



Improve the strength, heat resistance, and barrier performance of polyurethane by adding graphene oxide

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RESEARCH PROPOSAL

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Abstract

Polyurethane (PU) is one of those versatile materials that's everywhere from coatings and adhesives to flexible foams. It's strong, flexible, and easy to process, but it does have its limits. For example, it can struggle when exposed to high temperatures, abrasion, or moisture. Graphene oxide (GO) is a new player in material science that could help overcome these challenges. Its thin, layered structure and rich surface chemistry make it perfect for reinforcing polymers.

This project explores how the performance of a sail cloth with PU as matrix can be altered by adding GO as a filler. different GO concentrations, functionalization methods, and dispersion techniques will be tested during the experimental stage. The ultimate goal is to figure out the best combination that can be used in real-world applications while keeping the process scalable and reproducible.

Introduction & Background

Polyurethane (PU) is a segmented polymer, meaning it has "soft" and "hard" parts in its structure.

The way these segments separate affects how strong, flexible, and heat-resistant the polymer is. PUs is already very useful, but in extreme conditions like high heat, heavy wear, or humid environments they can start to fail.

Graphene Oxide (GO) offers an exciting solution. Its flat, sheet-like structure and chemical groups on its surface mean it can bond with the polymer and act like a nanoscale reinforcement. This can make PU stiffer, stronger, and more resistant to heat. GO sheets also create more complicated paths for gases and water to pass through, which helps improve barrier properties. And because it's so tough, it can help PU resist wear and abrasion.

That said, GO doesn't always mix well with PU. It likes to clump together, which can reduce its effectiveness. Past studies have also been inconsistent because different research groups used different GO qualities and processing methods. My project will take a careful, controlled approach to understand how GO type, functionalization, and processing methods affect PU properties.

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Please refer to high quality research paper.

Abbreviations should be identified at the first instance you mention in the document.

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POLYURETHANE REACTION

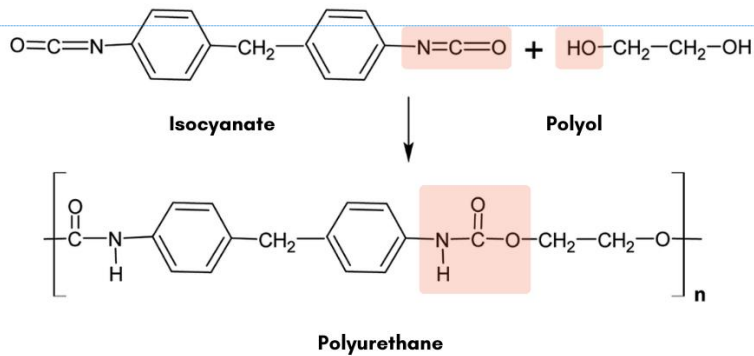


Figure 1: Poly urethane resin reaction
Source: Adapted from [1]

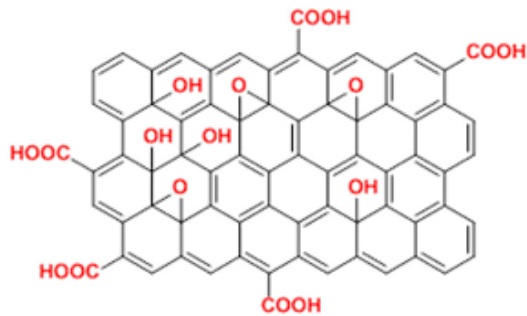


Figure 2: Graphene oxide structure
Source: Adapted from [2]

Problem Statement

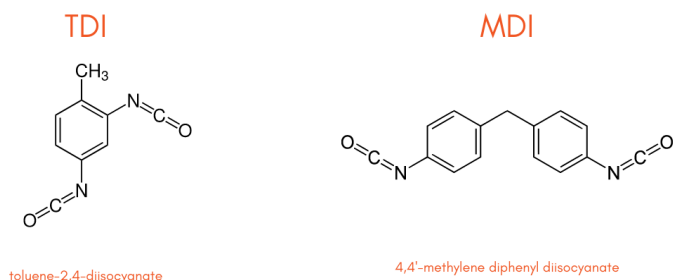
In the sail manufacturing process, we use carbon, aramid, ultra High Molecular Weight Polyethylene (UHMWPE), Polyester, and polypropylene mesh for reinforcement. The matrix is a polyurethane resin. It consists of polyol and isocyanate. There are two types of isocyanates, namely TDI and MDI.

Although PU is a versatile polymer, its thermal, mechanical, and barrier properties limit certain applications. Graphene oxide has the potential to improve these properties. By looking at how

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GO functionalization, dispersion, and interface engineering influence PU performance, this project aims to develop practical, high-performance PU–GO composites.



*Figure 1 Two types of Isocyanides, used to make polyurethane resin
Source: Adapted from [3]*

Objectives

Main Goal:

- To improve strength, heat resistance, and barrier performance of polyurethane by adding graphene oxide.

Specific Goals:

- Make PU/GO composites with different GO types and concentrations.
- Test mechanical properties like tensile strength, hardness, and toughness.
- Examine thermal stability and how the material degrades.
- Study the structure and interactions between PU and GO using microscopy and spectroscopy.

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Hypotheses

- Adding GO to PU will make it stronger and more durable.
- GO will help PU resist heat and delay degradation.
- There's a "sweet spot" for GO concentration—too little won't help, too much can cause clumping and reduce benefits.

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'Optimum GO concentration need to be identified to obtain the maximum properties for the product.'

Literature Overview

Research shows that GO can improve the performance of many polymers, including PU, if it's properly treated and dispersed. Functionalizing GO with chemical groups (amines, silanes, or isocyanates) improves its compatibility with the polymer and reduces clumping. Even small amounts of GO (<1%) can significantly improve strength, stiffness, and thermal stability without making the polymer hard to process.[1]

Barrier properties also benefit because GO sheets force water and gases to follow a more complicated path, slowing their movement. However, many studies only look at one variable at a time. There is a lack of systematic research comparing different GO types, functionalization methods, and dispersion techniques while considering PU's soft and hard segment morphology. This project addresses that gap by testing these factors together and analyzing their combined effect.[2]

Materials & Methods

Materials:

- ❖ Polyols (PTMEG or polyester)
- ❖ Diisocyanatos (MDI or TDI)
- ❖ Chain extenders (butanediol)
- ❖ Catalysts
- ❖ Graphene oxide (commercial or lab-made)
- ❖ Solvents: MEK, acetone
- ❖ Silane coupling agent.

GO Functionalization:

- ❖ Amines: Create strong bonds with PU
- ❖ Silanes: Improve dispersion in polyols
- ❖ Isocyanate grafting: Forms urethane/urea linkages with PU

Composite Preparation:

Two methods:

1. **Solution blending:** GO is mixed in solvent, sonicated, then added to PU.
2. **In situ polymerization:** GO is added during polymer formation to improve bonding.

Testing & Characterization:

- **Mechanical:** Tensile, hardness, impact, tear, abrasion
- **Thermal:** DSC, TGA, DMA
- **Barrier:** Water vapor and oxygen transmission, water uptake
- **Structure:** SEM, TEM, AFM, FTIR, XRD

Experimental Design:

A design-of-experiments approach will test the effects of GO type, loading, dispersion method, and curing conditions. Statistical methods like ANOVA and response surface methodology will help find the best combination.

Expected Outcomes

- PU composites with improved strength, stiffness, and toughness.
- Better heat resistance and delayed thermal degradation.
- Reduced permeability to water and oxygen.
- Clear understanding of how GO dispersion and functionalization affect performance.
- Guidelines for reproducible, scalable production.

Timeline (10 Months)

1. **Months 1–2:** Literature review, material preparation, baseline PU.
2. **Months 3–4:** Screening GO dispersion and loadings; preliminary tests.
3. **Months 5–6:** Interface optimization; full mechanical, thermal, barrier testing.
4. **Months 7–8:** DoE optimization; structural analysis.
5. **Months 9–10:** Validation, analysis, thesis writing, defense prep.

References

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- [1] Available: https://www.l-i.co.uk/uploads/Knowledge%20Centre/The%20chemistry%20of%20polyurethanes/Fig3_polyurethane_reaction.png
- [2] Available: https://www.thegraphenecouncil.org/resource/resmgr/images/products/product_9/product_10/graphene-3.jpg
- [3] Available: https://www.l-i.co.uk/uploads/Knowledge%20Centre/The%20chemistry%20of%20polyurethanes/Fig5_TDI_andMDI_structure.png
- [4] Albozahid, M., Naji, H. Z., Alobad, Z. K., Wychowaniec, J. K., & Saiani, A. (2022). Thermal, Mechanical, and Morphological Characterisations of Graphene Nanoplatelet/Graphene Oxide/High-Hard-Segment Polyurethane Nanocomposite: A Comparative Study. *Polymers*, 14(19), 4224. <https://doi.org/10.3390/polym14194224>
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