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The photophysical studies of a mixture of CdTe quantum dots and negatively charged zinc phthalocyanines

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ABSTRACT

Fluorescence resonance energy transfer (FRET) studies were carried out with quantum dots capped with thioglycolic acid (TGA) and 2-mercaptoethanol (2-ME) and negatively charged phthalocyanines {Zn tetracarboxy (ZnTCPc), Zn octacarboxy (ZnOCPc) and Zn tetrasulfo (ZnTSPc) phthalocyinines} in a 0.1 NaOH:EtOH (50:50) solvent mixture. The best overlap between emission spectra of the donor (QDs) and the absorption spectra of the acceptor (ZnPc derivatives) was observed for TGA capped QDs, very little overlap was obtained for 2-ME QDs. ZnTSPc gave the highest FRET efficiency (0.3), with ZnOCPc and ZnTCPc giving a FRET efficiency of 0.2. The Φ_T values of the MPcs generally decreased in the presence of the QD whereas the triplet lifetimes (τ_T) of the ZnPc derivatives were higher in the presence of QDs.

1. Introduction

Quantum dots (QDs) are a relatively new class of compounds with unique properties which have fueled increased research interest in a variety of disciplines [1–6], including applications in tagging of biological molecules, polymer electronics, as phosphors, in light emitting diodes and in photodynamic therapy (PDT) [7–19]. QDs are inorganic semiconductors which exhibit size dependent optical and electronic properties [1,4–6]. Among some of the unique optical properties exhibited by QDs are the narrow emission spectra and the excellent photochemical and chemical stability and [1–6,20–24]. QDs have a larger band gap as opposed to the bulk materials [1–6,20–22], and behave differently from the bulk material because of the difference in electronic makeup [5,11,25].

In this study, CdTe QDs were synthesized from aqueous solution and were stabilized by using water soluble thiols, 2-mercaptoethanol and thioglycolic acid. In addition to serving as stabilizers, these thiol cappings serve to passivate the surface of the QDs and thereby removing the surface traps which lower the photoluminescence (PL) efficiency of the quantum dots [1,3,5,20,22]. The capping agents are also a means by which QDs interact with other molecules and their environment [1,3,20–22]. Thiol cappings of QDs were found to suppress intermittence of emission known as blinking [26].

QDs can be linked to other molecules through covalent attachments, electrostatic forces [19] and hydrogen bonding. In this work we studied the behaviour of CdTe nanoparticles capped with thioglycolic acid (TGA) and 2-mercaptoethanol (2-ME), in the presence of negatively charged phthalocyanines: zinc tetracarboxy (ZnTCPc), octacarboxy (ZnOCPc) and tetrasulpho (ZnTSPc) phthalocyanines, Fig. 1. ZnTCPc and ZnTSPc are tetrasubstituted and consist of a mixture of isomers which are difficult to separate, whereas ZnOCPc is octasubstituted and is isomerically pure [27–30].

It has been shown in a number of studies [18,31,32] that QDs can serve as near infra-red (IR) energy donors and phthalocyanines (Pcs) can accept this energy in a process known as fluorescence resonance energy transfer (FRET). Most of the studies used non-water soluble MPc complexes. The use of water soluble QDs and MPc complexes is desirable for many applications. FRET is a photophysical process based on a non-radiative energy transfer between a donor and a suitable energy acceptor [33–35]. Moreover, the efficiency of energy transfer depends upon the amount of spectral overlap between the emission spectrum of the donor and the absorption spectrum of the acceptor [34]. In this work, FRET efficiency between the CdTe QDs and the negatively charged phthalocyanines was studied.

2. Experimental

2.1. Materials

Thioglycolic acid (TGA), 2-mercaptoethanol (2-ME), tellurium powder (200 mesh, 99.8%), 4-sulphophthalic acid, nitrobenzene, trimellitic anhydride, pyromellitic anhydride and zinc acetate dihydrate were obtained from Sigma–Aldrich. Cadmium chloride

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