
Preface

This thesis explores some low voltage operable OFETs fabricated using water processed gate dielectrics and their integration with FTM transferred film from the surface of the water (W-FTM) as a liquid substrate. Furthermore, the application of Water transferred FTM film of DPP-DTT in gas sensing and NIR phototransistor have also been explored. This work contributes towards eco-friendly processing of high performance and low voltage operable OFETs and their sensing applications.

Chapter 1 covers a brief introduction to OFET devices their working, parameter extraction, and, basic charge transport in organic semiconductors. Furthermore, this chapter includes a brief review of high k dielectrics used in OFETs, a brief review of recent OFET based NO₂ sensors, a brief review of NIR OPTs, solution process techniques for OSC, a brief introduction and, mechanism of Floating film transfer method followed by the benefits of Water transferred FTM (W-FTM) Film.

Chapter 2 presents the fabrication and characterization of LiO_x based OFETs. This chapter combines the advantages of ecofriendly water induced LiO_x and W-FTM transferred DPP-DTT film. HMDS vapor treatment was used to passivate the surface traps on the LiO_x. Water processed LiO_x was deposited on the Silicon substrate which was used as a substrate as well as the gate. The organic semiconductor DPP-DTT was transferred to the annealed and HMDS treated LiO_x film from the surface of the water using the FTM method. The chapter covers

leakage current behavior with respect to the applied voltage and areal gate capacitance of LiO_x film with respect to frequency. The Surface morphologies of HMDS treated LiO_x film have been studied using Atomic Force microscopy. The I_D - V_G and I_D - V_D (transfer and output respectively) characteristics have been characterized while I_D - V_G has been used to extract the performance parameters of OFETs. A repeated transfer scan for 3600 sec has been presented to see the ambient stability of the device. Current stress bias for 3600 sec continuously was studied to understand the electrical stability of the OFET. It covers the experimental details of film characterization and leakage current behavior and areal capacitance of LiO_x based dielectric characterization followed by electrical characterization and current bias stability analysis for one hour. It shows the integration of water based FTM transfer technology. The devices exhibited an average mobility (μ_{avg}) of $0.14 (\pm 0.035) \text{ cm}^2 \text{ V}^{-1} \text{ sec}^{-1}$ and a maximum saturation mobility (μ_{max}) of $0.184 \text{ cm}^2 \text{ V}^{-1} \text{ sec}^{-1}$. A good on/off ratio of $\sim 10^4$ was obtained with the threshold voltage of around $-1.12 (\pm 0.3)$. Moreover, LiO_x based OFET shows a good Subthreshold swing of $186 (\pm 15) \text{ mV/decade}$ and surface charge trap density (N_{it}) of $4.63 (\pm 0.42) \times 10^{12} \text{ cm}^{-2} \cdot \text{eV}^{-1}$.

Chapter 3 is devoted to the fabrication and characterization of ultra-low voltage operable OFETs with bilayer $\text{LiO}_x/\text{AlO}_x$ dielectrics. DI water has been used for processing of both the dielectric layers. OPDA solution has been used as the SAM (self-assembled monolayer) layer. The same FTM approach to transfer DPP-DTT film from the water surface has been utilized for the OSC layer. The Surface morphologies of the LiO_x , AlO_x , OPDA-treated AlO_x , and Water transferred DPP-DTT film have been studied using AFM. The leakage current behavior of LiO_x and $\text{LiO}_x/\text{AlO}_x$ bilayer has been studied along with band gap analysis using UV-vis analysis. The areal capacitance of LiO_x and $\text{LiO}_x/\text{AlO}_x$ structure has been characterized for

different frequency ranges. A detailed electrical characterization involving I_D - V_G and I_D - V_D has been carried out establishing under -1 V operation of the device. Positive bias stress, negative bias stress, and, continuous current bias stress to understand the electrical stability of the device have been carried out. An environmental stability test for six weeks has also been done and relative change in threshold voltage, Subthreshold swing, and, mobility has been plotted for 6 weeks. The device showed an on/off ratio of $\sim 10^5$, and a subthreshold swing of ~ 90 mV/decade approaching the theoretical limit.

Chapter 4 presents a highly sensitive and selective NO_2 sensor based on low voltage operable OFET. Here thin film has been used to improve the NO_2 sensing performance of OFETs. Water-processed AlO_x film has been deposited over the p-type silicon substrate and low-cost large area processing suitable FTM approach has been employed for OSC transfer (DPP-DTT). The film was transferred from the surface of the water as a liquid substrate. A detailed change in various parameters like mobility, threshold voltage, subthreshold swing, and trap density variation with respect to changes in different gas concentrations has been studied. A selectivity study using various other gases has been carried out. A study regarding the effect of humidity on gas sensing performance has also been done. An enhancement mechanism has been discussed along with transient analysis and comparative study with the recent reports.

Chapter 5 deals with the fabrication, characterization, and parameter extraction of ultra-low voltage operable Near Infrared Organic Phototransistors (NIR-OPTs). Biocompatible and water-soluble polyvinyl alcohol has been used as a dielectric layer while OSC has been transferred using the Floating film transfer method from the surface of the water. This report utilizes the charge trapping phenomenon at the interface of dielectric/semiconductors to

enhance the performance of NIR- OPTs. The PVA dielectric has a large number of hydroxyl groups that act as electron traps. Leakage current analysis of PVA dielectric and capacitance behavior has also been studied. The UV-Vis -NIR analysis of FTM transferred DPP-DTT film was carried out. The transfer characteristics of low voltage OFET with and without exposure to NIR light (850 nm) have been studied to extract parameters like responsivity, external quantum efficiency, and detectivity. A mechanism for performance enhancement has also been discussed based on the charge-trapping effect at the semiconductor dielectric interface.

Chapter 6 summarizes the obtained experimental results followed by a brief discussion on the contribution made by this thesis and a detailed pointwise list that can be incorporated for future work that may be carried out.