Impact of Electric Field on the Optical Properties of Hydrophilic Quantum Dots

Authors : Valentina V. Goftman, Vladislav A. Pankratov, Alexey V. Markin, Tangi Aubert, Zeger Hens, Sarah De Saeger, Irina Yu. Goryacheva

Abstract : The most important requirements for biochemical applicability of quantum dots (QDs) are: 1) the surface cap should render intact or improved optical properties; 2) mono-dispersion and good stability in aqueous phase in a wide range of pH and ionic strength values; 3) presence of functional groups, available for bioconjugation; 4) minimal impact from the environment on the QDs' properties and, vice versa, minimal influence of the QDs' components on the environment; and 5) stability against chemical/biochemical/physical influence. The latter is especially important for in vitro and in vivo applications. For example, some physical intracellular delivery strategies (e.g., electroporation) imply a rapid high-voltage electric field impulse in order to temporarily generate hydrophilic pores in the cell plasma membrane, necessary for the passive transportation of QDs into the cell. In this regard, it is interesting to investigate how different capping layers, which can provide high stability and sufficient fluorescent properties of QDs in a water solution, behave under these abnormal conditions. In this contribution, hydrophobic core-shell CdSe/CdS/CdZnS/ZnS QDs (λem=600 nm), produced by means of the Successive Ion Layer Adsorption and Reaction (SILAR) technique, were transferred to a water solution using two of the most commonly used methods: (i) encapsulation in an amphiphilic brush polymer based on poly(maleic anhydride-alt-1-octadecene) (PMAO) modified with polyethylene glycol (PEG) chains and (ii) silica covering. Polymer encapsulation preserves the initial ligands on the QDs' surface owing to the hydrophobic attraction between the hydrophobic groups of the amphiphilic molecules and the surface hydrophobic groups of the QDs. This covering process allows maintaining the initial fluorescent properties, but it leads to a considerable increase of the QDs' size. However, covering with a silica shell, by means of the reverse microemulsion method, allows maintaining both size and fluorescent properties of the initial QDs. The obtained water solutions of polymer covered and silica-coated QDs in three different concentrations were exposed to a low-voltage electric field for a short time and the fluorescent properties were investigated. It is shown that the PMAO-PEG polymer acquires some additional charges in the presence of the electric field, which causes repulsion between the polymer and the QDs' surface. This process destroys the homogeneity of the whole amphiphilic shell and it dramatically decreases the fluorescent properties (dropping to 10% from its initial value) because of the direct contact of the QDs with the strongly oxidative environment (water). In contrast, a silica shell possesses dielectric properties which allow retaining 90% of its initial fluorescence intensity, even after a longer electric impact. Thus, silica shells are clearly a preferable covering for bio-application of QDs, because – besides the high uniform morphology, controlled size and biocompatibility – it allows protecting QDs from oxidation, even under the influence of an electric field.

Keywords : electric field, polymer coating, quantum dots, silica covering, stability
Conference Title : ICQD 2015 : International Conference on Quantum Dots
Conference Location : London, United Kingdom
Conference Dates : December 10-11, 2015