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Surface modification of silica-coated gadolinium oxide nanoparticles with zinc tetracarboxyphenoxy phthalocyanine for the photodegradation of Orange G

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ABSTRACT

Zinc tetracarboxyphenoxy phthalocyanine was covalently linked to Gd_2O_3 nanoparticles for the photocatalytic degradation of Orange G. Characterization of the composite was carried out using XRD, TEM, XPS, UV–vis spectroscopy and FT-IR spectroscopy. The composite showed improved photophysical properties over the phthalocyanine alone and the catalyst was found to be reusable. Analyses of the photodegradation rates of the azo dye indicated pseudo first-order kinetics.

1. Introduction

Photocatalysis involves the use of photosensitizers which accelerate a reaction through the absorption of light and the photocatalyst is ideally capable of being recycled many times [1]. In environmental management, the photodegradation of organic pollutants, especially dye pollutants, is gaining enormous interest as a clean, efficient method to convert toxic pollutants to less noxious substrates.

Phthalocyanines, particularly metallophthalocyanines, attract a great deal of attention in a wide variety of applications including photodynamic therapy of cancer [2], non-linear optics [3], as well as photosensitized catalytic applications [4–7]. Properties such as their high extinction coefficients, remarkable absorption of visible light and photoactivity, high chemical and thermal stability, and their ability to generate singlet oxygen makes these phthalocyanines ideally suited to applications such as photocatalysis [4]. Phthalocyanines have been anchored to support systems such as amberlite [8,9] and zeolite [10], and more recently in our group, to iron oxide nanoparticles [11,12] to successfully degrade Orange G and aid recovery of the photocatalytic system. This work reports for the first time the synthesis and use of a phthalocyanine–Gd_2O_3 nanoparticle composite in the photodegradation of Orange G.

Magnetic nanoparticles possess attractive properties in that they are capable of being manipulated by a magnetic field. The have found applications in biomedicine (drug delivery) [13], data storage [14], magnetic resonance imaging (MRI) [15], hyperthermia therapy [16], cell separation [17] and environmental remediation [18]. Furthermore, the surface of the nanoparticles may be easily modified to allow for attachment to other functional molecules or biomolecules [19]. In this way, bifunctional or multifunctional platforms are obtained. Owing to their excellent magnetic properties, the effortless recovery of the bifunctional magnetic nanoparticle-photocatalyst (e.g., phthalocyanine) from solution is anticipated.

In this work, a zinc tetracarboxyphenoxy phthalocyanine was covalently linked to a Gd_2O_3 NP as a support to facilitate an easily recoverable, heterogenous photocatalytic system. The composite was subsequently applied to the photodegradation of Orange G (Fig. 1), a common organic pollutant used in the dye or textile industry [20]. The photocatalytic degradation of Orange G has been reported previously by our group using phthalocyanines together with gold nanoparticles [21] or magnetite [11,12], however this is the first report of a Pc–Gd_2O_3 NP photocatalytic system. Each component in the composite serves a purpose: i.e., the zinc tetracarboxyphenoxy phthalocyanine (ZnTCPPc) acts as the photosensitizer capable of generating singlet oxygen with ease [4] which would then accomplish the degradation of the azo dye [4,7,12]; while the magnetic nanoparticle serves as a support for the phthalocyanine (for heterogenous catalysis), enabling the easy recovery of the photocatalyst (by virtue of their magnetic

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