

UNIVERSITI TEKNOLOGI MARA

**GREEN SYNTHESIS OF GRAPHENE
OXIDE (GO) FROM WASTE TYRE
CARBON BLACK FOR
ANTIBACTERIAL
POLYPROPYLENE IN
HEALTHCARE**

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ABSTRACT

The synthesis of nanomaterials from waste resources has emerged as a promising approach to addressing global challenges of waste accumulation and pollution. Graphene oxide (GO), a widely researched nanomaterial, can be derived from carbon waste, offering a green and potentially cost-effective alternative to traditional production methods. However, the reliance on natural graphite as a raw material limits large-scale production due to its environmental impact and high extraction costs. This study investigates the synthesis of GO from recovered carbon black (rCB) derived from pyrolysed waste tyres. This research was conducted in three phases: (1) synthesis and optimization of GO from waste tyre-derived rCB using a modified Hummers' method, (2) evaluation of antibacterial properties of GO, (3) fabrication and enhancement of GO adhesion onto meltblown nonwoven polypropylene (PP) fabric via surface treatment, and (4) evaluation of thermal comfort and antibacterial activity of GO on the functionalized fabric. In this study, the modified Hummers' method was used to synthesize GO from waste tyre-derived recovered carbon black (rCB), optimizing key reaction parameters, including precursor amount (1-5 wt%), reaction time (60-180 min), and oxidant level. Results indicate that increasing reaction time and oxidant concentration enhance the oxidation degree of GO, with optimal conditions determined at 180 minutes and 5 g of KMnO_4 . Raman analysis revealed a reduction in the I_D/I_G ratio from 0.85 (rCB) to 0.76 for optimised GO, indicating effective removal of amorphous carbon and volatile residues and improved graphitic ordering. The optimised GO demonstrated notable antibacterial activity, producing an inhibition zone of 14.67 ± 0.47 mm against *Pseudomonas aeruginosa* at a concentration of 200 $\mu\text{g/mL}$. To enable textile application, GO was incorporated into meltblown nonwoven polypropylene (PP) fabric via immersion, supported by an alkaline-oxidative surface treatment combined with poly (vinyl alcohol) (PVA) to enhance adhesion and durability. The utilization of 9wt % NaOH, 0.02 vol. % H_2O_2 , and 3 wt. % PVA successfully improved the anchoring of GO nanoparticles to the fabric matrix. Key performance parameters, including air permeability, moisture management, water vapor permeability, water contact angle, and antibacterial activity, were evaluated before and after pretreatment of the PP fabric. The results demonstrate that the developed pretreatment of PP fabric, assisted with alkaline oxidation and PVA, provides the essential features required for optimal performance. This study highlights a green, potentially cost-effective approach to the synthesis of GO using new sources of carbon waste for functional healthcare textiles and aligns with the Sustainable Development Goals (SDGs).

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فَإِنَّ مَعَ الْعُسْرِ يُسْرًا

“So indeed, with hardship [will be] the ease (94: 5)”

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Graphene oxide (GO) is a functional graphene derivative and has emerged as a focus in advanced material research over the past decade due to its unique physicochemical properties and wide-ranging applications. It is also breaking into the global market, with the GO market value reaching approximately USD 237.69 million in 2024. It is projected to reach USD 8.86 billion by 2037, with an anticipated compound annual growth rate (CAGR) of around 32.1% over the forecast period (Research Nester, 2024). The growth of GO in the market was attributed to the rising demand in sectors like electric vehicle batteries, filtration systems, electronics, and biomedical technology, thus reflecting GO's use in technological innovation and expanding industrial applications (Khaliha et al., 2022; Wu et al., 2023).

GO is depicted as a layered carbon structure with oxygen-containing functional groups (=O, -OH, -O-, -COOH) attached to both sides of the layers and to the edges of the plane (Jiříčková et al., 2022). It offers unique properties, including a high surface area, excellent mechanical strength, and biocompatibility, making it an ideal candidate for various applications in materials science, electronics, and healthcare (Sindi, 2024). GO is a versatile material that can be functionalized with various chemicals and molecules, enhancing its applicability in multiple industries. Interestingly, GO exhibits antimicrobial properties that can be leveraged to combat bacterial infections, making it a promising material for healthcare-related textiles (Mohammed et al., 2020). GO can be synthesized by the oxidation of graphite into graphite oxide, followed by the exfoliation of this graphite oxide into GO.

Despite its versatility, large-scale production of GO typically relies on high-purity graphite, a non-renewable and costly precursor, thus hindering its wider implementation in materials science and technology (Silva et al., 2024). To unlock the full potential of graphene materials, many researchers have focused on developing an alternative material precursor for synthesizing graphene oxide, and because of this, scientists and researchers have started to find alternatives towards the development of new methods and precursors that exhibit low cost, sustainability, and environmental