

# Control of the direction of energy transfer in associates of colloidal quantum dots Ag<sub>2</sub>S/TGA and dye molecules

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**Abstract.** The possibilities for changing the direction of energy transfer in hybrid associates of colloidal Ag<sub>2</sub>S quantum dots (QDs) and thionine molecules are analyzed. The studies were performed by transmission electron microscopy, absorption and luminescence spectroscopy, PL decay study (time correlated single photon counting). An increasing of the average QDs size from 1.8 nm to 5.5 nm, and also a shift of the luminescence band from 630 nm to 950 nm, were found at using of TGA molecules and sodium sulfide as a sulfur precursor. Hybrid association of QDs (1.8 nm) with TH<sup>+</sup> molecules leads to quenching of QDs luminescence with a simultaneous reduction of the luminescence lifetime from 13.7 to 6.5 ns. An association of QDs with a luminescence band maximum of 950 nm with TH<sup>+</sup> molecules leads to quenching of TH<sup>+</sup> luminescence and a reduction in its lifetime of luminescence from 0.43 to 0.3 ns. It was concluded that the reduction of lifetime of luminescence caused by the resonant nonradiative energy transfer between the components of the associates. An increasing in the average size of QDs leads to a change in the direction of energy transfer between the components of the associates.

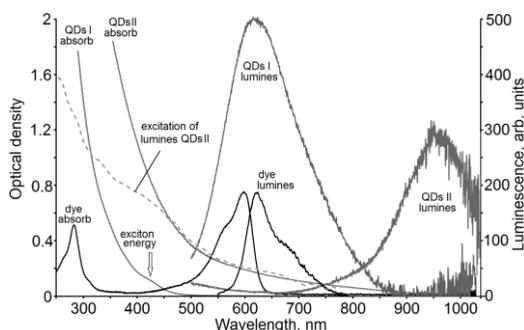
In recent years, organo-inorganic associates of colloidal semiconductor quantum dots (QDs) and dye molecules (Dye) have been actively studied. They are used as luminescent sensors, photosensitizers of singlet oxygen, disinfecting systems. This is due to the appearance of new properties for associates that are not characteristic of individual components. The main role in the formation of new properties is played by the processes of exchange of electronic excitations.

Currently, the most detailed cases are considered when energy donors are QDs. Dye molecules are acceptors. The main energy transmission channels are: nonradiative Forster resonance energy transfer (FRET), transport of charge carriers. Herewith it has been showed the principal possibility of nonradiative energy transfer from QDs excitons to the dye and from the center of recombination luminescence to the dye. The situation when dyes are donors of an energy, and QDs are acceptors, is practically not considered.

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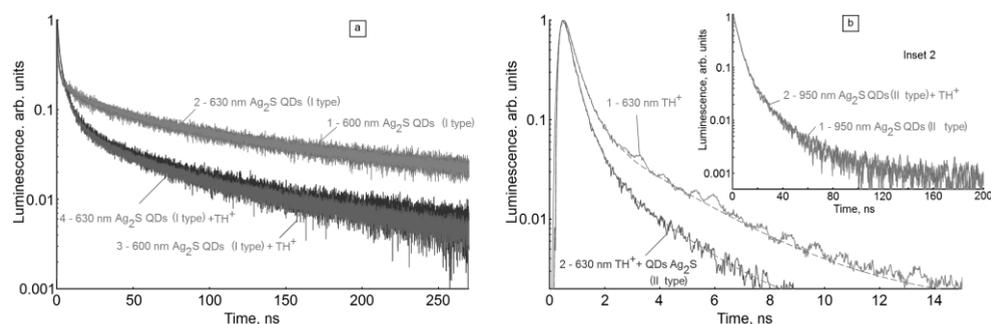
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The results of the study of nonradiative energy transfer in hybrid associates of colloidal  $\text{Ag}_2\text{S}$  quantum dots, passivated with thioglycolic acid ( $\text{Ag}_2\text{S}/\text{TGA}$ ) and thionine molecules ( $\text{TH}^+$ ) are presented below.



**Fig. 1.** Absorption and luminescence spectra of the components of hybrid associates.

Figure 1 shows the absorption and luminescence spectra of the components of hybrid associates. Samples of QDs of I and II type have luminescence bands with maxima located in the region of 630 nm and 950 nm, respectively. For type I QDs, the luminescence band overlaps with the absorption band of thionine. For type II QDs, the luminescence band is located on the long-wave side of the absorption and luminescence bands of thionine.



**Fig. 2.** Decay of luminescence curve.

At assembling of hybrid associates noticeable changes occurred in the absorption and luminescence properties of the components. The absorption spectra of thionine molecules increases in full width at half maximum toward shorter wavelengths to a few nanometers. For associates of type I QDs, thionine molecules were assembled into H aggregates. Also, the intensity and lifetime of the QDs luminescence decreased and simultaneously the luminescence of thionine increased. For associates of type II QDs, luminescence of thionine was quenched and luminescence of QDs increased. In addition, the lifetime of the luminescence of thionine molecules was reduced.

Thus, the quenching of luminescence and the shortening of its lifetime for one component and the increasing of luminescence of another component unambiguously indicate a nonradiative transfer of energy. In this case, the direction of the transfer is different for associates from the I and II type QDs.

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