UNIVERSITI TEKNOLOGI MARA

HETEROJUNCTION EFFECT FOR PHOTOCATALYTIC ENHANCEMENT AND ELECTROCHEMICAL STUDY OF g-C_3N_4/TiO_2 NANOPARTICLES FOR RR4 DYE

NUR AIEN BINTI MUHAMAD

MSc

December 2025

ABSTRACT

Titanium dioxide (TiCh) is widely recognized as a promising photocatalyst due to its strong oxidizing power, chemical stability, and low cost; however, its wide band gap (3.2 eV) and rapid electron-hole recombination restrict its photocatalytic activity under visible light. To address these limitations, graphitic carbon nitride (g-C3N4), a visible-light-responsive and metal-free semiconductor, was coupled with TiChto form a heteroj unction composite with enhanced charge separation efficiency. This study aims to synthesize g-CsNVTiCh composite catalysts via an in-situ sol-gel hydrothermal method using titanium butoxide and urea as precursors for improved heteroj unction formation, to elucidate their physicochemical and optoelectronic properties, and to evaluate their photocatalytic efficiency for the degradation of Reactive Red 4 (RR4) dye and recyclability. The g-C3NVTi02 composite (denoted as TCN) was successfully synthesized, with TCN5 (5 wt% g-C3N4) exhibiting the highest photocatalytic performance. Under 55 W visible-light irradiation, TCN5 achieved a degradation efficiency of 99.73% and an apparent rate constant (k) of 0.0920 min"^{1} for 30 mg L"^{1} RR4 dye. Structural and compositional analyses (FESEM-EDX, FTIR, XRD, and XPS) confirmed the successful incorporation of g-C_3N_4 into the Ti02 matrix. Optical analyses using UV-Vis DRS and PL revealed a narrowed band gap energy of 3.07 eV and reduced PL intensity, indicating suppressed electron-hole recombination. Electrochemical analyses further demonstrated enhanced charge transport, with a conductivity of 2.8 x 10"^{3} Q and a photocurrent density of 3.5 x 10"^{6} A/cm^{2}. Mott-Schottky plots identified conduction band positions of -0.45 eV for Ti02 and -0.61 eV for g-C3N4, confirming the formation of a type-II heteroj unction. The recyclability test revealed excellent durability of the in-situ synthesized TCN5, maintaining 73.94% degradation efficiency after eight cycles, outperforming the batchwise-prepared sample. Overall, the in-situ sol-gel hydrothermal synthesis effectively enhanced interfacial charge transfer, photocatalytic activity, and material stability, demonstrating the potential of g-C3N4/Ti02heterojunctions for environmental remediation applications.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful,

All praise be to Allah. I am grateful to Allah SWT, who has blessed me with the opportunity to successfully complete my master's thesis titled "Heterojunction Effect for Photocatalytic Enhancement and Electrochemical Study of g-CsNVTiCh Nanoparticle." This thesis was completed for the Faculty of Applied Science at Universiti Teknologi MARA (UiTM).

I would like to extend my sincere gratitude to my primary supervisor, Associate Prof. Dr. Wan Izhan Nawawi Wan Ismail, for his invaluable guidance throughout the research and thesis writing process. I also wish to thank my co-supervisors, Professor Ts. Dr. Mohd Azlan Mohd Ishak from Universiti Teknologi MARA (UiTM) Pedis and ChM. Dr. Sumiyyah Sabar, Universiti Sains Malaysia, Pulau Pinang.

My appreciation goes to the lecturers and staff members from the Faculty of Applied Science at Universiti Teknologi MARA (UiTM) Perlis, the School of Physics at Universiti Sains Malaysia, Pulau Pinang, and the Faculty of Science and Technology at Universiti Kebangsaan Malaysia (UKM), Bangi. Their cooperation, valuable insights, suggestions, and guidance were instrumental in the completion of my master's thesis, especially concerning the research aspects.

I extend my deepest gratitude and appreciation to my parents, Muhamad Mat Chik and , my sibling, Muhammad Amier Muhamad, my family, close friends, and others who have supported me, provided encouragement, offered constructive suggestions, and shown unwavering support throughout the research journey, from inception to completion. Additionally, I am thankful to all my friends and everyone who contributed by supporting my work and assisting me during the entirety of my master's degree research until its successful conclusion.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

In the past several years, the textile industry has seen significant growth and expansion, supported by the expanding global demand for textiles and apparel. Consumer interest in various clothes, home textiles, and industrial fabrics has prompted textile makers to increase production capacity and implement novel technologies (Bhogal & Govind, 2021). Based on the country of India, the textile sector is among the most significant industries, accounting for approximately 14% of the overall industrial production (Christian et al., 2023).

However, concerns have been raised within these sectors due to the discharge of wastewater. For many countries, especially those that manufacture textiles, the growing concerns about environmental sustainability and wastewater treatment have become major challenges. Textiles and other dye-intensive industries have made the issues even worse, despite being essential to the economies of many nations worldwide. As a result, this industry is today dealing with a severe and critical challenge. The textile industry produces a notable volume of wastewater as a consequence of the water and chemicals employed in its manufacturing processes, as noted by (Y. Zhang et al., 2021). In 2017, nearly 700,000 tons of harmful dyeing wastewater were generated, of which approximately 200,000 tons were disposed of without treatment. Additionally, (Solayman et al., 2023) states that dye wastewater is predominantly generated by the textile, printing, paper, food processing, and tannery industries. Globally, an annual production of 800,000 tons of dyes occurs, with textile dyes accounting for roughly 200,000 tons of this total.

Textile production generates wastewater containing harmful dyes and pollutants. Discharging this wastewater into natural water bodies poses a significant environmental threat. The presence of dyes and organic pollutants leads to water source contamination. This contamination harms aquatic life and disrupts ecosystems. Elevated levels of