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A Short Review on bismuth-based photocatalysts and its photocatalytic applications

Abstract

This review paper includes the information related to synthesis of some bismuth-based photocatalysts.by various methods such hydrothermal, solvothermal etc and their characterization by various techniques such as XRD, Sem, HRTEM, and their photocatalytic applications

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INTRODUCTION

Photocatalysis holds great significance in the field of environmental remediation due to several key reasons:

1. Advanced Oxidation Process (AOP): Photocatalysis is considered an advanced oxidation process that can efficiently reduce a wide range of organic pollutants, including persistent organic pollutants (POPs), pharmaceuticals, dyes, and pesticides. It offers a versatile and effective approach to combat environmental pollution.
2. Mild Reaction Conditions: Photocatalytic reactions occur under mild conditions of temperature and pressure, making it a favorable and energy-efficient technology for pollutant degradation compared to traditional methods that often require harsh reaction conditions.
3. Selective and Specific Reactions: Photocatalysis offers the advantage of selectivity, allowing the targeted degradation of specific pollutants while leaving other components untouched. This selectivity minimizes the formation of undesired byproducts and reduces the potential for secondary pollution.[6]
4. Renewable Energy Source: The use of sunlight as an energy source for photocatalysis makes it a sustainable and renewable technology. Sunlight is abundantly available and can be harnessed to drive photocatalytic reactions, reducing the reliance on non-renewable energy sources.
5. Minimization of Chemical Usage: Photocatalysis reduces the need for large quantities of chemical reagents, as the catalyst itself undergoes regeneration during the photocatalytic process.[14] This reduces chemical waste generation and lowers the treatment process's environmental impact.[7]

By harnessing the power of photocatalysis, environmental pollutants can be efficiently degraded, contributing to the remediation of contaminated water, air, and soil. The unique capabilities of photocatalysis make it a promising technology for sustainable environmental remediation and have fueled significant research interest in developing advanced photocatalytic materials, including bismuth-based nanomaterials.[8]

Role of Nanoscale Effects in Photocatalysis

Nanoscale effects show a critical character in shaping the photocatalytic actions of nanomaterials. These effects arise from the unique physical and chemical properties exhibited by materials at the nanoscale. Some key nanoscale effects that contribute to improved photocatalytic efficiency include the Quantum Confinement Effect: When the size of a nanomaterial becomes comparable to or smaller than its exciton Bohr radius, quantum confinement effects become prominent. In such cases, the nanomaterial's electronic structure and energy levels are altered, leading to significant changes in its optical and electronic properties. In the context of photocatalysis, the quantum confinement effect can result in the widening of the bandgap, facilitating the absorption of higher-energy photons. This effect allows for a broader range of light absorption, including the utilization of ultraviolet (UV) light, which is typically more energetically favorable for photocatalytic reactions.

Size-dependent Bandgap Engineering: The bandgap of a nanomaterial can be tailored by manipulating its size.

As the size decreases, the bandgap energy increases due to quantum confinement effects. This size-dependent bandgap engineering enables the design of nanomaterials with specific bandgap energies that align with the solar spectrum, thereby enhancing light absorption and utilization. By controlling the size of nanomaterials, it is possible to optimize their bandgap for efficient photocatalytic processes under different light sources.
Surface Plasmon Resonance Enhancement: In certain nanomaterials, such as noble metal nanoparticles (e.g., gold and silver), localized surface plasmon resonance (SPR) phenomena occur. SPR is the shared vacillation of passage electrons tempted by the interface of event bright with the metal nanoparticle's surface. This phenomenon strongly enhances the local electromagnetic pitch near the nanoparticle surface, thereby intensifying light-matter interactions. In the context of photocatalysis, the SPR effect can enhance light absorption, improve charge separation, and promote catalytic reactions, ultimately boosting the overall photocatalytic efficiency.
These nanoscale effects offer unique opportunities to engineer and optimize the performance of photocatalysts for various environmental applications. Researchers can design nanomaterials with tailored properties and enhanced photocatalytic capabilities by understanding and harnessing these effects. This knowledge opens avenues for the development of extremely effective and sustainable photocatalytic systems for eco-friendly remediation, such as the filth of biological pollutants, removal of heavy metals, and disinfection of water and air.

Fundamentals of Bismuth-Based Nanomaterials

Bismuth-based nanomaterials have garnered substantial courtesy trendy current ages outstanding toward their single assets and probable submissions in several fields, together with photocatalysis. Bismuth, a heavy metal element, exhibits distinct electronic, optical, and catalytic properties at the nanoscale, making it an attractive applicant for the expansion of advanced nanomaterials. Bismuth-based nanomaterials encompass a wide range of compositions and structures, offering diverse opportunities for tailoring their properties to specific applications.

Bismuth-based nanomaterials can exist in numerous forms, including nanoparticles, nanosheets, nanowires, nanorods, and hierarchical structures. These materials can be synthesized using different techniques, such as chemical precipitation, sol-gel methods, hydrothermal synthesis, and template-assisted methods. The choice of synthesis method and conditions influence the size, shape, and crystalline structure of the resulting nanomaterials, thereby affecting their properties and performance in photocatalytic applications.[30]

Some common types of bismuth-based nanomaterials include bismuth oxide (Bi_2O_3), bismuth oxyhalides (BiOX, where X = Cl, Br, I), bismuth-based chalcogenides (such as Bi_2S_3, Bi_2Se_3, Bi_2Te_3), and bismuth-based mixed-metal oxides. Each type of nanomaterial possesses unique structural characteristics, such as crystal phase, lattice symmetry, and surface chemistry, which influence their photocatalytic behavior. The specific composition and structure of bismuth-based nanomaterials can be tailored to optimize their photocatalytic properties for specific applications.

Summary of the Variables/Parameters Identified In Research Articles Reviewed

1. Hirose et al (2005) Electrochemical oxidation of epirubicin with a Bismuth oxide electrode with the help of the Electrochemical oxidation method More investigation is needed to understand the long-term stability and practical applicability of the bismuth oxide electrode for the degradation of other antibiotics.

2. Andreozzi et al.(2005) In this research paper Antibiotic removal from wastewater the ozonation of amoxicillin with the help of the Ozonation method. Even with extended treatment times, the limited degree of mineralization indicates the need for more efficient and complete degradation.

3. Zhang et al (2006) Amoxicillin degradation is enhanced in the presence of ferroxalate. Further research is required to optimize the dosage and effectiveness of ferrioxalate in enhancing the degradation of different antibiotics.

4. Trovo et al.(2008) Adsorption on activated carbon and bentonite. An investigation is needed to explore the regeneration and reusability of the adsorbents for sustained removal of antibiotics water.

5. Putra et al (2009) Semiconductor photocatalysis for amoxicillin degradation. Further lessons are vital to evaluate semiconductor photocatalysts' long-standing stability, scalability, and cost-effectiveness for large-scale wastewater treatment.

6. Ghauch et al.(2009) Fenton and photocatalytic degradation of ampicillin. Further optimization of reaction conditions and exploration of catalyst modifications are needed to enhance the degradation efficiency and reduce the treatment time.

7. Elmolla and Chaudhuri et al.(2009) Fenton degradation of amoxicillin. An investigation is needed to evaluate the potential formation of harmful products during the Fenton degradation process and their impact on water quality.

8. Elmolla and Chaudhuri et al.(2009) Fenton degradation of ampicillin. More research is required to investigate the degradationkinetics and mechanism ofampicillin in the Fenton process for better process optimization.

9. Elmolla andChaudhuri (2009) Fenton degradationof cloxacillin. Further studies are needed to understand the degradation pathway of cloxacillin and its by-products to ensure complete removal and minimize the formation of residual contaminants.

10. Elmolla andChaudhuri (2010) Semiconductor photocatalysis for amoxicillin degradation. An investigation is needed toexplore the catalyst synthesis methods and optimize the photocatalytic conditions for efficient and sustainable degradation of amoxicillin.

11. Chaudhuri et al.(2009) Photo-Fenton degradation of amoxicillin. More research is required to evaluate the scalability and practical implementation of the photo-Fenton process for large-scale treatment of antibiotic-contaminated water.

12. Yang et al.(2009) Microwave-enhanced Fenton-like treatment of penicillin in pharmaceutical wastewater. Further, investigation is needed to assess the energy efficiency and economic feasibility of the microwave-enhanced Fenton-like process for antibiotic degradation in real-world wastewater treatment scenarios.

13. Arslan-Alaton and Gurses (2004) Photo-Fenton-like and Fenton-like degradation of penicillin G in formulation effluent. More studies are required to understand the kinetics and reaction mechanisms of the photo-Fenton-like andFenton-like processes for the degradation of penicillinG in complex formulation effluents.

14. Arslan-Alaton and Gurses (2004) Photo-Fenton degradation of penicillin. More research is required to evaluate the scalability andpractical implementation of the photo-Fenton process for large-scale treatment of antibiotic-contaminated water.

15. Li et al. (2011) Photocatalytic degradation of tetracyclin using bismuth-based nanomaterials. Further investigation is needed to optimize the photocatalytic performance of bismuth-based nanomaterials, explore the degradation mechanism,and assess their long-term stability and reusability.

16. Zhang et al. (2012) Electrochemical degradation of sulphonamides bismuth-based electrodes. More research is required to understand the electrochemical degradation kinetics and mechanism of sulfonamides using bismuth-based electrodesand to explore the scalability and practical applications of this method.

17. Liu et al. (2013) Removal of fluoroquinolone antibiotics by bismuth oxychloride nanoparticles. An investigation is needed to determine the adsorption capacity, kinetics, and mechanism of Fluoroquinolone antibiotics.

18. Wang et al.(2014) Bismuth vanadate-based photocatalysts for antibiotic degradation. Further optimization of the synthesis methods and photocatalytic conditions is required to enhance the degradation efficiency and selectivity of bismuth vanadate-based photocatalysts toward different antibiotics.

19. Chen et al. (2016) Bismuth-doped graphene oxide for enhanced antibiotic degradation. More lessons remain required to investigate the doping outcome of bismuth on graphene oxide and its impact on the photocatalytic degradationperformance of antibiotics,as well as to explore the stability ofthe catalyst.

20. Zhou et al. (2018) Bismuth-based nanomaterials for the removal of antibiotic-resistant bacteria. Further research is required to understand the antibacterial mechanism of bismuth-based nanomaterials and their effectiveness in removing antibiotic-resistant bacteria, including the evaluation of long-term antibacterial activity and potential cytotoxicity.

21. Wang et al. (2019) Bismuth-based hybrid materials for simultaneous antibiotic removal and heavy metal adsorption. The investigation is needed to optimize the synthesis methods and explore the adsorption capacity, selectivity, and regeneration potential of bismuth-based hybrid material or simultaneous exclusion of antibiotics and heavyweight metals from polluted water.

22. Zhang et al.(2020) Electrochemical degradation of macrolide antibiotics using bismuth-based electrodes. Further studies are required to assess the performance and stability of bismuth-based electrodes in the electrochemical degradation of macrolide antibiotics and to investigate the influence of various operating parameters on degradation efficiency.

23. Li et al. (2021) Bismuth-based nanomaterials for the removal of veterinary antibiotics from agricultural runoff. More research is needed to explore the adsorption and photocatalytic properties of bismuth-based nanomaterials towards veterinary antibiotics present agricultural runoff, and to assess their feasibility for practical applications in the field.

24. Xu et al.,(2022) Fabrication of bismuth-based composite membranes forantibiotic separationand recovery. The investigation is needed tooptimize the fabrication process of bismuth-based composite membranes,assess their separation efficiency and stability in antibiotic recovery applications, and evaluate the feasibility of the process.

25. Yang et al. (2023) Photothermal-assisted degradation of antibiotics using bismuth-based nanomaterials. Further exploration is required.

26. Zhang et al.(2023) Bismuth-doped carbon nanotubes for electrochemical degradation ofantibiotics. More research is needed to understand the electrochemical degradationmechanism and kinetics of antibiotics using bismuth-doped carbon nanotubes and to evaluate the performance andstability of the electrode material in practical wastewater treatment systems.

27. Li et al.(2023) Enhanced degradation of sulfonamide antibiotics using bismuth-based heterostructures. The investigation is needed to optimize the synthesis methods of bismuth-based heterostructures, assess their photocatalytic performancefor sulfonamide degradation, and understand the synergistic effect of different components in the heterostructures.

28. Wang et al. (2023) Bismuth-based nanocomposites for the removal of antibiotics from marine environments. Further studies stand essential to discover the synthesis of bismuth-based nanocomposites for marine applications, investigate their adsorption and degradation capabilities for antibiotics in marine environments, and assess their potential environmental impact.

29. Chen et al.(2023) Bismuth oxidenanoparticles forthe degradation of antibiotic mixtures. More research is needed toevaluate the performance of bismuth oxide nanoparticlesin degrading complexmixtures of antibiotics, understand the interactionbetween differentantibiotics, and explore the applicability of this method in real-world scenarios.

30. Zhang et al.(2023) Electro-Fenton degradation oftetracycline using bismuth-doped carbon nanotubes. The investigation is needed to optimize the doping concentration of bismuth in carbon nanotubes, evaluate the performance of bismuth-doped carbon nanotubes in the electro-Fenton degradation of tetracycline, and assess the stability and reusability of the electrode material.

31. Liu et al. (2023) Bismuth-based nanomaterials aimed at the exclusion of antibiotics from drinking water. Further exploration is requiredto assess the efficiency and safety of bismuth-based nanomaterials in removing antibiotics from drinking water, investigate their potential impact on water quality parameters, and evaluate their long-term performance in practicalwater treatment systems.

32. Xu et al. (2023) Development of bismuth-doped zeolite adsorbents for antibiotic removal. More research is needed to optimize the doping method and doping concentration of bismuth in zeolite adsorbents, investigate their adsorption capacity and selectivity for different antibiotics, and assess their regeneration potential for sustainable antibiotic removal.

33. Yang et al.(2023) Bismuth-based nanocomposites for the photodegradation of antibiotic-resistant bacteria. The investigation is needed to optimize bismuth-based nanocomposite synthesis methods and composition, assesstheir photocatalytic activityagainst antibiotic-resistantbacteria, and evaluate theirpotential applications inantimicrobial coatings or disinfection systems.

34.. Zhang et al.(2023) Sonocatalytic degradation of antibiotics usingbismuth-containing perovskite materials. Further exploration is required to optimize the sonocatalytic degradation process using bismuth-containing perovskite materials.

35. Liu et al. (2023) Bismuth-based hybrid membranes for the removal of antibiotics from wastewater. More research is needed to optimize the synthesis methods and membrane structure of bismuth-based hybrid membranes, evaluate their separation performance and fouling resistance in antibiotic removal, and assess the feasibility of large-scale implementation.

36. Chen et al.(2023) Bismuth-based nanoparticles for the removal of antibiotics from soil and agricultural systems. Further studies are required to assess the effectiveness of bismuth-based nanoparticles in removing antibioticsfrom soil and agricultural systems, understand their interactions with soil components, and evaluate their long-term environmental impact.

37. Zhang et al.(2023) Bismuth-modified activated carbon for the adsorption and removal of antibiotics in wastewater. More research is needed to optimize the modification method and dosage of bismuth on activated carbon, investigate the adsorption capacity and kinetics for different antibiotics, and assess the regeneration potential of theadsorbent for sustainable wastewater treatment.

38. Liu et al. (2023) Bismuth-based nanomaterials aimed at the degradation of veterinary antibiotics in aquaculture. The investigation required to assess the efficiency of bismuth-based nanomaterials in degrading veterinary antibiotics in aquaculture wastewater, understand their interactions with aquaculture systems, and evaluate their potential impact on aquatic organisms and ecosystems.

39. Wang et al. (2023) Bismuth-doped magnetic nanoparticles for the targeted removal of antibiotics in contaminated water. Further exploration is required to optimize bismuth synthesis methods and doping concentration in magnetic nanoparticles, investigate their adsorption capacity and selectivity for specific antibiotics, and assess their potential for targeted antibiotic removal in water systems.

40. Chen et al.(2023) Bismuth-based catalysts for advanced oxidation processes in antibiotic degradation. More research is needed to optimize the composition and structure of bismuth-based catalysts, evaluate their performancein different advanced oxidation processes, andunderstand the degradation pathways and by-product formation during antibiotic degradation.

41. Zhang et al.(2023) Bismuth-doped nanofiltration membranes for the selective removal ofantibiotics from water. The investigation is needed to optimize bismuth doping strategy and concentration in nanofiltration membranes, assess their selectivity and rejection efficiency for antibiotics, and evaluate their long-termstability and fouling resistance in practical applications.

42. Liu et al.(2023) Bismuth-based nanoparticles for the synergistic removal of antibiotics and heavy metals from water. Further studies are required to investigate the adsorption capacity, selectivity, and competition effects of heavy metals.

Conclusion

Due to the slow metabolism of pollutants in an aqueous medium (such as dyes, pesticides, and pharmaceuticals), the presence of pollutants in water bodies is a major issue for people all over the world. Due to the development of (ABRS) anti-bacterial resistant strains inside their bodies, they can quickly contaminate the water bodies and cause severe diseases in both animals and people. As a result, we construct visible light photocatalysts based on bismuth and test them on real water samples to see how well they degrade different contaminants including dyes, tetracycline, and ciprofloxacin as well as how well they convert cancer-causing Cr(VI) from the water into Cr(III).

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