

Continuous development of technologies over time has significantly shortened the lifespan of devices, resulting in a substantial increase in electronic waste (E-waste) causing negative impact on environment and ecology. Flexible electronics has emerged as promising technology towards offering solution to this issue by capability of incorporation of nature originated materials in device fabrication through instilling eco-friendliness and potential biodegradability. Organic field-effect transistors (OFET) have been widely investigated as crucial device component for flexible electronics due to its applicability in circuit, sensing, and memory applications. This thesis is an effort to contribute towards flexible biodegradable electronics. Specific emphasis was given on the demonstration of eco-friendly OFETs for circuit and sensing applications with multi-functionality and eventual decomposability, which are essential requirements for smart and sustainable electronics.

To start with, various solution processed biocompatible or natural polymers including polyvinylpyrrolidone, silk fibroin, gelatin, chitosan, egg albumen, and cellulose derivative were explored as promising gate dielectrics in OFETs, either as single layer or in bilayer combination with other polymers or a thin high- k hafnium dioxide (HfO_2). All these devices were fabricated on indium tin oxide (ITO) coated glass or polyethylene terephthalate (PET) substrate, where ITO acting as bottom electrode. Widely explored pristine TIPS-Pentacene or TIPS-Pentacene: Polystyrene (PS) blend was utilized to form active layer with gold (Au) top electrodes working as source/drain, to demonstrate p-channel transistor characteristics for -5 V operation. Low voltage operation (-3 V) in flexible OFETs was demonstrated using a pristine layer of solution processed gelatin in combination with TIPS-Pentacene: PS blend. These devices exhibited excellent electrical characteristics with extracted field-effect mobility (μ) value approaching to as high as $3.0 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ with near-zero threshold voltage and low subthreshold swing (SS), along with remarkable operational stability as confirmed by various stability tests including bias-stress, repeatability, cyclic, bending and long-term ambient stability. A very high environmental stability over 24 weeks was observed with almost unchanged electrical characteristics. Circuit applicability of these devices was successfully demonstrated through resistive load inverters.

Multifunctionality in OFETs with gelatin/ HfO_2 hybrid bilayer gate dielectric and TIPS-Pentacene as semiconductor was demonstrated with multi-parameter sensing capabilities for visible/UV light and humidity, which also led to real time breath rate monitoring, a simple tool for wellness monitoring. Maximum field-effect mobility (μ_{max}) of $2 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ was exhibited with low SS value of $\sim 200 \text{ mV/dec.}$, and high current on-off ($I_{\text{on}}/I_{\text{off}}$) ratio $\sim 10^4$ for -5 V operation with excellent electrical, operational, and bending stability. For the enhancement of performance and stability in devices with nature originated dielectrics, a composite of gelatin and chitosan was investigated with chitosan acting as a tuning agent to modulate the gate dielectric properties through controlled crosslinking facilitated by the electrostatic interaction and strong hydrogen bonding between the functional groups of polymers. Devices fabricated with a gelatin: chitosan ratio of 10:5 exhibited better electrical stability upon bending for 100 repeated bending cycles compared to other ratios. Circuit applicability, high bias-stress stability, and shelf life for 24 months indicated overall high performance using the composite gate dielectrics.

Finally, devices were fabricated on paper substrate thorough process optimization for substrate planarization with polyvinyl alcohol (PVA), silver (Ag) as gate electrode, to move towards eco-sustainable electronics. Cyanoethyl cellulose (CEC), a synthesized version of cellulose was comprehensively investigated as a potential gate dielectric in OFET devices for eco-friendliness. Transistors with CEC dielectric and paper substrate were demonstrated in an effort to produce biodegradable systems for eco-sustainable electronics. These devices exhibited high performance with excellent saturation in the output characteristics for -5 V operation along with remarkable electrical and operational stability. High bendability of devices was confirmed upon application of tensile stress through bending along the channel for the bending radii of 12, 7, and

5-mm. Moreover, high cyclic stability was achieved in devices even after keeping the device in high humid environment with relative humidity reaching to ~100 %. High decomposability in water rich soil in ~20 days was observed due to the microorganisms present in soil environment, confirming excellent biodegradability which is highly essential for eco-sustainable electronics. Due to high performance and biodegradability, these paper-based devices can offer huge potential towards the future flexible and green electronics, and can help in minimizing the impact of E-waste on environment and ecology.

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