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Carbon dots as nano-modules for energy conversion and storage

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ABSTRACT

Materials for energy applications, in particular for conversion and storage of energy, have received an upsurge of interest. Materials of this kind require zero-toxicity, abundance, low-cost, robustness in uses, chemical stability, tunability of properties and ease of preparation to ensure their large scale applications. Carbon dots (C-dots) by virtue of their inherent properties appear to be the most promising material in this regard. C-dots comprising discrete, quasispherical particles with sizes below 10 nm have first been discovered in 2004. Since then research experiences numerous attempts to explore the unique properties of C-dots and to exploit them for energy applications. In this review, we report significant advances of this emerging family of carbon materials in three major fields of energy such as conversion of solar energy into electricity, catalytic splitting of water into hydrogen fuel and storage of electrical energy in supercapacitors and provide an in-depth analysis to highlight their prospects in future applications. At a juncture of global energy crisis, attempts have been made to establish a common venue for researchers working on C-dots for different energy applications. Finally, we address critical insights with the aim towards inspiring more exciting work on C-dots as nano-modules for new energy applications.

1. Introduction

Modern civilization relies on the production, storage, and use of energy on a large scale. The ever increasing global demand necessitates production of usable energy and extraction of prodigious energy stores. It is crucial that the efficient storage and distribution would minimize system loss arisen to offset between demand and supply of energy. Smart protocols are badly needed for production and storage of energy through the preferable use of non-toxic, cheap and environmentally-benign materials. The search of suitable energy-related materials and exploration of their prospects have thus been the key challenges to the material scientists, engineers, and technologists.

Eyes have recently been pointed on the use of the family of quasi-0D carbon-based materials, known as carbon dots (C-dots). Owing to their non-toxic nature, abundance and low-cost, C-dots have been recognized as fascinating materials for environmental and energy applications ranging from chemical catalysis, photocatalysis, electrocatalysis to energy storage such as batteries and capacitors. C-dots comprise discrete and quasispherical particles with sizes below 10 nm [1]. Synthesis of C-dots is rather simple; both a top-down approach, for instance, oxidative cutting of larger graphitic carbons and a bottom-up approach like carbonization of molecular precursors can be used. The unique physicochemical properties, which inter alia include: electron donor and acceptor behavior, and optical, and electrical properties have made C-dots intriguing in optronics, catalysis and sensors. Consideration of solubility, robust chemical inertness, facile modification and high resistance to photobleaching makes C-dots superior to other materials of this kind. The rich photoluminescence (PL) and photochemical properties also make C-dots efficient materials such as photocatalysts for selective oxidation, light-driven acid-catalysis and hydrogen bond catalysis [2]. They have also been very active additives commonly used in energy devices, e.g., solar cells [3], photoelectronic water splitting

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