ORIGINAL RESEARCH PAPER Volume - 12 | Issue - 09 | September - 2023 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

SMART TEXTILES WITH PHOTOCATALYTIC SELF-CLEANING POLYMERS USED IN VARIOUS FIELDS

Textile Design

Prathiba Meganathan Assistant Professor, Department of Textiles and Apparel Design, Periyar University, Salem-11

Lakshmi Manokari Selvaraj* Professor, Department of Textiles and Apparel Design, Periyar University, Salem-11 *Corresponding Author

ABSTRACT

Photocatalytic materials have emerged as key components in advancing next-generation technologies, owing to their ability to harness light energy and catalyse various chemical processes. Photo catalyst, a promising solar energy technology, harnesses light energy to catalyst chemical reactions and holds immense potential for solving various self-cleaning, textile waste water, environmental challenges and renewable energy generation. The photocatalytic process involves the activation of a semiconductor surface through solar light irradiation, initiating an oxidation/reduction reaction through photoelectron and hole excitation. This mechanism utilizes visible light absorption, continuous energy or charge transfer, and the presence of organic, metallic, metal, or organic promoters to accelerate the oxidation process within a photo catalytic system, two primary reactions occur, leading to the generation of oxidizing agents. The first reaction involves the oxidation of adsorbed H2O, predominantly generated by photo induced electron holes. The second reaction involves the reduction of an electron acceptor, created by photo induced electrons and produce hydroxyl radicals and superoxide anion radicals. Photocatalytic facilitated by photoactive catalysts, utilizes visible light, often from sunlight, to initiate chemical transformations. Self-cleaning properties of photo catalysts enable the degradation of organic pollutants through exposure to sunlight or UV light radiation This abstract presents a comprehensive overview of the methods employed in designing and optimizing photocatalytic self-cleaning textile materials, as well as their diverse applications in various fields.

KEYWORDS

Photocatalytic, textile, application, self-cleaning, polymer, pollutant

INTRODUCTION

In the pursuit of sustainable and environmentally friendly technologies, the exploration of advanced materials has emerged as a cornerstone of innovation. Among these materials, photocatalysts have garnered significant attention for their ability to harness light energy to drive chemical reactions, thus offering versatile solutions across a spectrum of applications[8] As researchers continue to push the boundaries of materials science, the integration of polymers with photocatalytic materials has unlocked new dimensions of functionality and efficiency, propelling the field towards next-generation advancements[5]

Photocatalysis, at its core, harnesses the extraordinary power of light-matter interactions to initiate chemical transformations[1]Utilizing semiconductor materials, such as titanium dioxide (TiO2) and zinc oxide (ZnO), photocatalytic processes have demonstrated remarkable potential in diverse fields, including environmental remediation, energy conversion, and sustainable synthesis[7]. Traditional photocatalytic materials, while efficient, often faced challenges related to stability, dispersibility, and targeted application. The strategic incorporation of polymers addresses these limitations, ushering in a new era of tailored and multifunctional photocatalytic systems. Polymers[2] with their diverse array of structures, tunable properties, and exceptional compatibility with various substrates, provide an ideal platform for enhancing and expanding the applications of photo catalysis. Through innovative design and engineering, polymers can serve as scaffolds, coatings, and functional groups that not only stabilize photocatalytic nanoparticles but also confer specific attributes to the composite material. The synergy between polymers and photocatalytic materials yields enhanced photocatalytic activity, prolonged lifetimes, and improved selectivity, thus unlocking opportunities for advanced materials in fields such as water purification, air quality control, self-cleaning surfaces, and renewable energy generation. The photocatalytic materials, focusing on the transformative role of polymers in shaping the landscape of next-generation applications. The principles of photo catalysis, the unique attributes of polymers, and their combined potential, we illuminate the path towards sustainable technological breakthroughs. The discussion spans diverse domains, showcasing polymer-modified photocatalytic systems across environmental, industrial, and biomedical sectors. Through comprehensive exploration and analysis, this review aims to inspire researchers, engineers, and innovators to harness the power of polymer-integrated photocatalytic materials for a more sustainable and prosperous future.

Self-cleaning In Textiles

Self-cleaning textiles, also known as "smart textiles" or "self-cleaning fabrics," refer to innovative textile materials that possess the ability to clean themselves by repelling dirt, stains, and other contaminants[12] .These textiles are designed to maintain their appearance and functionality over an extended period without requiring frequent cleaning or maintenance[11]. The concept of self-cleaning textiles has gained significant attention due to its potential to improve convenience, reduce water and energy consumption, and contribute to sustainability efforts.

Principles Of Self-cleaning Textiles

Self-cleaning textiles are often inspired by natural phenomena, such as the lotus leaf effect (super hydrophobicity) and photo catalysis. These principles are harnessed to create textiles that repel water, resist staining, and degrade organic matter. Many self-cleaning textiles utilize super hydrophobic coatings, which mimic the lotus leaf's ability to repel water. These coatings create a rough surface structure that traps air and prevents water or liquids from fully wetting the fabric. As a result, liquids roll off the surface, carrying away dirt and stains with them. Some self-cleaning textiles incorporate photocatalytic nanoparticles, such as titanium dioxide (TiO2). When exposed to light, these nanoparticles produce reactive oxygen species that break down organic compounds and pollutants, contributing to the degradation of stains and odour on the fabric.Smart textiles integrated with photocatalytic materials represent a cutting-edge intersection of textiles and advanced functional materials. These textiles are designed to have unique properties that combine the benefits of both materials, opening up exciting possibilities in various fields.

Photo Catalytic In Smart Textiles

Photo catalytic coatings or nanoparticles can be applied to textiles to create self-cleaning fabrics. These textiles can break down organic contaminants, such as dirt, stains, and even bacteria, when exposed to light. As a result, clothes made from these materials stay cleaner for longer periods, reducing the need for frequent washing and contributing to sustainability

Self-Cleaning Fabrics

 PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

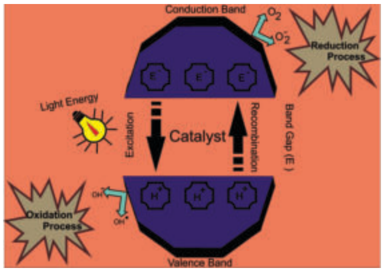
Air Purifying Textiles
Smart textiles embedded with photocatalytic nanoparticles can help purify the air around the wearer. These textiles can capture and degrade airborne pollutants, allergens, and odours when exposed to sunlight[13]. They find applications in clothing for individuals with respiratory conditions or for use in environments with poor air quality.

UV Protection and Skin Health
Photocatalytic textiles can provide enhanced ultraviolet (UV) protection by absorbing and degrading harmful UV radiation. This can contribute to preventing skin damage and reducing the risk of UV-related health issues. Such textiles are particularly valuable in outdoor clothing and accessories.

Water Purification Textiles
Photocatalytic textiles can be used for water purification applications[5].When exposed to sunlight, these textiles can help break down pollutants and contaminants in water, making it safer for consumption. They can be used in water filtration systems, outdoor gear, or even as part of clothing for outdoor enthusiasts.

Photovoltaic Textiles
The photocatalytic, some smart textiles combine light-absorbing and energy-generating properties[6] Photovoltaic textiles can harvest solar energy through integrated solar cells or other energy-converting mechanisms, potentially powering wearable devices or storing energy for later use[8]

Antimicrobial Textiles
Photocatalytic coatings can be used to create textiles with antimicrobial properties. These textiles can help inhibit the growth of bacteria and other microorganisms, leading to improved hygiene and reduced odor in clothing and healthcare products[5].Photocatalytic materials can also be applied to textiles for artistic or design purposes. Textiles with color-changing or luminescent properties can be created, responding to light exposure and enabling unique visual effects. The integration of photocatalytic materials into smart textiles opens up exciting possibilities for enhancing everyday fabrics with functional and environmentally friendly properties[6] These textiles not only provide improved performance and functionality but also contribute to sustainability and the development of innovative solutions for a range of application.



Photocatalytic Process

Photo Catalytic Mechanism
The photocatalytic process involves the use of photo catalysts to accelerate chemical reactions using light energy[10]. It is a green and sustainable technology with applications ranging from environmental remediation to energy generation light absorption works in photo catalyst absorbs photons of specific energies, triggering the formation of electron-hole pairs[12].The generated electron-hole pairs are separated, and the photo generated electrons and holes move to the catalyst's surface The surface-bound electrons and holes participate in redox reactions with target pollutants or reactant molecules. After the reactions, the catalyst reverts to its original state, ready for subsequent cycles

Key Factors Affecting Photo Catalyst
Photo catalyst material is a semiconductor material influences the absorption of light and the efficiency of charge separation. Different materials are suitable for specific applications. The band gap energy determines the wavelength of light that a photo catalyst can absorb. Proper band gap matching is crucial for efficient absorption and charge generation. A higher surface area allows more active sites for reactions to occur, enhancing the overall photo catalytic activity. Co-catalysts can be introduced to enhance charge separation and facilitate specific reactions, further improving efficiency. The type and intensity of the light source (UV, visible, or solar light) influence the photo catalytic efficiency and applicability. Factors such as pH, temperature, and the presence of other substances in the environment can influence the photo catalytic reactions.

Methods Of Polymer Used In Polymer
Polymer materials are not typically used as photo catalysts themselves, but they can play a role in enhancing or supporting photo catalytic processes. Photo catalysis is a process in which a catalyst, typically a semiconductor material, uses light energy to initiate chemical reactions. Polymers can be used in various ways in photo catalytic applications. Polymers can be used as a support material for immobilizing or anchoring photo catalytic nanoparticles (e.g., TiO_2, ZnO) onto their surfaces. This helps to prevent aggregation of nanoparticles and provides stability, making the catalyst more practical for applications. Polymeric Matrices Photo catalytic nanoparticles can be embedded within polymer matrices to create composite materials. These composites can exhibit enhanced photo catalytic activity, improved dispensability, and mechanical properties, making them suitable for various applications. Polymers can be used to form thin films or coatings that encapsulate photo catalytic materials. These coatings can protect the photo catalyst from environmental factors, control the release of reactants/products, and offer tailored surface properties. Polymers can be incorporated into membranes used in photo catalytic water treatment applications. These membranes can help in separating and concentrating reactants/products while allowing efficient light penetration for the photo catalytic process[13]Polymers with specific functional groups can be attached to the surface of photo catalysts to improve their selectivity, stability, or binding properties for specific reactions. Polymers can be used as templates for the synthesis of nanostructured photo catalysts, helping to control the size, shape, and distribution of nanoparticles. The combination of polymers and photo catalytic materials allows for the design of innovative materials and applications in various fields, such as environmental remediation, water purification, self-cleaning surfaces, and energy conversion.

Titanium Dioxide (TiO_2) is polymers such as acrylic polymers, silicone polymers, polyurethane (PU) polymers, and fluoro polymers can be used as coatings in combination with TiO_2 photo catalysts. These polymers provide protection to the photo catalyst and enhance the durability of the self-cleaning effect. Carbon Nitride (g-C_3N_4) is polymeric carbon nitride (g-C_3N_4) itself is a photo catalyst for self-cleaning applications. It is a polymerized form of melamine, which can be synthesized and applied directly as a coating on various substrates. The g-C_3N_4 coating exhibits excellent photo catalytic activity and can decompose organic contaminants under visible light. Poly aniline (PANI) is a conductive polymer that can be used in combination with photo catalysts like TiO_2 or g-C_3N_4.PANI coatings can improve the charge separation and electron transfer efficiency of the photo catalyst, enhancing the overall photo catalytic activity and self-cleaning performance[13] Polypyrrole (PPy) is another conductive polymer that can be used as a coating material with photo catalysts. When combined with TiO_2 or g-C_3N_4, PPy coatings can enhance the photo catalytic performance and provide stability to the photo catalyst under prolonged exposure to light and environmental conditions.

PEDOT- is a conductive polymer that can be utilized in self-cleaning applications. It can be used as a coating material with TiO_2 or other photo catalysts to improve their charge transfer properties and overall performance. PEDOT coatings can enhance the photo catalytic activity and stability of the photo catalyst. Zinc Oxide is a photo catalyst that can be combined with various polymers for self-cleaning applications. Polymers such as acrylics, polyurethanes, or silicone polymers can be used as coatings to protect and stabilize the ZnO photo catalyst, improving its self-cleaning efficiency.

Application Of Polymer In Photo Catalysts

Photo catalysts play a crucial role in addressing environmental challenges, such as air and water pollution. Their application in air purification can effectively degrade harmful pollutants, while in water treatment; they offer promising solutions for the removal of organic contaminants, heavy metals, and microorganisms. Photocatalytic materials are instrumental in harnessing solar energy for sustainable energy generation. Their role in photocatalytic water splitting to produce hydrogen gas and CO2 reduction for converting carbon dioxide into valuable fuels highlights their potential in advancing renewable energy technologies. The use of photo catalysis in green chemistry, where photocatalytic materials offer an environmentally friendly and energy-efficient route for synthesizing complex molecules and high-value chemicals. Photocatalytic coatings on building materials can enable self-cleaning properties, as they can decompose organic matter and pollutants when exposed to sunlight, leading to reduced maintenance and improved durability.

Photocatalytic materials find applications in sustainable building design, where they can contribute to indoor air purification and energy-efficient lighting through photocatalytic reactions. Photocatalytic materials are substances that can use light energy to drive chemical reactions, such as water splitting, pollutant degradation, organic synthesis. They are usually semiconductors with suitable band gaps that can generate electron-hole pairs. when irradiated by light photocatalytic materials are PANI,TiO2,ZnO,Fe2O3,BiVO4,PPy Photocatalytic materials have many potential applications in various fields, such as environmental remediation, energy conversion, biotechnology, nanotechnology, photocatalytic materials can be used to degrade organic pollutants in water or air, produce hydrogen or oxygen from water splitting, synthesize valuable chemicals from CO2 or N2 reduction, enhance the performance of solar cells or batteries, modify the surface properties of biomaterials or nanomaterial.

CONCLUSION

In conclusion, the fusion of smart textiles with photocatalytic self-cleaning polymers represents a remarkable convergence of innovation, where the worlds of advanced materials and functional textiles intertwine to revolutionize various fields. These textiles not only possess the intrinsic qualities of conventional textiles, such as comfort, flexibility, and aesthetics, but they also introduce a range of novel attributes that amplify their utility. This dynamic combination opens the door to a multitude of applications, each characterized by enhanced performance, sustainability, and a reimagining of traditional norms. By incorporating principles from nature and advanced materials science, self-cleaning textiles have the potential to revolutionize the way we interact with and care for textile products, contributing to a more sustainable and convenient future.

REFERENCES

[1] Al-Nuaim, M. A., Alwasiti, A. A., & Shnain, Z. Y. (2022). The photocatalytic process in the treatment of polluted water. Chemical Papers.
[2] Banerjee, S., Dionysiou, D. D., & Pillai, S. C. (2015). Self-cleaning applications of TiO2 by photo-induced hydrophilicity and photocatalysis. Applied Catalysis B: Environmental, 176-177, 396–428.
[3] Baudys, M., Krýsa, J., & Mills, A. (2017). Smart inks as photocatalytic activity indicators of self-cleaning paints. Catalysis Today, 280, 8–13.
[4] Fan, Yunde, et al. “Photocatalysis and Self-Cleaning from G-C3N4 Coated Cotton Fabrics under Sunlight Irradiation.” Chemical Physics Letters, vol. 699, May 2018, pp. 146–154.
[5] Fan, Yunde, et al. “Photocatalysis and Self-Cleaning from G-C3N4 Coated Cotton Fabrics under Sunlight Irradiation.” Chemical Physics Letters, vol. 699, May 2018, pp. 146–154.
[6] He, F., Jeon, W., & Choi, W. (2021). Photocatalytic air purification mimicking the self-cleaning process of the atmosphere. Nature Communications, 12(1), 2528.
[7] Hunge, Y. M., Yadav, A. A., Kang, S.W., & Mohite, B. M. (2022). Role of Nanotechnology in Photocatalysis Application. Recent Patents on Nanotechnology, Organic Coatings, 128, 52–58.
[8] Kaihong Qi, Xiaowen Wang, & Xin, J. H. (2010). Photocatalytic self-cleaning textiles based on nanocrystalline titanium dioxide. Textile Research Journal, 81(1), 101–110.
[9] Kale, B. M., Wiener, J., Rwawiire, S., & Militký, J. (2016). Development of Photocatalytic Self-Cleaning Cotton Fabric. Materials Science Forum, 866, 171–175.
[10] Khan, A., Huang, K., Sarwar, M. G., Cheng, K., Li, Z., Tuhin, M. O., & Rabnawaz, M. (2020). Self-healing and self-cleaning clear coating. Journal of Colloid and Interface Science, 577, 311–318.