J Nanopart Res (2021) 23: 124
https://doi.org/10.1007/s11051-021-05249-7

RESEARCH PAPER

Transmission electron microscopy and flow cytometry study of cellular uptake of unmodified Pr^{3+}:LaF_3 nanoparticles in dynamic

M. S. Pudovkin · N. I. Shamsutdinov · P. V. Zelenikhin · A. S. Nizamutdinov

Received: 8 April 2020 / Accepted: 30 May 2021 / Published online: 9 June 2021

Abstract The article represents the transmission electron microscopy (TEM) and flow cytometry study of A-549 (human lung carcinoma) cellular uptake of unmodified Pr^{3+}:LaF_3 nanoplates and nanospheres after 2, 10, and 24 h of nanoparticles exposure. The studied Pr^{3+}:LaF_3 (C_{Pr} = 1 mol.%) nanoplates (length = 64.0 ± 1.0 nm) and nanospheres (diameter = 13.0 0.4 nm) are hexagonal structured nanocrystals without amorphous phase. Both morphotypes of nanoparticles (nanoplates and nanospheres) are easily internalized by A-549 cells via macropinocytosis after 2, 10, and 24 h of nanoparticle exposure. The nanoparticles were not observed in cell nuclei and other organelles. During macropinocytosis, relatively large vesicles (0.2–5 μm) are formed. The flow cytometry experiments revealed that the internalized nanoparticles increase the cells' optical inhomogeneous that leads to an increase of side scattered light intensity by ~ 10% without any dynamic during 24 h (for both morphotypes of nanoparticles). Probably, it can be explained by the fact that macropinocytosis is a dynamic process and some macropinosomes appear and move in the cytoplasm, in turn, other macropinosomes travel back to the cell surface of the membrane and release the content to the extracellular space, consequently, the equilibrium is achieved.

Keywords Pr^{3+}:LaF_3 nanoparticles · Fluoride nanoparticles · Cell uptake · Cytotoxicity · A-549 cells · Flow cytometry · Biomedicine

M. S. Pudovkin (✉) · A. S. Nizamutdinov
Institute of Physics, Department of Quantum Electronics and Radiospectroscopy, Kazan Federal University, Kremlevskaya 18, Kazan 420008, Russian Federation
e-mail: jaz7778@list.ru

N. I. Shamsutdinov · P. V. Zelenikhin
Institute of Fundamental Medicine and Biology, Department of Microbiology, Kazan Federal University, Kremlevskaya 18, Kazan 420008, Russian Federation

Introduction

Luminescent nanoparticles are nowadays considered essential and versatile building blocks in modern biophotonics. They have been extensively used for a great variety of applications ranging from high-resolution bioimaging, intracellular sensing, and light-controlled drug delivery (Xing et al. 2012; Jalil and Zhang 2008; Zhou et al. 2011). Among the huge variety of luminescent nanomaterials, rare earth (RE)-doped fluoride nanoparticles hold a special place mainly because of their excellent photostability, long luminescent lifetimes (micro- to milliseconds), sharp emission bands, high chemical stability, and lack of photobleaching (Fedorov et al. 2011; Feofilov 2002).

Such fluoride nanoparticles as RE-doped $NaYF_4$, $NaGF_4$, SrF_2, and LaF_3 were successfully applied for bioimaging of cells and small animals. Specifically, Yb^{3+}, Er^{3+}:$NaYF_4$@Yb^{3+}, Nd^{3+}:$NaYF_4$