UNIVERSITI TEKNOLOGI MARA

OPTIMIZATION OF PHOTOCATALYST ZNO AND CU INTEGRATED ZNO NANOFLOWER STRUCTURE BY ANODIZATION AND ELECTRODEPOSITION AS ANTIBACTERIAL AGENT AGAINST BIOFILMS

NUR SYUHADA BINTI MOHD HAEIZAR

Thesis submitted in fulfilment
of the requirements for the degree of
Master of Science
(Material Science and Technology)

Faculty of Applied Sciences

April 2024

ABSTRACT

Biofilms are resilient bacterial communities posing significant health challenges. The integration of nanomaterials offers a promising way for combating bacterial biofilms. Metal oxide nanoparticles (NPs) and their nanocomposites have exhibited remarkable antimicrobial properties. This study explores the development of Cu-doped ZnO nanoflowers (Cu/ZnO NFs) as a promising strategy to combat bacterial biofilms. The aimed is to optimize the synthesis parameters of ZnO NFs using electrochemical anodization and investigate the effect of Cu nanoparticle (NPs) incorporation via electrodeposition on their photocatalytic and antibacterial properties. ZnO NFs were synthesized using different electrolyte concentrations, anodization times, and applied potentials. Cu NPs were then incorporated by varying the copper nitrate concentration and deposition time to control the density of Cu NPs coverage onto the surface of ZnO NFs. X-ray diffraction (XRD), Field-Emission Scanning Electron Microscope (FESEM) and Diffuse Reflectance Spectra (DRS) characterized the structure, morphology, and optical properties. Antibacterial activity against various bacterial strains was assessed through disc diffusion and semi quantitative adherence assay. The optimal ZnO NFs were obtained using a 50 mM sodium bicarbonate solution, 10 minutes anodization for 10 V, exhibiting uniform morphology, high crystallinity, and a low band gap. Cu/ZnO NFs with Cu NPs deposited at 6 mM copper nitrate for 120 seconds showed enhanced light absorption in the visible range and potentially reduced electron-hole recombination. Both ZnO NFs and Cu/ZnO NFs displayed good antibacterial activity, particularly against initial biofilm formation, likely through reactive oxygen species (ROS) generation.

ACKNOWLEDGEMENT

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

First and foremost, I would like to express my utmost appreciation to my supervisor, Ts. Dr. Nur Aimi Jani for her continuous advice, encouragement, guidance, and excellent supervision throughout this research journey. Her constant encouragement has helped me acquire and develop some of the skills and intricacies of good independent research. My extended appreciation also to my co-supervisor, Dr. Annie Maria Mahat for her undivided support and valuable contributions. Also, many thanks to Dr. Mohd Taufiq Mat Jalil for his direct contribution to this research. It has been a great honor for me to collaborate with both during these wonderful years.

My special gratitude to my beloved parents, Mohd Haeizar Zainon Hamzah, and for their encouragement, understanding, patience and unwavering faith in me throughout this journey. To my dearest siblings, Nur Syafiqa Adrina Mohd Haeizar, Adrin Shahira Mohd Haeizar and Intan Syakila Mohd Haeizar, I am thankful for your constant support and advice during this journey.

I would like to express my heartfelt gratitude to my dear friends, Hasnatul Fitriah Abd Rahim, Nur Asyiqin Azman and Mohd Hafiz Md Ali, who have always stood around me whenever I need help and encouragement. They are my source of strength to face the twists and turns of challenges throughout this study.

Lastly, I would like to thank Universiti Teknologi MARA for granting me the opportunity to pursue my studies and for providing the GIP grant that have supported me along this journey.

Nur Syuhada Mohd Haeizar

June 2023

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Research Background

The increase in utilization of medical implants and devices such as dental implant (Minkiewicz-Zochniak et al., 2021), catheter and prosthetic valve (Khatoon et al., 2018), has led to notable increase in device-related infections, accounting for approximately 60% to 70% of infections acquired in hospital (Pietrocola et al., 2022; Yadav et al., 2019). Hence these device-related infections had become a huge problem in medical settings. The capacity of microbes to form biofilms on implanted devices plays a key role in the malfunction of numerous clinical apparatuses, ultimately giving rise to infectious diseases and many medical complications (Yadav et al., 2019).

Biofilms represent a diverse and resilient form of bacteria, characterized by the presence of microbial communities embedded within an extracellular matrix. The process of biofilm formation in a bacteria believed to occur in four primary phases. During the first phase, the initial adherence of bacterial cells to a surface followed by the development of microcolony during the second phase and biofilm maturation in third phase. In the final phase of biofilm formation, the bacterial cells eventually separate from the biofilm in order to locate a new host (Banerjee et al., 2020). Biofilm formation enable the bacteria to survive in adverse conditions including physical, chemical, and biological factors. Furthermore, biofilm serves as a protective shield from the host immune system and antibiotic treatment. These biofilms present a significant challenge due to their stability and resistance, making their elimination difficult.

Conventional approaches for biofilm eradication have not been successful, further complicated by the growing problem of antibiotic resistance. As a result, there is a pressing need for new and effective methods to address this issue (Roy et al., 2018). Considering these challenges, the integration of nanomaterials offers a promising avenue for combating bacterial biofilms. Metal oxide nanoparticles (NPs) and their nanocomposites have exhibited remarkable antimicrobial properties, positioning them as potential candidates for addressing this persistent problem (Shkodenko et al., 2020).