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Optical properties research of cadmium sulphide nanoparticles received by the interaction of the reverse emulsions based on sodium bis(2-ethilhexyl) sulfosuccinate

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Abstract

By the inverted emulsions the sodium bis(2-ethilhexyl) sulfosuccinate, containing solutions of sodium sulfide and cadmium chloride, cadmium sulfide nanoparticles were synthesized. Based on UV-ranges of a transmission the band gap and the CdS particles' sizes were determined. Two groups of particles' depressiveness were identified. It is established that the order of the reversed emulsions coacervating with reagents changes the arrangement and properties of the formed colloidal particles. By the reverse emulsion coacervating with $CdCl_2$ solution to emulsion with Na_2S solution beside sulfide cadmium particles S_8 molecules are formed. These molecules restrained CdS particles growth.

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Keywords: AOT reverse emulsions; cadmium sulfide; nanoparticles; band gap.

1. Introduction

Cadmium halgenid nanoparticles are of a great interest among scientific researchers. Thanks to their unique optical properties such as the absorbtion band edge hypsochromic shift as the particles sizes are reduced, the high brightness of fluorescence these nanoparticles are perspective for use as the contrasting agents in a nuclear magnetic resonance tomography and the fluorescing biomarkers in microscopy [1, 2, 3]. The images received on the basis of a luminescent signal of markers allow to carry out early diagnostics and treatment of oncological diseases.

In the current research the cadmium sulphide nanoparticles optical properties that were received by the reverse emulsion coacervating with bis(2-ethilhexyl) natrium sulfosuccinate (AOT), containing natrium suphide and cadmium chloride solutions were studied.

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2. Experimental

The inverted emulsions with degrees of hydration ω = 10, the water defining the molar relation and AOT, prepared from 0.1M of AOT solution in n-hexane and 0.1 M of water Na_2S and $CdCl_2$ solutions when mixing with a speed of 500 rev./min within 15 min. For solutions preparation the deionized water received on the «Vodoley» device was used. The cadmium sulphide particles' synthesis was carried out by two reverse emulsions merging. In one of these emulsions solubilized water sodium sulphide solution was used, and in another - cadmium chloride. Mixes of the reverse emulsions were prepared with the reverse emulsion addition 0.05 – 14.14 ml and Na_2S solution for 14.14 ml of the reverse $CdCl_2$ emulsion, and addition of the same volumes of the reverse emulsion with $CdCl_2$ solution for the reverse Na_2S emulsion.

The microstructure and form of the synthesized particles were determined by the method of the scanning electronic microscopy (SEM) on the JSM-6460LV "JEOL" device supplied with the x-ray spectrum power dispersive analyser. Particles optical properties of cadmium sulphide in the reverse emulsions were studied with the methods of UV-spectroscopy and photometry on Specol 1500 and KFK-3-01 devices. The length of an optical layer is 1 cm. Measurements of optical density were taken at wavelength $\boldsymbol{\lambda = 400}$ nm.

From transmission specter in area 235 – 260 nm the band gap and the sizes of the synthesized particles were determined with use of the following formulas:

$$(\alpha E)^2 = A(E - E_R),$$
$$E = \hbar\omega = 2\pi\hbar c/\lambda,$$
$$\alpha = -\frac{\lg T}{l},$$
$$E_R = E_g + \frac{\hbar^2\pi^2}{2m^* R^2},$$

where α is the absorption coefficient; T is the transmission in relative units; l is the thickness of the absorbing layer in centimeters; E is the energy of a photon, eV; A is the coefficient that doesn't depend on the frequency of the falling radiation; Eg is the semiconductor's band gap with the particles size of R; Eg is the volume semiconductor band gap; m * is the specified mass of the exciton; $\hbar$ is the Plank's constant; ω is the falling radiation frequency; λ is the wavelength; c is the velocity light.

3. Results and discussion

Spectra of a transmission of the particles of sulfide of cadmium received by interaction of AOT reverse emulsions with $CdCl_2$ and Na_2S solutions are presented on Fig. 1, Fig. 2. From the drawings it is visible that when draining of the reverse emulsions at the volume contents of one of them from 0.36 to 1.80 vol. % spectra of a transmission are smooth function from the wavelength that points to monodispersion of the formed particles. At the volume maintenance of the reverse emulsions from 16.18 to 100 vol. % are formed particles of polydisperse structure. Thus to each group of the particles having the close band gap there corresponds a certain site of a spectrum of a transmission. Inflection points on a spectral curve correspond to transition from one group of particles to another. Irrespective of an order of draining of the reverse emulsions on spectra of a transmission it is possible to allocate two areas for an assessment of band gap and the size of particles. Band gap of particles of sulfide of cadmium was found by means of extrapolation of linear part of spectral dependence $(\alpha\hbar\omega)^2 = f(\hbar\omega)$ to an axis of energy of photons. The results of determination of band gap and the sizes of the particles of sulfide of cadmium received at various orders of draining and volume ratios of the reverse AOT emulsions are presented in Table 1. According to the obtained data, at the content in mix of one of the reverse emulsions from 0.36 to 1.80 vol. % are formed particles of one group of dispersion, and at the contents more than 16 vol. % - two groups. Within each group of particles with growth of concentration of one of the reverse emulsions band gap smoothly decreases and the sizes of particles smoothly increase. The largest particles of sulfide of cadmium are formed at addition to the reverse emulsion with emulsion cadmium chloride solution with sodium sulfide solution. Thus for particles of the second group of dispersion band gap comes nearer to value, characteristic for a volume monocrystal of CdS (2.53 eV). Particles in size of 2.3 – 2.9 nm have the considerable band gap that can be connected with small population loosening 3p- and σ* - conditions of bond of Cd – S. With increase in the size of particles the number of these states grows and the power gap between them is reduced. As a result, the edge of a strip of absorption in a range is displaced towards the big lengths of waves.

It is necessary to highlight that the order of draining of the reverse emulsions considerably affects appearance of spectras. So, at addition of the reverse emulsion with $CdCl_2$ solution to an emulsion with Na_2S solution in specter there is band of absorption with a maximum of 276 nm (fig. 2). It agrees [4], this band belongs to $\sigma \rightarrow \sigma^*$ to transition in a saturated molecule of