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Upconversion nanoparticles based on rare-earth elements

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Abstract. Using the hydrothermal method, we synthesized water soluble YVO_4: Yb, Er nanoparticles with a size less than 10 nm. Nanoparticles exhibit intense luminescence in the green region due to Er^{3+} ions when excited by laser radiation at a wavelength of 980 nm as a result of the up-conversion process. Bright and stable luminescence also persists in an aqueous solution of nanoparticles. Based on experimental data, it can be argued that the objects obtained are promising in biological applications, as well as up-conversion phosphors.

1 Introduction

Recently, special attention has been paid to new biocompatible nanoscale materials [1] and methods for their investigations [2-5]. In particular, it is possible to create brain neurons with ion channels that would be sensitive to optical radiation in the blue or green spectral region [6]. At the same time, a problem arises of an optical excitation source that is capable of luminescing at the required wavelengths. The most common approach is based on the use of optical fiber, which is inserted directly into living tissue. However, the use of small phosphors that can be placed in the required position with the least impact on living tissue looks more promising [7-9]. Luminescence is excited in an energy conversion process in which nanoparticles absorb infrared light, much less dangerous for living cells, and glow in the green or blue areas. This can be achieved using nanoparticles containing rare earth elements [10-12].

2 Results

We have synthesized nanoparticles based on sodium orthovanadate containing erbium, yttrium and ytterbium ions. The synthesis was carried out by the hydrothermal method followed by calcination. Nanoparticle growth was regulated by the addition of sodium citrate. To avoid the formation of agglomerates, the nanoparticles were coated with silica sol, later removed by washing with hydrofluoric acid. As a result, monodispersed

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nanoparticles with sizes of 10–20 nm were obtained, which did not form agglomerates in dry form, as well as in aqueous solution.

Ytterbium has a large absorption cross section when excited by laser radiation at a wavelength of 980 nm. In this case, it can act as an effective receiver of radiation. After absorption, energy is transferred through yttrium energy levels to erbium, which is known for its outstanding luminescent properties [13, 14].

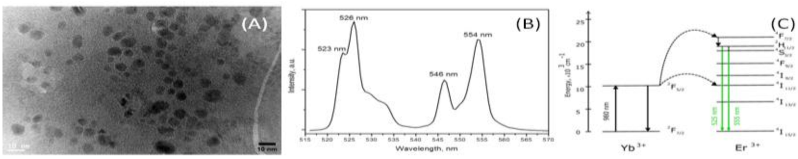

Fig. 1. (A) TEM image of the synthesized upconversion nanoparticles; (B) fluorescence spectrum; (C) energy transfer in upconversion nanoparticles.

The luminescent properties of the obtained nanoparticles were studied using a diode laser with a wavelength of 980 nm and an average power of 300 mW, a MDR-12 automated monochromator, and a FEU-79 photomultiplier tube. As a result, intense luminescence bands were recorded in the regions of 525 nm and 550 nm. Important is the fact that the luminescence efficiency decreases by only a comparatively small amount after switching from a dry powder to an aqueous solution, which indicates the resilience of the obtained nanoparticles to low-frequency quenchers, one of which is water, and the prospects of using such objects in biological applications.

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