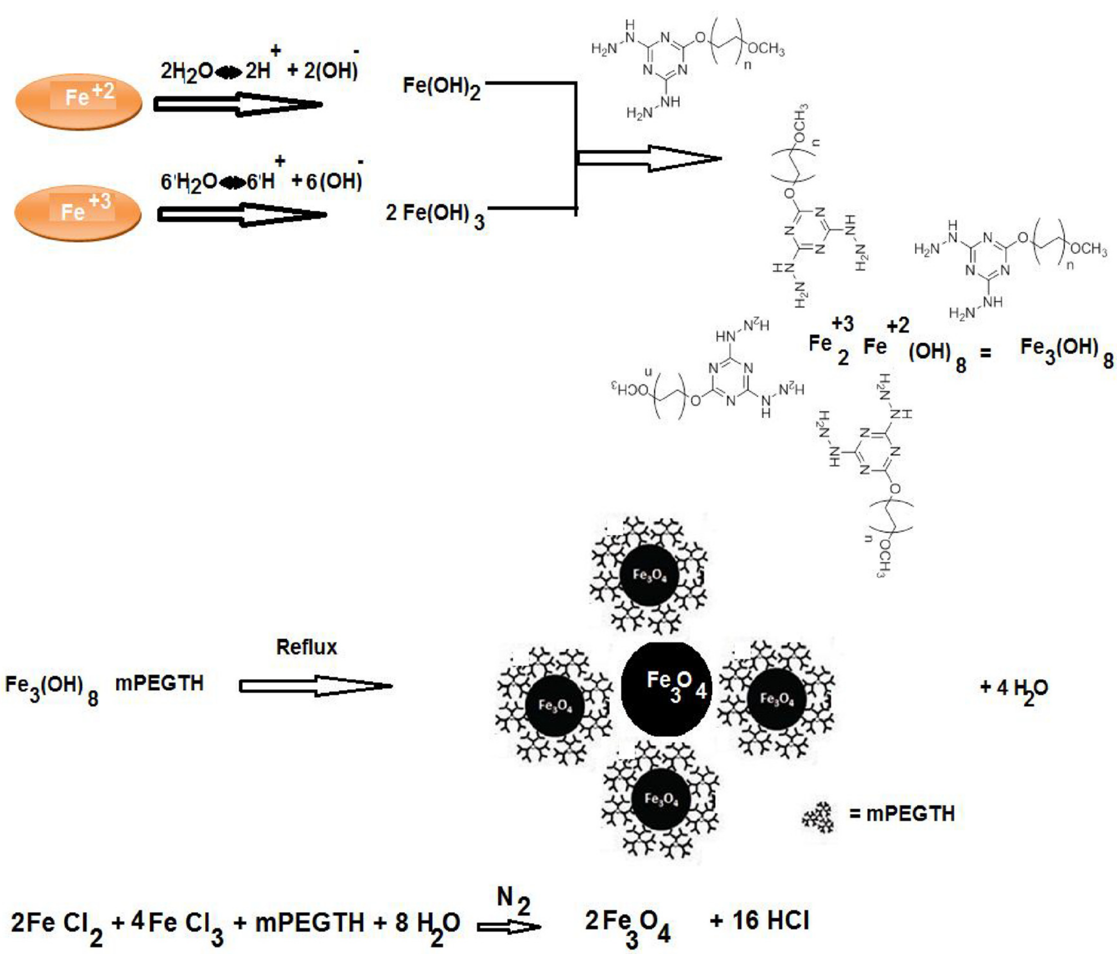


Scheme 1. Synthesis of mPEGTH.



Scheme 2. Preparation of Fe3O4 and Ag/Ag2O NPs capped with mPEGTH.