DEVELOPMENT OF NEW BIOLABELS BASED ON SILICON NANOCRYSTALS AND NANODIAMONDS

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Commercially used semiconductor quantum dots (e.g. cadmium containing quantum dots like CdS, CdSe, CdTe etc.) are toxic according to the latest results. They cannot be used in long-term biological studies in vitro and there is no safe method how to remove them after application in vivo. We are developing new non-toxic nanocrystalline silicon (Si-NCs) fluorescence labels which are biodegradable in living body and fluorescent nanodiamonds which are long-term stable (mainly for in vitro use).

Si-NCs have a crystalline core with size between 1 to 5 nm and their surface is most often covered by SiO_2. Photoluminescence (PL) emission bands of Si-NCs are ranging from ultraviolet to near infrared spectral regions [1]. The PL depend not only on the Si-NC size but the surface of nanocrystal plays also a crucial role. We are mostly interested in yellow-orange luminiscence band with slow streched-exponential decay. Lifetime of excited state of Si-NCs is ranging from 10 to 100 μs at room temperature. In the yellow-orange spectral region, there is not so strong autofluorescence of animal cells that could interfere with luminescence of these labels. In addition we can use normally available microscopes without any special filters for observing yellow-orange Si-NCs. We study in details luminescence spectra of single nanocrystals at room temperature in various chemicals and also in animal cells. We determine the size and shape of nanocrystals using atomic force microscopy (AFM).

Nanodiamond (ND) samples are produced by NanoCarbon UDD-TAH, Diamond Centre, St. Petersburg, Russia. The product consists of a mixture of 10 nm (56.6 Vol %) and 460 nm (43.4 Vol %) diamonds in de-ionized water. We are mostly studying the properties of 10 nm NDs, They emit in the visible part of the spectrum with PL peak between 600-800 nm [2].

The interaction of nanoparticles with bio-environment is studied on two cell culture lines: L929 mouse fibroblast and HeLa cells (human cervical cancer cells). The bio-interaction of nanoparticles is studied by optical transmission microscopy, time-lapse microphotography of cell culture evolution, fluorescence microscopy, fluorescence micro-spectroscopy, and scanning electron microscopy. The first cytotoxic tests are showing that Si-NCs and NDs are biocompatible and no significant damage or changes in cell system was observed. In case of bigger (1 μm) particles we observe necrosis of cells due to mechanical damage of the cell membrane.

In case of Si-NCs we observe a slight shift of the PL emission in the spectra when Si-NCs is interacting with internal environment of the cell. Similar shifts are observed when Si-NCs is introduced into surroundings of various chemicals nature.

Optical properties of Si-NCs and NDs are showing promising application potential as fluorescent labels. The size of these nanoparticles is smaller than commercially used CdS-based quantum dots (e.g. EviTag® around 25 nm). The next steps towards applicable fluorescent labels is the development of bioactivation procedures and technology for large scale production of Si and nanodiamond particles.

Keywords: Silicon nanocrystals, nanodiamonds, biocompatibility, quantum dot, fluorescence label, micro-spectroscopy

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