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Magneto-Luminescent Biocompatible Complexes Based on Alloyed Quantum Dots and Superparamagnetic Iron Oxide Nanoparticles

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Abstract : Magnetic-luminescent complexes based on superparamagnetic iron oxide nanoparticles (SPIONs) and semiconductor quantum dots (QDs) have been recognized as a new class of materials that have high potential in modern medicine. These materials can serve for theranostics of oncological diseases, and also as a target agent for drug delivery. They combine the qualities characteristic of magnetic nanoparticles, that is, magneto-controllability and the ability to local heating under the influence of an external magnetic field, as well as phosphors, due to luminescence of which, for example, early tumor imaging is possible. The complexity of creating complexes is the energy transfer between particles, which quenches the luminescence of QDs in complexes with SPIONs. In this regard, a relatively new type of alloyed ($Cd_xZn_{1-x}Se_yS_{1-y}$)-ZnS QDs is used in our work. The presence of a sufficiently thick gradient semiconductor shell in alloyed QDs makes it possible to reduce the probability of energy transfer from QDs to SPIONs in complexes. At the same time, Forster Resonance Energy Transfer (FRET) is a perfect instrument to confirm the formation of complexes based on QDs and different-type energy acceptors. The formation of complexes in the aprotic bipolar solvent dimethyl sulfoxide is ensured by the coordination of the carboxyl group of the stabilizing QD molecule (L-cysteine) on the surface iron atoms of the SPIONs. An analysis of the photoluminescence (PL) spectra has shown that a sequential increase in the SPIONs concentration in the samples is accompanied by effective quenching of the luminescence of QDs. However, it has not confirmed the formation of complexes yet, because of a decrease in the PL intensity of QDs due to reabsorption of light by SPIONs. Therefore, a study of the PL kinetics of QDs at different SPIONs concentrations was made, which demonstrates that an increase in the SPIONs concentration is accompanied by a symbatic reduction in all characteristic PL decay times. It confirms the FRET from QDs to SPIONs, which indicates the QDs/SPIONs complex formation, rather than a spontaneous aggregation of QDs, which is usually accompanied by a sharp increase in the percentage of the QD fraction with the shortest characteristic PL decay time. The complexes have been studied by the magnetic circular dichroism (MCD) spectroscopy that allows one to estimate the response of magnetic material to the applied magnetic field and also can be useful to check SPIONs aggregation. An analysis of the MCD spectra has shown that the complexes have zero residual magnetization, which is an important factor for using in biomedical applications, and don't contain SPIONs aggregates. Cell penetration, biocompatibility, and stability of QDs/SPIONs complexes in cancer cells have been studied using HeLa cell line. We have found that the complexes penetrate in HeLa cell and don't demonstrate cytotoxic effect up to 25 nM concentration. Our results clearly demonstrate that alloyed ($Cd_xZn_{1-x}Se_yS_{1-y}$)-ZnS QDs can be successfully used in complexes with SPIONs reached new hybrid nanostructures, which combine bright luminescence for tumor imaging and magnetic properties for targeted drug delivery and magnetic hyperthermia of tumors. Acknowledgements: This work was supported by the Ministry of Science and Higher Education of Russian Federation, goszadanie no. 2019-1080 and was financially supported by Government of Russian Federation, Grant 08-08.

Keywords : alloyed quantum dots, magnetic circular dichroism, magneto-luminescent complexes, superparamagnetic iron oxide nanoparticles

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