Enhancing hydroxyl radicals scavenging properties of CeO_{2-x} nanocrysrtals by annealing, size reduction, pre-irradiation and doping

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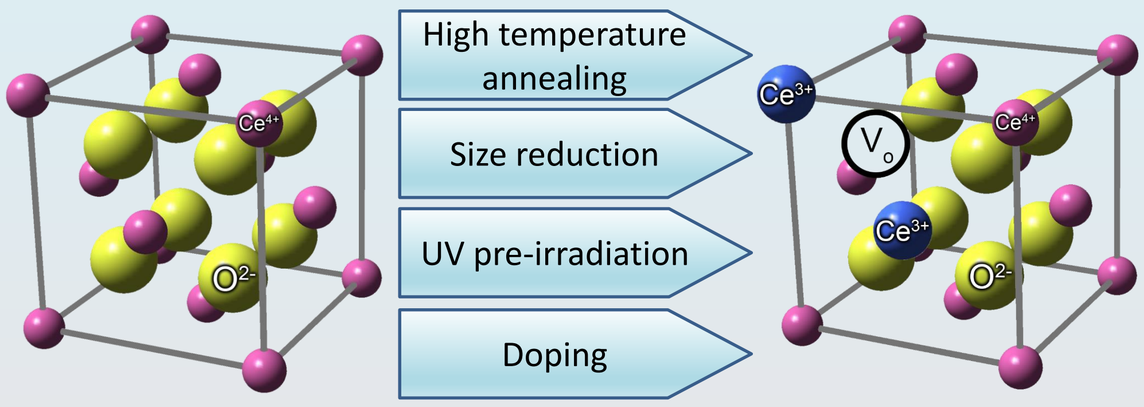
Abstract

Hydroxyl radicals (·OH) are usually considered as the most dangerous type of reactive oxygen species formed inside the living cells that leads to increasing demand for antioxidant nanomaterials able to effective ·OH elimination. Nanoceria (CeO_{2-x}) has recommended itself as the one of the most potent ·OH scavengers due to high content of Ce^{3+} ions and easy $Ce^{3+} \leftrightarrow Ce^{4+}$ switching making possible effective redox cycling.

In the paper the direct connection between Ce^{3+} content and ·OH scavenging ability is shown. The dependence of ·OH scavenging properties on the content of Ce^{3+} ions in nanoceria was confirmed by the simultaneous study of luminescence spectra and nanoceria - ·OH interaction processes. High temperature annealing, size reduction, doping of nanoceria by non-isovalent ions (Y^{3+}) or by ions with smaller ionic radius (Zr^{4+}), UV pre-irradiation of nanoceria leads to increase of both Ce^{3+} content and antioxidant activity of nanoparticles.

Methods

Methods of enhancing hydroxyl radicals scavenging properties of nanoceria

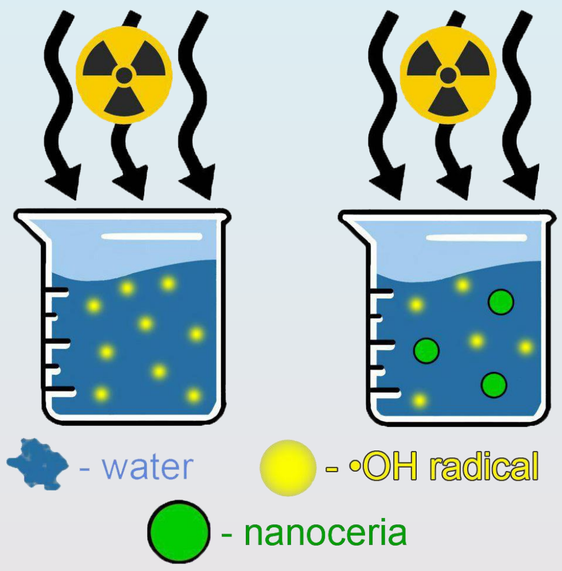


Hydroxyl radicals scavenging properties of nanoceria

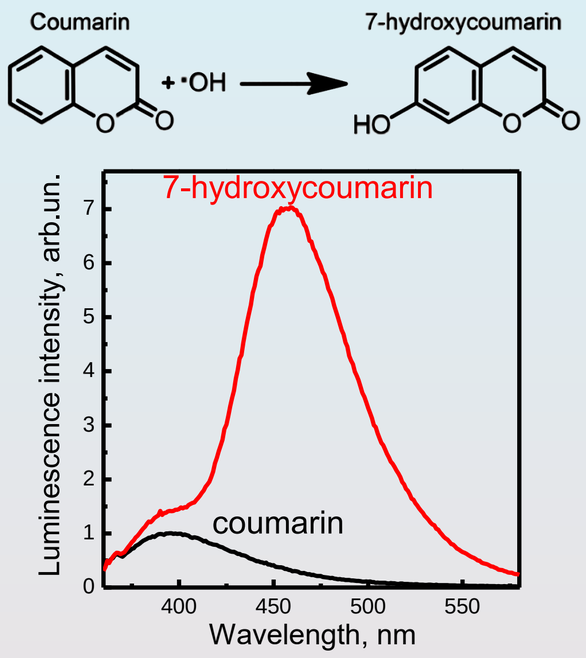
$$\bullet OH + Ce^{3+} \rightarrow OH^- + Ce^{4+}$$

Water radiolysis under X-ray irradiation

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



•OH radical sensor



Results and discussion

Effect of high temperature annealing

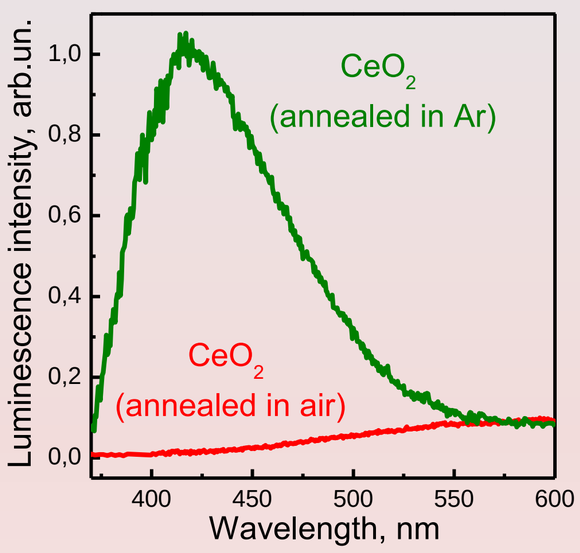


Fig.1. Luminescence spectra of nanoceria after annealing in different atmospheres

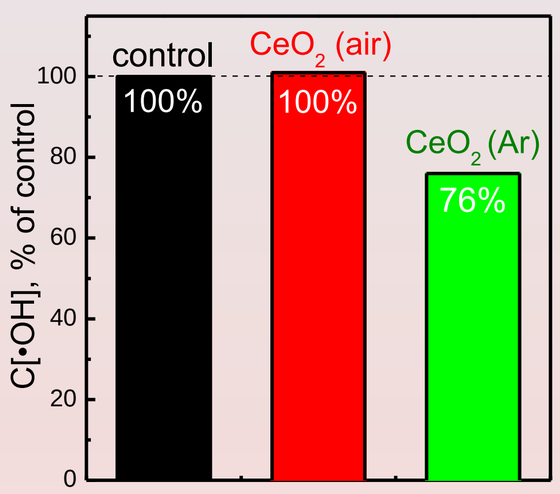


Fig.2. Concentration of OH radicals in nanoceria colloidal solution after X-ray irradiation

Effect of size reduction

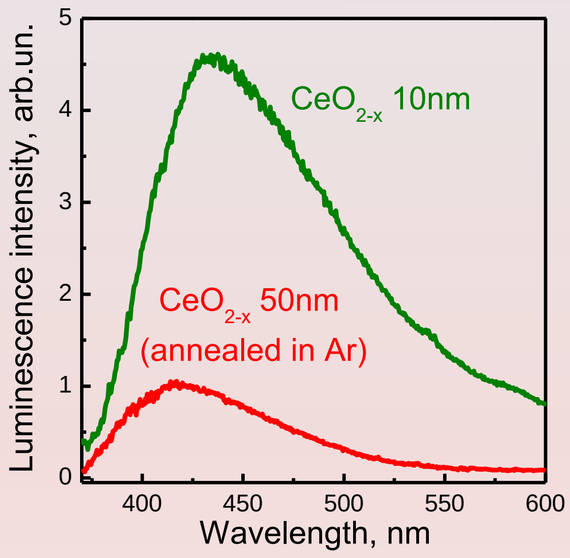


Fig.3. Luminescence spectra of nanoceria of different sizes

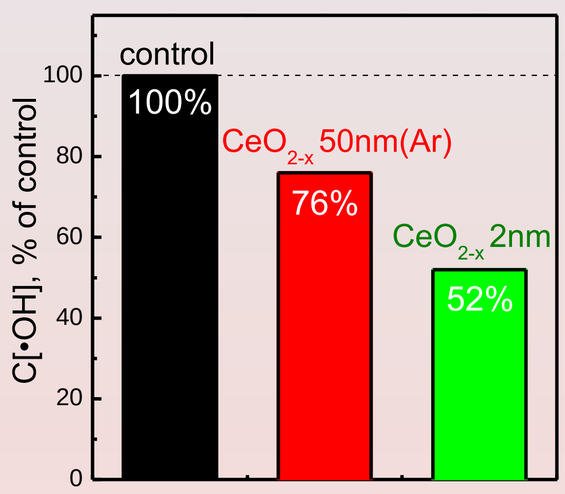


Fig.4. Concentration of OH radicals in nanoceria colloidal solution after X-ray irradiation

Effect of UV pre-irradiation

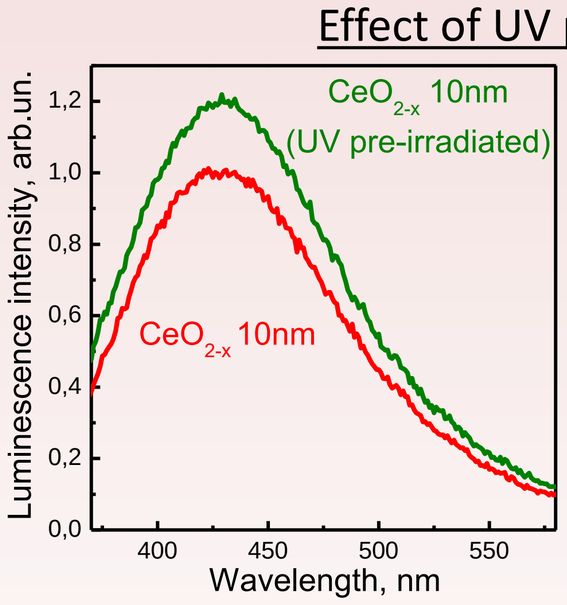


Fig.5. Luminescence spectra of nanoceria before and after UV pre-irradiation

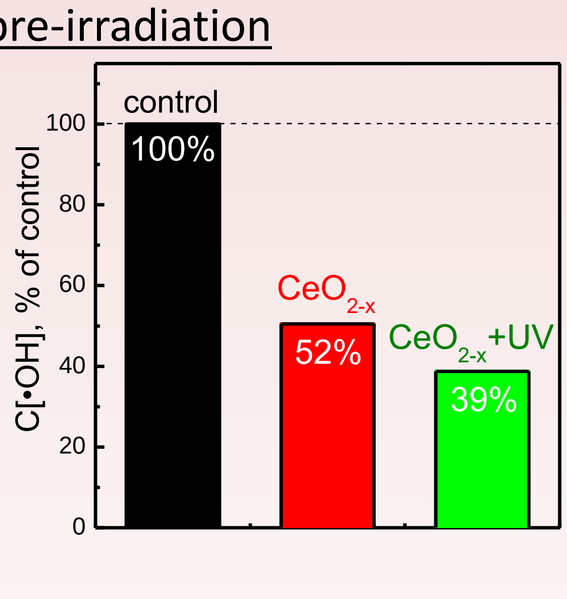


Fig.6. Concentration of OH radicals in nanoceria colloidal solution after X-ray irradiation

Effect of doping

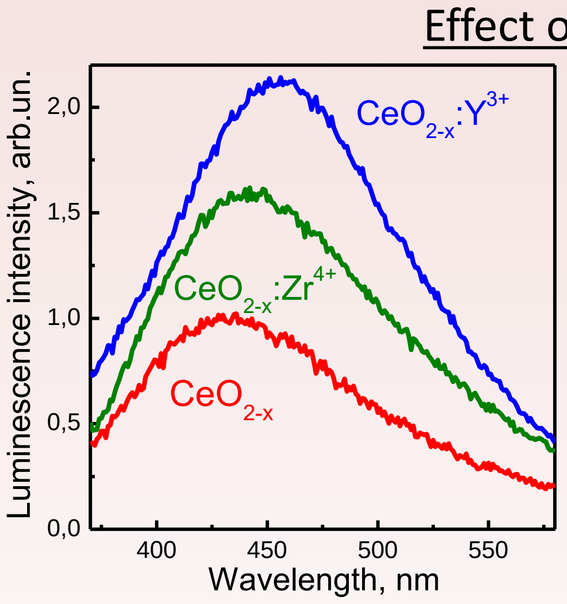


Fig.7. Luminescence spectra of pure and doped nanoceria

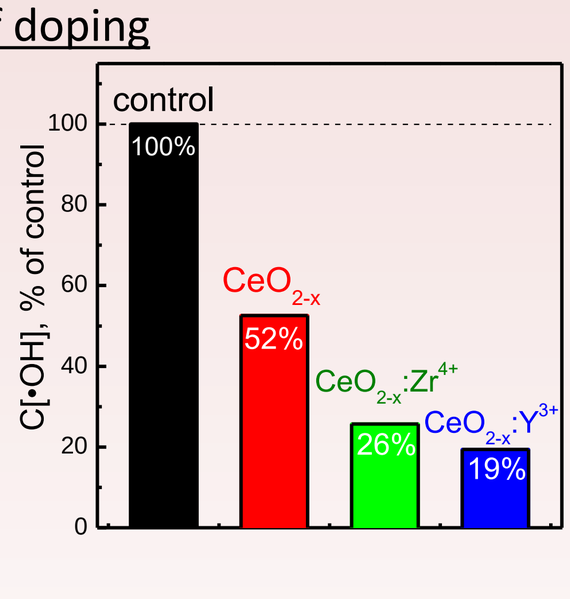


Fig.8. Concentration of OH radicals in nanoceria colloidal solution after X-ray irradiation

Conclusion

The observed effects are caused by formation of additional oxygen vacancies at high temperature annealing, size reduction, doping or pre-irradiation providing increase in the number of sites (Ce^{3+}-V_o-Ce^{3+} or Ce^{3+}-V_o-Re^{3+}) for ·OH scavenging. Remarkable ·OH scavenging properties and reversible redox characteristics make Y^{3+}- and Zr^{4+}-doped and pre-irradiated ceria nanocrystals the potent materials for ·OH scavenging in living cells.