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Research Article

Biological Applications of Platinum-Based Nanoclusters

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Abstract

This mini review briefly discusses the recent development of Pt-based nanoclusters towards biological applications. The ultra-small size plays a key role in the unique properties of Pt-based nanoclusters in these applications including biological imaging, enzyme-like property and cancer treatment. Future directions have also been shortly discussed.

Keywords: Platinum; Nanoclusters; Biological imaging; Enzyme; Cancer treatment

Introduction

Nanomaterials are materials which exist on a nanometer scale in at least one dimension. These materials, especially noble metal nanoparticles, exhibit distinct physical and chemical properties compared to their bulk counterparts due to the high surface to volume ratio and the quantum confinement effect, which make them highly compatible in materials science and biological applications. When the sizes are less than 2nm, nanoparticles become nanoclusters, whose electronic structures change from a continuous band into a discrete molecular-like orbital levels. Such unique electronic properties combined with the good biocompatibility and photostability, suggesting promising potentials of these noble metal nanoclusters for biological applications [1]. This mini review will focus on Platinum (Pt) nanoclusters and the corresponding biological applications specifically in biological imaging, enzyme-like properties and cancer treatment.

Discussion

Biological Imaging

Biological imaging provides unique advantages in cancer identification and drug delivery [2]. One of the most critical factors for successful biological imaging is the use of stable, biocompatible and sensitive markers [3]. Traditional markers including organic dyes and fluorescent proteins often experience stability concerns for long-term experiments. Quantum dots markers have disadvantages such as biocompatibility issues for in vivo use. In contrast, Pt nanoclusters illustrate high sensitivity in long-term experiments and biocompatibility, making them highly suitable for biological imaging. For example, it has been reported that Pt nanoclusters attached by polyamine could be used for staining in hematopoietic system [4]. In addition, cell membranes have been imaged by blue mercaptoacetic acid protected Pt nanoclusters, where the antibody receptors were expressed [5].

Enzyme-Like Activities

Except for the excellent photoluminescence properties for bioimaging, protein capped Pt nanoclusters have also illustrated enzyme-like properties, i.e. peroxidase, oxidase and catalase [6]. Peroxidases are type of enzymes that reduce the lipid peroxide or hydrogen peroxide, and high peroxidase activities of Pt-based nanoclusters have been reported by Wei and coworker [7]. Based on the inhibition behavior of the peroxidase enzymatic activities between Pt and Hg, Pt nanoclusters have been proposed and utilized for the detection of toxic metal ions [8]. Oxidases are type of enzymes that promote oxidation by molecular Oxygen (O_2).

Tseng and coworkers have shown that lysozyme ligand protected Pt nanoclusters could catalyze the oxidation reactions of organic substances such as dopamine and the degradation mechanism of organic pollutants by Pt nanoclusters have also been proposed [9]. Catalases are type of enzymes that decompose hydrogen peroxide into O_2 and H_2O. Nie, et al. have reported that the

Platinum-ferritin nanoclusters could catalyze the decomposition of H_2O_2, which further reduce the 5-Diethoxyphosphoryl-5-methyl-1-pyroline-N-oxide (DEPMPO)/OH˙ adduct signal in a H_2O_2/UV DEPMPO spin trap system [10].

Cancer Treatment

Platinum-Based drugs are widely used compounds for treatments of head, neck, cervical and lung cancers [11]. DNA-Pt adducts produced by cisplatin and other analogues are well-known for their anti-tumor activities decades ago. However, these drugs demonstrate little effect on breast, liver, and prostate cancers, as well as similar tumor sensitivity and susceptibility to tumor resistance. To overcome this, demethylcantharidin has been employed to introduce the selectivity of anti-tumor behavior towards liver cancer cells [12]. Additionally, demethylcantharidin-platinum complexes have also shown to be free from cross resistance with cisplatin. Chien et al. have reported a dendrimer-capped Pt nanocluster for targeting breast cancer cells [13]. Xia et al. have demonstrated polypeptide protected Pt nanoclusters could accelerate the release of Pt ions and overcome the cisplatin resistance problems [14].

Conclusion

Due to ultra-small size, Pt nanoclusters have illustrated distinct electronic properties compared to the bulk materials. Combined with the good biocompatibility and photoluminescence, Pt nanoclusters have demonstrated exciting potential for biological applications such as, biological imaging, enzyme-like property and cancer treatment. Future directions include synthesizing Pt nanoclusters with improved florescence character, enhancing enzyme activities and preparation of new ligand groups for targeting tumor cells with lower resistivity.

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