Latvian Academy of Sciences
University of Latvia
Institute of Electronics and Computer Sciences
Sumy State University
IEEE Nanotechnology Council

2024 IEEE 14th International Conference "Nanomaterials: Applications & Properties" (NAP-2024)

ABSTRACTS

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Book of Abstracts

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Effect of Hydrogen Peroxide Decomposition on Luminescence and Microstructure of $GdVO_4:Eu^{3+}$ Redox-Active Nanocrystals

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Hydrogen peroxide plays a crucial role in the functionality of living cells. It acts as a mediator in various physiological processes, impacting cellular metabolism and signaling pathways. Some key functions of hydrogen peroxide in cellular processes include cellular metabolism regulation, cell differentiation and proliferation, immune response, development of various pathologies and even cell death [1].

Sensing intracellular levels of hydrogen peroxide is crucial due to its potential to cause cell mutations and lead to various pathologies. Doped orthovanadate nanoparticles show promise as multifunctional theranostic agents [2] and intracellular hydrogen peroxide sensors [3]. Therefore, detailed studies are required to understand factors influencing their catalytic and luminescence properties, particularly the impact of hydrogen peroxide on their luminescent behavior.

In this study, we investigated the effects of hydrogen peroxide on Eu^{3+} luminescence quenching and microstructure of $GdVO_4:Eu^{3+}$ nanocrystals synthesized in an aqueous solution. The obtained nanocrystals were characterized using X-ray diffraction (XRD), high-resolution transmission electron microscopy (HR-TEM), X-ray photoelectron spectroscopy (XPS), and optical spectroscopy techniques.

To examine surface microstructure modifications of $GdVO_4:Eu^{3+}$ nanocrystals after exposure to hydrogen peroxide, we employed XPS analysis and time-resolved luminescence spectroscopy. Two mechanisms responsible for the observed Eu^{3+} luminescence quenching were identified: reduced efficiency of non-radiative resonance energy transfer from vanadate (VO_4^{3-}) groups to Eu^{3+} ions due to reducing of vanadium ions, and direct quenching of Eu^{3+} luminescence by OH^- groups formed on the surface as a result of hydrogen peroxide decomposition.

This study enhances our understanding of how hydrogen peroxide influences the luminescent properties and surface microstructure modifications of $GdVO_4:Eu^{3+}$ nanocrystals, thereby contributing to their potential as effective intracellular hydrogen peroxide sensors.

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Delayed Reactive Oxygen Species Production By UV Pre-irradiated Orthovanadate Nanocrystals

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Reactive oxygen species (ROS) like superoxide anions ($O_2^{\bullet-}$), hydroxyl radicals (•OH), and hydrogen peroxide (H_2O_2) are crucial for cellular functions [1]. At low physiological concentrations, ROS act as important redox messengers involved in intracellular signaling and regulation. In contrast, cancer cells maintain ROS levels near the threshold of cell death, making them more susceptible to additional oxidative stress caused by ROS-generating agents. [2]. Over the past decade, research into cancer treatments focused on modulating ROS has expanded significantly. Many researchers have dedicated efforts to exploring diverse strategies for inducing ROS production using various nanomaterials. This approach holds promise for developing effective therapies that exploit ROS to damage cancer cells [3]. That is why, nanomaterials that facilitate the generation of ROS and induce oxidative stresshave shown promising potential for various nanomedicine applications.

In this study, we report delayed pro-oxidant activity of UV pre-irradiated orthovanadate nanocrystals in water solutions without any external stimuli (in the darkness). The obtained nanocrystals were characterized using X-ray diffraction, transmission electron microscopy, and X-ray photoelectron spectroscopy. The delayed pro-oxidant activity of the obtained nanocrystals was studied using ROS-specific luminescence probes, as well as by measuring nonspecific dye degradation and lipid autoxidation.

Our experiments have revealed that orthovanadate nanocrystals demonstrate delayed pro-oxidant activity, specifically the generation of ROS, after UV pre-irradiation and subsequently keeping in darkness. This delayed pro-oxidant activity has been linked to the generation of $O_2^{\bullet-}$, •OH, and hydrogen peroxide H_2O_2. We hypothesize that the primary source responsible for the effective delayed generation of $O_2^{\bullet-}$ and •OH by orthovanadate nanocrystals in the dark is attributed to the abundance of V^{4+} ions and oxygen vacancies within the crystal lattice of the nanocrystals. Furthermore, due to its unsaturated nature, oxygen vacancy can promote O_2 adsorption at the surface of nanocrystals. In dark conditions, this oxygen adsorption can lead to the generation of $O_2^{\bullet-}$ through a reaction involving the electrons stored in V^{4+} ions. Simultaneously, photo-induced holes generated by UV pre- irradiation may become trapped within local metastable levels. These metastable levels arise due to random scattering potentials of oxygen vacancies. The presence of these metastable levels serves to localize the holes, delaying their transfer to the surface of the nanocrystal and generation of •OH.

The delayed redox activity observed in orthovanadate nanocrystals holds great promise for biomedical applications. This distinctive characteristic offers a novel strategy for advancing the treatment of malignant cells, potentially revolutionizing approaches in cancer therapy.

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