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Selenium nanomaterials: An overview of recent developments in synthesis, properties and potential applications

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ABSTRACT

Advances in science and nanotechnology have facilitated the development of new methods for the preparation of pure selenium as selenium nanomaterials. They offer remarkable potential for technological applications in the fields of medicine, diagnostics, therapeutics, toxicology, electronics, catalysis and so on. Moreover, selenium nanomaterials also find applications in photographic exposure metres, rectifiers, signal emitting devices and transmitting devices, because of their unique structural, optical and electronic properties. This study describes a detailed advanced report on the synthesis, assembly, characterization and various applications of selenium nanomaterials. In addition, relevant synthesis methods, properties, challenges and opportunities associated with selenium nanomaterials are also presented.

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1. Introduction

Selenium (Se), an element of the chalcogenide group, has been extensively used in various industries such as medicinal [1–4], chemical [5], electrical and electronics [6], ceramic [7], metallurgical [8–10], and glass making [11–14]. Used widely for the fabrication of pigments [11], selenium has also been utilized for the compounding of rubber [15], manufacturing of rectifiers [16], and as an alloying element to improve the machinability of copper alloys and stainless steel [17,18]. Electrical resistance changes under light irradiation were first found in selenium in 1873 [19,20]. Se is also considered an important material for laser printing, photovoltaic cells, fuel cells, X-ray instruments and so on [21–24]. Notably, a trace amount of selenium is essential for proper cellular and metabolic functioning in all animals [25], and various studies have revealed the health-endorsing properties of selenium [26,27]. It efficiently advances the restorative competence and selectivity of anticancer drugs [28], and has many useful applications in nutritional complement drugs [29]. Because of its biological importance, selenium is comprehensively used in pharmaceutics [30–39], and is also considered one of the important constituents for regulating spermatogenesis, whose deficiency may have adverse effects on sperm quality [40–42]. In addition, selenium has also been revealed as a crucial component in the fields of agriculture and horticulture [30].

Recent advances in nanotechnology have facilitated the production of pure selenium as selenium nanoparticles [31–35]. The strong electron-contributing tendency of selenium is significantly enhanced in the nanoscale [36,37]. Photostability and decreased photo-assisted deterioration have directed the use of selenium nanoparticles in photocatalysis [38]. Selenium is also used for generating chemically doped, industrially significant materials [41].

This study focuses on the recent advances in the synthesis, assembly, characterization and applications of selenium nanomaterials prepared by various techniques. Furthermore, the roles of various physiochemical characteristics, such as particles shapes and sizes, anisotropy, exterior surface area and functionalization, on the electronic, catalytic and biological properties of Se nanomaterials are extensively reviewed. Finally, various potential applications of Se nanomaterials, such as in diagnostics and therapy, electronic devices, catalysts, chemical sensors and other specific applications, are presented.

2. Historical developments of selenium

The position of Se in the periodic table explains its biological interfaces with sulphur, arsenic and its neighbour phosphorus [43,44]. Scientific investigation on Se was started way back in 1817 at Uppsala University, Sweden, and the first report on its dual character was published by Berzelius in 1818 [45,46]. Afterwards, numerous studies [18,29,47–53] demonstrated the development of selenium research and the discoveries that have shaped the current knowledge in this field. Bock and Stadtman [54] laid the foundation by studying seleno-cysteins, while a narrative description of seleno-proteins was given by Flohe [55,56] in *The Labour Pains of Biochemical Selenology: The History of Selenoproteins Biosynthesis*. Previous studies primarily highlighted the potential uses of Se for human health or examined the toxicities of Se compounds [57,58]. However, in this study, we review the recent information on the synthesis, characterization, properties and various applications of Se nanoparticles. This study provides a complete summary of Se nanoparticles from their growth to applications in various high-technological areas of science and technology.