WEARABLE PERSPIRATION PROFILING SYSTEM

Submitted
By
Vadde Poorna Chandra- BU21EECE0100094
P. R. Poojitha Reddy- BU21EECE0100587

Under the Guidance of
DR. LIGNESH B DURAI, DEPT OF EECE

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Department of Electrical, Electronics and Communication Engineering
GITAM School of Technology
GITAM
(DEEMED TO BE UNIVERSITY)
(Estd. u/s 3 of the UGC act 1956)
NH 207, Nagadenehalli, Doddaballapur taluk, Bengaluru-561203,
Karnataka, INDIA.

DECLARATION

I/We declare that the project work contained in this report is original and I have done it under the guidance of my project guide.

Date:

Name:

Vadde Poorna Chandra - BU21EECE0100094

P. R. Poojitha Reddy   - BU21EECE0100587

Signature of the Student:

Department of Electrical, Electronics and Communication Engineering
GITAM School of Technology, Bengaluru-561203

CERTIFICATE

This is to certify that Vadde Poorna Chandra, P.R. Poojitha Reddy bearing Regd. No.: BU21EECE0100094, BU21EECE0100587 has satisfactorily completed the Mini Project Entitled in partial fulfillment of the requirements as prescribed by the University for the semester, Bachelor of Technology in "Electrical, Electronics and Communication Engineering" and submitted this report during the academic year 2024-2025.

Signature of the Guide   **Signature of HOD**

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Chapter 1: Introduction

1.1 Overview of the problem statement

Alzheimer's disease (AD) is a leading cause of death, globally affecting over 50 million people worldwide, with significant mortality rates. Existing diagnostic methods are often costly, invasive, and inaccessible, particularly in resource-limited settings, delaying early detection and treatment. There is a critical need for a non-invasive and cost-effective solution that enables continuous real-time AD monitoring. Such a solution would improve early detection and personalized care, potentially reducing the high mortality rates associated with AD and enhancing overall patient outcomes.

1.2 Objectives and Goals

To develop a cost-effective, non-invasive wearable patch that uses colorimetry to detect sweat-based biomarkers for Alzheimer's disease (AD). By integrating this patch with a mobile application, the project aims to enhance early detection

and personalized care through real-time data analysis, making AD diagnosis more accessible.

This innovation will empower patients by enabling continuous, at-home monitoring of their condition, reducing the need for frequent and invasive clinical visits. Additionally, by addressing challenges such as environmental variability, lower biomarker concentration, and potential contamination, the project ensures accurate and reliable results. Ultimately, this approach has the potential to revolutionize AD management, improving patient outcomes and quality of life while significantly impacting future generations.

Chapter 2: Literature Review

Title	Author	Year	Summary
Alzheimer Disease	Anil Kumar, Jaskirat Sidhu, Forshing Lui, Jack W. Tsao	February 12, 2024	Alzheimer's disease starts with memory loss and worsens to severe cognitive and behavioral issues, requiring increasing care. Quality of life declines significantly, and effective management remains uncertain, needing further research.

Recent Developments in Alzheimer's disease therapeutics	Michael S Raafii, Paul S Aisen	February 19, 2009	Anti-amyloid strategies dominate Alzheimer's research, with numerous disease-modifying therapies in trials. Success is uncertain, but a future combination of agents may alter neurodegeneration and reduce the disease's global impact.
Recent Advances in Wearable Sensors for the Monitoring of Sweat: A Comprehensive Tendency Summary	Zhe Xing, Jianan Hui, Bo Lin, Zhenhua Wu, Hongju Mao	23 August, 2023	Wearable sweat sensors offer real-time, non-invasive monitoring. Recent advances span biomarkers, materials, and system designs, focusing on integrated sensors for practical applications, with future innovations expected in physiological signal detection.
Neurology	Bryan D.James, Sue E.Leurgans, Liesi E.Hebert, Paul A.Scherr, Kristine Yaffe, David A.Bennett	25 March, 2014	In an 8-year study, 21.8% developed Alzheimer's dementia, with an average diagnosis age of 86.5. Median survival was 3.8 years, with 72% of those diagnosed eventually dying.

A wearable patch for continuous analysis of thermoregulatory sweat at rest	Hnin Yin Yin Nyein, Mallika Bariya, Brandon Tran, Christine Heera Ahn, Brenden Janatpour Brown, Wenbo Ji, Noelle Davis, Ali Javey	23 March, 2021	The wearable device analyzes sweat in real-time, linking sweat rates to physiological conditions like hypoglycemia and stress, offering non-invasive monitoring and new insights into health through sweat analysis.
A review of Wearable biosensors for sweat analysis	Seongbin Jo, Daeun Sung, Sungbong Kim, Jahyun Koo	07 May,2021	Recent research on wearable sensors focuses on advanced devices for real-time monitoring, using skin-interfaced microfluidics and integrated electronics for accurate health data collection and analysis in various applications.

Recent Developments in Sweat Analysis and Its Applications	Int J Anal Chem	09 March, 2015	Sweat analysis, combined with genomics and proteomics, reveals biomarkers for diseases like cancer and diabetes. This makes sweat a promising biofluid for diagnosing illnesses and exploring new treatments.
A Simple Approach to Stepwise Synthesis of Graphene Oxide Nanomaterial	Paulchamy, Arthi, Lignesh B Durai	01 Jan, 2015	This paper explores graphene oxide (GO) synthesis via Hummer's and Modified Hummer's methods, its characterization (XRD, FT-IR, SEM), and potential applications in water purification, supercapacitors, antibacterial activity, solar cells, and coatings.

Chapter 3: Strategic Analysis and Problem Definition

3.1 SWOT Analysis

1)Strengths:

- **New and advanced technology:** The project uses innovative materials that are safe for the body, making it stand out from other options.
- **Good at early Alzheimer's detection:** The system can detect Alzheimer's disease early, giving people more time for treatment.
- **Non-invasive and works in real-time:** It doesn't require blood tests or other painful procedures and can monitor your health instantly.
- **Accessible for everyone:** The device is designed to be easy to use by many people, including those in remote or low-resource areas.
- **Affordable:** It is cost-effective, meaning it won't be too expensive for people to buy or use, making it more widely available.

2)Weaknesses:

- **Enzyme stability issues:** The system relies on enzymes that can be unstable, which might affect how well it works in different environments.
- **Approval hurdles:** It will face strict rules and regulations before it can be used in the healthcare system, which can take a long time and require changes to the design.
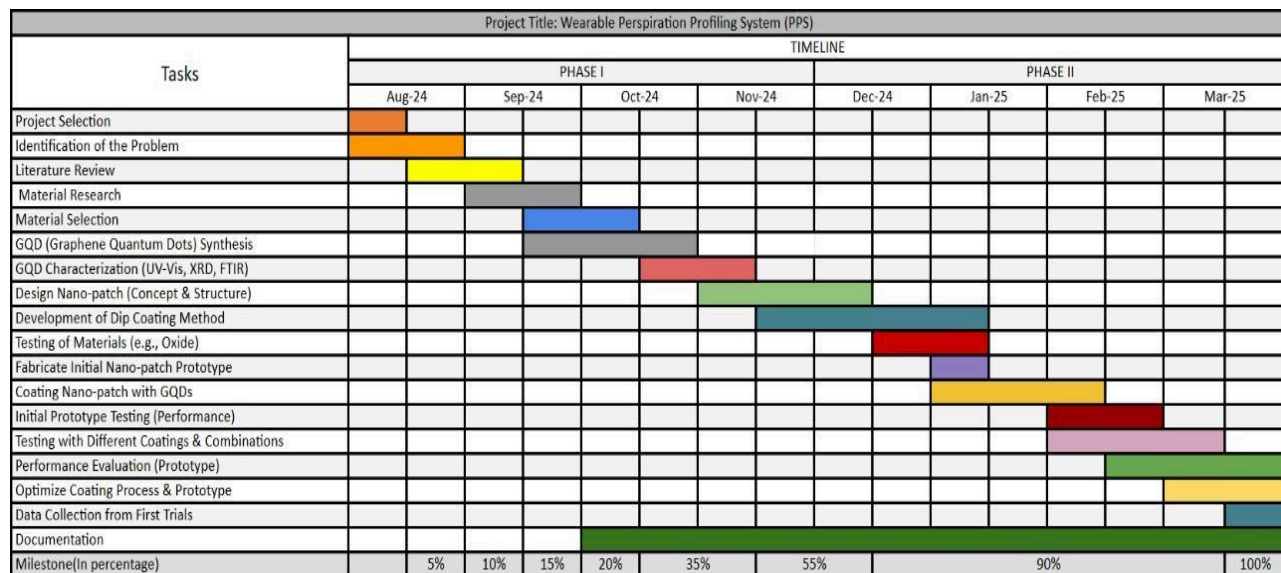
3)Opportunities:

- **Can be used for other diseases**: The technology could be applied to detect other diseases like Parkinson's, expanding its usefulness.
- **Can connect to existing health systems**: It could integrate with health devices like smartwatches, making it part of a bigger health monitoring system.
- **Growing demand for non-invasive tools**: More people want health solutions that don't involve needles or surgery, and this system fits that trend.

4)Threats:

- **Competitors**: Other companies are working on similar products, so the project will need to stay competitive.
- **Fast-changing technology**: Technology is evolving rapidly, so there's a risk that this system could become outdated if newer devices are developed.

3.2 Project Plan - GANTT Chart

Project Title: Wearable Perspiration Profiling System (PPS)								
Tasks	**TIMELINE**							
	PHASE I				**PHASE II**			
	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25
Project Selection								
Identification of the Problem								
Literature Review								
Material Research								
Material Selection								
GQD (Graphene Quantum Dots) Synthesis								
GQD Characterization (UV-Vis, XRD, FTIR)								
Design Nano-patch (Concept & Structure)								
Development of Dip Coating Method								
Testing of Materials (e.g., Oxide)								
Fabricate Initial Nano-patch Prototype								
Coating Nano-patch with GQDs								
Initial Prototype Testing (Performance)								
Testing with Different Coatings & Combinations								
Performance Evaluation (Prototype)								
Optimize Coating Process & Prototype								
Data Collection from First Trials								
Documentation								
Milestone(In percentage)	5%	10% 15%	20% 35%	55%		90%		100%

1)Project Planning and Research:

The team sets project goals, conducts research, and organizes resources and responsibilities to start the project.

2)Nanomaterials Synthesis:

Special nanomaterials are created and tested to ensure they can detect Alzheimer's biomarkers through sweat analysis.

3)Wearable Patch Development:

The wearable patch is designed with integrated nanomaterials, and prototypes are developed and tested for functionality.

4)Mobile Application Integration:

A smartphone app is created to receive and display data from the patch, ensuring real-time monitoring and proper connectivity.

5)Testing, Validation, and Reporting:

The patch and app are tested together, and validated for accuracy, and the results are compiled into a final report for review.

Chapter 4: Methodology

4.1) Materials Required

The synthesis of Graphene Quantum Dots (GQDs) involves carefully selected materials and methods. Active graphene (0.30 g) acts as the precursor, while sulfuric acid (H_2SO_4) serves as a vital oxidizing agent for breaking down graphene. Nitric acid (HNO_3) is combined with sulfuric acid to enhance oxidative cleavage. After oxidation, deionized water is utilized for dilution and rinsing, while sodium carbonate (Na_2CO_3) neutralizes the acidic solution, adjusting the pH to 8. The purification of GQDs is conducted using a dialysis bag to eliminate smaller molecules and ions. This method, involving controlled mixing, dilution, and neutralization, yields high-purity GQDs suitable for various applications in nanotechnology and biomedical fields.

4.2) Chemicals Required for Synthesis

Graphene Quantum Dots (GQDs) synthesis utilizes active graphene, sulfuric acid, nitric acid, deionized water, sodium carbonate, and a dialysis bag to ensure optimal breakdown, purification, and desired application properties.

4.3) Synthesis process

1. Oxidation:

- 0.30 g of active graphene was mixed with 60 mL sulfuric acid and 20 mL nitric acid. This breaks the graphene into smaller fragments.

2. Sonication:

- The mixture was sonicated (ultrasound treatment) for 4 hours to break down the graphene into nanoscale particles further.

3. Stirring and Heating:

- The solution was heated and stirred for 18 hours at three temperatures:120°C.

4. Dilution and Neutralization:

- After 18 hours, the mixture was diluted with water, and its pH was adjusted to 8 using sodium carbonate, neutralizing and stabilizing the solution.

4.4) Method for Synthesizing Graphene Quantum Dots (GQDs)

1. **Preparation of Graphene Oxide:**

   Begin with the oxidation of graphite using Hummer's method to produce graphene oxide (GO), ensuring an adequate concentration of functional groups necessary for GQD formation.

2. **Mixing with Acids:**

   In a fume hood, combine the prepared GO with sulfuric acid (H_2SO_4) and nitric acid (HNO_3) in a reaction vessel, maintaining controlled temperature and stirring to facilitate efficient oxidation.

3. **Oxidation Process:**

   Stir the mixture vigorously for several hours, allowing the strong oxidizing agents to cleave carbon bonds effectively, thus breaking down the graphene structure into smaller fragments.

4. **Dilution:**

   Once the oxidation is complete, gradually add deionized water to the mixture to dilute the acids and halt the oxidative process, minimizing further reactions.

5. **Neutralization:**

   Introduce sodium carbonate (Na_2CO_3) to the diluted solution to neutralize the acidity, adjusting the pH to approximately 8, which stabilizes the resulting GQDs.

6. **Purification:**

Transfer the solution into a dialysis bag and place it in deionized water for several hours to remove smaller impurities and unreacted chemicals, ensuring the high purity of the GQDs.

7. **Centrifugation:**

Centrifuge the purified solution to isolate the GQDs from the liquid, facilitating the collection of solid GQDs for further analysis.

8. **Characterization:**

Finally, characterize the synthesized GQDs using techniques such as Transmission Electron Microscopy (TEM) and UV-Vis spectroscopy to confirm their size, shape, and functional groups.

4.5) Patch Design
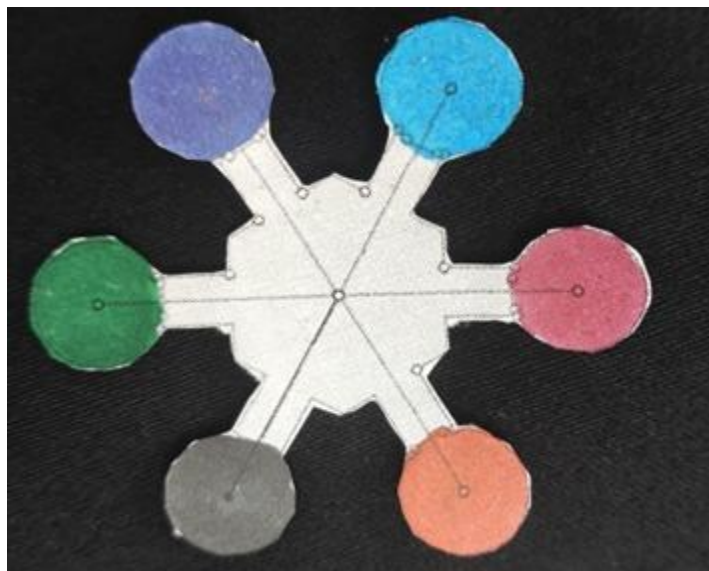
Chapter 5: Implementation

5.1)Description of how the project was executed

5.1.1) GQD Synthesis:

Graphene Quantum Dots (GQDs) were synthesized from active graphene through a meticulous chemical oxidation process using sulfuric acid (H_2SO_4) and nitric acid (HNO_3). This synthesis involved a comprehensive protocol, starting with 4 hours of ultrasonication to ensure uniform dispersion of the graphene flakes, followed by 12 hours of magnetic stirring to facilitate thorough oxidation. The resulting GQDs were characterized using various advanced techniques, including Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), X-ray Photoelectron Spectroscopy (XPS), Raman spectroscopy, X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), and photoluminescence analysis. These characterizations provided valuable insights into the structural and optical properties of the synthesized GQDs, confirming their suitability for subsequent applications.

5.1.2) Wearable Patch Fabrication

The fabrication of the wearable patch commenced with the selection of Quantum Dots, which were then coated with the synthesized GQDs using a dip-coating method. This technique ensured a uniform layer of GQDs, enhancing their interaction with sweat. The patch was specifically functionalized to detect sweat-based biomarkers, focusing on key indicators of Alzheimer's disease, including amyloid-beta and tau proteins.

5.1.3) Colorimetric Detection

The interaction between the targeted sweat biomarkers and the GQDs results in a distinct visible color change, which is crucial for detection. This colorimetric change can be accurately detected using smartphone cameras, enabling real-time monitoring of Alzheimer's disease biomarkers. This innovative approach combines advanced materials science with practical health applications, aiming to enhance early detection and management of Alzheimer's disease through non-invasive methods.

Chapter 6:Results

6.1 Outcomes

The Project successfully synthesized Graphene Quantum Dots (GQDs) and NiAlO$_2$ Oxide, which demonstrated potential for sweat-based biomarker detection. A wearable patch was designed and fabricated with an integrated GQD-based sensing layer using the dip-coating method, ensuring uniform deposition and enhanced interaction with perspiration. The functionalized patch exhibited a measurable colorimetric response upon interaction with target biomarkers, as validated through UV-Vis spectroscopy, FTIR, and XRD characterization. Additionally, a mobile application was developed for real-time perspiration data acquisition, processing, and health monitoring, enabling non-invasive diagnostics and continuous health tracking.

6.2 Interpretation of Results

Experimental validation of the synthesized GQDs confirmed their strong photoluminescence and structural stability, making them suitable candidates for biomarker interaction. The colorimetric assay exhibited significant and reproducible spectral shifts upon exposure to Alzheimer 's-related biomarkers, confirming the system's sensitivity. The integration of the mobile application facilitated seamless data acquisition and real-time monitoring, offering a scalable and user-friendly diagnostic platform. These findings suggest that sweat-based biomarker profiling using GQD-functionalized patches could serve as a cost-effective and accessible alternative to conventional diagnostic methods.

6.3 Comparative Analysis with Existing Technologies

A comparative evaluation of the proposed system against conventional diagnostic methodologies is presented in **Table 1**.

Feature	Proposed Wearable Patch	Traditional Diagnostic Methods
Detection Method	Non-invasive, Sweat-based biomarker analysis	Invasive(Blood draw,imaging techniques)
Cost	Low-cost, scalable solution	High cost, requiring specialized infrastructure
Portability	Lightweight, Wearable, real-time biomarkers	Hospital-based, requiring specialized equipment
Real-Time Monitoring	Continuous tracking of biomarkers	Discrete testing at clinical facilities
Early Detection Potential	High, real-time biomarker fluctuation detected	Moderate requires periodic testing

The developed system provides a paradigm shift in non-invasive diagnostics, demonstrating feasibility for continuous, real-time sweat biomarker analysis with potential applications in personalized healthcare, remote patient monitoring, and early-stage disease detection. Future research will focus on enhancing biomarker specificity, multiplexed sensing capabilities, and large-scale clinical validation to further establish the efficacy of this technology.
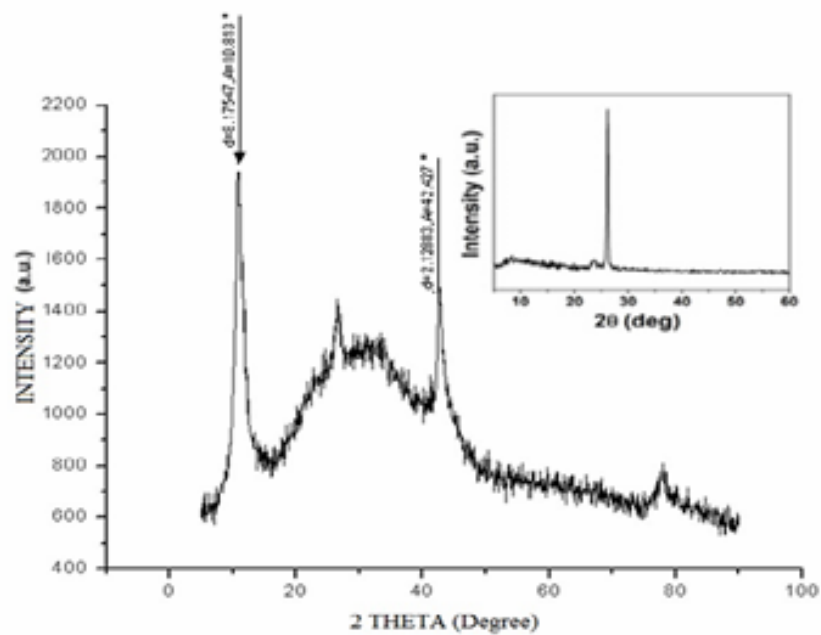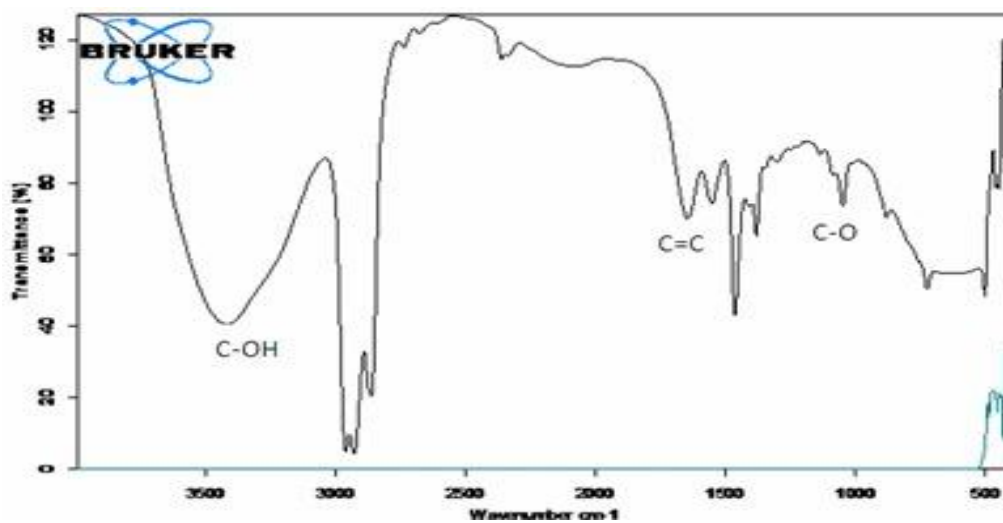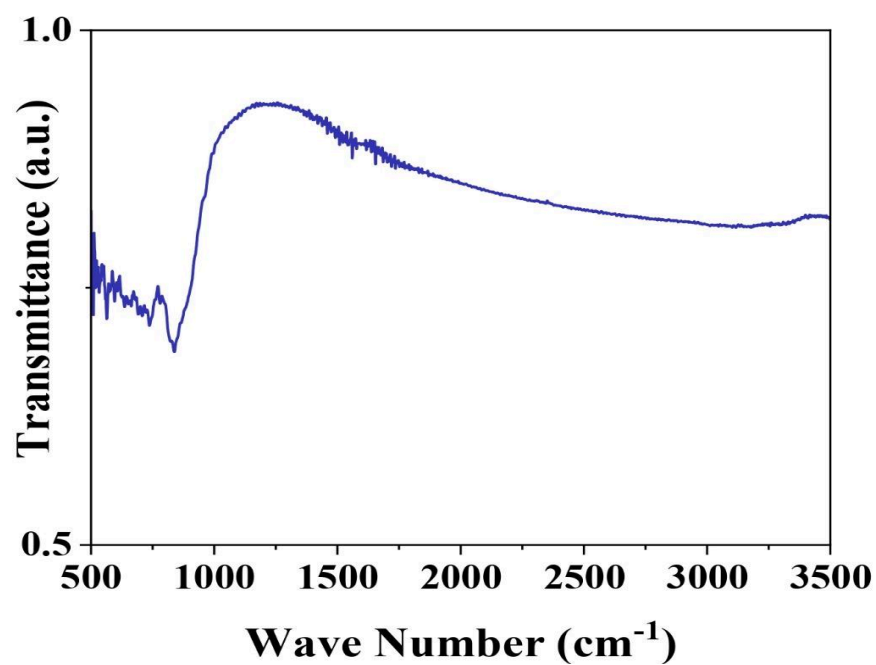
Fig 1   FTIE Graph of GQD

Fig 2 XRD Result Of GQD
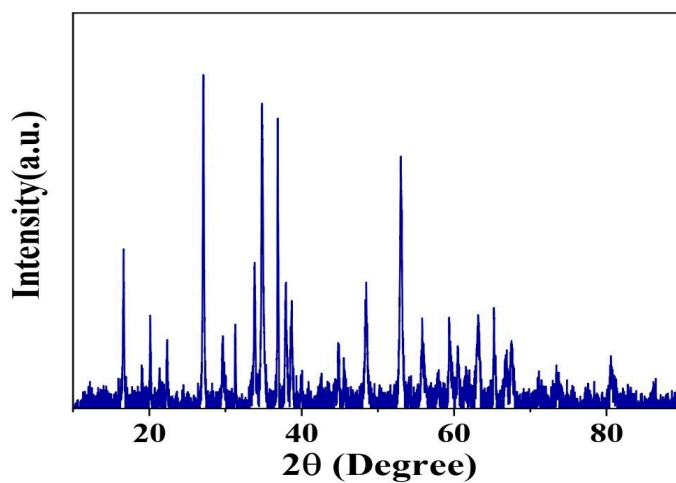
Fig 3 XRD Result Of NiAlO2

Fig 3 FTIR Result Of NiAlO2

Chapter 7: Conclusion

The Wearable Perspiration Profiling System (WPPS) successfully demonstrates the feasibility of sweat-based biomarker detection using Graphene Quantum Dots (GQDs) and colorimetric sensing techniques. Through rigorous material synthesis, device fabrication, and mobile application integration, this study establishes a non-invasive, cost-effective, and real-time diagnostic platform with significant potential for early detection of Alzheimer's disease. The results validate the system's ability to detect biochemical changes in perspiration, paving the way for next-generation wearable diagnostics.

Although the current research establishes a strong foundation, the base solution requires further optimization and large-scale validation before real-world deployment. This project not only presents a novel scientific breakthrough but also offers a scalable business opportunity. Moving forward, we aim to transition this research into a startup venture, bridging the gap between laboratory innovation and practical healthcare applications.

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Chapter 8: Future Work

Building on the promising results of this research, our future work will focus on:

1. Optimizing Sensor Sensitivity & Specificity

   ○ Enhancing the stability and selectivity of GQDs for multiplexed biomarker detection.
   ○ Developing hybrid nanomaterial coatings to improve detection accuracy under diverse physiological conditions.
2. Real-World Validation & Clinical Trials

   ○ Conducting extensive clinical trials to benchmark the system against gold-standard diagnostic tools.
   ○ Collaborating with healthcare institutions to refine the detection methodology.
3. Product Development & Market Readiness

   ○ Miniaturizing the patch for seamless integration into daily wearables.
   ○ Ensuring regulatory compliance (FDA, CE, ISO standards) for medical-grade adoption.
4. Startup & Commercialization Roadmap

   ○ Refining the technology for mass production and scalability.
   ○ Exploring partnerships with health-tech investors, hospitals, and wearable device manufacturers.
   ○ Expanding beyond Alzheimer's detection to include hydration monitoring, electrolyte balance, and stress analysis.

With continued development, this project has the potential to revolutionize non-invasive diagnostics, empowering individuals with accessible, real-time health insights. The transition from research to commercialization will bridge the gap between academic innovation and societal impact, establishing WPPS as a disruptive solution in healthcare technology.

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