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Exploring Afterglow Carbon Dots in Organic Matrixes: Synthesis, Luminescent Properties, and Emerging Applications

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Abstract

Afterglow Carbon Dots (ACDs) have emerged as a promising class of nanomaterials due to their unique optical properties, particularly their ability to exhibit persistent luminescence after the excitation source is turned off. These materials have garnered significant attention in various fields, including bioimaging, sensing, and optoelectronics. In recent years, the integration of ACDs with organic matrixes has provided new avenues for enhancing their luminescent properties, stability, and potential applications. This article reviews the latest advancements in the development of afterglow carbon dots in organic matrixes, discussing their synthesis, properties, and the integration strategies that optimize their performance in different fields. Additionally, the challenges and future directions for research in this area are discussed.

Keywords: Afterglow carbon dots; Organic matrixes; Persistent luminescence; Nanomaterials; Bioimaging; Optoelectronics; Synthesis; Luminescent properties; Sensing; Stability

Introduction

Afterglow Carbon Dots (ACDs) are a subclass of carbon-based nanomaterials that exhibit long-lasting luminescence after the cessation of an excitation source. Unlike conventional fluorescence, ACDs are capable of emitting light for seconds to minutes or even hours, depending on the specific formulation and environmental conditions. This unique property, known as persistent luminescence, makes ACDs highly attractive for a range of applications, including bioimaging, environmental monitoring, and optoelectronics. Organic matrixes, including polymers, small organic molecules, and biopolymers, have been utilized as platforms for embedding ACDs, improving their stability, dispersibility, and luminescence. The combination of ACDs with organic matrixes offers significant advantages over traditional systems, particularly in enhancing the afterglow efficiency and controlling the emission wavelength. This integration enables the development of novel devices with potential applications in the fields of biomedical imaging, optoelectronic devices, and sensing technologies [1,2].

Description

Synthesis of afterglow carbon dots

The synthesis of ACDs involves a variety of methods, including top-down and bottom-up approaches. In top-down strategies, carbon-based materials such as graphite, graphite oxide, or activated carbon are subjected to physical or chemical treatments, such as laser ablation, chemical oxidation, or hydrothermal treatment, to produce carbon dots with a size range of 1-10 nm. Bottom-up methods, on the other hand, involve the synthesis of carbon dots through the polymerization of organic precursors or the pyrolysis of small organic molecules. The persistent luminescence of ACDs is typically achieved by introducing specific dopants or functional groups that facilitate charge transfer processes, such as transition metal ions (e.g., europium or terbium) or nitrogen-doped carbon. These dopants help trap charge carriers and enable the sustained release of light even after the excitation source is removed [3].

Organic matrixes for ACDs

To enhance the performance of ACDs, they are often embedded in organic matrixes. The organic matrixes serve several purposes: they help improve the dispersion and stability of ACDs in various environments, enhance their luminescent efficiency, and provide functional groups that can further tune the emission properties of the ACDs. The choice of matrix material is crucial, as it determines the compatibility with ACDs and the resulting afterglow properties. Polymeric matrixes, such as polylactic acid (PLA), polyvinyl alcohol (PVA), and polyurethane, have been commonly used to encapsulate ACDs due to their biocompatibility and ease of processing. Biopolymer-based matrixes like alginate and chitosan also show promise for biomedical applications due to their inherent biodegradability and non-toxicity [4].

Mechanism of afterglow in ACDs

The mechanism behind the afterglow in carbon dots involves the trapping of electrons and holes within the material. When excited, ACDs generate electron-hole pairs, which can be trapped in localized states, often due to defects or dopants in the carbon structure. These trapped charge carriers can then recombine over an extended period, resulting in the emission of light even after the external excitation source is removed. The persistence of this luminescence depends on the trap depth, the presence of dopants, and the interaction between the ACDs and the organic matrix [5].

Results

Recent studies have demonstrated that embedding ACDs in organic matrixes significantly improves their afterglow properties. For example, ACDs encapsulated in polymeric matrixes show enhanced photostability and a prolonged afterglow time compared to free ACDs. The incorporation of transition metal ions, such as europium (Eu^{3+}),

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into the organic matrix has been found to further extend the afterglow duration and improve the overall luminescent efficiency. Moreover, the incorporation of ACDs in organic matrixes has led to the development of materials with tunable afterglow emission, making them suitable for various applications. For example, ACDs in a polyurethane matrix have been shown to emit light in the near-infrared region, which is highly desirable for deep tissue imaging in biomedical applications. Additionally, the flexibility of organic matrixes allows for the creation of flexible afterglow materials that can be used in wearable electronics [6,7].

Discussion

Applications of ACDS in organic matrixes

ACDs embedded in organic matrixes show promise for a wide range of applications. In bioimaging, their persistent luminescence enables imaging over extended periods without the need for continuous illumination, reducing phototoxicity. In optoelectronics, ACDs can be integrated into light-emitting devices, such as Organic Light-Emitting Diodes (OLEDs) and solar cells, to improve efficiency and stability. Moreover, their application in sensors for detecting environmental pollutants, metal ions, or biological analytes is another promising area [8].

Challenges and future directions

Despite the promising advancements, several challenges remain in the field of afterglow carbon dots in organic matrixes. One of the primary challenges is achieving consistent and reliable afterglow performance across different batches of ACDs. The synthesis methods need to be refined to ensure reproducibility and scalability. Additionally, the long-term stability of ACDs in various environments needs further investigation, particularly in biological systems. Future research should focus on optimizing the synthesis methods to enhance the luminescent properties of ACDs, exploring new organic matrixes with better compatibility, and identifying novel applications in emerging fields like flexible electronics and wearable devices. Furthermore, the development of ACDs with tunable afterglow times and emission spectra will expand their potential applications in multiplexed sensing and diagnostics [9,10].

Conclusion

The integration of afterglow carbon dots into organic matrixes has led to significant advancements in the field of luminescent nanomaterials. By improving the stability, dispersion, and afterglow properties of ACDs, organic matrixes have enabled their use in a variety of applications, including bioimaging, optoelectronics, and sensing. While challenges remain, the future of ACDs in organic matrixes looks promising, with potential applications across a wide range of scientific and technological fields.

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None

Conflict of Interest

The authors declare no conflict of interest.

References

1. Wu YH, Wu YR, Li B, Yan ZY(2020) Cryptotanshinone A review of its pharmacology activities and molecular mechanisms. Fitoterapia 145: 104633.
2. Li H, Gao C, Liu C, Liu L, Zhuang J, et al. (2021) A review of the biological activity and pharmacology of cryptotanshinone, an important active constituent in Danshen. Biomed Pharmacother 137: 111332.
3. Chen ZM, Huang L, Li MM, Meng L, Ying SC, et al. (2018) Inhibitory effects of isocryptotanshinone on gastric cancer. Sci rep 8: 9307.
4. Wang J, Zhang G, Dai C, Gao X, Wu J, et al. (2017) Cryptotanshinone potentiates the antitumor effects of doxorubicin on gastric cancer cells via inhibition of STAT3 activity. J Int Med Res 45: 220-230.
5. Wang Y, Lu HL, Liu YD, Yang LY, Jiang QK, et al. (2017) Cryptotanshinone sensitizes antitumor effect of paclitaxel on tongue squamous cell carcinoma growth by inhibiting the JAK/STAT3 signaling pathway. Biomed Pharmacother 95: 1388-1396.
6. Shen L, Zhang G, Lou Z, Xu G, Zhang G (2017) Cryptotanshinone enhances the effect of Arsenic trioxide in treating liver cancer cell by inducing apoptosis through downregulating phosphorylated- STAT3 in vitro and in vivo. BMC Complement Altern Med 17: 106.
7. Chakrabarti S, Wintheiser G, Tella SH, Oxencis C, Mahipal A (2021) TAS-102: A resurrected novel Fluoropyrimidine with expanding role in the treatment of gastrointestinal malignancies. Pharmacol ther 224: 107823.
8. Lenz HJ, Stintzing S, Loupakis F (2015) TAS-102, a novel antitumor agent: a review of the mechanism of action. Cancer treat rev 41: 777-783.
9. Vodenkova S, Buchler T, Cervena K, Veskrnova V, Vodicka P, et al. (2020) 5-fluorouracil and other fluoropyrimidines in colorectal cancer: Past, present and future. Pharmacol ther 206: 107447.
10. Emura T, Suzuki N, Yamaguchi M, Ohshimo H, Fukushima M (2004) A novel combination antimetabolite, TAS-102, exhibits antitumor activity in FU-resistant human cancer cells through a mechanism involving FTD incorporation in DNA. Int J Oncol 25: 571-578.