GaP BASED STRUCTURES WITH LUMINESCENT NANOPARTICLES FOR BIOPHOTONICS AND PHOTOSENSORS SYSTEMS

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Systems based on whisker nanocrystals (NWs) are very promising for use in various biological studies: NW electrode arrays are capable of recording and stimulating neuronal activity intracellularly [1], functionalized NW arrays can be used to capture and quantify a specific cell type [2], the possibility of using NWs as a platform for introducing biomolecules into living cells was also demonstrated in [3]. Transfection due to mechanoporation is a promising method for delivering genetic material to target cells. Such perforation of the cell membrane can be realized by cultivating a cell line on a surface with vertically oriented whisker nanocrystals, while quantum dots act as a phosphor, which makes it possible to determine the efficiency of mechanoporation and the localization of nanosized particles with a similar interaction of nanocrystals with a cell. Systems based on whisker nanocrystals and luminescent nanoparticles are also actively studied for application in photocatalytic technologies [4], for photoanodes [5], and also for creating spectrally sensitive photodetectors [6–7]. In the present work, the application of NW/nanoparticle systems for cellular studies was demonstrated and the properties of such structures were studied.

In the first part of the work, we studied the efficiency of using NWs for cell mechanoporation, where AgInS/ZnS ternary quantum dots (QDs) stabilized with glutathione were used as luminescent labels. The cell line of cervical carcinoma HeLa was used as a biological object. To evaluate the more efficient accumulation of nanoparticles in cells, several methods for creating samples were tested. In the first case, HeLa cells were incubated on an array of vertically oriented NWs, and after 24 hours a QD solution was added to the nutrient medium. In the second case, cells were incubated in the presence of NWs with QDs already deposited on the surface. Using confocal laser scanning microscopy, the efficiency of penetration and accumulation of QDs in cells was evaluated. Fluorescent images (Fig. 1), images in transmitted and reflected light were obtained, and local luminescence intensity spectra of quantum dots in the created samples were analyzed.

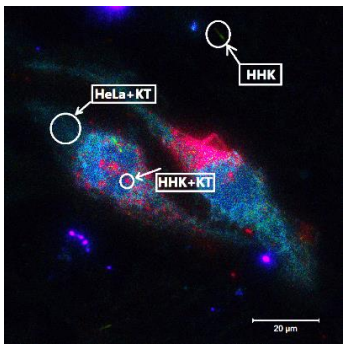

Fig. 1. Fluorescent image in real colors of a sample on a silicon substrate with a vertically oriented array of NWs perforating the cell membrane in the presence of a QD solution in a cell nutrient medium, objective 20x/0.75, excitation wavelength 405 nm

In the second part of the work, whisker GaP nanocrystals were used to create hybrid structures with carbon dots (CDs). Such structures have the potential to create multispectral sensitive photodetectors. The hybrid nanostructure was created on the basis of gallium phosphide NWs and "blue" or "red" carbon dots (B-CD and R-CD) on the surface, its optical and morphological properties were studied using electron and laser scanning confocal microscopy. The CD luminescence lifetimes were studied by time-resolved microscopy, and the impedance spectra were measured to determine the electrical properties.

In this work, the delivery of QDs to various parts of the cell during perforation of its NWs was studied, and it was discovered that free quantum dots in a nutrient medium penetrate the cell more efficiently. When hybrid nanostructures are used for delivery, the efficiency is slightly lower, since QDs are attached to the NW surface. Investigations using confocal luminescence and time-resolved microscopy have shown that the optical properties of CDs are preserved in created hybrid nanostructures. In this case, a decrease in the lifetime of the CD luminescence relative to the initial solution is observed. The measured impedance spectra of the obtained hybrid structures show a decrease in their resistance under the impact of UV radiation. It can be concluded that, in the NW/CD structures, the transfer of charge carriers from the CD to the NW is observed.

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[1] Robinson J. T., *Nat. nanotechnol.*, **7**, №3, 180-184, (2012).
[2] Lee S. K., *Nano Lett.*, **12**, №6, 2697-2704, (2012).
[3] Shalek A. K., *Proc. Natl. Acad. Sci.*, **107**, №5, 1870-1875, (2010).
[4] Chen Z., *Chin. J. of Catalysis*, **39**, 841-848, (2018).
[5] Xu X., *Carbon*, **121**, 201-208, (2017).
[6] Yin C., *Sensors and Actuators*, **321**, 112590, (2021).
[7] Shen X., *Mater. Res. Express*, **6**, 045002, (2019).