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A Review on various synthesis routes of Carbon Dots

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Abstract : Carbon dots (CDs), discovered in 2004, have gained significant attention in the field of carbon nanomaterials. Researchers have explored various synthesis methods, focusing on simplicity, cost-effectiveness, and scalability. The photoluminescence mechanisms of CDs have been extensively studied, revealing key factors such as molecular state, surface state, and carbon core state. Due to their excellent optical properties, biocompatibility, catalytic activity, and small size, CDs have been widely applied in fields like catalysis, biomedicine, optoelectronics, and sensing. This overview highlights the development of CD synthesis strategies, discusses potential and challenges, and aims to inspire researchers to address technical hurdles and fully harness the potential of CDs.

IndexTerms **– Carbon dots, Hydrothermal, Microwave, Fluorescence**

I. INTRODUCTION

Traditional quantum dots (QDs) that contain heavy metals like cadmium and lead exhibit excellent optical properties and have vast potential for various applications. However, their toxicity and environmental hazards significantly limit their use, particularly in biological applications [1-3]. Therefore, developing eco-friendly QDs is crucial. Fortunately, carbon dots (CDs), a novel class of zero-dimensional fluorescent carbon nanomaterials, were discovered by Xu et al. in 2004 during the purification of single-walled carbon nanotubes [4]. Unlike semiconductor QDs, CDs possess lower toxicity, higher biocompatibility, and superior photostability, making them a promising and safer alternative. CDs are carbon nanoparticles with diameters below 10 nm that exhibit fluorescent properties [5-6]. A single CD structure typically consists of a carbon core and heteroatoms like nitrogen, sulfur, and oxygen, as well as functional groups such as –OH, –COOH, and $–NH_2$ [7]. Due to their complex structure and numerous variants, CDs with diverse morphologies have been referred to by different names. Yang's group categorized CDs into three types based on their carbon core and surface chemical states: carbon nanodots (CNDs), graphene quantum dots (GQDs), and polymer dots (PDs) [6]. Anisotropic graphene quantum dots (GQDs) exhibit quantum confinement and consist of single or multiple graphene layers with crystalline structures and lateral dimensions. In contrast, carbon nanodots (CNDs) have a spherical morphology with heights roughly equal to their lateral dimensions. CNDs can be further categorized into amorphous carbon nanoparticles (CNPs) and cross-linked CNDs with polymer dots (PDs), which are formed through the polymerization of small molecule or polymer precursors and do not exhibit quantum confinement effects. The diversity of carbon dots (CDs) largely stems from differences in carbon sources and synthetic techniques.

Various carbon nanomaterials, such as carbon nanotubes (CNTs), carbon nano-onions (CNOs), nanodiamonds, graphene, fullerenes, and their derivatives, have several advantages. These include (1) favorable optical properties, where CDs exhibit controllable photoluminescence (PL) emission, high resistance to photobleaching, and photoluminescence quantum yields (PLQYs) near 100% [8], unlike pure CNOs, nanodiamonds, CNTs, graphene, and fullerenes, which rarely show visible PL due to their zero optical bandgap. (2) Simple and cost-effective synthesis: although various preparation methods have been developed for these carbon nanomaterials, they often have drawbacks such as high costs, poor yields, and complex processes. In contrast, CDs can be synthesized using a wide range of precursors, including glucose, graphene oxide (GO), citric acid, CNTs, and even household garbage [9-19], through various techniques like hydrothermal synthesis, chemical oxidation, microwave treatment, and pyrolysis. This makes obtaining CDs at a low cost relatively easier. (3) Excellent stability and solubility: unlike other carbon nanomaterials, which have poor solubility and stability due to limited surface groups and chemical inertness, CDs exhibit good long-term solubility and stability in aqueous solvents due to their abundant surface groups. Moreover, the polarity of CDs can be easily modified by choosing suitable precursors, allowing them to be dispersed in a variety of solvents. CDs also show promising catalytic activity due to their unique electronic structures and energies. As a result, CDs are attracting increasing attention, with many efforts being made to achieve simple, economical, and large-scale preparation. Recently, Chen's team developed a magnetic hyperthermia method to rapidly and easily produce multicolor luminescent CDs on a large scale [23]. Although the synthesis of CDs has advanced significantly, the specific mechanism of their PL is still under discussion, with current perspectives focusing on the carbon core state, surface state, molecule state, and their synergistic effect. The benefits of CDs include favorable optical properties, attractive catalytic performance, chemical inertness, small size, ecological friendliness, and ease of synthesis [20-31]. Several notable reviews have recently been published on the photoluminescence (PL) mechanisms, synthetic methods, and potential applications of carbon dots (CDs). For example, Tan's group [32] and Lu's group [17] have provided updates on the development of CDs in light-emitting diodes (LEDs) and nanomedicine up to 2020. In another review, Lu's group discussed the

PL mechanisms of CDs, including crosslink-enhanced emission, internal factor-dominated emission, and external factor-dominated emission. Additionally, Yang's group [33] and Ding's group [34] have outlined advancements in chiral CDs and solid-state CDs, respectively, up to 2020. However, the field of CDs is rapidly evolving, and there is a lack of a comprehensive study that systematically presents synthesis procedures, PL mechanisms, and potential applications of CDs. It is well-known that the synthesis methods, PL mechanisms, and potential applications of CDs are interconnected and support each other. For instance, the ability to prepare multicolor emitting CDs at controlled temperatures promotes their application in bioimaging and optoelectronic devices. Furthermore, the creation of CDs with well-defined structures using suitable precursors and reaction conditions facilitates the understanding of their PL mechanism. Meanwhile, the discovery of the PL mechanism will guide the synthesis of CDs with controlled PL, which is crucial for biomedicine applications that require CDs with stable PL, good photoluminescence quantum yields (PLQYs), and low toxicity.

A deeper understanding of the origin of PL in CDs will also facilitate the development of applications that rely on PL changes, such as sensing and bioimaging. Therefore, a comprehensive examination is necessary to carefully explain the synthetic processes, the source of fluorescence, and the prospective uses of CDs. This study aims to thoroughly document the development of common preparation procedures, the most widely recognized theories for PL mechanisms, and potential CD applications. The various methods used to create CDs, including electrochemical, pyrolysis reaction, chemical oxidation, microwave treatment, laser ablation, hydrothermal synthesis, and other methods, are described in detail.

2.0 Synthesis Methods

The synthesis methods for carbon dots (CDs) can be categorized into two main approaches: bottom-up and top-down routes, which are concisely illustrated in Figure 1.

Carbon Dots(CDs)	Source	Method	Cytotoxicity/ Detection Limit Range	Reference
CDs	Gelatin	Hydrothermal Mthod	1−75 µmol L^{-1}	98
CDs	carbohydrate	Hydrothermal Method	0 to 1×10^{3}	99
CDs	DEA	Microwave Method	5.0×10^{-2} to 8.0	100
CDs	catechol	Hydrothermal Method	1×10^{-2} to 25	101
CDs	citric acid	Hydrothermal Method	8.0×10^{-2} to 50	102
CDs	citric acid and urea	Hydrothermal method	23 mM	164
CDs	Free Gum Tragacanth and Chitosan	Hydrothermal method	50µg/mL	165
N-CDs	Citric acid and ethylenediamine	Microwave-assisted solvothermal method	0.089 µmol/L	168
N-CDs	Citric acid and ethanediamine	Hydrothermal method	0.076 nM	169

2.1 Chemical Oxidation Method

The chemical oxidation method involves oxidizing reactants to produce carbon dots (CDs) using strong acidic solutions like concentrated HNO_3 and H_2SO_4 or oxidants like H_2O_2 and $FeCl_3$. This approach typically introduces numerous oxygen-containing functional groups, making CDs more water-soluble and suitable for bioimaging applications. Xu et al. first reported the synthesis of CDs using arc-discharge soot and strong HNO_3 in 2004, resulting in CDs with low photoluminescence quantum yields (PLQYs) of up to 1.6% [4]. Although the PLQY was low, this pioneering work opened up a new area of research in carbon nanomaterials. Later, Mao, Ray, and colleagues used candle soot as a carbon source to synthesize CDs with a PLQY of 3% and

good water-solubility [39, 40]. Sun's group developed a two-step approach to create CDs with high PLQYs of up to 60% using PEG1500N as a functionalizing agent [41]. This method involved refluxing carbon soot with HNO3 to create precursor carbon nanoparticles, followed by reaction with PEG1500N to produce PEG-passivated CDs.

Other researchers have also used chemical oxidation to synthesize CDs with high PLQYs by combining surface passivation and chemical oxidation [42, 43]. However, this method often requires strong acids, which can be environmentally hazardous. To address this issue, some researchers have used H_2O_2 as an oxidant to synthesize CDs with reduced environmental risks [49-51]. Additionally, using small molecules as precursors has been shown to alleviate some of the limitations of chemical oxidation, such as low yields and PLQYs [52, 53].

The chemical oxidation approach is one of the earliest methods for synthesizing CDs and allows for the rapid creation of multicolor-emitting CDs from various carbon sources. However, the procedure often requires time-consuming post-treatments and surface passivation to achieve high PLQYs. Furthermore, the use of acid oxidizing agents poses environmental concerns and falls short of the desire for green preparation. While using non-acid oxidizing agents and small precursor molecules can reduce environmental risks and produce CDs with good PLQYs, it remains challenging to produce CDs with specific groups and intended emissions. As a result, chemical oxidation has limitations in its broad applicability.

2.2 Laser Ablation Process

The laser-ablation method typically involves using a high-energy laser beam to attack a carbon target, resulting in the exfoliation of carbon nanoparticles that are then functionalized to create carbon dots (CDs). Notably, this method can directly produce CDs without further passivation by carefully selecting the carbon target or medium. Sun's group was the first to report the use of a Nd:YAG laser with a wavelength of 1064 nm and a carbon target composed of cement and graphite powder to produce CDs with a PLQY of 10% in 2006 [54]. This work demonstrated the feasibility of CDs for bioimaging but had limitations, such as the need for high temperatures and low pressures, as well as organic species for passivation.

Du's team later improved the experimental settings to create CDs through a single-step laser-ablation process, streamlining the operations and eliminating the need for challenging preparation phases [55]. They dispersed graphite powders in PEG200N and exposed them to a Nd:YAG laser for 2 hours, resulting in CDs with a size of 3.2 nm and a PLQY of 5%. The formation of CDs was attributed to the creation of a high-pressure and high-temperature environment in the PEG200N solvent, leading to the condensation of carbon plasma and subsequent surface oxidation and reaction with PEG200N.

Despite these advances, the issues of low yields, low PLQYs, and non-tunable morphology and PL of CDs persisted. Yang's team later demonstrated the ability to control the size and PL of CDs by adjusting the laser pulse width, creating CDs with average diameters of 3, 8, and 13 nm [56]. Li and colleagues also showed that the input of laser fluence could adjust the sizes and PL emissions of CDs, using toluene as a carbon precursor and eliminating the need for passivators like PEG [57]. They revealed the formation process of CDs through real-time detection of PL changes, showing that large pieces of graphene were formed as an intermediate before being laser-ablated to produce CDs.

Kang's group further demonstrated that the surface flaws of graphene quantum dots (GQDs) could be functionalized with shorter laser wavelengths, and that multiple GQD surface states could be created by adjusting the laser wavelength [58]. This discovery provided a new idea for modifying the shape and PL of CDs.

2.3 Electrochemical Method

Good conductivity carbon materials are typically used as working electrodes and carbon sources in electrochemical synthesis. When a certain voltage is applied, an oxidation reaction occurs at the anode, leading to the separation of carbon dots (CDs) from carbon precursors. Additionally, the electrolyte can serve as a carbon source, enabling bottom-up electrochemical synthesis of CDs [59]. Sham and colleagues first used the electrochemical method in 2007 to directly produce blue-light-emitting CDs with a PLQY of 6.4% [60]. They used a three-electrode system with multi-walled carbon nanotubes (MWCNTs) as the carbon source and acetonitrile solution containing tetrabutylammonium perchlorate (TBAP) as the electrolyte.

The production of CDs was attributed to the intercalation of TBA cations into the gap of MWCNTs, followed by their exfoliation into the electrolyte solution [60]. Although this research introduced a novel strategy for the direct synthesis of water-soluble CDs, the yields, PLQYs, and fluorescence tunability of CDs needed to be improved. Later, CDs with an average diameter of 2.0 nm were prepared using a graphite rod as the working electrode and phosphate buffer solution as the electrolyte [61].

In another instance, a two-electrode system was used to fabricate CDs, reducing the cost of production by using petroleum coke as the carbon source [62]. Ionic liquids (ILs) were also employed as the electrolyte to complete the electrochemical synthesis of CDs, and graphene sheet and screen-printed carbon electrodes were used as electrodes [63]. The production of hydroxyl and oxygen radicals by anodic oxidation of water was thought to be responsible for the hydroxylation or oxidation of graphite and subsequent release of CDs from the anode.

The produced CDs had high crystallinity, superior water solubility, and limited size distribution, making them suitable for cell imaging and photovoltaics [63]. However, the issues of poor yields, low PLQYs, and monotonous CD fluorescence persisted. Li et al. later demonstrated that changing the electrolytes could affect the morphology and fluorescence performance of graphene quantum dots (GQDs) [64]. Pang and colleagues showed a controlled electrochemical approach for the size-selective synthesis of monodisperse luminous CDs [65], although it was unable to significantly alter the PL emissions of CDs.

Kang's team demonstrated the ability to adjust the current intensity in an alkali-assisted electrochemical system to produce CDs with size-dependent PL that changed from blue to brown as diameters increased from 1.2 to 3.8 nm [66]. They also created CDs with various PL emissions and sizes by varying the parallel spacing of graphite rods [67]. However, the yields of CDs were low in both cases.

Liu and colleagues presented a simple bottom-up production approach of CDs by electrochemical carbonization of ILs-containing nitriles as both electrolyte and carbon sources [59]. The creation mechanism of CDs was hypothesised based on structural properties, and the produced CDs had exceptional water solubility and a PLQY of more than 10%, making them suitable for cell imaging and ion detection.

The electrochemical method can produce water-soluble CDs with uniform size and high crystallinity, making them suitable for catalysis and photovoltaics [66, 67]. However, this technology has clear drawbacks, such as poor yields, low PLQYs of CDs, and a time-consuming process, making it challenging to produce CDs on a wide scale for a low cost.

2.4 Hydrothermal Route

The hydrothermal/solvothermal method involves adding reactants containing small molecules or bulk materials to water or other solvents, which are then sealed in a container and subjected to high temperatures and pressures to undergo polymerization, carbonization, or cutting to form carbon dots (CDs). Wu's group first reported a hydrothermal method for producing graphene quantum dots (GQDs) with a PLQY of 5% by slicing oxidized graphene sheets [68]. Although this method was simple, it had limitations, such as low PLQYs, non-uniform GQD sizes, and the need for pretreatment of source materials.

Hiroyuki et al. later used the solvothermal method to synthesize amino-functionalized GQDs with a PLQY of up to 29% and a narrow size distribution, demonstrating the ability to tailor PL colors of GQDs by adjusting the reaction temperature [69]. However, this study used expensive oxidized graphene sheets as the carbon source. To address this issue, researchers have used sustainable and renewable leaves as carbon sources to create CDs, significantly reducing costs [22, 70]. For example, poplar leaves were used to create CDs with a PLQY of 10.64% and a high throughput of 1.4975 kg, providing an environmentally friendly method for mass-producing CDs [70].

The hydrothermal/solvothermal method has been used to create CDs with various properties, such as high photostability and minimal cytotoxicity, making them suitable for electrocatalytic water splitting, sensing, and bioimaging [70]. Additionally, waste expanded polystyrene has been transformed into high-value CDs using a one-step solvothermal process [71]. However, the top-down hydrothermal/solvothermal approach often requires difficult post-processing to eliminate unreacted byproducts, increasing preparation time and expense.

Dai's team developed a productive hydrothermal approach to synthesize GQDs using starch as a precursor, eliminating the need for time-consuming post-treatment [72]. Small molecules as precursors have been shown to be more adaptable in altering the optical and structural characteristics of CDs during hydrothermal/solvothermal processes than bulk materials [74]. Yang's team demonstrated that tailoring CDs with heteroatoms could effectively alter their physicochemical properties, especially enhance PLQYs, by hydrothermally preparing blue-emitting CDs with a PLQY of ca. 80% using citric acid and ethylenediamine (EDA) as the respective carbon and nitrogen sources [76].

Various nitrogen sources have been used to create N-doped CDs, including anilines and their derivatives [28, 77-82], urea [83], EDA [84, 85], and even organic pollutants [73]. The creation mechanism of N-doped CDs generated from reactive red 2 involved

the breakdown of the precursor into tiny carbon particles, followed by polymerization, expansion, and oxidation to produce N-doped CDs [73]. The hydrothermal method has been shown to be widely applicable, with CDs being used in bioimaging, WLEDs, and other applications [81].

2.5 Pyrolysis Method

The pyrolysis method typically involves carbonizing carbon sources at high temperatures, followed by post-treatment and purification processes such as filtration, centrifugation, dialysis, and chromatographic separation to collect carbon dots (CDs). However, the separating process can be stopped by encapsulating CDs with a suitable template to restrain their development and shape during pyrolysis [97]. The pyrolysis method can be divided into liquid-phase and solid-phase pyrolysis depending on the state of the carbon source.

Liu's group developed a pyrolysis technique to create oil-soluble CDs with a high PLQY of 53% by carbonizing citric acid anhydrous in a hot mixture of octadecene and 1-hexadecylamine [98]. This study demonstrated that the optical properties of CDs can be changed by altering the pyrolysis parameters, such as agents, solvents, or pyrolysis duration. Wu's group later developed a one-step solid-phase pyrolysis method to create blue luminous CDs with a PLQY of 31.6%-40.6% by calcining the disodium salt of ethylenediaminetetraacetic acid at 400°C for two hours without any solvent or agent [99].

The CDs produced by pyrolysis have simple manipulation and desirable PLQYs, but their application potential in catalysis is limited by their non-uniform size and propensity to aggregate [101]. To address this issue, researchers have used templating methods to control the shape and size of CDs during pyrolysis [101-103]. Additionally, N-doped CDs with high PLQYs have been created by sensibly choosing surface passivation agents or precursors [104-107]. For example, N-doped GQDs with a high PLQY of 59.2% were generated by one-step pyrolysis using tris(hydroxymethyl)aminomethane as a surface passivation agent and a dopant, as well as citric acid as a carbon source [108].

The pyrolysis method has several advantages, including easy operation, inexpensive carbon sources, and large-scale preparation. However, the approach is labor-intensive, consumes a lot of energy, and is unable to avoid the tiresome post-treatment and purification required to produce high-quality CDs of a consistent size. The preparation of long-wavelength CDs by pyrolysis is particularly challenging, severely restricting the use of CDs in optoelectronics and biomedicine.

2.6 Microwave method

The microwave treatment method allows for the quick production of carbon dots (CDs) in just a few minutes. During the treatment, reactants with polar molecules absorb microwave energy and transform it internally, resulting in rapid heating of the reactants. This method differs from the hydrothermal/solvothermal method, where the internal energy is produced from within the materials. Yang's group first reported the use of microwave treatment to prepare CDs in 2009 by mixing PEG200N and glucose [Yang's group reference].

The microwave method has been used to create CDs with various properties, including high PLQYs and multicolor emission. Doping with nitrogen has been shown to significantly raise PLQYs and alter PL hues. For example, N-doped CDs with a high PLQY of 15% were created by microwave irradiating citric acid and urea [119]. The PLQY of N-doped CDs could be increased to 40.2% when EDA was used instead of urea as the nitrogen source [119]. Additionally, magneto-fluorescent CDs doped with iron and nitrogen were synthesized by microwave treatment of citric acid and EDA in the presence of $FeCl_2$ [121].

The microwave method has also been used to create multicolor PL CDs. Liu et al. created CDs using microwave irradiation and poly(ethyleneimine) solution with glutaraldehyde (GA) added to it, resulting in multicolor luminous CDs with an adjustable wavelength ranging from 464 to 556 nm [122]. The microwave approach has also been shown to contribute to preventing direct pep contacts or excessive resonance energy transfer in order to produce self-quenching-resistant solid-state PL CDs [119, 123-125].

Large-sized raw materials can also be used to create CDs using the microwave method. For example, GO as the carbon source was used to create greenish-yellow luminous GQDs with a PLQY of 11.7% using the microwave technique in an acid environment [126]. However, this study needed a 3-hour reaction time and employed strong acids as the solvent, restricting its widespread use. Wang's group later used microwave technology to manufacture B-doped GQDs with a PLQY of 21.1% while avoiding the need of strong acids and cutting the reaction time to 30 min [127].

The microwave method has several advantages, including quick and uniform heating, reduced reaction time, and increased product yields. This method is more practical, cost-effective, and time-saving than previous approaches, showing great promise for widespread industrialization. However, microwave-derived CDs often have wilder size distributions and lower PLQYs compared to hydrothermal/solvothermal CDs, which can affect their performance in fields like biomedicine and optoelectronics.

2.7 Other Chemical Processes

In addition to the methods mentioned above, extensive research has been conducted to examine additional chemical techniques for the quick and effective manufacture of carbon dots (CDs). Chen's group used a plasma-induced technique to significantly reduce reaction time by employing inexpensive, natural chicken eggs as the precursor [129]. Yan et al. developed a solvent-free gaseous detonation technique to transform benzoic acid into powdered blue-emitting graphene quantum dots (GQDs) within milliseconds [130].

The ultrasonic method is unique in that it benefits from low-tech requirements, cheap equipment, and easy manipulation. A simple ultrasonic approach to create CDs was given by Lee [131], Meral [132], Liu [133], Yan [134], Leblanc [7, 135], et al. They used a variety of carbon sources, including citric acid, blueberries, graphene, and even food waste. Orange-emission N-doped CDs were made by ultrasound method [135] employing deionized water as the solvent, citric acid and o-phenylenediamine (oPD) as carbon and nitrogen sources.

Other straightforward methods for making CDs have been created, including the photo-Fenton reaction and the sono-Fenton reaction [136, 137]. Liu's team showed how to produce graphite-based GQDs with a size of 8 nm using a magnetron sputtering technique [138]. Additionally, a number of environmentally friendly and sustainable synthesis methods, such as the Schiff base reaction [21], self-exothermic synthesis [20, 24], co-polymerization reaction [138], base catalysis, and reduction methods [16], have attracted a lot of interest due to their advantages, including energy conservation, ease of use, and lack of specialized equipment.

Chen's group introduced a new rapid magnetic hyperthermia strategy to produce multi-fluorescence CDs using carbamide and citrate with three different cations as precursors [23]. This method fully exploited the magneto caloric effect to quickly and easily synthesize CDs with a yield of 60% and a production rate up to 85 g per hour.

In conclusion, a lot of work has been put into thoroughly researching the creation of CDs, and a lot of progress has been accomplished. Numerous methods, including chemical oxidation, laser-ablation, electrochemistry, hydrothermal/solvothermal synthesis, pyrolysis reaction, and microwave treatment, have been used to create CDs. The hydrothermal/solvothermal approach is regarded as the best preparation technique for efficiently fabricating CDs. Other chemical techniques, such as gaseous detonation [130], magnetic hyperthermia [23], self-exothermic reaction [24], and the aldol condensation method [27], have also been developed and paved the way for industrial preparation.

The vast majority of carbon-containing substances have manifested as precursors [5, 6, 9-18], laying the groundwork for inexpensive CD preparation. However, there are still unavoidable drawbacks, including ill-defined optical qualities and CD sizes, undesirable purity, and intermittent manufacture, that must be overcome to improve the application potential of CDs. Therefore, it is imperative to improve the current processes and continue to research new avenues for the quick, effective, environmentally friendly, scaled-up, and manageable production of CDs. Improved knowledge of the photoluminescence (PL) genesis of CDs is anticipated to fundamentally direct and improve their synthesis methods.

References

[1] Michalet X, Pinaud FF, BentolilaLA, TsayJM, Doose S, Quantum dots for live cells, in vivo imaging, and diagnostics, Science2005, 307 (5709), 538-544.

[2] Kirchner C, Liedl T, Kudera S, Pellegrino T, Javier AM, Gaub HE, Stolzle S, Fertig N, Parak WJ, Cytotoxicity of colloidal cdse and cdse/zns nanoparticles, Nano Lett.2005, 5 (2) 331-338.

[3] Derfus AM, Chan WCW, Bhatia SN, Probing the cytotoxicity of semiconductor quantum dots, Nano Lett. 2004, 4 (1), 11-18.

[4] Xu X, Ray R, Gu Y, Ploehn HJ, Gearheart L, Raker K, ScrivensWA, Electrophoretic analysis and purification of fluorescent single-walled carbon nanotube fragments, J. Am. Chem. Soc. 2004,.126 (40), 12736-12737.

[5] Baker SN, Baker GA, Luminescent carbon nanodots: emergent nanolights, Angew. Chem. Int. Ed. 2010, 49 (38), 6726-6744.

[6] Zhu S, Song Y, Zhao X, Shao J, Zhang J, Yang B, The photoluminescence mechanism in carbon dots (graphene quantum dots, carbon nanodots, and polymer dots): current state and future perspective, Nano Res. 2015, 8 (2), 355-381.

[7] MintzKJ, Bartoli M, Rovere M, Zhou Y, Hettiarachchi SD, Paudyal S, Chen J, Domena JB, Liyanage PY, Sampson R, Khadka D, Pandey RR, Huang S, Chusuei CC, Tagliaferro A, Leblanc RM, A deep investigation into the structure of carbon dots, Carbon2021, 173 433-447.

[8] Chen X, Zhang X, Xia LY, Wang HY, Chen Z, Wu FG, One-step synthesis of ultrasmall and ultrabrightorganosilicananodots with 100% photoluminescence quantum yield: long-term lysosome imaging in living, fixed, and permeabilized cells, Nano Lett.2018, 18 (2) 1159-1167.

[9] Hai X, Feng J, Chen X, Wang J, Tuning the optical properties of graphene quantum dots for biosensing and bioimaging, J. Mater. Chem. B 2018, 6 (20), 3219-3234.

[10] Yan Y, Gong J, Chen J, Zeng Z, Huang W, Pu K, Liu J, Chen P, Recent advances on graphene quantum dots: from chemistry and physics to applications, Adv. Mater. 2019, 31 (21),180-186.

[11] Kang Z, Lee ST, Carbon dots: advances in nanocarbon applications, Nanoscale 2019, 11 (41), 19214-19224.

[12] Fernando KA, Sahu S, Liu Y, Lewis WK , Guliants EA, Jafariyan A, Wang P, Bunker CE, Sun YP, Carbon quantum dots and applications in photocatalytic energy conversion, ACS Appl. Mater. Interfaces 2015, 7 (16), 8363-8376.

[13] He C,Shuang E, Yan H, Li X, Structural engineering design of carbon dots for lubrication, Chin. Chem. Lett. (2021), https://doi.org/10.1016/ j.cclet.2021.03.026.

[14] Hu C, Li M, Qiu J, Sun YP, Design and fabrication of carbon dots for energy conversion and storage, Chem. Soc. Rev. 2019, 48 (8) , 2315-2337.

[15] Li Y, Xu X, Wu Y, Zhuang J, Zhang X, Zhang H, Lei B, Hu C, Liu Y, A review on the effects of carbon dots in plant systems, Mater. Chem. Front.2020, 4 (2), 437-448.

[16] Liu ML, Chen BB, Li CM, HuangCZ, Carbon dots: synthesis, formation mechanism, fluorescence origin and sensing applications, Green Chem. 2019, 21 (3) , 449-471.

[17] Wang B, Song H, Qu X, Chang J, Yang B, Lu S, Carbon dots as a new class of nanomedicines: opportunities and challenges, Coord. Chem. Rev.2021, 442 , 214010.

[18] Yao B, Huang H, Liu Y, Kang Z, Carbon dots: a small conundrum, Trends Chem 2019 1 (2) 235-246.

[19] Wu Y, Cao M, ZhaoQ, Wu X, Guo F, Tang L, Tan X, Wu W, Shi Y, Dai C, Novel high-hydrophilic carbon dots from petroleum coke for boosting injection pressure reduction and enhancing oil recovery, Carbon 2021, 184 ,186-194.

[20] Chen BB, Liu ZX, Deng WC, Zhan L, Liu ML, Huang CZ, A large-scale synthesis of photoluminescent carbon quantum dots: a self-exothermic reaction driving the formation of the nanocrystalline core at room temperature, Green Chem. 2016, 18 (19) 5127-5132.

[21] Liu ML, Yang L, Li RS, Chen BB, Liu H, Huang CZ, Large-scale simultaneous synthesis of highly photoluminescent green amorphous carbon nanodots and yellow crystalline graphene quantum dots at room temperature, Green Chem.2017, 19 (15) 3611-3617.

[22] Li W, Liu Y, Wang B, Song H, Liu Z, Lu S, Yang B, Kilogram-scale synthesis of carbon quantum dots for hydrogen evolution, sensing and bioimaging, Chin. Chem. Lett.2019, 30 (12) , 2323-2327.

[23] Zhu Z, Cheng R, Ling L, Li Q, Chen S, Rapid and large-scale production of multi-fluorescence carbon dots by a magnetic hyperthermia method, Angew. Chem. Int. Ed. 2020, 59 (8), 3099-3105.

[24] Song SY, Sui LZ, Liu KK, Cao Q, Zhao WB, Liang YC, Lv CF, Zang JH, Shang Y, Lou Q, Yang XG, Dong L, Yuan KJ, Shan CX, Selfexothermic reaction driven large-scale synthesis of phosphorescent carbon nanodots, Nano Res. 2021, 14 , 2231-2240.

[25] Du XY, Wang CF, Wu G, Chen S, The rapid and large-scale production of carbon quantum dots and their integration with polymers, Angew. Chem. Int. Ed.2021, 60 (16), 8585-8595.

[26] Fang L, Wu M, Huang C, Liu Z, Liang J, Zhang H, Industrializable synthesis of narrow-dispersed carbon dots achieved by microwave-assisted selective carbonization of surfactants and their applications as fluorescent nano-additives, J.Mater.Chem. A 2020, 8 (40), 21317-21326.

[27] Li L, Li Y, Ye Y, Guo R, Wang A, Zou G, Hou H, Ji X, Kilogram-scale synthesis and functionalization of carbon dots for superior electrochemical potassium storage, ACS Nano 2021,15 (4) , 6872-6885.

[28] Shuang E, Mao QX, Wang JH, Chen XW, Carbon dots with tunable dual emissions: from the mechanism to the specific imaging of endoplasmic reticulum polarity, Nanoscale 2020, 12 (12) , 6852-6860.

[29] Zhu P, Tan K, Chen Q, Xiong J, Gao L, Origins of efficient multiemission luminescence in carbon dots, Chem. Mater. 2019,31 (13) ,4732-4742.

[30] Zhi B, Yao X, Wu M, Mensch A, Cui Y, Deng J, Duchimaza-Heredia JJ, Trerayapiwat, T. Niehaus KJ, Nishimoto Y, Frank BP, Zhang Y, Lewis RE,Kappel EA, Hamers RJ, Fairbrother HD, Orr G, Murphy CJ, Cui Q, Haynes CL, Multicolor polymeric carbon dots: synthesis, separation and polyamide-supported molecular fluorescence, Chem. Sci.2021, 12 (7) , 2441-2455.

[31] Song Y, Zhu S, Zhang S, Fu Y, Wang L, Zhao X, Yang B, Investigation from chemical structure to photoluminescent mechanism: a type of carbon dots from the pyrolysis of citric acid and an amine, J. Mater. Chem. 2015, 3 (23) ,5976-5984.

[32] Zhao B, Tan Z, Fluorescent carbon dots: fantastic electroluminescent materials for light-emitting diodes, Adv. Sci.2021, 8 (7), 2001977.

[33] Ru Y, Ai L, Jia T, Liu X, Lu S, Tang Z, Yang B, Recent advances in chiral carbonized polymer dots: from synthesis and properties to applications, Nano Today2020, 34 , 100953.

[34] Xu A, Wang G, Li Y, Dong H, Yang S, He P, Ding G, Carbon-based quantum dots with solid-state photoluminescent: mechanism, implementation, and application, Small2020, 16 (48) , 2004621.

[39] Tian L, Ghosh D, Chen W, Pradhan S, Chang X, Chen S, Nanosized carbon particles from natural gas soot, Chem. Mater.2009, 21 (13) , 2803-2809.

[40] Dong Y, Chen C, Zheng X, Gao L, Cui Z, Yang H, Guo C, ChiY, Li CM, Onestep and high yield simultaneous preparation of single- and multi-layer graphene quantum dots from cx-72 carbon black, J. Mater. Chem.2012, 22 (18) , 8764-8766.

[41] Wang X, Cao L, Yang ST, Lu F, Meziani MJ, Tian L, Sun KW, Bloodgood MA, Sun YP, Bandgap-like strong fluorescence in functionalized carbon nanoparticles, Angew. Chem. Int. Ed. 2010, 49 (31) , 5310-5314.

[42] Shen J, Zhu Y, Chen C, Yang X, Li C, Facile preparation and upconversion luminescence of graphene quantum dots, Chem. Commun. 2011, 47 (9) , 2580-2582.

[43] Qiao ZA, Wang Y, Gao Y, Li H, Dai T, Liu Y, Huo Q, Commercially activated carbon as the source for producing multicolorphotoluminescent carbon dots by chemical oxidation, Chem. Commun.2010, 46 (46) , 8812-8814.

[44]Peng J,Gao W, Gupta BK, Liu Z, Romero-Aburto R, Ge L, Song L, Alemany LB, Zhan X, Gao G, Vithayathil SA, Kaipparettu BA, Marti AA, Hayashi T, Zhu JJ, Ajayan PM, Graphene quantum dots derived from carbon fibers, Nano Lett. 2012,12 (2) , 844-849.

[45] Liu C, Xiao G, Yang M, Zou B, Zhang ZL, Pang DW, Mechanofluorochromic carbon nanodots: controllable pressure-triggered blue- and red-shifted photoluminescence, Angew. Chem. Int. Ed. 2018, 57 (7) , 1893-1897.

[46] Ye R, Xiang C, Lin J, Peng Z, Huang K, Yan Z, Cook NP, Samuel EC, Hwang C, G. Ruan, G. Ceriotti, A.R. Raji, A.A. Marti, J.M. Tour, Coal as an abundant source of graphene quantum dots, Nat. Commun. 4 (2013) 2943.

[47] HuC,Yu C, Li M, WangX, Yang J, Zhao Z, Eychmuller A, Sun YP, Qiu J, Chemically tailoring coal to fluorescent carbon dots with tuned size and their capacity for cu(ii) detection, Small, 2014 10 (23), 4926-4933.

[48] Jia J, Sun Y, Zhang Y, Liu Q, Cao J, Huang G, Xing B, Zhang C, Zhang L, Cao Y, Facile and efficient fabrication of bandgaptunable carbon quantum dots derived from anthracite and their photoluminescence properties, Front Chem., 2020, 8, 123-129.

[49] Jiang F, Chen D, Li R, Wang Y, Zhang G, Li S, Zheng J, Huang N, Gu Y, Wang C, ShuC, Eco-friendly synthesis of size-controllable amine-functionalized graphene quantum dots with antimycoplasma properties, Nanoscale, 2013, 5 (3), 1137-1142.

[50] Zhu C, Yang S, Wang G, Mo R, He P, Sun J, Di Z, Kang Z, Yuan N, Ding J, Ding G, X. Xie, A new mild, clean and highly efficient method for the preparation of graphene quantum dots without by-products, J. Mater. Chem. B 3 (34) (2015) 6871e6876

[51] Lu Q, Wu C, Liu D, Wang H, Su W, Li H, Zhang Y, Yao S, A facile and simple method for synthesis of graphene oxide quantum dots from black carbon, Green Chem. 2017, 19 (4), 900-904.

[52] Liu MX, Ding N, Chen S, Yu YL, Wang JH, One-step synthesis of carbon nanoparticles capable of long-term tracking lipid droplet for real-time monitoring of lipid catabolism and pharmacodynamic evaluation of lipidlowering drugs, Anal. Chem. 93 (12) (2021) 5284e5290.

[53] J. Xia, S. Chen, G.Y. Zou, Y.L. Yu, J.H. Wang, Synthesis of highly stable redemissive carbon polymer dots by modulated polymerization: from the mechanism to application in intracellular ph imaging, Nanoscale, 2018, 10 (47), 22484-22492.

[54] Sun YP, Zhou B, Lin Y, Wang W, Fernando KAS, Pathak P, Meziani MJ, Harruff BA, Wang X, Wang H, LuoPG, Yang H, Kose ME, Chen B, Veca LM,. Xie SY, Quantum-sized carbon dots for bright and colorful photoluminescence, J. Am. Chem. Soc.2006, 128 (24), 7756-7757.

[55] Hu SL, Niu KY, Sun J, Yang J, Zhao NQ, Du XW, One-step synthesis of fluorescent carbon nanoparticles by laser irradiation, J. Mater. Chem.2009, 19 (4), 484-488.

[56] Hu S, Liu J, Yang J, Wang Y, Cao S, Laser synthesis and size tailor of carbon quantum dots, J. Nanopart. Res.2011, 13 (1 2), 7247-7252.

[57] Yu H, Li X, Zeng X, Lu Y, Preparation of carbon dots by non-focusing pulsed laser irradiation in toluene, Chem. Commun. 2016, 52 (4), 819-822.

[58] Kang S, Ryu JH, Lee B, Jung KH, Shim KB, Han H, Kim KM, Laser wavelength modulated pulsed laser ablation for selective and efficient production of graphene quantum dots, RSC Adv. 2019, 9 (24), 13658-13663.

[59] Niu F, Xu Y, Liu M, Sun J, Guo P, Liu J, Bottom-up electrochemical preparation of solid-state carbon nanodots directly from nitriles/ionic liquids using carbon-free electrodes and the applications in specific ferric ion detection and cell imaging, Nanoscale,2016, 8 (10) 5470-5477.

[60] Zhou J, Booker C, Li R, Zhou X, Sham TK, Sun X, Ding Z, An electrochemical avenue to blue luminescent nanocrystals from multiwalled carbon nanotubes (mwcnts), J. Am. Chem. Soc. 2007, 129 (4), 744-745.

[61] Zheng L, Chi Y, Dong Y, Lin J, Wang B, Electrochemiluminescence of watersoluble carbon nanocrystals released electrochemically from graphite, J. Am. Chem. Soc.2009, 131 (13), 4564-4565.

[62] Li Y, Hu Y, Zhao Y, Shi G, Deng L, Hou Y, Qu L, An electrochemical avenue to green-luminescent graphene quantum dots as potential electronacceptors for photovoltaics, Adv. Mater.2011, 23 (6), 776-780.

[63] Xu Y, Liu J, Zhang J, Zong X, Jia X, Li D, Wang E, Chip-based generation of carbon nanodots via electrochemical oxidation of screen printed carbon electrodes and the applications for efficient cell imaging and electrochemiluminescence enhancement, Nanoscale, 2015, 7 (21), 9421-9426.

[64] Li Y, Liu X, Wang J, Liu H, Li S, Hou Y, Wan W, Xue W, Ma N, Zhang JZ, Chemical nature of redox-controlled photoluminescence of graphene quantum dots by post-synthesis treatment, J. Phys. Chem. C, 2016, 120 (45), 26004-26011.

[65] BaoL, ZhangZL, Tian ZQ, Zhang L, Liu C, Lin Y, Qi B, Pang DW, Electrochemical tuning of luminescent carbon nanodots: from preparation to luminescence mechanism, Adv. Mater. 2011, 23 (48), 5801-5806.

[66] Li H, He X, Kang Z, Huang H, Liu Y, LiuJ, Lian S, Tsang CH, Yang X, Lee ST, Water-soluble fluorescent carbon quantum dots and photocatalyst design, Angew. Chem. Int. Ed. 2010, 49 (26), 4430-4434.

[67] Han Y, Huang H, Zhang H, Liu Y, Han X, Liu R, Li H, Kang Z, Carbon quantum dots with photoenhanced hydrogen-bond catalytic activity in aldol condensations, ACS Catal.2014, 4 (3), 781-787.

[68] Pan D, Zhang J, Li Z, Wu M, Hydrothermal route for cutting graphene sheets into blue-luminescent graphene quantum dots, Adv. Mater. 2010, 22 (6), 734-738.

[69] Tetsuka H, Asahi R, Nagoya A, Okamoto K, Tajima I, Ohta R, Okamoto A, Optically tunable amino-functionalized graphene quantum dots, Adv. Mater. 2012, 24 (39) ,5333-5338.

[70] Liu J, Geng Y, Li D, Yao H, Huo Z, Li Y, Zhang K, Zhu S, Wei H, Xu W, Jiang J, Yang B, Deep red emissive carbonized polymer dots with unprecedented narrow full width at half maximum, Adv. Mater.2020, 32 (17), 1906641.

[71] SonH., LiuX., Wang B, Tang Z, Lu S, High production-yield solid-state carbon dots with tunable photoluminescence for white/multi-colorlightemitting diodes, Sci. Bull. 2019 64 (23), 1788-1794.

[72] Chen W, Li D, Tian L, Xiang W, Wang T, Hu W, Hu Y, Chen S, Chen J, Dai Z, Synthesis of graphene quantum dots from natural polymer starch for cell imaging, Green Chem.2018, 20 (19), 4438-4442.

[73] Chen W, ShenJ, Wang Z, Liu X, Xu Y, Zhao H, Astruc D, Turning waste into wealth: facile and green synthesis of carbon nanodots from pollutants and applications to bioimaging, Chem. Sci.2021, 12, 11722-11729.

[74] Zhang B, Liu C, Liu Y, A novel one-step approach to synthesize fluorescent carbon nanoparticles, Eur. J. Inorg. Chem.2010, 28, 4411-4414.

[75] BriscoeJ, Marinovic A, Sevilla M, Dunn S, Titirici M, Biomass-derived carbon quantum dot sensitizers for solid-state nanostructured solar cells, Angew. Chem. Int. Ed.2015, 54 (15), 4463-4468.

[76] Zhu S, Meng Q, Wang L, Zhang J, SongY, Jin H, Zhang K, Sun H, Wang H, Yang B, Highly photoluminescent carbon dots for multicolor patterning, sensors, and bioimaging, Angew. Chem. Int. Ed. 2013, 52 (14), 3953-3957.

[77] Li H, Han S, Lyu B, Hong T, Zhi S, Xu L, F. Xue, Sai L, Yang J, Wang X, He B, Tunable light emission from carbon dots by controlling surface defects, Chin. Chem. Lett. (2021), https://doi.org/10.1016/j.cclet.2021.03.051.

[78] Xu X, MoL, Li W, Li Y, Lei B, Zhang X, Zhuang J, HuC, Liu Y, Red green and blue aggregation-induced emissive carbon dots, Chin. Chem. Lett. 2021, https://doi.org/10.1016/j.cclet.2021.05.056.

[79] Jiang K, Sun S, Zhang L, Lu Y, Wu A, Cai C, Lin H, Red, green, and blue luminescence by carbon dots: full-color emission tuning and multicolor cellular imaging, Angew Chem. Int. Ed. Engl.2015, 54 (18), 5360-5363.

[80] Guo X, Zhao B, Xu K, Yang S, Liu Z, Han Y, Xu J, Xu D, Tan Z, Liu SF, Ptype carbon dots for effective surface optimization for near-record-efficiency cspbi2 br solar cells, Small 2021, 17, 2102-2118.

[81] Zhang T, Zhao F, Li L, Qi B, Zhu D, Lu J, Lu C, Tricolor white-light-emitting carbon dots with multiple-cores@shell structure for wled application, ACS Appl. Mater. Interfaces 2018, 10 (23), 19796-19805.

[82] Wang B, LiJ, Tang Z, Yang B, Lu S, Near-infrared emissive carbon dots with 33.96% emission in aqueous solution for cellular sensing and light-emitting diodes, Sci. Bull.2019, 64 (17), 1285-1292.

[83] Shuang E, Mao QX, Yuan XL, Kong XL, Chen XW, Wang JH, Targeted imaging of the lysosome and endoplasmic reticulum and their ph monitoring with surface regulated carbon dots, Nanoscale2018, 10 (26), 12788-12796.

[84] Liu B, ChuB, Wang YL, Hu LF, Hu S, Zhang XH, Carbon dioxide derived carbonized polymer dots for multicolor light-emitting diodes, Green Chem.2021, 23 (1), 422-429

[97] Mikhraliieva A, Zaitsev V, Xing Y, Coelho-Júnior H, Sommer RL, Excitationindependent blue-emitting carbon dots from mesoporousaminosilicananoreactor for bioanalytical application, ACS Applied Nano Materials, 2020, 3 (4), 3652-3664.

[98] Wang F, Pang S, Wang L, Li Q, Kreiter M, Liu CY, One-step synthesis of highly luminescent carbon dots in noncoordinating solvents, Chem. Mater.2010, 22 (16) 4528-4530.

[99] Pan D, Zhang J, Li Z, Wu C, Yan X, Wu M, Observation of ph-, solvent-, spin-, and excitation-dependent blue photoluminescence from carbon nanoparticles, Chem. Commun. 2010, 46 (21), 3681-3683.

[100] Dong Y, Shao J, Chen C, Li H, Wang R, Chi Y, Lin X, Chen G, Blue luminescent graphene quantum dots and graphene oxide prepared by tuning the carbonization degree of citric acid, Carbon, 2012, 50 (12), 4738-4743.

[101] Gu ZG, Li DJ, Zheng C, Kang Y, Woll C, Zhang J, Mof-templated synthesis of ultrasmallphotoluminescent carbon-nanodot arrays for optical applications, Angew Chem. Int. Ed. Engl.2017, 56 (24), 6853-6858.

[102] Zhou K, Zhang WJ, Luo YZ, Pan CY, Photoluminescent carbon dots based on a rare 3d inorganic-organic hybrid cadmium borate crystal, Dalton Trans.2018, 47 (22), 7407-7411.

[103] Li Z, Liu W, Ni P, Zhang C, Wang B, Duan G, Chen C, Jiang Y, Lu Y, Carbon dots confined in n-doped carbon as peroxidase-like nanozyme for detection of gastric cancer relevant d-amino acids, Chem. Eng. J. 2022, 428, 131396.

[104] Miao X, Qu D, Yang D, Nie B, Zhao Y, Fan H, Sun Z, Synthesis of carbon dots with multiple color emission by controlled graphitization and surface functionalization, Adv. Mater.2018, 30 (1), 1704-1740.

[105] Ye Y, Yang D, Chen H, Guo S, Yang Q, Chen L, Zhao H, Wang L, A highefficiency corrosion inhibitor of n-doped citric acid-based carbon dots for mild steel in hydrochloric acid environment, J. Hazard Mater. 2020, 381, 121019.

[118] Qu S, Wang X, Lu Q, Liu X, Wang L, A biocompatible fluorescent ink based on water-soluble luminescent carbon nanodots, Angew. Chem. Int. Ed.2012, 51 (49), 12215-12218.

[119] Choi Y, Kang B, Lee J, Kim S, Kim GT, Kang H, Lee BR, Kim H, Shim SH, Lee G, Kwon OH, Kim BS, Integrative approach toward uncovering the origin of photoluminescence in dual heteroatom-doped carbon nanodots, Chem. Mater.2016, 28 (19), 6840-6847.

[120] Wang C, Jiang K, Wu Q, Wu J, Zhang C, Green synthesis of red-emitting carbon nanodots as a novel "turn-on" nanothermometer in living cells, Chem. Eur J.2016, 22 (41) 14475-14479.

[121] Liu R, Facile synthesis of magneto-fluorescent carbon dots by one-step microwave-assisted pyrolysis, J. Alloys Compd.2021, 855, 157456.

[122] Liu H, He Z, Jiang LP, Zhu JJ, Microwave-assisted synthesis of wavelengthtunablephotoluminescent carbon nanodots and their potential applications, ACS Appl. Mater. Interfaces 2015, 7 (8), 4913-4920.

[123] Shao J, Zhu S, Liu H, Song Y, Tao S, Yang B, Full-color emission polymer carbon dots with quench-resistant solid-state fluorescence, Adv. Sci.2017, 4 (12), 1700395.

[124] Zheng J, Wang Y, Zhang F, Yang Y, Liu X, Guo K, Wang H, Xu B, Microwave-assisted hydrothermal synthesis of solid-state carbon dots with intensive emission for white light-emitting devices, J. Mater. Chem. 2017, C 5 (32), 8105-8111.

[125] Wang HJ, Hou WY, Kang J, Zhai XY, Chen HL, Hao YW, Wan GY, The facile preparation of solid-state fluorescent carbon dots with a high fluorescence quantum yield and their application in rapid latent fingerprint detection, Dalton Trans.2021, 50, 12188-12196.

[126] Li LL, Ji J, Fei R, Wang CZ, Lu Q,.Zhang JR, Jiang LP, Zhu JJ, A facile microwave avenue to electrochemiluminescent two-colorgraphene quantum dots, Adv. Funct.Mater.2012, 22 (14), 2971-2979.

[127] Hai X, Mao QX, Wang WJ, Wang XF, ChenXW, Wang JH, An acid-free microwave approach to prepare highly luminescent boron-doped graphene quantum dots for cell imaging, J. Mater. Chem. B2015,3 (47), 9109-9114.

[128] Feng J, Wang WJ, Hai X, Yu YL, Wang JH, Green preparation of nitrogendoped carbon dots derived from silkworm chrysalis for cell imaging, J. Mater. Chem. B2016, 4 (3) 387-393.

[129] Wang J, Wang CF, Chen S, Amphiphilic egg-derived carbon dots: rapid plasma fabrication, pyrolysis process, and multicolor printing patterns, Angew. Chem. Int. Ed. 2012, 51 (37), 9297-9301.

[130] Yan H, He C, Li X, Zhao T, A solvent-free gaseous detonation approach for converting benzoic acid into graphene quantum dots within milliseconds, Diam. Relat. Mater.2018, 87, 233-241.

[131] Park SY, Lee HU, Park ES, Lee SC, Lee JW, Jeong SW, Kim CH, Lee YC,. Huh YS, Lee J, Photoluminescent green carbon nanodots from food-wastederived sources: large-scale synthesis, properties, and biomedical applications, ACS Appl. Mater. Interfaces, 2014, 6 (5), 3365-3370.

[132] Aslandas AM, , Balcı N, Arık M, Akiroglu HS, Onganer Y, Meral K, Liquid nitrogen-assisted synthesis of fluorescent carbon dots from blueberry and their performance in fe3þ detection, Appl. Surf. Sci. 2015, 356, 747-752.

[133] Zhu H, Liu A, Shan F, Yang W, Zhang W, Li D, Liu J, One-step synthesis of graphene quantum dots from defective cvdgraphene and their application in igzouv thin film phototransistor, Carbon2016, 100, 201-207.

[134] He V, Yan H, Li X, Wang X, In situ fabrication of carbon dots-based lubricants using a facile ultrasonic approach, Green Chem.2019, 21 (9), 2279-2285.

[135] Zhou Y, Mintz KJ, Oztan CY, Hettiarachchi SD, Peng Z, Seven ES, Liyanage PY, De La Torre S, CelikE, Leblanc RM, Embedding carbon dots in superabsorbent polymers for additive manufacturing, Polymers, 2018, 10 (8), 921-928.

[136] Zhou X, Zhang Y, Wang C, Wu X, Yang Y, Zheng B, Wu H, Guo S, ZhangJ, Photo-fenton reaction of graphene oxide: a new strategy to preparegraphene quantum dots for DNA cleavage, ACS Nano., 2012, 6 (8), 6592-6599.

[137] P. Routh, S. Das, A. Shit, P. Bairi, P. Das, A.K. Nandi, Graphene quantum dots from a facile sono-fenton reaction and its hybrid with a polythiophene graft copolymer toward photovoltaic application, ACS Appl. Mater. Interfaces 2013, 5 (23), 12672-12680.

[138] H. Zhu, A. Liu, Y. Xu, F. Shan, A. Li, J. Wang, W. Yang, C. Barrow, J. Liu, Graphene quantum dots directly generated from graphite via magnetron sputtering and the applications in the thin film transistors, Carbon2015, 88, 225-232.