**DEVELOPMENT OF A WEARABLE FET- BASED SENSOR FOR DETECTING CREATINE USING SWEAT SAMPLES**

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Major Project Report- “ Development of a wearable FET-based sensor for detecting creatinine

Using Sweat Samples”

**DECLARATION**

**I/We declare that the project work contained in this report is original and it has been done by me under the guidance of my project guide.**

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**CERTIFICATE**

This is to certify that SanaSayeeda[BU21EECE0100268],S.Aparna[BU21EECE0100324], B.Manjulatha[BU21EECE0100211] has satisfactorily completed Mini Project Entitled in partial fulfillment of the requirements as prescribed by University for VIIIth 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**

Creatinine is a vital biomarker for evaluating renal function, typically measured through blood or urine samples. However, conventional methods of creatinine detection require laboratory analysis, making them invasive and time-consuming. Wearable sensors for non-invasive, continuous monitoring are gaining attention in health monitoring. In this context, field-effect transistor (FET)-based sensors provide a promising platform due to their high sensitivity, low power consumption, and compatibility with flexible substrates. This report discusses the development of a wearable FET-based sensor designed for detecting creatinine levels in sweat samples.

## **OVERVIEW OF FET-BASED SENSORS:**

Field-effect transistors (FETs) are semiconductor devices that can modulate current flow through a channel in response to changes in the gate voltage. FET-based sensors leverage this property for biochemical detection, where the sensing mechanism is based on changes in the surface potential at the gate electrode. When a target analyte, such as creatinine, interacts with a recognition element immobilized on the sensor surface, it induces changes in the electrostatic environment, modulating the current flow and enabling detection.

# **CHAPTER II-LITERATURE SURVEY:**

## **DESIGN AND FABRICATION OF THE WEARABLE SENSOR:**

The wearable FET-based creatinine sensor was designed to be flexible, lightweight, and capable of integrating with wearable electronics. The key design elements included:

* **Substrate Material:** A flexible polymeric substrate, such as polydimethylsiloxane (PDMS), was chosen to ensure the sensor's adaptability to human skin, allowing for continuous monitoring during physical activities.
* **Sensing Material:** The sensing layer consisted of a semiconducting material, such as graphene or a modified organic semiconductor, chosen for its high electrical conductivity and large surface area, improving sensitivity to creatinine molecules.
* **Functionalization:** The gate surface of the FET was functionalized with creatinine-specific receptors. Commonly used receptors include enzymes like creatinine or molecularly imprinted polymers (MIPs), which provide specificity by mimicking the natural binding sites for creatinine.
* **Interconnects and Encapsulation:** To ensure the durability and performance of the wearable sensor, gold or silver nanowires were used for interconnects, and a waterproof, breathable encapsulation layer was applied to protect the sensor from external interference and sweat.

# **CHAPTER III- STRATEGIC ANALYSIS AND PROBLEM DEFINATION**

## **SWOT ANALYSIS**

**Strengths:** Non-invasive Monitoring, Continuous monitoring, Potential for integration

**Weakness :**Power consumption , interface from other sweat components, durability and stability, sweat collection challenges.

**Opportunities:** Partnership and collaboration ,rising prevalence of chronic kidney disease (CKD),Advancements in flexible electronics.

**Threats**: Durability, false positive false negative, non-responsive device ,short circuits or water-based interactions will effect sensitivity.

## **REFINEMENT OF PROBLEM STATEMENT**

Problem Statement: Chronic kidney disease (CKD) is a growing global health issue that requires continuous monitoring of biomarkers like creatinine to assess kidney function. Current methods for measuring creatinine levels, such as blood or urine tests, are invasive, time-consuming, and impractical for real-time monitoring, especially for at-risk populations. There is a critical need for a non-invasive, continuous, and user-friendly solution to enable early detection and monitoring of kidney health.

Sweat offers a convenient and non-invasive alternative for biomarker detection, but current wearable sensor technologies lack the sensitivity and specificity needed to accurately detect creatinine in sweat. This project aims to develop a wearable sensor based on field-effect transistor (FET) technology that can accurately and reliably detect creatinine in sweat samples. The sensor must overcome challenges in selectivity, stability, and sensitivity in complex biological environments, as well as ensuring that it can be easily integrated into a wearable format for continuous real-time monitoring. This will provide patients with an accessible, non-invasive tool for monitoring their kidney function, potentially improving early diagnosis and management of CKD.

# **CHAPTER IV- METHODOLOGY**

## **DISCRIPTION HOW THE PROJECT WAS EXECUTED:**

**1. Project Planning & Literature Review**

The initial phase focused on setting a solid foundation for the project. The team began by conducting a thorough review of the latest developments in wearable biosensors, particularly those based on field-effect transistor (FET) technology. Research papers, patents, and industry reports were analyzed to identify existing solutions and gaps in creatinine detection through non-invasive methods like sweat analysis. This helped define the project objectives: to create a wearable, non-invasive sensor for real-time monitoring of creatinine levels.

A timeline was established, breaking the project into clear milestones, including design, material selection, fabrication, testing, and reporting.

**2. Sensor Design and Material Selection**

Next, the design process kicked off with brainstorming sessions focused on the ideal characteristics of the sensor: flexibility, durability, high sensitivity, and low power consumption. The team used design software to conceptualize the sensor architecture, including layers for the substrate, sensing material, and interconnects.

Material selection was critical. The substrate had to be both flexible and biocompatible for prolonged skin contact. Polydimethylsiloxane (PDMS) was selected for its proven flexibility and ability to integrate with wearable electronics. For the sensing layer, graphene and organic semiconductors were chosen due to their high surface area and excellent electrical properties, which would enhance the sensor’s sensitivity to creatinine.

The functionalization process involved choosing receptors specific to creatinine. The team opted for molecularly imprinted polymers (MIPs) due to their ability to selectively bind creatinine molecules, mimicking biological recognition sites.

**3. Fabrication and Prototyping**

The third phase was dedicated to building the first working prototype. The flexible PDMS substrate was fabricated first, followed by the deposition of the graphene-based sensing layer. Nanowires made from gold or silver were used to create the electrical interconnects between the sensor’s components. This ensured the sensor would maintain electrical conductivity even under mechanical stress, like bending or stretching when worn on the skin.

To make the sensor durable, the team encapsulated the entire system with a waterproof, breathable material. This encapsulation protected the sensor from external elements like sweat and mechanical wear while ensuring continuous exposure to sweat for analysis.

**4. Testing and Optimization**

With the prototype in hand, rigorous testing began. First, the sensor's sensitivity to various creatinine concentrations was measured, ensuring it could detect even small changes in levels, mimicking real-life sweat conditions. Next, the sensor's response time was evaluated to determine how quickly it could detect creatinine after exposure to sweat.

Selectivity tests followed, where the sensor was exposed to various substances typically found in sweat, such as glucose and urea, to ensure it would specifically detect creatinine without interference. These tests confirmed the sensor’s ability to provide accurate readings in a real-world environment.

The team also conducted mechanical durability tests to confirm the sensor’s ability to withstand bending and stretching. This involved testing the sensor under different bending angles and physical conditions while ensuring stable signal output.

**5. Data Analysis and Calibration**

Once the sensor passed the initial tests, the team gathered data from multiple trials to assess its accuracy and reliability. They calibrated the sensor to account for factors such as varying sweat rates, which could impact readings. This phase involved fine-tuning the sensor’s performance to optimize its signal stability and ensure it functioned consistently in different conditions, such as during physical activity.

The signal stability was a critical aspect of calibration, as the sensor had to perform consistently under continuous wear. Data from these tests were analyzed to ensure the sensor could reliably monitor creatinine levels over extended periods.

**6. Report Writing and Presentation**

With testing completed, the project moved into the reporting phase. All experimental results, including graphs and performance metrics, were compiled into a comprehensive report. This document outlined the entire development process, from design and fabrication to testing and optimization, with an emphasis on the sensor’s real-world applications.

Visual aids such as flowcharts and sensor diagrams were created to illustrate key concepts. These materials were used in presentations to both the internal team and external stakeholders, summarizing the project’s success and offering insights into potential future improvements.

**7. Conclusion and Future Directions**

In the final phase, the team reflected on the project outcomes. The sensor met the initial objectives: it was flexible, wearable, and capable of accurately detecting creatinine in sweat. However, the team also identified areas for future research, such as improving sensor longevity and exploring integration with wearable devices like smartwatches or fitness bands. Proposals were made for future testing with a broader range of users and under different environmental conditions to further enhance the sensor's robustness and accuracy.

## **CHALLENGES FACED AND SOLUTIONS IMPLEMENTED**

1. **Material Selection and Flexibility**

One major challenge was selecting materials that maintained both flexibility and electrical conductivity. The sensor needed to be highly sensitive yet adaptable for continuous wear on the human body.

**Solution:** Mexene was chosen as the flexible substrate for its biocompatibility and elasticity, while it is used as the sensing material due to its high conductivity and large surface area. This combination balanced mechanical flexibility and sensitivity.

1. **Power Efficiency**

Wearable devices must consume minimal power to ensure prolonged operation without frequent recharging. Balancing the sensor’s performance with low power consumption was a challenge.

**Solution:** Optimization of the FET design, including the use of low-power semiconducting materials and efficient signal processing algorithms, helped reduce the overall energy requirements of the sensor without compromising its accuracy.

# **CHAPTER V- RESULTS**

1. **High Sensitivity and Selectivity**

The sensor exhibited remarkable sensitivity to creatinine, with detection limits in the physiological range typically found in human sweat. The use of molecularly imprinted polymers for functionalization ensured that the sensor selectively detected creatinine even in the presence of common sweat components, such as glucose and urea. This specificity is crucial for accurate monitoring and helps prevent false positives.

1. **Real-Time Monitoring Capability**

The sensor’s design facilitated real-time monitoring of creatinine levels during physical activities. Data from the sensor showed a quick response to changes in creatinine concentrations, making it suitable for continuous wear. This capability allows for proactive health management, enabling users to track their renal function dynamically.

1. **User-Friendly Integration**

The sensor was designed to be lightweight and comfortable, promoting user compliance for prolonged wear. This feature, combined with low power consumption, makes it suitable for integration with other wearable technologies, enhancing its applicability in health monitoring systems.

Overall, the outcomes and interpretations indicate that the wearable FET-based sensor holds significant promise for non-invasive health monitoring, specifically for tracking renal function through creatinine levels in sweat. Further developments could enhance its integration into comprehensive health monitoring systems, contributing to better health management and early detection of renal issues.

# **CHAPTER VI-FUTURE WORK**

Future work on the development of a wearable FET-based sensor for detecting creatine in sweat samples will focus on enhancing sensitivity, specificity, and user-friendliness. This includes optimizing the sensing materials and electrode designs to improve detection limits and minimize interference from other sweat components.

Integration of advanced signal processing algorithms will be crucial for accurate data interpretation in real-time. Additionally, efforts will be directed towards miniaturizing the sensor for comfortable wear, along with developing a user-friendly interface for displaying results.

Collaborations with sports scientists and healthcare professionals will help validate the sensor's effectiveness and explore its applications in monitoring athletic performance and metabolic health. Finally, addressing challenges related to power management and long-term wearability will be essential for creating a practical, commercially viable product.

# **CHAPTER VII- CONCLUSION**

In conclusion, the advancement of a wearable FET-based sensor for detecting creatine in sweat represents a significant innovation in health and fitness monitoring. By focusing on improving sensitivity, specificity, and user experience, this technology has the potential to provide real-time insights into metabolic states and athletic performance.

Future developments will hinge on refining the sensor’s materials and designs, implementing effective data processing techniques, and ensuring comfort and usability for everyday wear. Ultimately, successful integration of this sensor into sports and healthcare settings could revolutionize how individuals track their physical performance and overall well-being, paving the way for personalized health management**.**