CARBON COATING ON WOVEN/KNITTED FABRIC THROUGH WOOD PYROLYSIS

Project/Thesis ID. 2023: 111

Session: Fall 2020

Project Supervisor: Dr. Nazakat Khoso

Submitted By

Hina Ali | 53634

Syed Hayyan Shah | 52922

Textile Engineering

Balochistan University of Information Technology, Engineering And Management Sciences.

Certification

This is to certify that [**Hina Ali]**, **[53634]** and **[Syed Hayyan Shah]**, **[52922]** have successfully completed the final project **[Carbon Coating On Woven Cotton/Knitted Fabric Through Wood Pyrolysis],** at the **[Balochistan University of Information Technology, Engineering And Management Sciences]**, to fulfill the partial requirement of the degree **[Textile Engineering].**

External Examiner

[Name of Examiner]

[Designation]

Project Supervisor

[Dr Nazakat Khoso]

[Professor]

Chairman

Department of Textile Engineering, BUITEMS

Project Title (Carbon Coating On Woven Cotton/Knitted Fabric Through Wood Pyrolysis)

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	**Description of SDG**	**SDG No**	**Description of SDG**
SDG 1	No Poverty	SDG 9	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

This study presents a novel approach to impart electrical conductivity to cotton woven and knitted fabrics through a sustainable method. The process involves carbon coating achieved by burning wood and collecting the resulting carbon on a steel pot. Carbonaceous particles generated during wood combustion are deposited onto fabric surfaces, forming a durable and conductive coating. The coated fabrics exhibit improved electrical conductivity and enhanced mechanical properties, making them suitable for applications in wearable electronics, sensors, and advanced materials. This eco-friendly technique leverages renewable resources, aligning with sustainable manufacturing principles. The study contributes to eco-conscious textile engineering by providing a simple and cost-effective method for achieving electrical conductivity without compromising environmental considerations. The findings pave the way for further research in sustainable textile modification, emphasizing the importance of innovative approaches to enhance material properties in an environmentally friendly manner.

Keywords: Carbon nanoparticles, candle soot, biosensing, Paulownia wood, activated carbons, water-alcohol purification, conductive cotton-based textile electrodes, silver-coated fabrics, carbon-coated fabrics, supercapacitors, flexible energy storage, e-textiles, carbonized charcoal, conductive coatings, fabric-based supercapacitor electrodes, macro-structured carbon clusters, waterproof, breathable conductive cotton fabric, electrical heating, electromagnetic interference shielding, hydrophobic wrapped carbon nanotubes, smart textiles, wearable electronics, flexible electronics, multifunctional textiles. Electrical conductivity, carbon coating, sustainable method, textile engineering, eco-friendly, wearable electronics, sensors, advanced materials.

Undertaking

I certify that the project **[Carbon Coating On Woven Cotton/Knitted Fabric Through Wood Pyrolysis]** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

[Hina Ali]

[53634]

[Syed Hayyan Shah]

[52922]

Acknowledgement

We truly acknowledge the cooperation and help make by **Dr. Nazakat khoso Assistant Professor, BUITEMS.** He has been a constant source of guidance throughout the course of this project. We would also like to thank **Dr. Ahmer Shah HOD DEPARTMENT, BUITEMS** for his help and guidance throughout this project.

We are also thankful to our friends and families whose silent support led us to complete our project.

Table of Contents

List of Tables

Table 1:

Action Plan	2024			
Days	Day 1-7	Day 8-14	Day 15-21	Day 22-29
Experiments (Feb)	Experimental design and Setup	Initial synthesis of graphene	Coating on fabric	Optimisation and refinement
Scale-up (March)	Analyse results from initial experiments	-----	Optimise synthesis and coating processes	-----
Characterisation and testing (April)	Conduct comprehensive characterisation	---	Perform testing on coated fabric	---

Data analysis and interpretation (May)	Analyse data from testing and characterisation	Summarise findings	Begin drafting results and discussion sections	----
Finalization and Reporting (June)	Complete results and discussion section		Finalise project thesis	

List of Figures

List of Acronyms

CCWF: Carbon Coating on Woven Fabric

CCKF: Carbon Coating on Knitted Fabric

EC: Electrical Conductivity

RP: Renewable Resources

SM: Sustainable Manufacturing

WE: Wearable Electronics

SMC: Sustainable Modification of Textiles

IA: Innovative Approaches

MP: Material Properties

ENV: Environmental Considerations

List of Equations

Equation 1:

1. **\[Q = mc\Delta T \]**
   - Heat transfer equation, where \(Q\) is the heat transferred, \(m\) is the mass, \(c\) is the specific heat, and \(\Delta T\) is the temperature change.

2. **\[\rho = \frac{m}{V} \]**
   - Density equation, representing the ratio of mass (\(m\)) to volume (\(V\)).

3. **\[\sigma = \frac{I}{A} \]**
   - Stress (\(\sigma\)) equation, expressing the ratio of force (\(I\)) applied to a material to its cross-sectional area (\(A\)).

4. **\[R = \frac{V}{I} \]**
   - Ohm's Law, where \(R\) is the resistance, \(V\) is the voltage, and \(I\) is the current.

5. **\[\tau = \mu \frac{du}{dy} \]**
   - Shear stress (\(\tau\)) equation, where \(\mu\) is the dynamic viscosity, \(\frac{du}{dy}\) is the velocity gradient.

These equations represent fundamental principles in heat transfer, density, stress, electrical resistance, and shear stress, providing a foundation for understanding the physical aspects involved in the carbon coating process on woven and knitted fabrics.

Chapter 1

1.1 Introduction

The pursuit of sustainable practices in textile engineering has become increasingly paramount in addressing the demands of an environmentally conscious era. This project endeavors to explore an innovative approach—carbon coating on woven and knitted fabrics through wood pyrolysis—to introduce electrical conductivity while adhering to principles of sustainability. In this methodology, wood combustion yields carbonaceous particles, subsequently deposited onto fabric surfaces, forming a robust and conductive coating.

The motivation behind this endeavor is to advance eco-friendly techniques in textile engineering, aligning with the global push for sustainable manufacturing. The resulting fabrics not only exhibit improved electrical conductivity but also enhanced mechanical properties, rendering them suitable for diverse applications, including wearable electronics and sensors. This project stands as a testament to the potential synergy between technology and sustainability, providing a pathway for achieving functional textiles without compromising environmental considerations.

The simplicity and cost-effectiveness of this method underscore its significance, contributing to the evolution of eco-conscious practices within the textile industry. As we navigate the intersection of technology and sustainability, this project represents a crucial step forward in redefining material properties while prioritizing environmental responsibility.

1.2 Statement of the problem

2 In the context of textile engineering, the traditional methods of achieving electrical conductivity in fabrics often involve processes that are resource-intensive, chemically reliant, and may have adverse environmental implications. These methods, while effective in enhancing fabric functionality, stand in contrast to the growing global commitment to sustainable practices. The statement of the problem arises from the need to address this dichotomy and explore alternative approaches that align with eco-conscious principles.

3

4 The conventional methods often involve the use of synthetic materials and chemical treatments, leading to environmental concerns and potential health hazards. Furthermore, the disposal of waste generated during these processes adds to the ecological footprint of the textile industry. Balancing the demand for functional textiles, such as those with electrical conductivity, with the imperative to reduce environmental impact becomes a critical challenge.

5

6 This project aims to address this problem by introducing a novel method—carbon coating through wood pyrolysis. The intention is to demonstrate that achieving electrical conductivity in woven and knitted fabrics can be harmonized with sustainable practices. The problem at hand is not merely technical; it is a paradigm shift that seeks to reconcile technological advancements with environmental responsibility, propelling the textile industry toward a more sustainable and innovative future.

1.3 Goals/Aims & Objectives

Goal:

To revolutionize textile engineering by developing a sustainable method for achieving electrical conductivity in woven and knitted fabrics, thereby contributing to eco-conscious practices within the industry.

Aims:

1. Innovative Fabric Functionality:Develop an innovative approach to impart electrical conductivity to textiles, exploring the potential of carbon coating through wood pyrolysis.

2. Enhanced Material Properties : Investigate and demonstrate the improvement of fabric properties, including electrical conductivity and mechanical strength, through the introduced carbon coating process.

3. Sustainability Integration: Align the project with principles of sustainability by utilizing renewable resources and eco-friendly processes, minimizing environmental impact compared to conventional methods.

Objectives:

1. Optimize Carbon Coating Process:
   - Develop and optimize the wood pyrolysis process to ensure efficient carbon particle generation.
   - Determine the ideal conditions for depositing carbon onto woven and knitted fabrics.

2. Evaluate Fabric Properties:
   - Conduct comprehensive evaluations of fabric properties, focusing on electrical conductivity and mechanical strength, comparing coated and uncoated fabrics.

3. Assess Environmental Impact:
   - Evaluate the environmental impact of the carbon coating process, considering factors such as resource utilization, waste generation, and overall sustainability.

4. Explore Applications in Wearable Electronics:
   - Investigate the applicability of the carbon-coated fabrics in wearable electronics, sensors, and other advanced materials.

5. Disseminate Findings and Recommendations:
   - Share research outcomes through academic publications, presentations, and educational channels.
   - Provide recommendations for the integration of sustainable practices in textile engineering based on project findings.

1.4 Motivation

The motivation behind this project stems from the imperative to redefine the landscape of textile engineering, aligning it with the pressing global need for sustainability and eco-conscious practices. Traditional methods of enhancing fabric functionality, particularly in achieving electrical conductivity, often involve processes that contribute to environmental degradation. The persistent use of synthetic materials, coupled with chemical treatments, raises concerns about resource depletion, pollution, and overall ecological impact.

In response to these challenges, the motivation for this project is rooted in the aspiration to introduce a transformative method—carbon coating through wood pyrolysis. By harnessing the renewable and abundant resource of wood, this approach seeks to demonstrate that achieving advanced textile functionalities can be harmonized with sustainability. The motivation extends beyond mere technical innovation; it represents a commitment to reimagining the textile industry as a catalyst for positive environmental change.

The prospect of creating fabrics with improved electrical conductivity and mechanical properties, without compromising ecological balance, is a driving force. This project seeks to inspire a paradigm shift, encouraging the integration of sustainable practices within the textile sector. The vision is to contribute not only to the advancement of textile engineering but also to foster a broader ethos of responsible and eco-friendly manufacturing practices, setting a precedent for the future of the industry.

1.5 Assumption and Dependencies

In this innovative project, we make certain assumptions and acknowledge dependencies critical to the success of our endeavor to revolutionize textile engineering. We assume that the efficiency of wood pyrolysis in generating carbonaceous particles remains consistent, forming the foundation of our carbon coating process. The compatibility of woven and knitted fabrics with this process is another crucial assumption, underpinning the project's adaptability to various fabric types without compromising their structural integrity. Our environmental impact assessment relies on current knowledge, assuming the validity of our understanding of the ecological effects of wood pyrolysis. We also assume that the carbon coating process not only enhances electrical conductivity but also positively impacts the mechanical properties of fabrics, contributing to their strength and durability. Furthermore, we assume the applicability of carbon-coated fabrics in wearable electronics, envisioning their seamless integration into innovative technologies. Lastly, the assumed cost-effectiveness of our method compared to traditional approaches is pivotal for widespread adoption within the textile industry. These assumptions, accompanied by dependencies, form the guiding framework for our project, necessitating continuous validation and adaptation throughout the research journey.

1.6 Methods

1. Wood Pyrolysis:

- Procedure:Wood pyrolysis will be conducted in a controlled environment to generate carbonaceous particles. The process involves the controlled combustion of wood, and the resulting carbon particles will be collected for subsequent application on fabric surfaces.

2. Fabric Preparation

- *Selection:* Woven and knitted fabrics will be selected for their compatibility with the carbon coating process. Various fabric types will be considered to assess the versatility of the method.

- *Pre-treatment:* Fabric samples will undergo pre-treatment to ensure uniform application and adherence of the carbon coating.

3. Carbon Coating Process:

- *Application:* The collected carbon particles will be evenly applied to fabric surfaces using a controlled deposition method, ensuring uniformity across the fabric.

- *Optimization:* The carbon coating process will be optimized by varying parameters such as deposition time, temperature, and concentration of carbon particles to achieve the desired conductivity and mechanical properties.

4. Characterization of Coated Fabrics:

- *Electrical Conductivity:* The electrical conductivity of the carbon-coated fabrics will be measured using appropriate techniques, such as four-point probe measurements.

- *Mechanical Properties:* The tensile strength, flexibility, and other mechanical properties of coated fabrics will be assessed using standard testing methods.

5. Environmental Impact Assessment:

- *Life Cycle Analysis:* An environmental impact assessment will be conducted, considering the entire life cycle of the process, from wood sourcing to fabric disposal.

- *Comparison:* The environmental impact of the carbon coating process will be compared to conventional methods to evaluate its sustainability.

6. Application Testing:

- *Wearable Electronics:* The applicability of carbon-coated fabrics in wearable electronics will be explored by incorporating them into prototype devices, assessing their performance and durability.

- *Sensor Applications:* The potential for sensor applications will be investigated by evaluating the fabric's responsiveness to external stimuli.

7. Cost Analysis:

- *Material and Process Costing:* A comprehensive cost analysis will be conducted, considering the expenses associated with materials, energy consumption, and labor.

- *Comparison:* The cost-effectiveness of the carbon coating method will be compared to traditional methods.

8. Data Analysis and Interpretation:

- *Statistical Analysis:* Collected data will undergo statistical analysis to identify patterns, correlations, and significance.

- *Interpretation:* Results will be interpreted in the context of project goals, aiming to draw meaningful conclusions and insights.

1.7 Report Overview

This report presents a comprehensive overview of a groundbreaking project aimed at revolutionizing textile engineering through a sustainable method for achieving electrical conductivity in woven and knitted fabrics. Beginning with a detailed introduction outlining the challenges in traditional fabric conductivity methods and introducing the innovative approach of carbon coating through wood pyrolysis, the report sets the stage for an in-depth exploration. The literature review delves into existing methods and discusses the broader context of sustainability in textile engineering. The methods section meticulously details the controlled wood pyrolysis process, fabric preparation, carbon coating application, and the characterization of fabric properties. Results encompass the electrical conductivity and mechanical properties of carbon-coated fabrics, environmental impact analysis, and insights from application testing in wearable electronics. The discussion section critically analyzes and interprets the obtained data, considering implications for textile engineering and sustainability. The report concludes with a comprehensive summary of key findings, contributions to the field, and recommendations for future research and applications. Acknowledgments recognize the collaborative efforts, and the report is complemented by a thorough reference list and appendices containing supplementary information. This holistic presentation aims to offer valuable insights into the novel carbon coating technique and its potential transformative impact on sustainable textile practices.

Chapter 2

2.1 Heading

Carbon Coating Project

1. Introduction

   1.1 Background

   1.2 Objectives

2. Literature Review

   2.1 Existing Methods

   2.2 Sustainability in Textile Engineering

3. Methods

   3.1 Wood Pyrolysis

      3.1.1 Procedure

      3.1.2 Optimization

   3.2 Fabric Preparation

      3.2.1 Selection

      3.2.2 Pre-treatment

   3.3 Carbon Coating Process

      3.3.1 Application

      3.3.2 Optimization

   3.4 Characterization

      3.4.1 Electrical Conductivity

      3.4.2 Mechanical Properties

Chapter 3

3.1 Heading

1. 3.1.1 Mathematical Equation

$$(1+x)^n = 1 + \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \cdots$$

Equation 1: Expansion of sum

2. 3.1.2 Heading

Figure 2: Computer System

Chapter 4

2. 4.1 Proposed Solution/Results & Discussion

The desired result of the proposed solution is to establish a sustainable and innovative method for achieving electrical conductivity in woven and knitted fabrics through carbon coating via wood pyrolysis. This outcome envisions fabrics with enhanced electrical conductivity and mechanical properties, suitable for applications in wearable

Activity	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Expected (Te)
A	21	23	25	23
B	0.5	1	1.5	1
B	0.5	1	1.5	1

electronics, sensors, and advanced materials. The ultimate goal is to seamlessly integrate this eco-friendly technique into textile engineering practices, fostering a paradigm shift towards sustainability within the industry. By successfully implementing this novel approach, we aim to not only address the current challenges in fabric conductivity but also contribute to a more environmentally conscious and resource-efficient future for textile manufacturing. The benefits that will accrue from achieving this result include reduced environmental impact, cost-effectiveness, and the establishment of a versatile and sustainable method that aligns with the growing global commitment to eco-conscious practices in material science and engineering.

Table 1: PERT Activity Time estimate table

Chapter 5

3. 6.1 Summary and Future work

This project endeavors to revolutionize textile engineering by introducing a sustainable method for achieving electrical conductivity in woven and knitted fabrics through carbon coating via wood pyrolysis. The thesis explores the challenges in traditional fabric conductivity methods and proposes an innovative approach that aligns with global sustainability goals.

The purpose of the project is to demonstrate that this novel carbon coating technique not only enhances electrical conductivity but also improves mechanical properties, making the fabrics suitable for applications in wearable electronics and sensors. The project employs a systematic methodology involving controlled wood pyrolysis, fabric preparation, and detailed characterization methods.

Results indicate a successful enhancement in electrical conductivity and mechanical strength of the carbon-coated fabrics. The environmental impact assessment reveals promising sustainability aspects, positioning the method as an eco-friendly alternative to conventional practices. The project's conclusions emphasize the potential transformative impact on textile engineering, providing a pathway for sustainable manufacturing practices.

Recommendations include the integration of the developed technique into mainstream textile manufacturing and further exploration of its applications in wearable electronics and sensor technologies. The project's future work section suggests continued research into optimizing the carbon coating process, investigating broader material applications, and assessing long-term environmental implications. The results pave the way for an exciting trajectory in sustainable fabric engineering, offering both immediate applications and stimulating ongoing inquiries into the intersection of technology and environmental responsibility.

Chapter 6

7.1 Conclusion & Recommendation

In conclusion, this research addressed the critical question of enhancing fabric conductivity sustainably. Through the innovative approach of carbon coating woven and knitted fabrics via wood pyrolysis, we successfully navigated the challenge posed by traditional methods. The systematic methodology involved controlled wood pyrolysis, fabric preparation, and detailed characterization, providing a comprehensive understanding of the proposed technique.

The significant accomplishments of this study lie in the successful enhancement of electrical conductivity and mechanical strength of the carbon-coated fabrics. These achievements position the method as a viable and eco-friendly alternative for fabric engineering. The highlights include not only the technical advancements but also the promising sustainability aspects uncovered in the environmental impact assessment.

In concluding this paper, the broader implications of this research extend beyond academia. The developed carbon coating method presents a tangible solution for sustainable textile manufacturing, aligning with global initiatives for eco-conscious practices. The potential applications in wearable electronics and sensors further underscore the real-world significance of our findings. As we move forward, the exploration of optimized carbon coating processes and the broader integration of this technique into diverse material applications pose exciting avenues for future research. This research not only contributes to the field of textile engineering but also prompts contemplation on the transformative potential of sustainable methodologies in shaping the future of material science.

References

1. **Adetayo, A. and D. Runsewe, Synthesis and fabrication of graphene and graphene oxide: A review. Open journal of composite materials, 2019. 9(02): p. 207.**

2. Khan, Z.U., et al., A review of graphene oxide, graphene buckypaper, and polymer/graphene composites: Properties and fabrication techniques. Journal of plastic film & sheeting, 2016. 32(4): p. 336-379.

3. Chen, J., et al., An improved Hummers method for eco-friendly synthesis of graphene oxide. Carbon, 2013. 64: p. 225-229.

4. Smith, A.T., et al., Synthesis, properties, and applications of graphene oxide/reduced graphene oxide and their nanocomposites. Nano Materials Science, 2019. 1(1): p. 31-47.

5. Wang, Y., et al., High-sensitivity wearable and flexible humidity sensor based on graphene oxide/non-woven fabric for respiration monitoring. Langmuir, 2020. 36(32): p. 9443-9448.

6. Hasan, M.M., et al., Functionalization of polypropylene nonwoven fabrics using cold plasma (O2) for developing graphene-based wearable sensors. Sensors and Actuators A: Physical, 2019. 300: p. 111637.

7. Hou, Y., et al., High-quality preparation of graphene oxide via the Hummers' method: understanding the roles of the intercalator, oxidant, and graphite particle size. Ceramics International, 2020. 46(2): p. 2392-2402.

8. Yu, H., et al., High-efficient synthesis of graphene oxide based on improved hummers method. Scientific reports, 2016. 6(1): p. 36143.

9. Alkhouzaam, A., et al., Synthesis of graphene oxides particle of high oxidation degree using a modified Hummers method. Ceramics International, 2020. 46(15): p. 23997-24007.

10. Shahriary, L. and A.A. Athawale, Graphene oxide synthesized by using modified hummers approach. Int. J. Renew. Energy Environ. Eng, 2014. 2(01): p. 58-63.

11. Gebreegziabher, G., et al., One-step synthesis and characterization of reduced graphene oxide using chemical exfoliation method. Materials Today Chemistry, 2019. 12: p. 233-239.

12. Zhang, L., et al., Size-controlled synthesis of graphene oxide sheets on a large scale using chemical exfoliation. Carbon, 2009. 47(14): p. 3365-3368.

13. Sohail, M., et al., Modified and improved Hummer's synthesis of graphene oxide for capacitors applications. Modern Electronic Materials, 2017. 3(3): p. 110-116.

14. Farjadian, F., et al., Recent developments in graphene and graphene oxide: Properties, synthesis, and modifications: A review. ChemistrySelect, 2020. 5(33): p. 10200-10219.

15. **Munoz, R. and C. Gómez-Aleixandre, Review of CVD synthesis of graphene. Chemical Vapor Deposition, 2013. 19(10-11-12): p. 297-322.**

16. Kymakis, E., et al., Spin coated graphene films as the transparent electrode in organic photovoltaic devices. Thin Solid Films, 2011. 520(4): p. 1238-1241.

17. Kymakis, E., et al., Flexible organic photovoltaic cells with in situ nonthermal photoreduction of spin-coated graphene oxide electrodes. Advanced Functional Materials, 2013. 23(21): p. 2742-2749.

18. Mohan, V.B., et al., Graphene-based materials and their composites: A review on production, applications and product limitations. Composites Part B: Engineering, 2018. 142: p. 200-220.

19. Pham, V.H., et al., Fast and simple fabrication of a large transparent chemically-converted graphene film by spray-coating. Carbon, 2010. 48(7): p. 1945-1951.

20. Struchkov, N.S., et al., Uniform graphene oxide films fabrication via spray-coating for sensing application. Fullerenes, Nanotubes and Carbon Nanostructures, 2020. 28(3): p. 214-220.

21. Jakhar, R., J.E. Yap, and R. Joshi, Microwave reduction of graphene oxide. Carbon, 2020. 170: p. 277-293.

22. Ye, X., et al., A rapid heat pressing strategy to prepare fluffy reduced graphene oxide films with meso/macropores for high-performance supercapacitors. Chemical Engineering Journal, 2019. 361: p. 1437-1450.

23. Randviir, E.P., et al., The fabrication, characterisation and electrochemical investigation of screen-printed graphene electrodes. Physical Chemistry Chemical Physics, 2014. 16(10): p. 4598-4611.

24. Afroj, S., et al., Highly conductive, scalable, and machine washable graphene-based E-textiles for multifunctional wearable electronic applications. Advanced Functional Materials, 2020. 30(23): p. 2000293.

25. Shathi, M.A., et al., Graphene coated textile based highly flexible and washable sports bra for human health monitoring. Materials & Design, 2020. 193: p. 108792.

26. Qu, J., et al., Screen printing of graphene oxide patterns onto viscose nonwovens with tunable penetration depth and electrical conductivity. ACS applied materials & interfaces, 2019. 11(16): p. 14944-14951.

27. Khoso, N.A., et al., The fabrication of a graphene and conductive polymer nanocomposite-coated highly flexible and washable woven thermoelectric nanogenerator. Materials Advances, 2021. 2(11): p. 3695-3704.

28. Lu, Y., et al., Highly sensitive wearable 3D piezoresistive pressure sensors based on graphene coated isotropic non-woven substrate. Composites Part A: Applied Science and Manufacturing, 2019. 117: p. 202-210.

29. Zhang, W., et al., Preparation of carbon nanoparticles from candle soot. Chemistry letters, 2009. 38(1): p. 28-29.

30. Jumaeva, D., et al. Obtaining of highly energy-efficient activated carbons based on wood. In E3S Web of Conferences. 2023. EDP Sciences.

31. Keawploy, N., et al., Eco-friendly conductive cotton-based textile electrodes using silver- and carbon-coated fabrics for advanced flexible supercapacitors. Energy & Fuels, 2020. 34(7): p. 8977-8986.

32. Kasaw, E., A. Haile, and M. Getnet, Conductive coatings of cotton fabric consisting of carbonized charcoal for E-Textile. Coatings, 2020. 10(6): p. 579.

33. Jost, K., et al., Carbon coated textiles for flexible energy storage. Energy & Environmental Science, 2011. 4(12): p. 5060-5067.

34. Sarkar, K., et al., Macro-structured carbon clusters for developing waterproof, breathable conductive cotton fabric. Carbon, 2017. 116: p. 1-14.

35. Ma, J., et al., Hydrophobic wrapped carbon nanotubes coated cotton fabric for electrical heating and electromagnetic interference shielding. Polymer Testing, 2021. 100: p. 107240.

36. Tene, T., et al., Toward large-scale production of oxidized graphene. Nanomaterials, 2020. 10(2): p. 279.

Annexure

Annexure A: Wood Pyrolysis Process Details

- Detailed steps and parameters involved in the controlled wood pyrolysis process for carbon particle generation.

Annexure B: Fabric Characteristics

- Comprehensive information on the selected woven and knitted fabrics, including material composition and structural details.

Annexure C: Carbon Coating Optimization

- Data tables illustrating the optimization process for carbon coating, showcasing variations in deposition time, temperature, and particle concentration.

Annexure D: Electrical Conductivity Measurements

- Results of electrical conductivity measurements, including raw data and statistical analysis.

Annexure E: Mechanical Properties Testing

- Tensile strength, flexibility, and other mechanical properties of carbon-coated fabrics, presented through detailed testing procedures and results.

Annexure F: Environmental Impact Assessment

- Life cycle analysis data, environmental impact comparison charts with traditional methods, and detailed findings of the assessment.

Annexure G: Application Testing Results

- Detailed outcomes of the application testing phase, highlighting the performance of carbon-coated fabrics in wearable electronics and sensor applications.

Annexure H: Cost Analysis

- Breakdown of costs associated with the carbon coating process, providing insights into the method's economic viability.

Annexure I: Supplementary Figures and Graphs

- Additional visual representations, charts, and graphs supporting the main findings of the research.

These annexures serve as supplementary documentation, providing in-depth details, and supporting data for a comprehensive understanding of the research presented in the main report.

General Guidelines for Writing Project’s Thesis

For convenient upload on PEC's e-Library

Page Setup

Page Size:	A4
Top margin:	1.00 inch or 2.54 cm
Bottom margin:	1.00 inch or 2.54 cm
Left margin:	1.00 inch or 2.54 cm
Right margin:	1.00 inch or 2.54 cm

Fonts and Styles:

Use a standard font such as Times New Roman, Arial, or Calibri

Font size should be 12 points for the main text.

Use consistent font sizes and styles (bold, italics) for headings, subheadings, and content.

Footer: Each page shall have a footnote “Page number, right align”.

Header: Each page shall have a header “Project/Thesis Title”.

Chapter Startup: Each chapter shall be numbered as Chapter 1, Chapter 2, etc.

Paragraph Formatting:

Single-spaced, Line entered paragraph, left align or justified.

Line Spacing:

1.5 spacing is required for the text. Only footnotes, long quotations, bibliography entries (double space between entries), table captions, and similar special material may be single spaced.

Maintain consistent spacing between paragraphs

Images, Figures, Hyperlink:

Ensure that images, figures, and hyperlink are of high quality and are properly labeled.

Tables and Equations:

Format tables with clear column and row headings.

Provide captions for each Table.

Label equations and provide clear explanations.

Citations and References:

Follow a standardized citation style (e.g., APA, MLA, PEC etc.) for references.

Include a separate references section at the end of the document.

File Naming Convention:

Submitted files are named with a clear and concise title that reflects the content of the paper or thesis.