

Transition Metal-doped Ceria Nanozymes: Enhancement of Enzyme-like Activity and Their Applications

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Abstract

The precise detection of excessive heavy metal ions, oxyanion pollutants, and other contaminants in the environment is of great significance for ensuring ecological safety. However, existing detection methods often suffer from limitations such as heavy reliance on instruments, complex operation, and poor anti-interference ability. Due to their tunable catalytic activity and good stability, ceria nanozymes have become important materials for constructing novel sensing platforms. Nevertheless, their selectivity, sensitivity, and anti-interference ability in the detection of complex real samples still need to be improved. To address these issues, the synergistic strategies combining transition metal doping and surface functionalization are employed to precisely regulate the electronic structure and surface properties of ceria nanozymes, thereby constructing nanozyme systems with significantly enhanced enzyme-like activity. Manganese-doped CeO_2 nanoparticles and cobalt/manganese dual-metal co-doped CeO_2 nanoparticles were prepared, leading to a significant improvement in phosphatase-like activity than CeO_2 nanoparticles without doping. The metal-doping-enabled modulation of the surface electronic structure considerably elevated both the oxygen vacancy concentration and the Ce^{4+} fraction, thereby serving as a key function of the substantially enhanced phosphatase-like activity. Utilizing the inhibitory effect of environmental pollutants on the enzyme-like activity of nanoparticles, these systems achieved highly sensitive and specific detection of Al^{3+} , and environmental oxyanion pollutants (PO_4^{3-} , MoO_4^{2-} , WO_4^{2-}), respectively. The proposed nanozyme-based sensing platforms both exhibited outstanding analytical performance, including high detection accuracy, long-term operational stability, and strong anti-interference capability, even when applied to complex environmental matrices such as real water samples and simulated wastewater containing diverse coexisting substances. These favorable features underscore their significant potential for practical applications in real-world environmental monitoring and pollution control.

Keywords

Nanozyme, Enzyme-like Activity, Sensor