E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

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PTDI, UiTM Cawangan Johor Kampus Pasir Gudang

ORGANIZED BY:

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A-ST046: DEVELOPMENT OF AN EGFET PH SENSOR USING TIO_2-PANI COMPOSITE THIN FILMS FOR SOIL CHARACTERIZATION

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ABSTRACT

Regular pH soil testing is needed to ensure soil health and improve crop yield. This can be done through laboratory testing or utilizing a commercially available sensor. The soil lab test was unappealing due to inconvenient soil sampling procedures and a high cost. Commercial soil sensors, however, are an undesirable method due to their poor precision and reliability. Thus, this study aims to develop an effective and reliable soil sensor using a highly sensitive extended gate field effect transistor (EGFET) pH sensor based on TiO_2-PANI composite thin film. The deposited sample was tested for pH application in the range of pH 2 to 12. The sample demonstrated a super-Nernstian behavior with 66.1 mV/pH and a linearity of 0.9931. Additional testing revealed that the sample exhibited good repeatability with a standard deviation of 0.49%, and a low drift rate of 4.96, 5.54 and 3.32 mV/h in pH 4, 7 and 10, respectively for 6 hours, indicating that the sample is stable in the long term. Besides, the laboratory test and direct characterization via soil EGFET measurements were compared. The results show that the fabricated TiO_2-PANI composite thin film in this work is beneficial for soil testing.

Keywords: TiO_2-PANI thin film, EGFET method, pH sensor, spin-coating, soil testing

1. Product Description

A highly sensitive TiO_2-PANI composite thin film as a sensing electrode for pH sensors was fabricated using a facile sol-gel spin-coating method. The thin film was deposited on a 2cmx 1cmx0.1cm ITO glass substrate, making it smaller and more portable. The sample was tested for pH application in a pH range of 2 to 12 using the EGFET method. The EGFET approach in electrochemical sensors is among the simplest, affordable, dependable and practical sensors available. The sample showed a super-Nernstian response with 66.1 mV/pH and a linearity of 0.9931. Further analysis showed that the sample was stable over the long term, with a low drift rate of 4.96, 5.54 and 3.32 mV/h in pH 4, 7 and 10 for 6 hours. The measurement was performed five times for repeatability with a standard deviation of 0.49%. Results from laboratory tests conducted by the Malaysian Agricultural Research and Development Institute (MARDI) and soil EGFET measurements were compared.

2. Results and Discussion

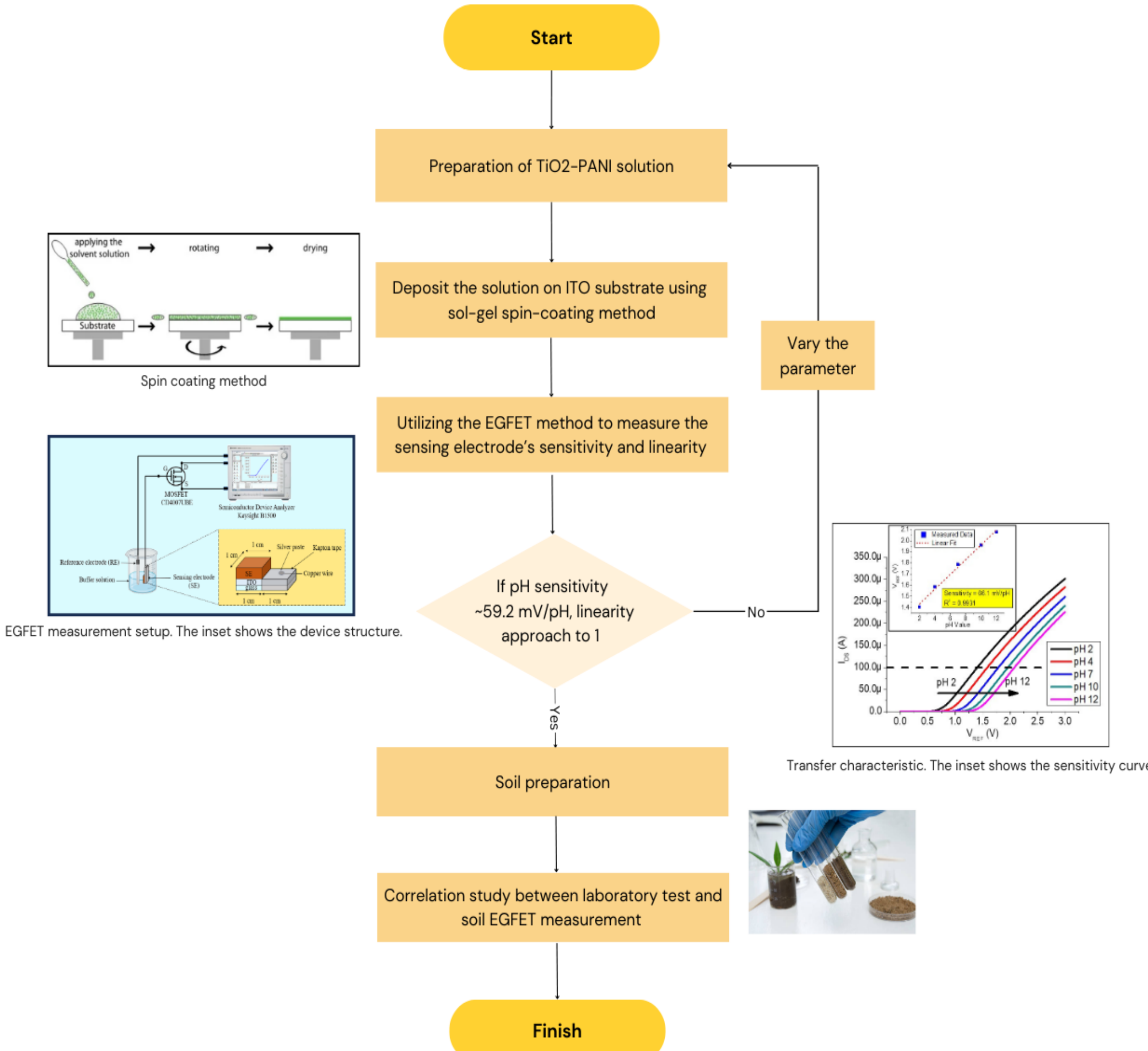

Figure 1. Flowchart of the project

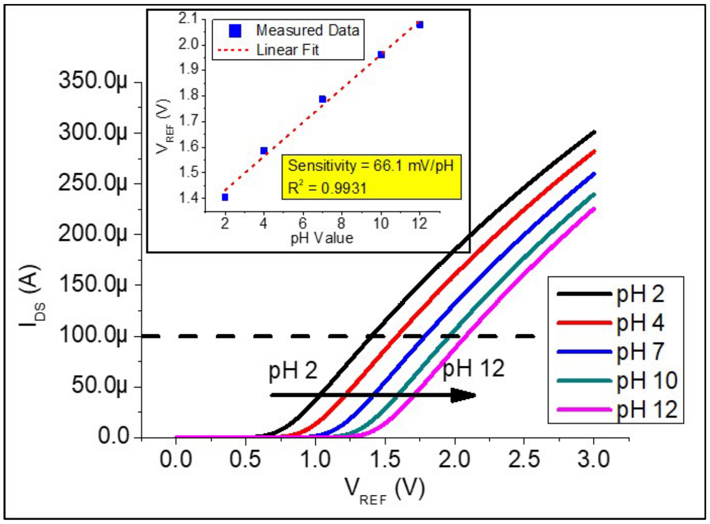

Figure 2. Transfer characteristic of the TiO_2-PANI composite thin film. The inset shows the sensitivity curve of the sample.

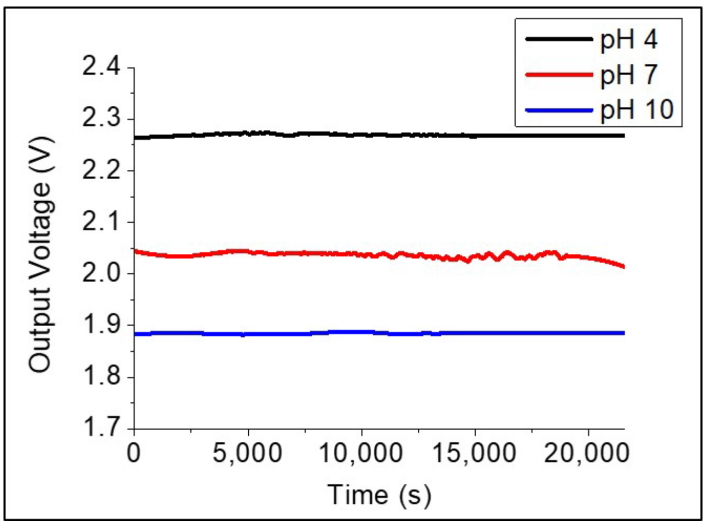

Figure 3. Drift measurement of the TiO_2-PANI composite thin film.

Table 1. Comparison of MARDI laboratory test results and soil EGFET measurement for pH measurement.

Soil Sample	*MARDI Laboratory Test*	*Soil EGFET Measurement*	*Δ pH Difference*
Sample 1	3.70	3.60	0.10
Sample 2	4.11	4.33	0.22
Sample 3	3.83	4.17	0.34

3. Novelty and uniqueness

The TiO_2-PANI composite is a novel material that can be used as a sensing electrode in pH sensors. PANI is a conductive polymer that reacts very quickly to pH variations. Although PANI is sensitive, it might be unstable in certain conditions. In comparison to TiO_2, which particularly resists degradation, the electrode can remain precise even after repeated use. Thus, the combination of the two materials enhances the device's sensitivity, making it highly responsive to pH changes. Besides, the drift measurement indicates that the composite thin film is stable over an extended period and works well over a wide pH range. Moreover, the nanoscale structure of the composite allows for the development of smaller, more portable sensors while maintaining performance which is suitable to be used for on-the-go testing.

4. Benefit to mankind

The TiO_2-PANI composite as a sensing electrode offers high sensitivity and long-term stability as pH sensors. This benefit is especially helpful in applications involving continuous monitoring, as the electrode's longevity lowers maintenance needs. The durability and long lifespan minimize waste, contributing to sustainable practices in various industries such as water quality monitoring, and soil analysis for agriculture, chemical manufacturing, healthcare and food industry.

5. Innovation and Entrepreneurial Impact

The fusion of TiO_2 and PANI is a novel approach that combines the high sensitivity of conductive polymers with the robustness of semiconductors. With the rising demand for real-time environment data, the composite is beneficial to be integrated with emerging technologies such as IoT-enabled sensors for water and soil quality testing, targeting government and private sectors.

6. Potential commercialization

The fabricated TiO_2-PANI composite in this work can meet a wide range of demands, due to the increasing need for precise pH measuring solutions in various chemical and biological applications, especially in the agriculture sector. The sample has been tested for soil testing using EGFET measurement, and the results obtained were compared with laboratory tests. The findings indicate that the soil EGFET method closely aligns with the MARDI laboratory test, with a maximum deviation of 0.34 pH units. Even though there are small variations, especially with Sample 3, the sensing electrode shows feasibility for efficient soil analysis with potential adjustments for increased accuracy.

7. Acknowledgment

The authors would like to acknowledge technical staff from Nano-ElecTronic (NET), School of Electrical Engineering, College of Engineering, UiTM Shah Alam.

8. Authors' Biography

Nur Syahirah Kamarozaman is a student who is currently undertaking her PhD study program at the College of Engineering, Universiti Teknologi MARA (UiTM) Shah Alam. She holds a BSc and MSc degrees in electronic electrical engineering from UiTM Shah Alam in 2011 and 2015, respectively. She joined UiTM in 2015 and presently serves as a lecturer in the School of Electrical Engineering at Terengganu Branch, Dungun Campus.

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Sukreen Hana Herman received her Ph.D. (Materials Science) in 2009 from the Japan Advanced Institute of Science and Technology (JAIST). Sukreen was with Sharp-Roxy before pursuing her Master's. She joined Universiti Teknologi MARA (UiTM) in 2004 and now is a senior lecturer at the School of Electrical Engineering, College of Engineering UiTM. She is a member of the Integrated Sensor Research group at the College of Engineering. Her research interests include the fabrication and characterization of semiconductor materials in general and mainly focused on sensor applications.