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Utilization of TiO2 Nanoparicles for Methylene Blue Degradation

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Abstract

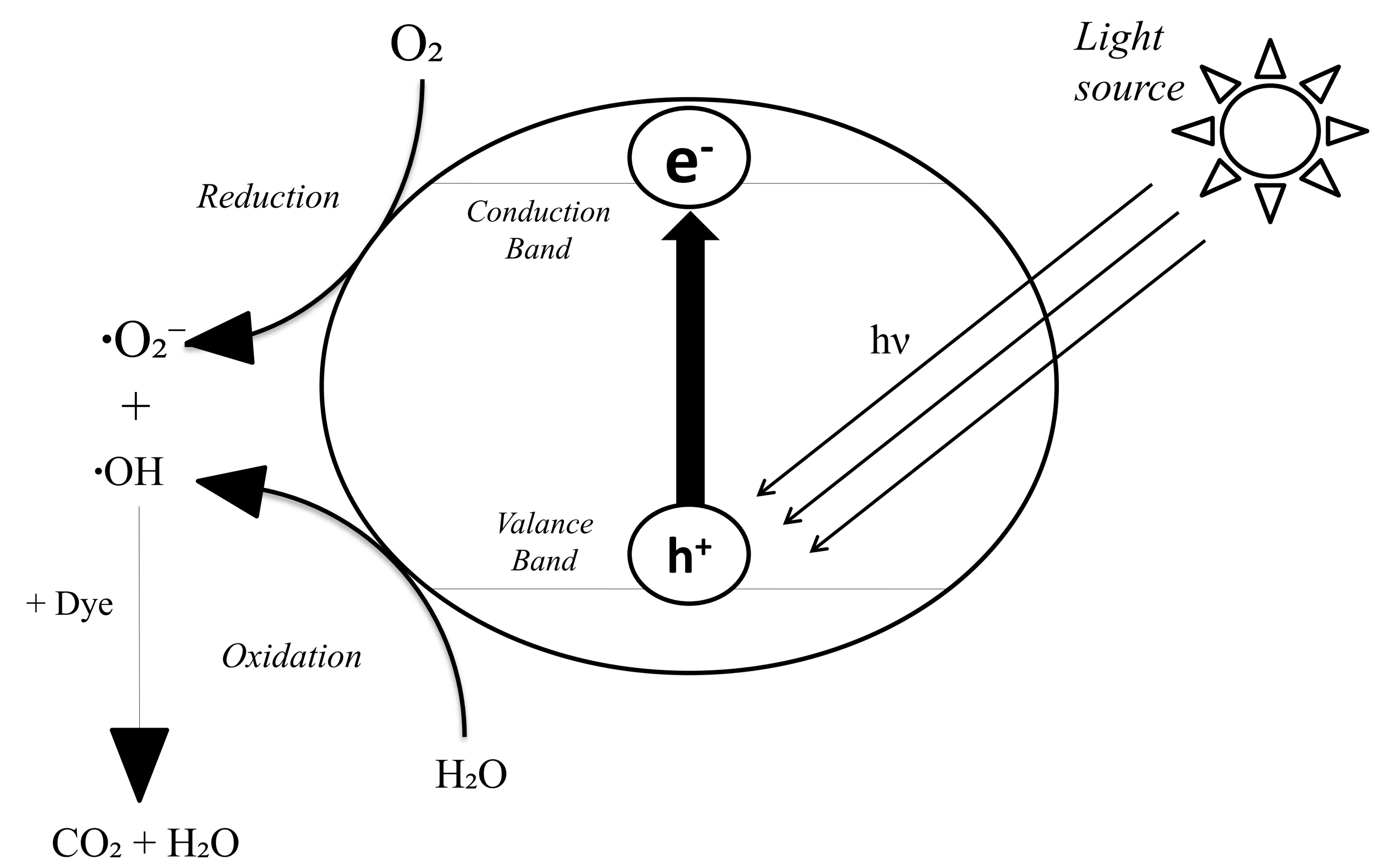
Nanoparticles (NPs) of titanium dioxide (TiO_2) have attracted a lot of attention as a potential photocatalyst for the degradation of pollutants, especially synthetic dyes like methyl orange, rhodamine B, and methylene blue (MB). Understanding the applicability of TiO_2 nanoparticles in MB degradation requires emphasizing their unique physicochemical qualities, such as their large surface area, substantial oxidative potential, and outstanding chemical stability. The formation of reactive oxygen species (ROS) via photoinduced synthesis of electron-hole pairs under ultraviolet (UV) light irradiation is the central focus of a thorough investigation of the photocatalytic process of TiO_2. Through redox processes started by these electron-hole pairs exposed to solar light, TiO_2 aids in the breakdown of MB into less harmful byproducts in wastewater treatment. The important variables influencing photocatalytic performance are particle size, crystal phase (anatase, rutile, and brookite), surface modifications, and the addition of metal or non-metal dopants to enhance visible light absorption. The electron hole pair separation make TiO_2 NPs feasible for photocatalysis, and this is possible for their large band gap which was not in their bulk form. In the nano form, they have the electrons number same as their bulk form but a large band gap at the semiconductor level. The main objective of this study is to fill knowledge gaps on TiO_2-based photocatalysis for MB degradation and suggest improvements to make these systems better for future wastewater treatment that is both efficient and sustainable.

Introduction

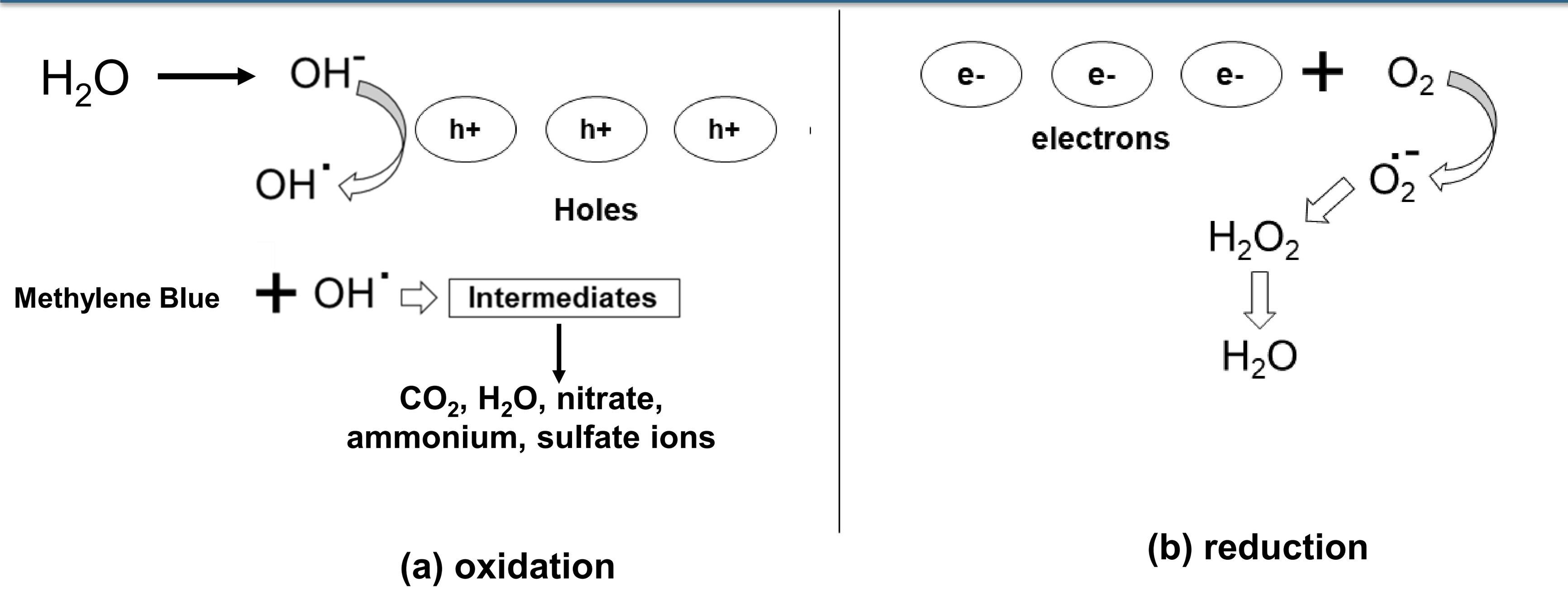
Access to clean water and sanitation is one of the most important problems affecting people over the world, even in regions traditionally considered water-rich. New research is done in methods of purifying water at lower cost and minimizing the use of chemicals. Additionally, to traditional compounds such as heavy metals, new emerging micropollutants (endocrine disrupters, pesticides, pharmaceutical products, etc.) are present in the aquatic environment and their toxic, persistent and bio accumulative properties may have chronic direct or indirect effects on ecosystems and on human health. This poster explores photocatalysis mechanism ,synthesis method and some key factors.

Mechanism

1. **Light Absorption**: TiO_2 (bandgap: 3.2 eV for anatase) absorbs UV light, exciting electrons (e^-) from the valence band (VB) to the conduction band (CB), leaving holes (h^+).
2. **Radical Formation**:
    1. h^+ reacts with H_2O to produce hydroxyl radicals (·OH).
    2. e^- reduces O_2 to superoxide radicals ($O_2^{\cdot -}$).
3. **Dye Degradation**: Reactive radicals mineralize dyes into CO_2, H_2O, and inorganic ions.



Electrons Can Participate in Reduction, Holes Can Participate in Oxidation



Electrons can convert O_2 in superoxide anion radical, holes convert H_2O to hydroxyl radical

Parameters

Parameters	Effect	
Particle size	Size	Reaction
Crystal Phase	Anatase	Photocatalytic Activity Maximum
Surface	Surface Area	Absorption of Solar Energy

Active Sites and Recombination Rates are Important

Smaller particles → larger surface area
→ more active sites
→ higher reaction likelihood

small size particle → easy for photo for electron/hole pair
→ reduced recombination
→ enhanced photocatalytic activity

TiO_2 nanoparticle's holes serve as effective oxidizing agents in the valence band, while electrons function as proficient reducing agents in the same band, exhibiting distinct redox potentials for both holes and electrons. 1.0–3.5 V for hole and 0.5 to 1.5 V for electron, respectively, relative to the typical hydrogen electrode. An excellent photocatalyst should possess a broad band gap and little electron recombination.

Strategies to overcome Challenges

Doping:
1. C,N,S are used to dope catalyst
2. Facilitate the charge carriers to the surface of the catalyst

Heterostructure:
1. RGO-TiO_2-x nanocomposite enhanced photocatalytic activity

CONCLUSION

TiO_2 catalyst is widely used in degradation of dyes. But doped photocatalyst is more useful for this degradation. We enhance photocatalysis rate through many ways. Strategy for e-/h+ separation based on chemical bond structure opened a new approach to enhanced photocatalytic degradation of organic pollutants.

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