Hydroxyl radicals scavenging by small oxide nanocrystals with variable valence ions

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Pavel Maksimchuk, Kateryna Hubenko, Vladyslav Seminko, Andrey Onishchenko, Iryna Bespalova, Vladimir Klochkov, Svetlana Yefimova

pavel.maksimchuk@gmail.com

Yu.V. Malyukin
Department of Nanostructured Materials,
Institute for Scintillation Materials
Kharkiv, Ukraine

Abstract

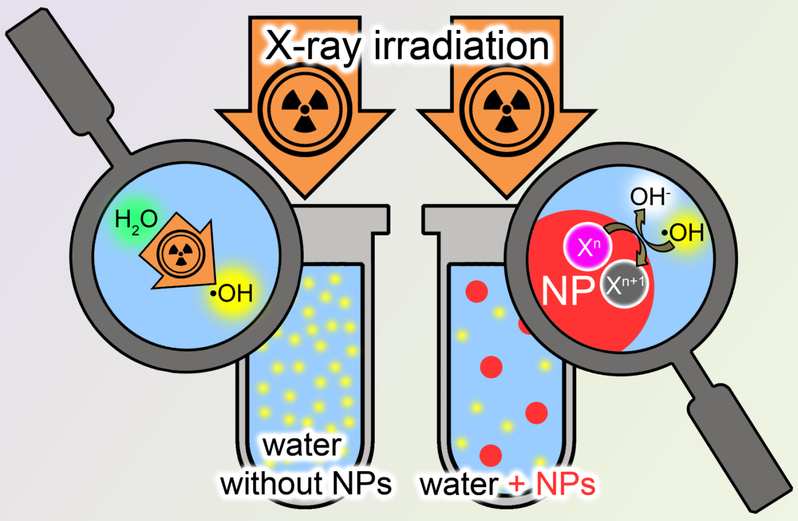
Reactive oxygen species (superoxide anions, hydrogen peroxide and hydroxyl radicals) are biologically active molecules which are formed inside the mitochondria of living cells during cellular respiration. Some of them play indispensable role in the metabolism of the cell. At the same time, an increase of the content of hydroxyl radicals (·OH) which are the strongest oxidants among all reactive oxygen species can trigger the number of pathological processes inside the cell from enhanced lipid peroxidation of cell membranes to DNA damage.

Hydroxyl radicals are formed at water radiolysis during X-ray or gamma-irradiation of the cell. Extremely high reactivity of ·OH radicals (average ·OH lifetime in the biological environment of only few nanoseconds) makes the task of its effective elimination by the internal systems of the living cell rather difficult. We propose three different types of small oxide nanocrystals with variable valence ions (CeO_2, $GdYVO_4$ and TiO_2) as promising materials for effective elimination of hydroxyl radicals.

Methods

Water radiolysis under X-ray irradiation

$$H_2O \rightarrow H^+ + \bullet OH$$



•OH radical sensor

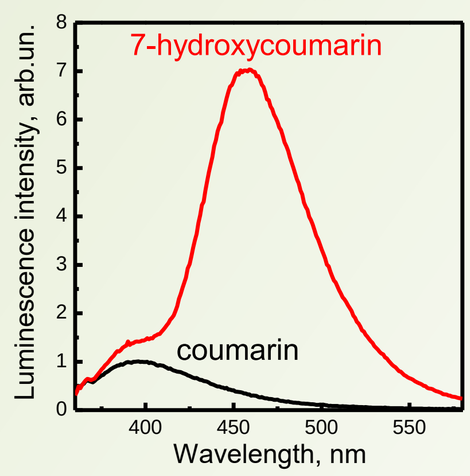


Fig.1. Luminescence spectra of coumarin and 7-hydroxy coumarin

Results and discussion

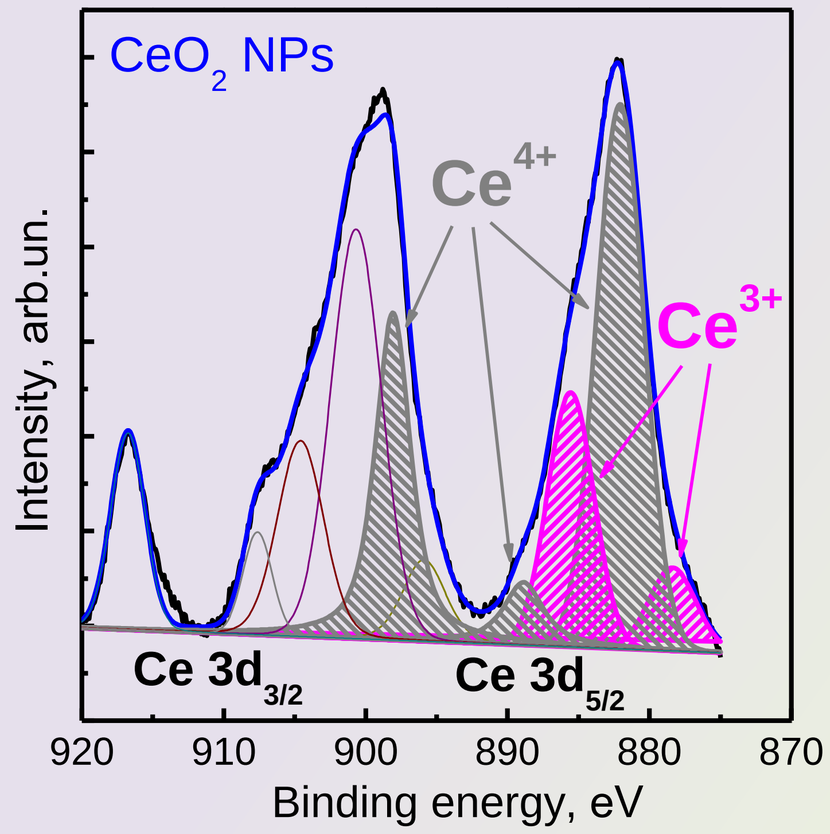


Fig.2. XPS of CeO_2 nanocrystals

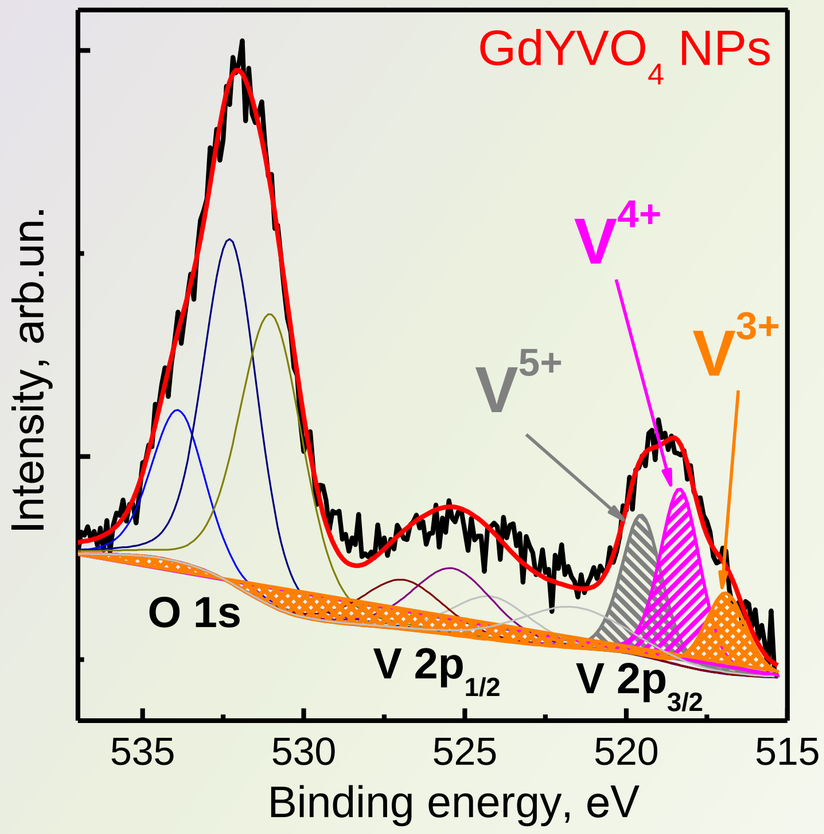


Fig.3. XPS of $GdYVO_4$ nanocrystals

Fig.4. XPS of TiO_2 nanocrystals

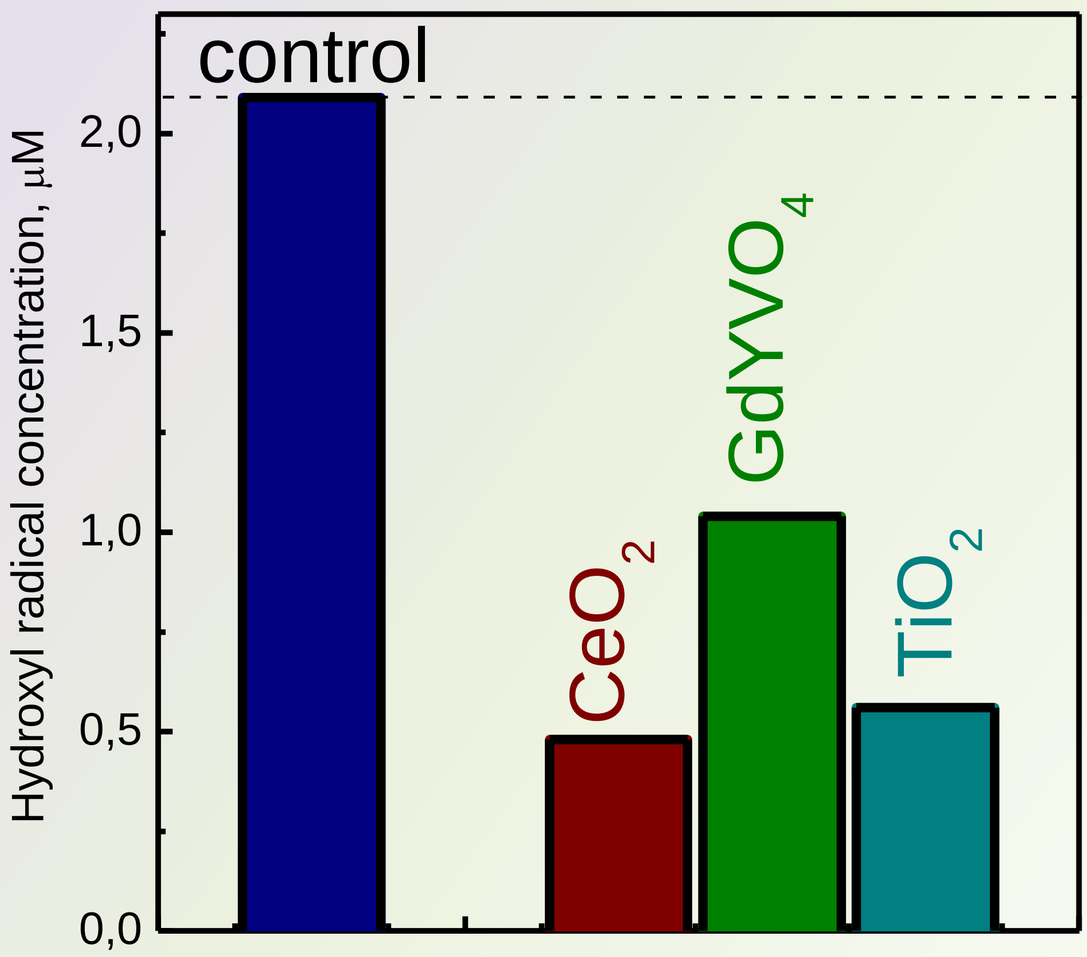


Fig.4. ROS scavenging activity against hydroxyl radicals formed during X-ray irradiation of water solutions

Conclusion

CeO_2, $GdYVO_4$ and TiO_2 nanocrystals demonstrate high ROS scavenging activity against hydroxyl radicals formed during X-ray irradiation of water solutions. Hydroxyl radicals scavenging properties have been revealed to be directly related to the high content of reduced variable valence ions (Ce^{3+} for CeO_2, V^{4+} and V^{3+} for $GdYVO_4$, Ti^{3+} for TiO_2) which could donate electrons in hydroxyl radical neutralization reaction. A large amount of structural defects, such as oxygen vacancies, is a feature of small oxide nanocrystals. Formation of oxygen vacancies can be accompanied by the reduction of neighboring atoms, which were shown by XPS experiment for all types of nanocrystals.

The efficiency of hydroxyl radicals scavenging by small oxide nanocrystals with variable valence ions (CeO_2, $GdYVO_4$ and TiO_2) in water solutions allows suggesting such materials as effective antioxidants in living cells as well.

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Yu.V.Malyukin department of nano • structured • materials