Abstract and Keywords

In this dissertation, I have reported the fabrication and characterization of hybrid materials-based low operating voltage (< 2 V) organic field-effect transistors (OFETs). I have used two hybrid materials, namely (i) porous inorganic-organic metal-organic framework (MOF) and (ii) PVDF and gold nanoparticles (AuNps) composite. MOF has been used as a sensing layer to detect diethyl sulfide (DES) vapor, which is a stimulant of sulfur mustard bis(2-chloroethyl) sulfide (BCES). Whereas, PVDF and gold nanoparticles (AuNps) composite has been used as a dielectric layer for possible memory applications. The effect of humidity on the performance of the memory devices is explored. I have adopted a bottom gate top contact (BGTC) configuration for the OFETs fabrication with pentacene as a p-type organic semiconductor. For the fabrication of MOF-assimilated OFET-based DES sensors, CPO-27-Ni MOF is used as a sensing layer, which is spin-coated on the pentacene layer. Prior to the fabrication of OFETs, the growth mechanism of MOF on pentacene film has been studied through statistical analysis of rough surfaces. The used MOF crystallites showed bi-modal size distribution, where the smaller crystallites of 165 nm average diameter diffused through the grain boundaries of the pentacene film, resulting in the structural modification of the crystallinity of pentacene film due to diffusion-induced compressive stress and initiated recrystallization of the pentacene bulk phase. The MOF as a receptor showed excellent sensitivity at room temperature of more than 4 % for 10 ppm DES vapor within 31.33 (±1.52) s. A linear discrimination analysis approach showed adequate discrimination in selectivity among the other toxic gases. In addition, I have developed a prototype module connected to an Android App through Bluetooth connection for wearable detection of a chemical warfare agent (CWA). The use of PVDF and gold nanoparticles (AuNps) composite as a dielectric layer is to reduce the operating voltage. The metallic gold nanoparticles-polymer nanocomposite-based OFETs showed excellent bistability at different humidity conditions. Our fabricated OFETs are extremely stable for up to 300 days and display significant bias-stress stability at different relative humidity (RH). The OFETs displayed a pronounced hysteresis window (ΔV_{th}) of 1.67 (±0.30) V by sweeping the gate voltage from ±2 V at ~45 % RH. Though, the significant hysteresis of 0.81 (±0.10) V persists at vacuum (~10^{-5} mbar), affirming the charge trapping capability of AuNps. Water molecules create large trap states at the surface of the semiconductor and the interfaces, responsible for significant threshold voltage shifts in both directions. Excess proton ($2H_2O \Leftrightarrow H_3O^+ + OH^-$) generation due to the self-ionization of the water molecules creates a large current at 0 V. In addition, temperature-dependent charge transport behavior has been studied. Temperature-dependent hysteresis is checked in transfer and capacitance-voltage (C-V) characteristics. A reversal in hysteresis direction is observed around 100 K. A dual activation energy has been observed. In order to compare the effects, I have explored the activation energies of another inorganic ferroelectric (barium titanate) dielectric-based OFETs, which showed much lower values compared to the nanocomposite dielectric-based OFETs.

Keywords: **organic field-effect transistors (OFETs), low operating voltage, hybrid material, metal-organic frameworks (MOF), diffusion through grain boundaries, recrystallization, chemical warfare agents (CWAs), DES, nanocomposite dielectric, hysteresis, trap states, hopping-assisted charge transport**