Optical properties of heterogeneous systems with Ag nanoparticles

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Abstract: The optical properties of heterogeneous systems, including organic (dye) and inorganic (Ag nanoparticles and CdS quantum dots) compounds were studied. The effect of Ag nanoparticles influence on molecular structuring of methylene blue dye and on luminescence intensity of CdS quantum dots was found.

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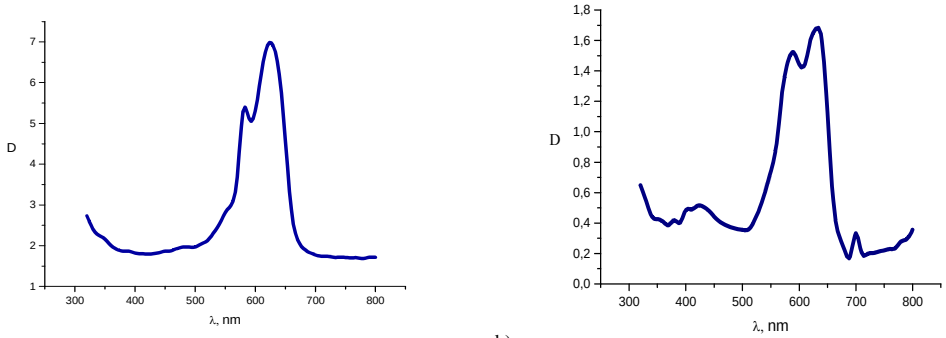
The creation of distributed and hybrid systems of optoelectronic components is rapidly developing field in modern nanotechnology. Such systems can be composed of metal nanoparticles, quantum dots, organic molecules and components associations. Organics-inorganic systems are promising for technical solutions, as well as for biomedical applications.

In this paper we investigate the optical properties of the two hybrid nanosystems, which are composed of silver nanoparticles (Ag NPs) with methylene blue dye (MB) and Ag NP with CdS quantum dots (CdS QDs). Each of the nano-components have a number of unique properties that are used in various practical applications. Thus, the dependence of optical, electrical and magnetic properties on the size and shape of nanoparticles used in antibacterial and biosensor applications. On the basis of Ag NP the composite materials for nanoelectronics and nanobiology can be created. Cationic thiazine dyes, which include MB are widely used in biology and medicine, pharmacology, and as biological markers. Concidering that, the study of the influence of Ag NP on the structural and optical properties of MB dye and the mechanism of their interaction, as well as investigation of Ag NPs influence on the luminescent properties of CdS QDs seem to be promising directions of research. CdS QDs were obtained by colloid chemistry methods.

The size of the test QDs was equal to 3 ÷ 4 nm [1]. Silver NPs of spherical form were obtained by chemical reduction of silver salt by sodium citrate [2]. The resulting silver nanoparticles show in the spectrum an absorption band caused by local surface - plasmon resonance (LSPR). The maximum of Ag NPs LSPR is localized at λ_{max} = 420 nm and corresponds to 20-30 nm average size of Ag nanoparticles.

The absorption spectrum of MG dye in long wavelength region consists of two strips (Fig. 1. (a)). The main peak corresponds to the molecular form of the dye is localized at λ_{max} = 633 nm. At shorter wavelengths region there is a well defined maximum with λ_{max} = 590 nm associated with the aggregation of the dye molecules. Such aggregates may be composed of two dye molecules - dimers or more molecules, for example, the aggregation of two or more dimers.



a) b)

Fig.1. The absorption spectra of Ag NPs - MB dye nanosystem without NPs (a) and with Ag NPs (b).

The absorption spectrum of the system changes when the silver nanoparticle solution is added (Figure 1 (b).) The characteristic changes of the absorption spectra of a complex system compared with those without Ag NP are observed, namely, the bands transformation. The intensity of the band due to aggregation of the dye molecules increases at the absorption spectra of Ag NPs + MB dye nanostructures. The increase in the half-width of this band can indicate the aggregation of two molecular dimers. Moreover, the maximum of 700 nm appear, the nature of which, according to the literature [3] is associated with the formation of complex aggregates consisting of several dimers and having foot-type structure. Such units are called J-aggregates. It is

also characteristic that the intensity of the Ag LSPR band in the sample decreases with the increasing of dye concentration.

Thus, the observed features in the absorption spectra of Ag NPs - MB dye system shows the interaction of silver nanoparticles with a dye, expressed in the structuring of their molecules.

The results of the influence of Ag NPs on the radiative properties of CdS QDs were also studied in this work. As a result of the fact that the QD, being in contact with Ag NPs, are getting excited in SPR conditions, the increase of the probability of enhancing their luminescence should be observed. The process parameters of Ag NP - CdS QDs system producing were investigated, in which the luminescence of CdS QDs exceeds in 2 times the luminescence of CdS QDs without Ag (Fig.2.).

Thus, the study of the optical properties of heterogeneous systems has shown that the addition of Ag NP into the media containing organic (MB dye) and inorganic (CdS QDs) compounds, leads to changes of their properties, both in structural and radiation characteristics, respectively.

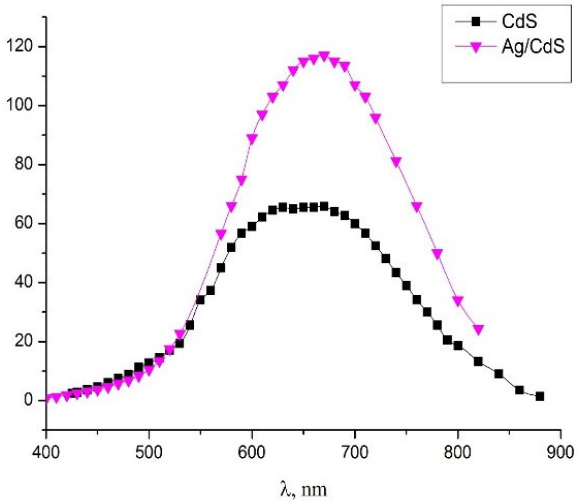


Fig.2. The influence of Ag NP on the spectrum of luminescence of cadmium sulfide QD.

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