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Surface functionalization of CdS quantum dots and their application in bioimaging

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CdS Quantum dots (QDs) are semiconducting nanomaterials with unique optical and electronic properties. These nanoparticles have a diverse range of applications: they can be used as quantum-dot fluorescent biomarkers and cell labeling agents in biological studies. Also they may apply for pathogen and toxin detection, immuno-fluorescent labeling of proteins, novel biosensors as well as the components of solar cells, light emitting diodes in optoelectronics. Synthesis of CdS nanoparticles has been carried out using various chemical and physical methods such as microwave irradiation, ultrasonic irradiation, photoetching, hydrothermal synthesis. However, described approaches often require toxic stabilizers, are time consuming and harmful for the environment. Therefore the use of biological synthesis is an alternative approach for obtaining eco-friendly semiconductor nanoparticles [1]. Polymers are widely used to form a protective coating around the nanoparticles, because a contact of Cd-containing nanoparticles with biological environment occurs through their surface. Organic materials increase water-solubility of nanoparticles, also they are the carriers of reactive functional groups, ensuring the use of biocompatible quantum dots for bioimaging and detection of cellular structures [2]. Thus an aim of our study was to develop a surface modification of CdS nanoparticles using a polyethylene glycol (PEG) and show a possible application of luminescent CdS QDs for bioimaging studies.

Methods of the biosynthesis of CdS QDs are reported in [3-5]. An aqueous solution of PEG (10 mg / ml) was used for surface functionalization. A colloidal solution of CdS QDs was added to the PEG polymer matrix at the ratio of 2:1. The samples were investigated by optical spectrophotometry. Luminescence spectra were measured using the serial spectrophotometer Cary Eclipse (Varian Inc., Agilent Tech. USA). Excitation λ = 340 nm and 380 nm. In order to apply functionalized CdS QDs in biological imaging we have used luminescent microscopy of *Allium cepa* cells, treated with PEG-capped QDs. Wavelength of a light filter was 420 nm – 485 nm.

It was found that in luminescent spectrum of functionalized QDs appears an extended maximum at the range of 460 nm – 470 nm under excitation at 340 nm. This maximum is absent in the spectrum of initial CdS quantum dots. The resulted spectrum of functionalized nanoparticles does not contain shortwave peak at 384 nm, which is observed in the initial spectrum of PEG solution. Similar changes were found under the excitation at 380 nm. A broad maximum at the range from 450 nm to 475 nm was established. A shortwave peak at 435 nm which corresponds to PEG solution does not observed. It indicates a binding of PEG molecules with CdS quantum dots surface. It should be noted that CdS nanoparticles, obtained by biological synthesis have a complex surface layer which depends on the type of biological matrix. Thus, surface functionalization include the interaction between PEG molecules and the biological components of CdS surface as well as the binding of PEG with CdS core. Functionalization is carried out to form a polymer coating around CdS nanoparticles for targeted interaction with functional groups for further application of these QDs in cell biology studies.

In particular, it was revealed that functionalized CdS QDs can be used for labeling of plant cells. Nanoparticles are accumulated in the cell nuclei that was found by luminescent microscopy. PEG increases the permeability of QDs across the cell membrane and reduces undesirable effects of Cd-based nanoparticles on plant cells. Summing up, biofunctionalized CdS nanoparticles have a high luminescence intensity and can be used as biocompatible non-toxic luminescent probes for detection of intracellular structures. It is important that biocompatibility of QDs remains the major challenge which should be carefully explored in the future.

1. *Sweeney R.Y., Mao C., Gao X*. Bacterial biosynthesis of cadmium sulfide nanocrystals // Chemistry & Biology. – 2004. – **11**, №. 11. – P. 1553–1559.
2. *Shen L.* Biocompatible polymer/quantum dots hybrid materials: current status and future developments // J. Funct. Biomater. 2011. – **2.** – P. 355-372.
3. *Borovaya M.N., Naumenko A.P., Yemets A.I., Blume Ya.B.* Stability of the CdS quantum dots, synthesized by the bacterium *Escherichia coli* // Trans. Natl. Acad. Sci. – 2014. – N **7**. – P. 145 – 151.
4. *Borovaya M., Pirko Y., Krupodorova T., Naumenko A., Blume Y., Yemets A.* Biosynthesis of cadmium sulphide quantum dots by using *Pleurotus ostreatus* (Jacq.) P. Kumm // Biotechnol. & Biotec. Eq. – 2015. – **29**. – P.1156 – 1163.
5. *Borovaya MN, Naumenko AP, Matvieieva NA, Blume Ya.B., Yemets A.I.* Biosynthesis of luminescent CdS quantum dots using plant hairy root culture // Nanocsale Res. Lett. – 2014. – **9**. – P.1–7.
6. *Borovaya M.N.,. Burlaka O.M., Naumenko A.P., Blume Ya.B., Yemets A. I.* Extracellular synthesis of luminescent CdS quantum dots using plant cell culture // Nanocsale Res. Lett. – 2016. – **11**. – P.1-8.