

## List of Figures

<b>Figure 1.1:</b> Schematic diagram and charge transportation in TFT channel under the applied electric field with bottom gate top contact geometry.....	2
<b>Figure 1.2:</b> Schematic diagram of the configuration of TFT <b>a)</b> staggered bottom gate <b>b)</b> staggered top gate <b>c)</b> coplanar bottom gate and <b>d)</b> coplanar top gate.....	3
<b>Figure 1.3:</b> Typical <b>a), c), e)</b> output and <b>b), d), f)</b> transfer characteristics of an n-type, p-type, and ambipolar oxide TFT, respectively .....	5
<b>Figure 1.4:</b> Different polarization mechanism of dielectric; <b>a)</b> electronics polarization, <b>b)</b> ionic polarization, <b>c)</b> orientation polarization, <b>d)</b> chain relaxation, <b>e)</b> free counter ion polarization in an electrolyte, <b>f)</b> interfacial polarization, <b>g)</b> electrode or EDL polarization, <b>h)</b> the influence of the different polarization mechanism to the dielectric constant with several frequency regions.....	10
<b>Figure 1.5:</b> Schematic diagram of the basic mechanism of parallel plate metal-insulator-metal capacitor <b>a)</b> without dielectric layer, <b>b)</b> with a dielectric layer, <b>c)</b> dipole polarization mechanism under the absence and presence of an applied electric field.....	11
<b>Figure 1.6:</b> Benchmarks to select the high-k dielectric for a thin film transistor.....	13
<b>Figure 1.7:</b> Schematic of dielectric constant vs. measured bandgap of the several metal oxide dielectric [46].....	14
<b>Figure 1.8:</b> d block metal elements with $(n-1)d^{10}ns^0$ ( $n \geq 4$ ) configuration [68].....	19
<b>Figure 1.9:</b> <b>a)</b> First Brillouin zone and <b>b)</b> band structure of graphene with the linear dispersion around the K points [76, 77] .....	21
<b>Figure 1.10:</b> <b>a)</b> TEM images of graphene films with different thicknesses, <b>b)</b> typical Raman spectra obtained from different thickness regions of graphene film (with an increasing number of layers from bottom to top) [71].....	23
<b>Figure 1.11:</b> Solution-processed ion-conducting metal oxide thin film transistor <b>a)</b> crystal structure of SBA dielectric $Na^+$ ion is denoted by a blue dot, and red and yellow color represents oxygen and aluminum atoms respectively, <b>b)</b> transfer and <b>c)</b> output characteristics of ZTO transistor with sol-gel coated SBA dielectric based TFT.....	25
<b>Figure 2.1:</b> <b>a)</b> Flow chart of the cleaning process and <b>b)</b> flow chart of the device fabrication.....	36
<b>Figure 2.2:</b> Arrangement of the MIM device structure for C-f and I-V measurements.....	43
<b>Figure 2.3:</b> Layout of the BG-TC device structure for TFT characterization.....	44

<b>Figure 3.1:</b> Schematic diagram of <b>a)</b> charge polarization of the $\text{Li}_2\text{ZnO}_2$ ionic dielectric thin film due to $\text{Li}^+$ ion shift under the external bias and <b>b)</b> influence of that dielectric on the flow of electron in an active channel at low voltage.....	47
<b>Figure 3.2:</b> TGA and DTA of the precursor powder of $\text{Li}_2\text{ZnO}_2$ .....	49
<b>Figure 3.3:</b> <b>a)</b> XRD analysis of $\text{Li}_2\text{ZnO}_2$ powder annealed at $500^\circ\text{C}$ , <b>b)</b> GIXRD analysis of $\text{Li}_2\text{ZnO}_2$ thin film annealed at $500^\circ\text{C}$ .....	50
<b>Figure 3.4:</b> <b>a)</b> XRD analysis of $\text{SnO}_2$ powder annealed at $500^\circ\text{C}$ , <b>b)</b> GIXRD analysis of $\text{SnO}_2$ thin film annealed at $500^\circ\text{C}$ .....	50
<b>Figure 3.5:</b> <b>a)</b> Optical transmittance spectra of the solution-processed $\text{Li}_2\text{ZnO}_2$ dielectric thin film annealed at $500^\circ\text{C}$ for $\text{Li}_2\text{ZnO}_2/\text{quartz}$ (inset), <b>b)</b> Tauc's plot corresponding to $\text{Li}_2\text{ZnO}_2$ thin-film .....	51
<b>Figure 3.6:</b> XPS spectra of a different metal element present in $\text{Li}_2\text{ZnO}_2$ dielectric thin film <b>a)</b> Li 1s <b>b)</b> O 1s and <b>c)</b> Zn 2p from the sample of $p^+-\text{Si}/\text{Li}_2\text{ZnO}_2$ annealed at $500^\circ\text{C}$ .....	53
<b>Figure 3.7:</b> 2-D Surface morphology (scan area $5 \times 5 \mu\text{m}$ ) of $\text{Li}_2\text{ZnO}_2/p^+-\text{Si}$ annealed at the temperature of <b>a)</b> $500^\circ\text{C}$ (2D topography) and <b>b)</b> $500^\circ\text{C}$ (3D topography) and $\text{Li}_2\text{O}/p^+-\text{Si}$ annealed at the temperature of <b>c)</b> $500^\circ\text{C}$ (2D topography) and <b>d)</b> $500^\circ\text{C}$ (3D topography)(scan surface area $5 \times 5 \mu\text{m}$ ) .....	54
<b>Figure 3.8:</b> <b>a)</b> Leakage current density vs. applied voltage of $\text{Li}_2\text{ZnO}_2$ and <b>c)</b> $\text{Li}_2\text{O}$ thin film; <b>b)</b> capacitance vs. frequency curves of solution-processed ionic dielectric $\text{Li}_2\text{ZnO}_2$ and <b>d)</b> $\text{Li}_2\text{O}$ thin-film .....	56
<b>Figure 3.9:</b> <b>a)</b> Output, <b>b)</b> transfer characteristics of the $\text{SnO}_2$ TFT with $\text{Li}_2\text{ZnO}_2$ dielectric; <b>c)</b> Output and <b>d)</b> transfer characteristics of the $\text{SnO}_2$ TFT with $\text{Li}_2\text{O}$ dielectric annealed at $500^\circ\text{C}$ with device architecture $p^+-\text{Si}/\text{Li}_2\text{ZnO}_2/\text{SnO}_2/\text{Al}$ and $p^+-\text{Si}/\text{Li}_2\text{O}/\text{SnO}_2/\text{Al}$ .....	59
<b>Figure 3.10:</b> Operational Stability of the ionic dielectric and evolution of the transfer curves of an ionic dielectric <b>a)</b> $\text{Li}_2\text{ZnO}_2/\text{SnO}_2$ TFT and <b>b)</b> $\text{Li}_2\text{O}/\text{SnO}_2$ TFT at a fixed $V_D$ of 2V during the stress test. ....	61
<b>Figure 4.1:</b> Schematic view of the device structure.....	66
<b>Figure 4.2:</b> Thermal gravimetric analysis (TGA) and differential thermo-gravimetric analysis (DTA) curves of precursor powder <b>a)</b> $\text{LiInO}_2$ and <b>b)</b> $\text{LiGaO}_2$ .....	67
<b>Figure 4.3:</b> GIXRD analysis of <b>a)</b> $\text{LiInO}_2$ and <b>b)</b> $\text{LiGaO}_2$ thin film at $550^\circ\text{C}$ annealing temperature and GIXRD analysis of <b>c)</b> $\text{LiInO}_2$ and <b>d)</b> $\text{SnO}_2$ thin film at $500^\circ\text{C}$ annealing temperatures .....	68
<b>Figure 4.4:</b> Surface morphologies (scan surface area $3 \times 3 \mu\text{m}$ ) of the solution-processed $\text{LiInO}_2$ dielectric thin films for $\text{LiInO}_2/p^+-\text{Si}$ surface <b>a)</b> 2-D topography <b>b)</b> 3-D topography,	

for  $\text{LiGaO}_2/p^+\text{-Si}$  surface **c**) 2-D topography **d**) 3-D topography, and for  $\text{Li}_2\text{ZnO}_2/p^+\text{-Si}$  surface, **e**) 2-D topography **f**) 3-D topography.....69

**Figure 4.5:** Optical transmittance spectra of the solution-processed dielectric thin film annealed at  $550^\circ\text{C}$  **a**)  $\text{LiInO}_2/\text{quartz}$  (inset) and **c**)  $\text{LiGaO}_2/\text{quartz}$  (inset), The Tauc's plot corresponding to dielectric thin film **b**)  $\text{LiInO}_2$  and **d**)  $\text{LiGaO}_2$  .....71

**Figure 4.6:** **a**) Leakage current density vs. applied voltage of  $\text{LiInO}_2$  thin film annealed at  $550^\circ\text{C}$  with  $p^+\text{-Si}/\text{LiInO}_2/\text{Al}$  device structure and capacitance vs. frequency curves of solution-processed ionic dielectric **b**)  $\text{LiInO}_2$  **c**)  $\text{LiGaO}_2$  and **d**)  $\text{Li}_2\text{ZnO}_2$  .....72

**Figure 4.7:** **a**) Schematic view of the device structure, **b**) interdigitated mask with width ( $W$ ) to channel length ( $L$ ) ratio of 118 ( $23\text{ mm}/0.2\text{ mm}$ ), **c**) photograph of actual devices with three TFT fabricated on  $15\text{ mm} \times 15\text{ mm}$  substrate, **d**) cross-sectional SEM image of TFT with  $\text{LiInO}_2$  gate dielectric .....74

**Figure 4.8:** **a**) Output and **d**) transfer characteristics of the  $\text{SnO}_2$  TFT with  $\text{LiInO}_2$  dielectric annealed at  $550^\circ\text{C}$ , **b**) Output and **e**) transfer characteristics of the  $\text{SnO}_2$  TFT with  $\text{LiGaO}_2$  dielectric annealed at  $550^\circ\text{C}$  and **c**) Output and **f**) transfer characteristics of the  $\text{SnO}_2$  TFT with  $\text{Li}_2\text{ZnO}_2$  dielectric annealed at  $500^\circ\text{C}$  with device architecture  $\text{Al}/\text{SnO}_2/\text{LiInO}_2/p^+\text{-Si}$ ,  $\text{Al}/\text{SnO}_2/\text{LiGaO}_2/p^+\text{-Si}$  and  $\text{Al}/\text{SnO}_2/\text{Li}_2\text{ZnO}_2/p^+\text{-Si}$  respectively, under n-channel operation and transfer characteristics with gate leakage current ( $I_D/I_G$  vs.  $V_G$ ) under n-channel operation **g**)  $\text{LiInO}_2$ , **h**)  $\text{LiGaO}_2$  and **i**)  $\text{Li}_2\text{ZnO}_2$  respectively.....77

**Figure 4.9:** **a**) Output and **c**) transfer characteristics of the  $\text{SnO}_2$  TFT with  $\text{LiInO}_2$  dielectric annealed at  $550^\circ\text{C}$ , **b**) Output and **d**) transfer characteristics of the  $\text{SnO}_2$  TFT with  $\text{LiGaO}_2$  dielectric annealed at  $550^\circ\text{C}$  with device architecture  $\text{Al}/\text{SnO}_2/\text{LiInO}_2/p^+\text{-Si}$ , and  $\text{Al}/\text{SnO}_2/\text{LiGaO}_2/p^+\text{-Si}$  under p-channel operation.....78

**Figure 4.10:** Schematic of deep acceptor level with tin oxide ( $\text{SnO}_2$ ) for **a**) In, **b**) Ga and **c**) schematic presentation of dielectric/semiconductor interfacial doping.....81

**Figure 4.11:** Schematic demonstration of the electrical networks for the inverter based on two identical ambipolar transistors.....83

**Figure 4.12:** Inverter characteristics for **a**) first and **b**) third quadrants with supply voltages ( $V_{DD}$ ) of  $\pm 1\text{ V}$ , respectively, and corresponding gain of the complementary inverter **c**) first and **d**) third quadrants under the supply voltages ( $V_{DD}$ ) of  $\pm 1\text{ V}$ .....84

**Figure 5.1:** Schematic illustration showing the fabricated GFET device.....89

**Figure 5.2:** **a**) Optical micrograph of graphene sheet transferred on  $p^+\text{-Si}/\text{SiO}_2$  substrate, **b**) SEM micrograph of graphene sheet **c**) TEM image of a graphene sheet on lacey carbon-coated TEM grid where lighter region corresponds to the monolayer graphene while darker

region corresponds to the folded graphene layer, and **d**) Raman spectrum of graphene.....93

**Figure 5.3:** Output characteristics of graphene transistors with different channel lengths (**a-f**), respectively and transfer characteristics of graphene transistors of corresponding channel lengths (**g-l**), respectively .....96

**Figure 5.4:** **a**) Output characteristics for a Graphene field-effect transistor (GFET) using SiO<sub>2</sub> as a gate dielectric **b**) Capacitance vs. frequency (C-f) curve of Li<sub>5</sub>AlO<sub>4</sub> dielectric thin film with a device structure of Al/Li<sub>5</sub>AlO<sub>4</sub>/p<sup>+</sup>-Si.....97

**Figure 5.5:** **a**) Variation of mobility with channel length **b**) Variation of a shift in Dirac point with channel length.....97

**Figure 5.6:** **a**) Schematic illustration of the device structure of back-gated graphene transistors, **b**) Channel length-dependent Li<sup>+</sup> ion effect in graphene transistors, **c**) and **d**) Transfer characteristics of back-gated graphene transistors at V<sub>D</sub> = -2V with different channel lengths.....98

**Figure 5.7:** **a**) Variation of total resistance with the different channel length, and **b**) Variation of contact resistance of device with different channel length.....100

**Figure 5.8:** **a**) Transconductance of the devices with channel length varies from 0.2 mm to 1.65 mm and **b**) channel length varying from 2.85 mm to 5.7 mm as a function of back-gate voltage under a bias of -2V.....102

**Figure 6.1:** **a**) Illustrating fabricated parallel electrode GFET Devices and **b**) schematic of the device with p<sup>+</sup>-Si/Li<sub>5</sub>AlO<sub>4</sub>/Graphene/Ag/MoOx.....106

**Figure 6.2:** Gas sensing experimental measurement setup.....110

**Figure 6.3:** **a**) Raman characteristics of the graphene sheet **b**) SEM micrograph of graphene sheet **c**) TEM image of a graphene sheet on lacey carbon-coated TEM grid where lighter region corresponds to the monolayer graphene while darker region corresponds to the folded graphene layer **d**) GIXRD (inset: UV-Vis absorbance spectrum) **e**) 2D and **f**) 3D surface morphology of p<sup>+</sup>-Si/Li<sub>5</sub>AlO<sub>4</sub> dielectric thin film annealed at 500°C.....111

**Figure 6.4:** **a**) C-f and, **b**) J-V characteristics of dielectric with the structure of p<sup>+</sup>-Si/Li<sub>5</sub>AlO<sub>4</sub>/Al **c**) Output characteristics (I<sub>D</sub> vs. V<sub>D</sub>) and **d**) Transfer characteristics (I<sub>D</sub> vs. V<sub>G</sub>) of GFET.....112

**Figure 6.5:** Transfer characteristics in the presence of ammonia from **a**) 0 to 1 ppm and **b**) 1 to 3 ppm **c**) Variation of Dirac Voltage and **d**) change in resistivity with a concentration of gas **e**) gas response **f**) current vs. time response of ammonia gas sensor.....114

