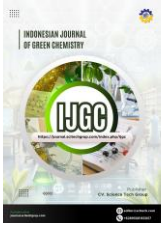

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Application of Titanium Dioxide as an Anti-Bacterial: Mini Review

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Abstract

This mini-review discusses the application of Titanium Dioxide (TiO_2) as an antibacterial agent, particularly in the context of its use in paint formulations for buildings in tropical climates. The increasing demand for durable and hygienic building materials necessitates innovative solutions that not only enhance aesthetics but also provide self-cleaning and antibacterial properties. TiO_2, a semiconductor with photocatalytic capabilities, generates reactive radicals upon exposure to sunlight, effectively degrading organic pollutants and bacteria on surfaces. While TiO_2-based coatings have shown promise, challenges such as poor UV stability limit their long-term efficacy. The review highlights recent advancements in modifying TiO_2 to improve its photocatalytic performance and durability, suggesting that future research should focus on integrating these coatings with new technologies for broader applications in environmental remediation. By addressing these limitations, TiO_2 can play a crucial role in sustainable building practices and public health improvements.

Keywords: *TiO_2, antibacterial, photocatalytic, environmental, materials*

1. Introduction

The rapid population growth has driven the construction of large-scale buildings, increasing the demand for durable and aesthetically pleasing paints. In tropical countries like Indonesia, where the climate alternates between hot and rainy seasons, environmental factors such as dust, pollutants, and bacteria tend to adhere more easily to building surfaces. This affects the longevity of the materials used in construction and raises concerns about hygiene and health, as bacterial contamination can spread through direct contact with walls. Thus, there is a pressing need for innovative solutions in paint formulations beyond mere aesthetics, offering self-cleaning and antibacterial properties to prevent dirt and bacteria from adhering to surfaces (Wang et al., 2014; Cai et al., 2020).

Titanium Dioxide (TiO_2), a semiconductor with photocatalytic properties, has emerged as a promising candidate in the development of self-cleaning surfaces. When exposed to sunlight, TiO_2 generates reactive radicals that can degrade organic pollutants and bacteria on surfaces. Research has demonstrated that TiO_2-based superhydrophobic suspensions are effective in cleaning external surfaces via photocatalytic activity (Cai et al., 2020). However, a significant limitation of these coatings lies in their poor UV stability, which hampers long-term performance (Nagasawa et al., 2021). This challenge necessitates the modification of the TiO_2 anatase phase to enhance its durability and maintain its self-cleaning efficacy over time. Despite these advancements, current research on TiO_2-based coatings has yet to address several key challenges. One of the primary limitations is the difficulty in ensuring consistent UV stability in outdoor applications, which remains critical for the practical use of photocatalytic paints. Moreover, the potential for integrating photocatalytic activity with new technologies, such as 3D polymer blends, has not been fully explored. Future studies should focus on improving the durability of TiO_2 coatings while also expanding their application in environmental remediation, particularly in reducing atmospheric pollutants (Park et al., 2013). By leveraging simple, scalable methods, the development of innovative, photocatalytic paints could significantly contribute to sustainable building practices.

2. Literature Review

Several studies have been conducted to modify TiO_2 semiconductors to enhance their photocatalytic performance, especially in environmental and energy applications (**Table 1**). These modifications aim to address TiO_2's limitations, such as its low visible light response and poor UV stability.

Table 1. Summary of TiO_2 semiconductor modifications, methods, and results

Materials	Modification Method	Results	Reference
Recent developments in TiO_2 as n- and p-type transparent semiconductors	Doping for p-type semiconductivity	Enhanced transparency and conductivity for energy applications	Anitha et al., 2015
Inorganic-modified TiO_2 nanotube arrays	Non-metal, metal, and semiconductor modifications	Improved photocatalytic degradation of organic dyes	Wang et al., 2014
Modification of TiO_2 nanowires with GaOxNy	GaOxNy core-shell modification	Significant enhancement in photoelectrochemical performance	Tao et al., 2020
Surface modification of TiO_2 photocatalyst for environmental applications	Metal-loading, impurity doping, polymer coating	Enhanced visible light activity and modified reaction kinetics	Park et al., 2013
A Review on Metal Ions Modified TiO_2	Metal ions doping	Improved photocatalytic efficiency under visible light	Jiang et al., 2021

Research by Anitha et al. (2015) focused on doping TiO_2 to develop a p-type semiconductor, which naturally exhibits n-type behavior. This modification improved transparency and conductivity, making TiO_2 more effective for transparent electronics and energy devices, such as UV-based solar cells (Anitha et al., 2015).

Similarly, Wang et al. (2014) investigated the modification of TiO_2 nanotubes with non-metals, metals, and other semiconductors. Their results showed significant improvements in the photocatalytic degradation of organic pollutants, particularly in water treatment. These modifications enhanced the chemical and mechanical stability of TiO_2, making it more suitable for environmental remediation applications (Wang et al., 2014).

Tao et al. (2020) introduced GaOxNy as a core-shell coating on TiO_2 nanowires, leading to a remarkable improvement in photoelectrochemical performance. The core-shell structure enhanced the absorption of visible light and significantly increased photocurrent density, offering a promising solution for improving the efficiency of solar energy devices (Tao et al., 2020).

Park et al. (2013) focused on surface modification of TiO_2 through metal loading, impurity doping, and polymer coating. These modifications enhanced TiO_2's activity under visible light by accelerating charge transfer processes, making the material more effective in environmental applications, particularly for pollutant degradation in visible light (Park et al., 2013). Finally, Jiang et al. (2021) reviewed the effects of metal ion doping on TiO_2, which improved its photocatalytic efficiency under visible light. The study showed that doping reduces electron-hole recombination rates, enhancing TiO_2's effectiveness in industrial wastewater treatment (Jiang et al., 2021).

Conclusion

These studies demonstrate that modifying TiO_2 can significantly improve its photocatalytic properties, making it more effective for environmental and energy applications. The methods of doping, surface modification, and the creation of core-shell structures have proven to enhance TiO_2's efficiency under visible light, addressing its traditional limitations. These advancements are essential for expanding the use of TiO_2 in sustainable technologies, such as water purification and solar energy conversion.

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