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REVIEW

Review on Carbon Dots and Their Applications

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Abstract: Carbon dots (Cdots) have become a potential material for biosensing, drug delivery and bioimaging because of their excellent optical properties, high biocompatibility and low toxicity. Thus the preparation, properties and applications of Cdots have drawn great attention. In this review, Cdots were classified into two groups: grapheme nanodots and carbon nanodots, based on the difference in precursors and preparation methods. The synthetic methods of Cdots were summarized and their luminescence mechanism was analyzed. The applications of Cdots in biosensing, drug delivery and bioimaging were also discussed. The issues and challenges of Cdots were analyzed for their further development.

Key Words: Carbon dots; Synthesis method; Luminescence mechanism; Biosensing; Bioimaging; Review

1 Introduction

Carbon dots (denoted as Cdots) are a new member of fluorescent carbon material with the diameter below 10 nm. Cdots are becoming a promising alternative to metal-based quantum dots because of their composition and biocompatibility[1]. Cdots were explored as biosensors[2], gene transmission[3], drug carriers[4–8], and bioimaging probes[9,10] due to their excellent fluorescence properties, good biocompatibility and low toxicity. The favorable fluorescence properties of Cdots exhibited a great potential for the applications in analytical chemistry, especially in environmental and biological sensing and imaging[2,10–16].

Xu *et al*[17] found fluorescent fraction that was proved to be carbon nanomaterial by the characterization of atomic force microscopy (AFM) during the purification of carbon nanotubes. This fraction was drawn much attention since then. The important events of Cdots development are illustrated in Fig.1. Sun *et al*[18] obtained Cdots with high quantum yield via chemical-passivation method, which provided an effective route to enhance the fluorescence of Cdots by polyethylene glycol (PEG) passivation. Liu *et al*[19] obtained different color fluorescent Cdots by gel separation, providing detailed information for the fluorescence mechanism of Cdots. Zheng *et al*[20] used an electrochemical approach to prepare Cdots, and found these Cdots had excellent electrochemiluminescence (ECL) properties. These researches divided carbon materials into Cdots by using physical or chemical methods, and therefore denoted as "top-down" method. With the development of microwave and hydrothermal technologies, various "bottom-up" methods were explored to prepare Cdots from small molecules, biomolecules, and biomass. For example, organic molecules on the surface of SiO_2 were carbonized to prepare Cdots[21]. Microwave method was convenient for prepare Cdots within 10 min[22]. Zhu *et al*[23] prepared Cdots in hydrothermal method and studied their formation mechanism, sensing, and multi-color imaging.

In this review, Cdots were divided into graphene nanodots and carbon nanodots according to the preparation methods and carbon sources; the synthesis, luminous mechanism, sensing, and imaging applications of Cdots were extensively reviewed.

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2 Synthetic methods

The synthetic methods for Cdots are generally classified into two main groups: "top-down" methods with graphite materials as carbon sources, and "bottom-up" methods with organic molecules as carbon sources (Fig.2). Therefore, Cdots can be also denoted as graphene nanodots and carbon nanodots, respectively.

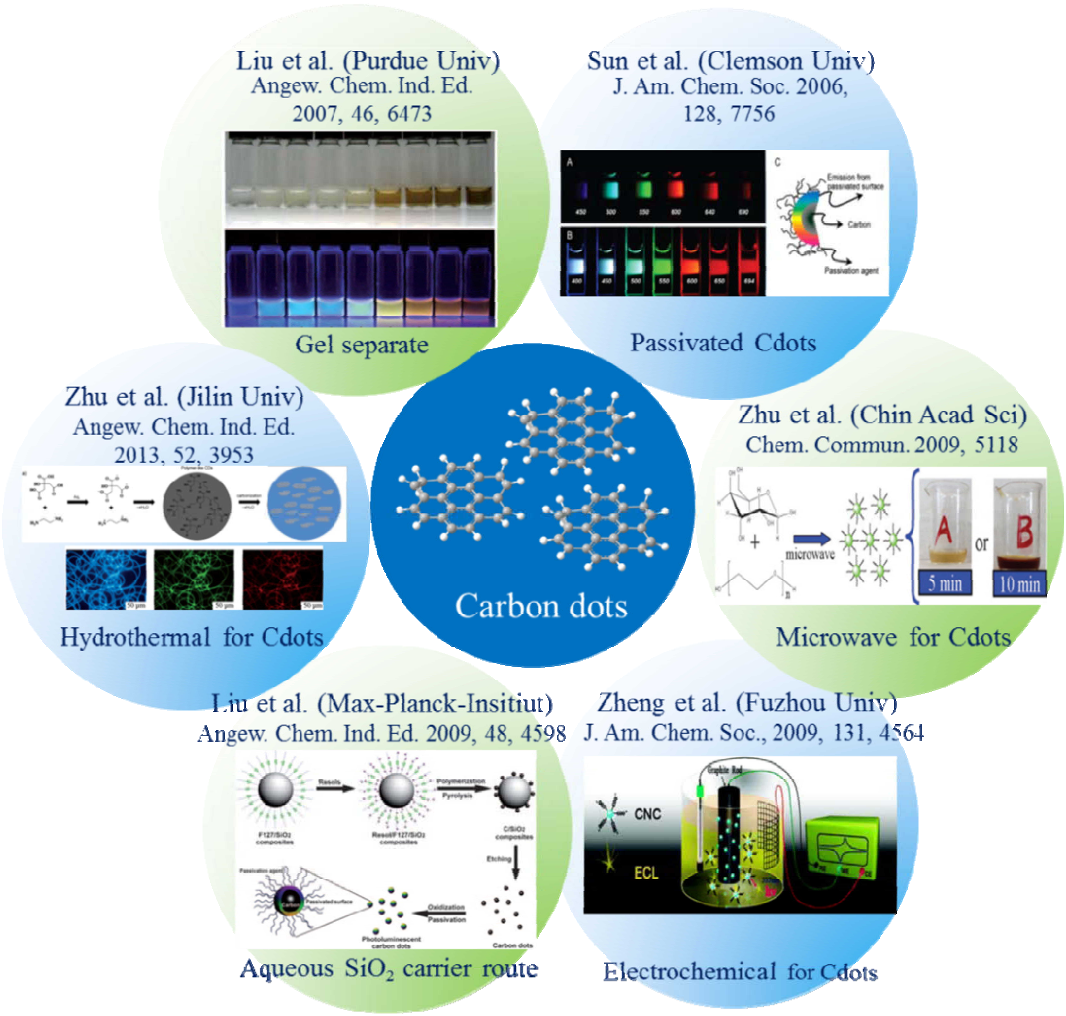

Fig.1 Schematic illustrations of synthesis of various Cdots[18–23]

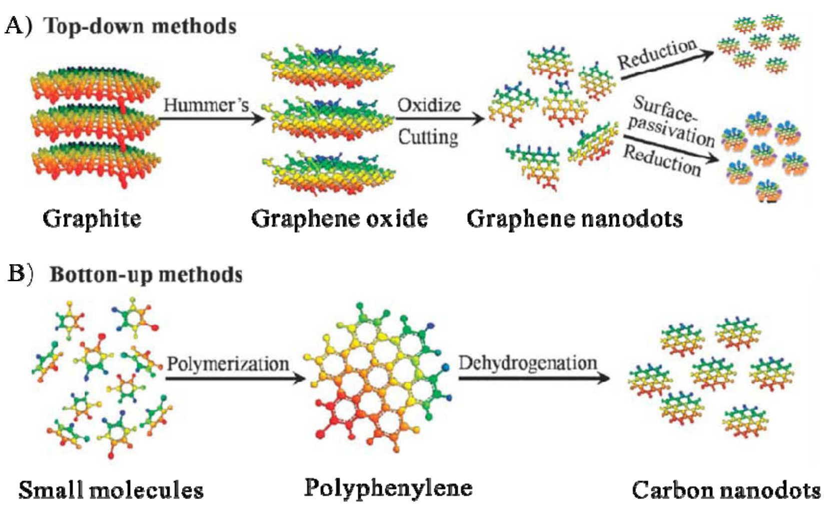

Fig.2 Synthesis of graphene nanodots/carbon nanodots with (A) top-down method and (B) bottom-up method[24]