Electrical and Optical Properties of Colloidal Quantum Dots: Role of Surface States

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ABSTRACT

The objective of this paper is to determine the role of surface states in determining the electrical and optical properties of semiconductor quantum dots in colloidal suspensions. Absorption spectra and photoluminescence (PL) spectra of colloidal cadmium sulfide (CdS) quantum dots are analyzed to investigate the role of surface states in determining the electrical and optical properties of these semiconductor quantum dots. Among the new results are: (a) the finding that the wavelength for the onset of the optical absorption of such a colloidal suspension shifts as the concentration of the electrolyte is changed; and (b) binding of selected amino-acid based biomolecules to the surface states of these quantum dots leads to quenching of the photoluminescence (PL) form these quantum dots. As depicted in Figures 1 and 2, bandbending associated with the field caused by the intrinsic spontaneous polarization of these würtzite quantum dots leads to a shift in the absorption threshold as a function of the electrolytic concentration. More specifically, Figure 1 depicts bandbending due to spontaneous polarization in the presence screening of anions and cations present in the electrolytic suspension of semiconductor quantum dots. In addition, Figure 2, illustrates bandbending due to spontaneous polarization when there is no electrolytic screening. Figure 3 illustrates the shift in the threshold for absorption as a function of the electrolytic concentration. In another surface-state related effect, Figure 4 depicts the quenching of the PL intensity of a suspension of colloidal cadmium sulfide (CdS) quantum dots. These and related surface-state effects are of importance in determining a number of electrical and optical properties of semiconductor quantum dots in colloidal suspensions. These altered electronic and optical properties underlie a number of applications of these nanocrystals in sensing electrolytic concentrations, in tuning optical transition energies, as well as in the potential control of quantum dot blinking.

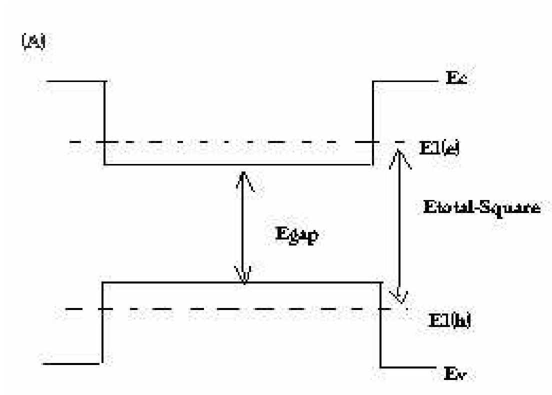

Figure 1. Bandbending due to spontaneous polarization in the presence of electrolytic screening.

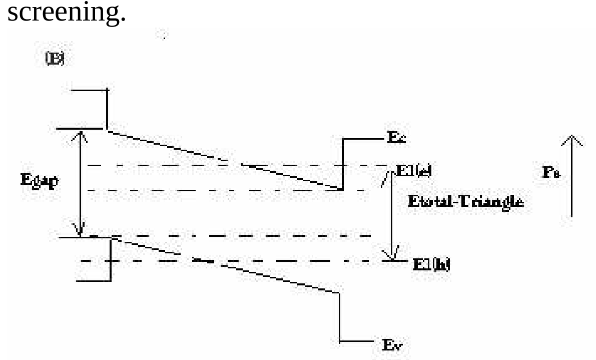

Figure 2. Bandbending due to spontaneous polarization in the absence of electrolytic screening.

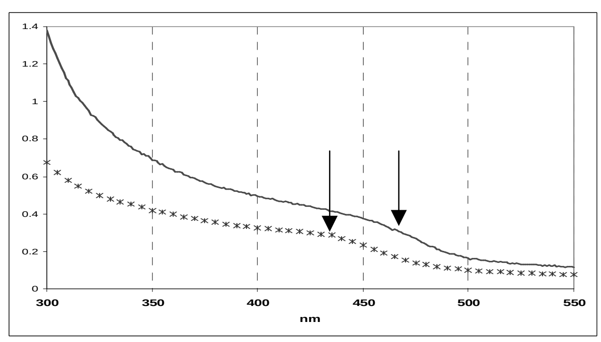

Figure 3. Shift in the absorption threshold for a suspension of colloidal CdS quantum dots for (a) a 5 mM concentration of NaCl (lower curve) and (b) for the same suspension diluted by an order of magnitude.

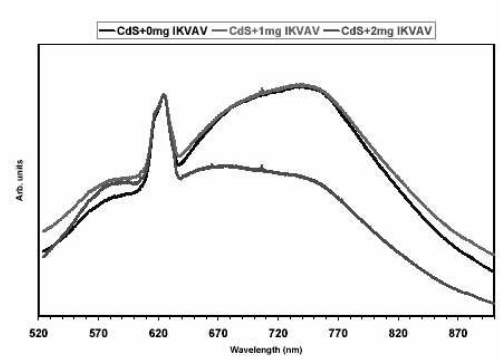

Figure 4. Quenching of PL intensity with increasing concentrations of IKVAV-based peptides.