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A comparative study on fabrication of a highly effective corrosion protective system based on graphene oxide-polyaniline nanofibers/epoxy composite

Y. Hayatgheib, B. Ramezanzadeh*, P. Kardar, M. Mahdavian

Department of Surface Coatings and Corrosion, Institute for Color Science and Technology (ICST), PO 16765-654, Tehran, Iran

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ABSTRACT

Graphene oxide nanosheets were functionalized with polyaniline (PANI) nanofibers through three methods In method II the polymerization of aniline was done in the presence of sodium dodecyl sulfate as a surfactant and ammonium persulfate as an initiator. In method I the surfactant and in method III the initiator were eliminated during polymerization procedure. The morphology and chemistry of the nanosheets were characterized. Then, the GO/epoxy and GO-PANIs/epoxy nanocomposites were fabricated and their corrosion protection performance was studied on steel substrate by electrochemical impedance spectroscopy. Results revealed that GO-PANI remarkably improved the barrier performance and provided active inhibition for epoxy coating.

1. Introduction

Defect-free monolayer graphene is impermeable to all gases and liquids. So, as a corrosion protection barrier, it has been become one of the most interesting research areas in recent years [1]. Prasai et al. [2] used electrochemical methods to study the corrosion protection of copper and nickel surface covered with multilayers of graphene nanosheets. They showed that the metal oxidation and oxygen reduction reactions can be effectively quenched by the graphene film, which is the thinnest corrosion-protective coating. Kirkland et al. [3] reported the efficient protective effect of graphene layers on nickel and copper surface as an anticorrosion coating. Chen et al. [4] conducted a study on the oxidation resistance of graphene coated Cu and Cu/Ni alloy and confirmed that graphene layer works as a barrier for the metals against air and chemical oxidation in the solution. Schriver et al. [5] revealed the short comings of graphene as an anticorrosive coating for long term protection. Their results showed that, despite of the effective short-term oxidation protection that graphene could offer, it works reversely over long time scales and boosts the wet corrosion even more than that observed for a bare, unprotected Cu surface [6,7]. Graphene sheets, due to theirs large surface area and strong van der Waals forces among the sheets, are incompatible with most of the organic solvents and polymers, leading to poor interaction and dispersion. The aggregates produce defect sites i.e free volumes and cavities in the polymer matrix, declining the coating barrier performance. A solution to deal with this problem is to take bilayers of graphene sheets as a replacement for monolayer, as the defects of layers will rarely coincide at the same location. The other solution is using other graphene derivatives, which not only have the great properties of graphene, but also are more compatible with solvents and polymers. These derivatives can be in the oxide or modified forms.

Graphene oxide (GO) is another form of carbon nanosheets that can easily be obtained through chemical oxidation and exfoliation of graphite flakes. GO consists of many reactive functional groups such as carboxylic acid at the edge, and epoxide and hydroxyl groups in the basal plane of GO, which makes it incompatible with organic solvents and polymer media based on these solvents [8]. Chemical functionalization of GO with organic/inorganic compounds are the easiest and common methods of making GO readily dispersible in polymers and enhancing theirs interfacial interactions [9]. Also, this would result in higher degree of GO exfoliation and intercalation in polymers enhancing its thermal, mechanical and barrier performance. There are several factors influencing the polymeric coating performance including the type and mechanism of grafting. Improving the GO sheets dispersion through chemical functionalization is a promising way of enhancing the polymer coating barrier properties. Ramezanzadeh et al. enhanced the interaction between GO and a polyurethane matrix by covalent functionalization of GO nano-flakes with polyisocyanate resin [10]. Also they proved that incorporation of 0.1 wt.% of amine functionalized GO nanosheets into an epoxy matrix enhanced ionic resistance and barrier properties of the coating significantly [11]. In another work, they found that chemical functionalization of GO with 3-aminopropyl triethoxysilane (APTES) improves the corrosion resistance of epoxy coating and reduces its cathodic delamination rate [12]. Due to GOs' chemical inert and thermal stable structure (below 400 °C), it would be a perfect candidate for providing a corrosion protection film, which suspends the

* Corresponding author.
E-mail addresses: ramezanzadeh@aut.ac.ir, ramezanzadeh-bh@icrc.ac.ir (B. Ramezanzadeh).

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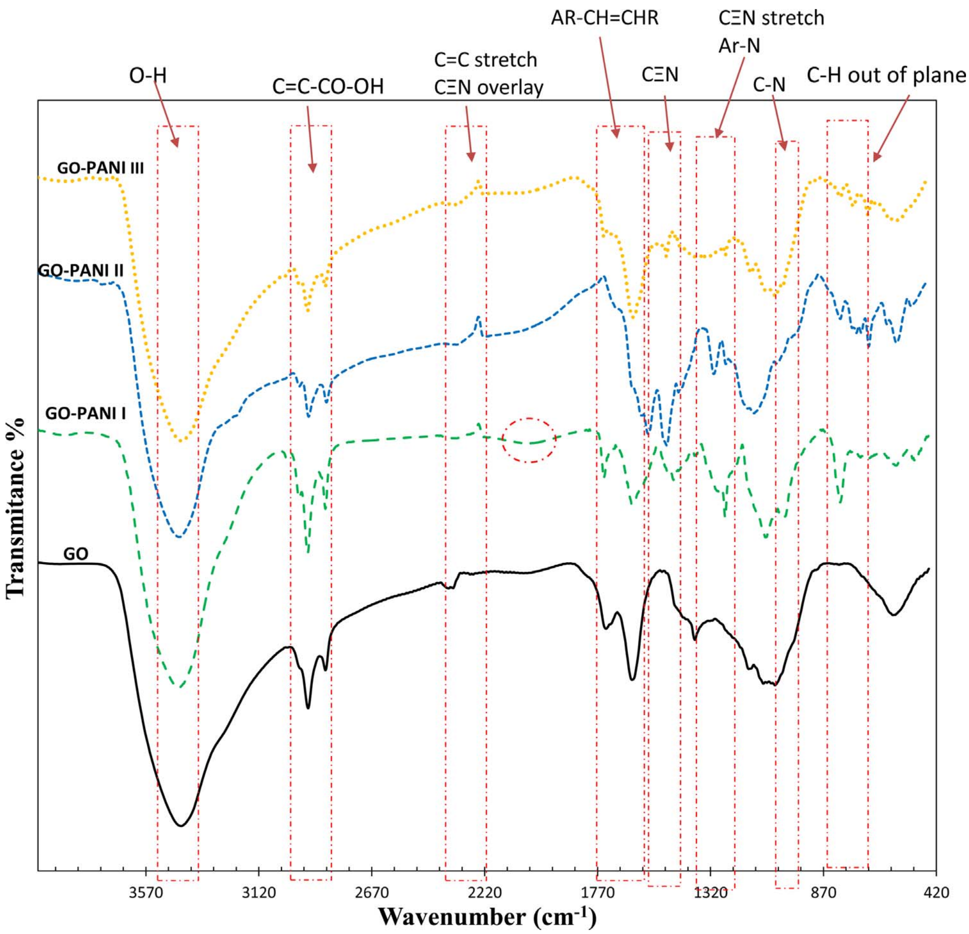

Fig 1. FT-IR spectra of GO-PANI nanosheets obtained from three different methods; (I), (II) and (III).

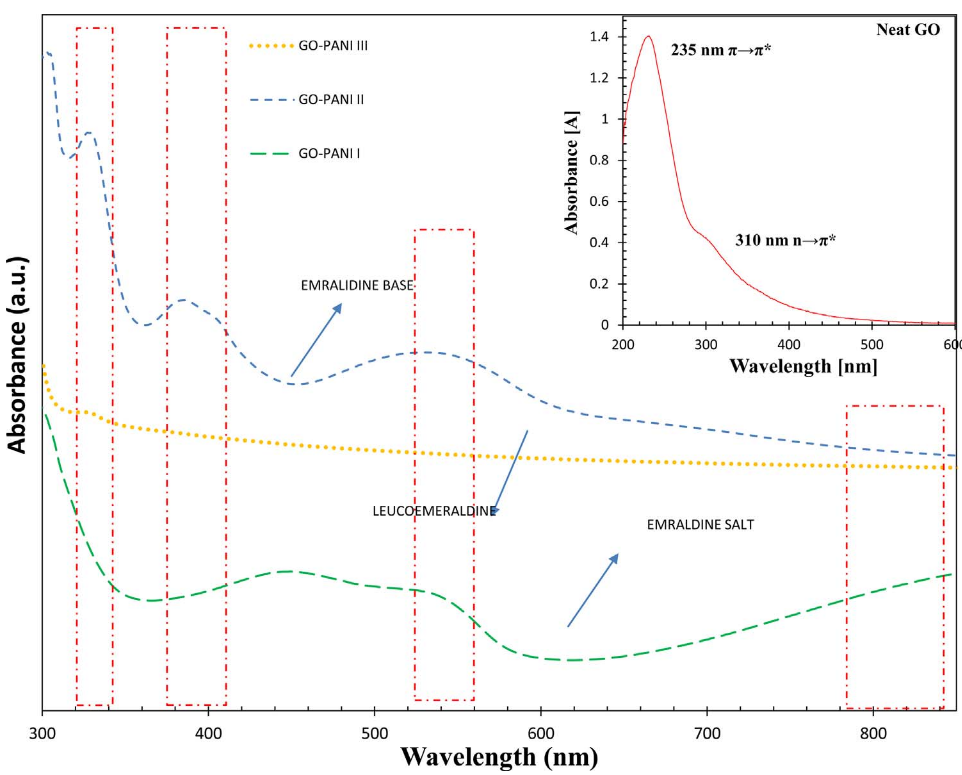

Fig. 2. UV–vis spectra of neat GO, GO-PANI I, GO-PANI II and GO-PANI III in water after sonication and stablization.