SOLUTION-PROCESSED ORGANIC THIN FILM TRANSISTORS FOR HYDROGEN SULFIDE SENSING APPLICATION

Thesis submitted in partial fulfillment for the Award of Degree

DOCTOR OF PHILOSOPHY

BY

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2023

CHAPTER-5

Summary and Future Scope of Research

5.1 Summary

The objective of this thesis is to conduct a comprehensive investigation into the development and characterization of organic thin film transistors (OTFTs) specifically for the purpose of hydrogen sulfide sensing applications. The present work has endeavored to address the issue of fabrication complexity by employing a straightforward, economically viable, and waste-minimizing floating film transfer method (FTM) for the fabrication of organic thin-film transistors (TFTs). This thesis incorporates the optimization of the procedures connected with the fabrication of low-voltage operated devices in conjunction with the advancements in fabrication technologies and processes. Furthermore, it explores the use of these optimized methodologies in the field of hydrogen sulfide sensing. The main contribution of the thesis is illustrated in **Figure 5.1**.

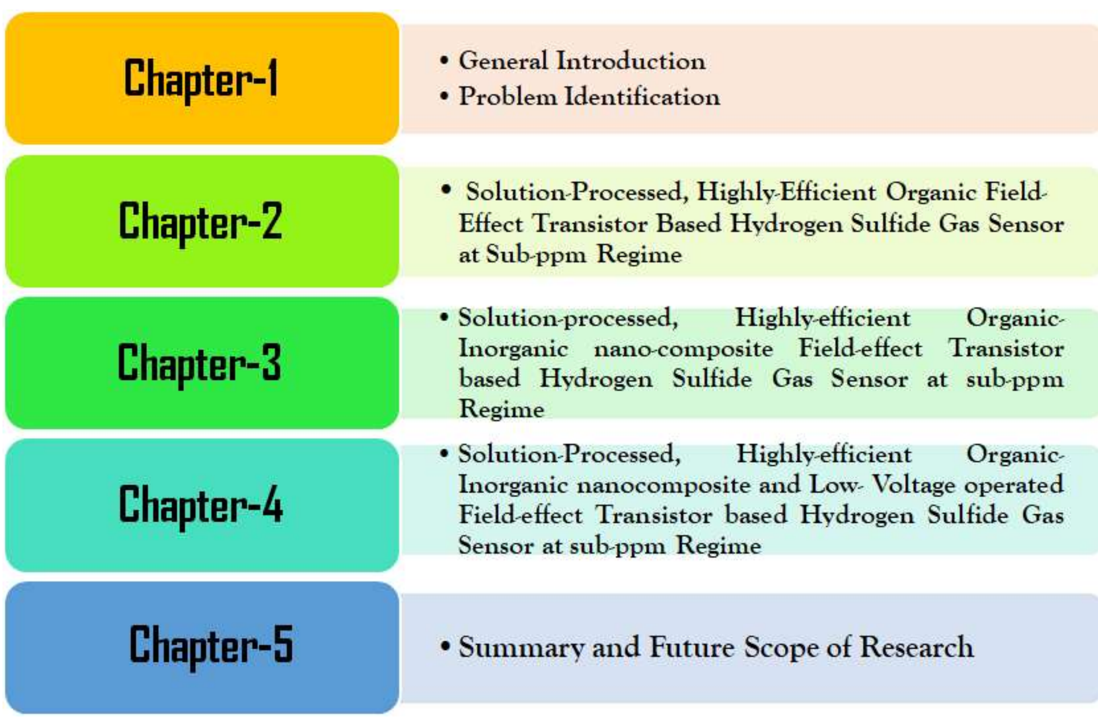

Figure 5.1 Thesis chapter outlines.

The finding and comparison between performed works have been summarized in the **Table 5.1**.

Table 5.1 Performance Comparison between Performed Works

Parameters	PCPDTBT TFT for H_2S Sensing	PCPDTBT/CdS nanocomposite TFT for H_2S Sensing	PCPDTBT/MoS_2 nanocomposite with HfLaOx dielectric TFT for H_2S Sensing
Sensing Material	PCPDTBT	PCPDTBT/CdS	PCPDTBT/MoS_2
Oxide/Dielectric Layer	SiO_2	SiO_2	HfLaOx
OSC Deposition Technique	FTM	FTM	FTM
Dielectric Deposition Technique	Dry Oxidation	Dry Oxidation	Spin Coating
Dielectric Deposition Temperature	1100 ºC	1100 ºC	500 ºC
Dielectric Constant	3.9	3.9	~25
Dielectric Bandgap	~9 eV.	~9 eV.	~5.2 eV.
Areal Capacitance	~10 nF/cm^2	~ 10 nF/cm^2	~367 nF/cm^2
Operation Voltage	-40 V	-40 V	-5 V
Threshold Voltage	-3.62 V	-4.9 V	-1.038 V
Sensing Response	71.3% (1 ppm)	80.2 % (1 ppm)	93.2 % (1 ppm)
Response Time	8 sec	5 sec.	4 sec.
Recovery Time	250 sec	90 sec.	55 sec.
Nature of Substrate	Rigid Silicon	Rigid Silicon	Rigid Silicon
Mobility (*10-3)	1.01 cm^2/V. sec	3.41 cm^2/V. sec	14.38 cm^2/V. sec

5.2 Future Scope of Research

Despite the considerable number of outstanding researches that has been undertaken to develop thin film transistors for diverse electrical and sensing applications, it is important to note that the potential for future advancements in this area is not constrained. To optimize the performance of thin-film transistors (TFTs) for their intended applications, it is essential to conduct further research and include further theoretical analysis, such as compact modeling. For example, a modified thin-film transistor (TFT) architecture has the potential to be utilized in many medical contexts and biosensing applications. This technology facilitates the identification and measurement of biomolecules, bacteria, viruses, glucose levels, blood tests, and other relevant parameters. The study described here can open new opportunities for doing additional research studies in this field. Transparent and flexible electronics are currently in great demand in the market, both in consumer electronics and in scientific applications. The future scope for organic thin-film transistor (OTFT)-based gas sensors is promising, driven by ongoing advancements in materials science, electronics, and sensor technology. Here are several potential directions and areas of growth for the future of OTFT-based gas sensors:

Low Voltage Transistors for various Applications: A few different high-k dielectrics might be tested for low-voltage OTFT. The proposed high-k dielectric material may be combined with other active semiconductor materials to create low-voltage OTFTs for usage in a variety of optoelectronic and sensing applications. Other high-k dielectric materials that are appropriate can improve the performance of the bilayer high-k dielectric-based organic TFT. Low-voltage devices that have been developed can then be utilized to create low-power logic gates, inverters, and memory.

Improved Sensitivity and Selectivity: Research and development efforts can focus on enhancing the sensitivity and selectivity of OTFT-based gas sensors. This includes the exploration of novel organic materials and thin-film architectures to improve the detection limits and specificity for various gases.

Multi-Gas Sensing Platforms: The design of OTFT-based sensors capable of detecting multiple gases simultaneously is an exciting prospect. Developing sensors with broad applicability across different gas types will be valuable for environmental monitoring and industrial safety.

Flexible and Wearable Sensors: Leveraging the inherent flexibility of organic materials, the future may see the development of flexible and wearable gas sensors based on OTFTs. These sensors could be integrated into clothing or wearable devices, providing real-time, on-the-go monitoring for personal safety and health applications.

Miniaturization and Integration: Continued efforts in miniaturization and integration can lead to the development of compact and integrated OTFT-based gas sensing devices. Integration into IoT platforms and smart systems could enable seamless connectivity and data sharing for comprehensive environmental monitoring.

Low-Cost Manufacturing: Exploring cost-effective manufacturing techniques for OTFT-based gas sensors is crucial for widespread adoption. The development of scalable fabrication processes and the use of economical organic materials can contribute to reducing overall sensor production costs.

Energy-Efficient Sensors: Focus on designing energy-efficient OTFT-based gas sensors is essential for applications where power consumption is a critical consideration. Low-power consumption can extend the operational lifetime of battery-powered devices and contribute to sustainable sensor solutions.

Environmental Monitoring and Smart Cities: OTFT-based gas sensors can play a pivotal role in environmental monitoring initiatives and the development of smart cities. These sensors could be deployed in urban areas to monitor air quality, detect pollution sources, and contribute to data-driven decision-making for city planning.

Biomedical Applications: Exploring the potential of OTFT-based gas sensors in biomedical applications is an exciting avenue. These sensors could be developed for non-invasive monitoring of biomarkers in exhaled breath, opening up possibilities for early disease detection and health monitoring.

Machine Learning Integration: Integration with machine learning algorithms can enhance the data analysis capabilities of OTFT-based gas sensors. This can lead to more intelligent and adaptive sensor systems that can learn and improve their detection performance over time.

Collaboration with Other Sensor Technologies: Collaborations with other sensor technologies, such as optical and electrochemical sensors, can lead to hybrid sensor systems with complementary strengths, providing a more comprehensive understanding of the gas environment.

As research in organic electronics and gas sensing technologies advances, the future of OTFT-based gas sensors holds exciting possibilities for addressing challenges in safety, health, and environmental monitoring.