

## Declaration

I hereby declare that the work presented in this thesis titled *Operationally Stable Flexible Organic Field-Effect Transistors on Unconventional Substrates* submitted to the Indian Institute of Technology Jodhpur in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work carried out under the supervision of Professor Shree Prakash Tiwari. The contents of this thesis in full or in parts, have not been submitted to, and will not be submitted by me to, any other Institute or University in India or abroad for the award of any degree or diploma.



Vivek Raghuvanshi  
P16VSS003



## Certificate

This is to certify that the thesis titled *Operationally Stable Flexible Organic Field-Effect Transistors on Unconventional Substrates*, submitted by *Vivek Raghuwanshi* (P16VSS003) to the Indian Institute of Technology Jodhpur for the award of the degree of *Doctor of Philosophy*, is a bonafide record of the research work done by him under my supervision. To the best of my knowledge, the contents of this report, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.



*Shree Prakash Tiwari*  
Ph.D. Thesis Supervisor



## Acknowledgements

The journey of my PhD was like climbing a steep hill. But there were people around me who acted like ropes and couldn't let me fall in this tough journey and helped me throughout in achieving various milestones. While writing this I am more than happy to acknowledge all those people who directly or indirectly helped me in making me the current individual.

Foremost, I would like to express my sincerest appreciation to my research advisor, *Dr. Shree Prakash Tiwari* for his continuous motivation, mentorship and research guidance. He is one of the kindest people I have ever met and he is more like a father to me rather than a thesis supervisor. He never let me work under any pressure and always motivated all the group members by sharing his experiences. I thank him for being my PhD mentor and giving me the chance to work with one of the coolest supervisor. I also thank *Dr. Mahesh Kumar, Dr. Ambesh Dixit, and Dr. Satyajit Sahu*, Members of the Doctoral Committee, for their kind suggestions and always helping me in need.

I would like to thank my senior cum elder brother *Dr. Deepak Bharti*, who has always been there whenever needed. He is the one who motivated me to start this journey and his achievements always shown us that no matter how difficult the path is, if you believe in yourself, sooner or later you will definitely achieve your goal. Thank you *Dr. sahab*.

I express my sincere gratitude to my seniors *Mr. Ajay Kumar Mahato and Mr. Ishan Varun*. Their valuable suggestions and timely guidance during the research work have been of great help.

I would like to express my thanks to my lab mates *Abhishek Sahu, Abhishek Kumar, Adarsh Nigam, Amit Kumar Shringi, Neeraj Goel, Nitin, Pulkit Saxena, Rahul Kumar, Sachin Rahi, Swati Gahlaut and Vijendra Singh Bhati*, for their support, affection, and maintaining a healthy and enthusiastic research environment in the laboratory.

Now I would like to thank the ones who were always there to distract me from my work and have shown me the importance of enjoying life with their nonsense philosophies. The ones who have always been there to make me laugh. My friends *Anchal Gahlaut, Bhawna Chaubey, Sumitra Godara, and Shubham Vaishnav*. Life without them at IITJ is unimaginable for me. Thank you all for being my family and supporting me in my bad times.

I would like to thank my buddies with whom I started my journey at IITJ, *Anshul Gupta, Charu Gupta, Raj Singh Parihar and Piyush Jaiswal*. The very first friends at IITJ and the friends for lifetime. I also like to thank my classmates during the coursework, *Amit Gangwar, Gaurav Jajoo, Shreya Goyal, Naveen Kumar Mangal and Deepak Dhillon* for helping me to pass my coursework with good grades. I would like to thank my seniors *Nidhi Sharma, Shalini Singh, Manju Kaushik, Parveen Dagar, Tushar Shinde and Jyoti Faujdar* for supporting me and giving their kind suggestions.

I would like to thank Visvesvaraya Ph.D. Scheme (Ministry of Electronics & IT) for providing financial assistance for my projects.

I strongly believe that nothing can be achieved without parent's blessings. I would like to thank my father *Shri Dhanraj Singh Raghuwanshi*, my mother *Smt. Nisha Raghuwanshi* and my sweet sister *Shradha Raghuwanshi* for their blessings, love, sacrifices and moral support because of which I could complete this journey.

*Vivek Raghuwanshi*  
PhD Student



## List of Figures

Figures	Title	Page
1.1	Graph showing continuous growth in the printed electronics market and expected demand in the future (Source: IDTechEx Market research).	3
1.2	(a) Digital image of the fabricated organic electronics devices on flexible Polyethylene Terephthalate (PET) substrate demonstrating the mechanical flexibility of organic electronics. (b) Roll to roll processing use in fabricating organic electronic devices (Source: vttresearch.com).	4
1.3	Applications of organic electronics on flexible platforms. (a) Circuit board printed on a flexible substrate (Source: wsj.com). (b) Bendable organic light-emitting display (Source: prweb.com). (c) An organic solar panel on a flexible substrate (Source: ise.fraunhofer.de). (d) Printed flexible RFID tag (Source: elechouse.com). (e) wearable organic light-emitting display (Source: theconversation.com).	5
1.4	Devices that use OLED displays (a) Apple 4 series watch with an OLED display (Source: appleinsider.com). (b) LG 88-inch 8k OLED TV (Source: cnet.com). (c) Samsung foldable smartphone Samsung galaxy fold with AMOLED display (Source: techradar.com).	6
1.5	Chemical Structure of various small molecule organic semiconductors (a) TIPS-pentacene (b) PC <sub>60</sub> BM (c) TES-ADT (d) Pentacene (e) PTCBI (f) Rubrene (g) SubPC (h) Anthracene and (i) C8BTBT.	8
1.6	Chemical structure of various polymeric organic semiconductors (a) F8BT (b) P3HT (c) PCDTBT (d) PCPDTBT (e) PDPP-TTT (f) MEH-PPV (g) PBTBT (h) P(NDI <sub>2</sub> OD-T <sub>2</sub> ) and (i) BBL.	8
1.7	An ethylene molecule.	9
1.8	Bonding-antibonding interaction of energy levels between the pair of ethylene molecule.	10
1.9	OFET device architectures; (a) Bottom gate top contact. (b) Bottom gate bottom contact. (c) Top gate bottom contact. (d) Top gate top contact.	11
1.10	Schematic representation of energy band diagram of ideal MIS structure with p-type OSC under (a) equilibrium, under application of (b) negative bias and (c) positive bias.	12
1.11	Operating Principle of OFET in (a) linear regime (b) onset of saturation (c) saturation regime.	13
2.1	An ultrasonic cleaner from Rivotek.	24
2.2	(a) Bottom gate top contact OFET architecture. (b) Shadow mask for Source/Drain.	24
2.3	Schematic representation of the e-beam evaporation system.	25
2.4	(a) Schematic representation of the thermal evaporation system and (b) Digital image of SC-Triaxis e-beam and thermal evaporation system from Semicore used in experiments.	26
2.5	(a) Schematic representation of film formation with ALD system, and (b) digital image of savannah S-200 thermal ALD system from Cambridge nanotech used in the experiments.	27
2.6	(a) Schematic representation of the sputtering system and (b) digital image of the sputtering system used in experiments.	28
2.7	(a) Schematic representation of film formation with spin coating method and (b) digital image of WS-650 MHz-BNPP/LITE spin coating system from Laurell.	29
2.8	(a) Schematic representation of semiconductor deposition through drop-casting method, and the digital image of the (b) semiconductor solution drop casted over flexible sample, (c) semiconductor crystals formed after solvent evaporation.	29
2.9	(a) Schematic illustration of the photo-lithography process and (b) digital image of the photolithography machine.	30
2.10	(a) Schematic illustration of stylus profilometer and (b) digital image of DekTak-XT surface profiler system from Bruker that was used in experiments.	31
2.11	(a) Illustration of the working principle of X-ray diffraction measurement. (b) D8 advanced X-ray diffraction system from Bruker that is used in experiments.	32
2.12	(a) Surface roughness analysis through the atomic force microscopy system. (b) SPM XE-70 AFM system from Park Systems.	33
2.13	(a) Image capturing using an optical microscope. (b) The optical microscope used in the experiments.	33
2.14	(a) Surface imaging using scanning electron microscopy. (b) SEM EVO-18 special edition system from Carl-Zeiss.	34

2.15	(a) Schematic illustration of UV-visible spectroscopy process. (b) UV-1800 UV-visible spectro-photometer from Shimadzu used for characterization.	35
2.16	(a) 4200-semiconductor characterization system from Keithley. (b) Cascade Microtech PM5 probe station used for characterization.	36
2.17	Typical (a) transfer and (b) output characteristics of a p-type OFET.	37
3.1	Schematic representation of bottom gate top contact OFETs fabricated with (a) Neat and (b) Blended active layer.	44
3.2	Surface morphology of semiconductor crystals obtained from solutions of neat TIPS-pentacene (a), TIPS-pentacene: PS blends in the ratio of 3:1 (b), 1:1 (c), and 1:3 (d), showing similar terracing structure.	45
3.3	X-ray diffractogram of semiconductor crystals obtained from neat and blended active layer films, showing an increase in crystalline nature with the increase in PS content.	46
3.4	Transfer and output characteristics of representative neat TIPS-pentacene OFET (a) & (b), TIPS-pentacene:PS blend OFET with mixing ratio of 3:1 (c) & (d), 1:1 (e) & (f), and 1:3 (g) & (h).	47
3.5	Bias stress-induced decay in normalized drain current for various TIPS-pentacene OFETs for pristine devices.	48
3.6	Demonstration of the bending strategy used to test the electromechanical stability.	49
3.7	Bias stress-induced decay in normalized drain current for various TIPS-pentacene OFETs after applying strain.	49
3.8	Threshold voltage shift as a function of stress duration for various TIPS-pentacene OFETs for (a) pristine and (b) strained condition.	50
3.9	Recovery characteristics after bias stress of a representative neat TIPS-pentacene OFET (a), TIPS-pentacene:PS blend OFET with mixing ratio of 3:1 (b) 1:1 (c), and 1:3 (d) in pristine situation.	51
3.10	Recovery characteristics after bias stress of a representative neat TIPS-pentacene OFET (a), TIPS-pentacene: PS blend OFET with mixing ratio of 3:1 (b) 1:1 (c), and 1:3 (d) after applying strain.	52
3.11	(a) Transfer characteristics of a representative neat TIPS-pentacene OFET, TIPS-pentacene:PS blend OFET with mixing ratio of 3:1 (b), 1:1 (c), and 1:3 (d) before and after 100 measurement cycles.	53
4.1	(a), (b) Schematic representation and (c), (d) digital image of bottom gate top contact OFETs fabricated on rigid and flexible substrates. Chemical structure of (e) TIPS-pentacene and (f) Polystyrene used in active layer preparation.	60
4.2	(a) X-ray diffractograms of the BST films grown at different temperatures. Atomic force microscopic images of the BST film grown at (b) R <sub>T</sub> (c) 200 °C (d) 400 °C (e) 500 °C and (f) 600 °C.	61
4.3	(a) Capacitance - frequency and (b) Current density - Voltage curve for BST films deposited at various temperatures.	62
4.4	Transfer and output characteristics of OFETs fabricated with (a), (b) 300 nm thermally grown SiO <sub>2</sub> , (c), (d) room temperature deposited BST and (e), (f) 600 °C deposited BST film as dielectric.	63
4.5	(a) J-V and (b) C-f characteristics of room-temperature deposited BST films on flexible PET substrate.	64
4.6	(a) AFM image showing terracing structure, and (b) X-ray diffractogram of TIPS-pentacene crystals deposited over the amorphous BST layer.	65
4.7	(a) Transfer and (b) output characteristics of the flexible OFETs	65
4.8	Representation of flexible device operational stability with 500 continuous multiple transfer scans.	66
4.9	(a) Transfer characteristics, (b) extracted mobility and the threshold voltage of the flexible OFETs with varying bending radius.	66
4.10	(a) Normalized drain current decay and (b) shift in threshold voltage of the device, induced due to bias stress for pristine and after bending the devices to 5 mm radius.	67
4.11	Optical Microscope image of the top view of the device for (a) Pristine, after (b) 5 mm and (c) 2 mm bending showing developed cracks at lower bending radii.	68
4.12	Illustration of a single bending cycle for mechanical stress test comprising of tensile and compressive strain.	68
4.13	(a) Transfer characteristics and (b) variation in mobility and threshold voltage with an increasing number of bending cycles.	69



4.14	Variation in transfer characteristics with increasing bending duration showing long term bending stability in flexible OFETs.	69
4.15	C-f measurement of the BST film with (a) varying bending radius and (b) increasing number of bending cycles.	70
5.1	(a) Schematic of the bottom gate top contact OFET structure. (b) Digital image of the Kapton tape substrate used in OFET fabrication. (c) Optical microscopic image of the fabricated device from the top. Chemical structure of (d) TIPS-pentacene, (e) Polystyrene, (f) PVP and (g) PVA.	74
5.2	Surface morphology of HfO <sub>2</sub> layer grown over (a) PVP and (b) PVA layer.	75
5.3	XRD pattern for TIPS-pentacene: PS crystals obtained for type 1 and type 2 devices respectively.	76
5.4	(a), (b) Transfer and Output characteristics of the representative type 1 and (c), (d) type 2 OFETs.	76
5.5	Transfer characteristics of the representative devices measured at regular intervals during storage in the ambient environment for (a) type 1 and (b) type 2 device. The plot of variation in $\mu_{sat}$ and $V_{TH}$ with ambient storage time for (c) type 1 and (d) type 2 device.	78
5.6	Effect on bias stress induced normalized drain current decay after exposure of devices in the ambient environment for (a) type 1 and (b) type 2 device. Threshold voltage shift as a function of stress duration after exposure to ambient environment up to 5 months for (c) type 1 and (d) type 2 device.	79
5.7	Operational stability test with 100 continuous transfer cycle measurements for the pristine case and after exposure to the ambient environment to 5 months for (a), (b) type 1 device and (c), (d) type 2 device.	80
5.8	(a) Schematic representation of the inverter circuit with resistive load, Voltage transfer characteristics of the resistive load inverter circuits with different resistive load for (b) type 1 and (c) type 2-inverter circuit, Static gain obtained with different resistive load for (d) type 1 and (e) type 2 device.	81
5.9	Dynamic switching behavior for (a) type 1 and (b) type 2 resistive load inverter with 144 M $\Omega$ resistive loads. The upper pulse is the input voltage ( $V_{in}$ ) given and the lower one is the measured output signal ( $V_{out}$ ) for both the cases.	82
6.1	(a) Digital image of the paper substrate, (b) Device structure of the top contact bottom gate TIPS-pentacene paper OFET and (c) Digital image of the fabricated device on paper substrate.	86
6.2	Surface morphology of (a) Bare paper substrate, (b) PVA coated paper substrate, (c) PVP dielectric surface and (d) HfO <sub>2</sub> surface over which active layer was deposited. (e) Surface morphology of TIPS-pentacene crystal (f) C-f and (g) J-V characteristics for PVP/HfO <sub>2</sub> bilayer dielectric.	88
6.3	(a) Transfer, and (b) Output characteristics of the representative paper device.	89
6.4	(a) Measured transfer characteristics with increasing bias stress ( $V_{DS} = V_{GS} = -10$ V) duration up to 3600 s, (b) Bias stress induced decay in normalized drain current, (c) Threshold voltage shift as a function of stress duration, and (d) Continuous transfer cycle measurement up to 100 scans.	90
6.5	(a) Transfer characteristics scan with varying device exposure time to humidity (Relative Humidity = 95%) and (b) Plot of variation in mobility and threshold voltage with varying humidity exposure time.	91
6.6	Effect on transfer characteristics of the devices measured during storage in the ambient environment for a period of 6 months in (a) logarithmic and (b) linear scale and (c) Plot of variation in mobility and threshold voltage as a function of time (months).	92
6.7	Surface morphology of TIPS-pentacene crystals for (d) pristine and (e) after 6-month environmental exposure.	93
6.8	The plot of variation in (a) Transfer characteristics, (b) Mobility, threshold voltage and $I_{DON}$ (maximum ON current at $V_{GS} = -10$ V) with annealing temperatures.	94
6.9	Optical micrographs of semiconductor crystals for (a) Pristine, (b) 60 °C, and (c) 100 °C annealed devices.	94
6.10	Surface morphology of (a) pristine and (b) 100 °C annealed active layer, showing crystal rupture at high-temperature annealing leading to performance deterioration of devices.	95
6.11	X-ray diffractogram of the active layer for pristine and annealed samples.	95
6.12	(a) Transfer and (b) Output characteristics of paper OFET under UV illumination. (c) Effect of UV illumination time on the transfer characteristics of the OFET. (d) The plot of variation	96

of mobility, threshold voltage and  $I_{DON}$  (maximum ON current at  $V_{GS} = -10$  V) with increasing UV illumination time.

- 6.13 (a) Output and (b) Transfer characteristics of the representative paper OFET with PVA/HfO<sub>2</sub> bilayer dielectric. 97
- 6.14 (a) Voltage transfer characteristics of the resistive load inverter circuit with paper OFET. 98  
(b) Static gain with different resistive loads.

## List of Tables

<i>Table</i>	<i>Title</i>	<i>Page</i>
1.1	Summary of various studies reporting high-performance OFETs on the plastic substrate. Subs: Substrate; Dev. Str.: Device Structure; OSC.: Organic semiconductor; Op. Vol.: Operating Voltage; Flex. Test: Flexibility Test.	13
1.2	Summary of various studies on OFETs fabricated on paper substrate. Surface Mod.: Surface Modification.	16
3.1	Summary of some high-performance semiconductor: polymer blend OFETs with their deposition strategy.	43
3.2	Summary of the extracted electrical parameters for neat and blend OFETs.	48
3.3	Extracted electrical parameters before and after applying strain.	50
4.1	Summary of some high-k dielectrics used for low-voltage OFETs.	58
4.2	Summary of electrical parameters extracted from room temperature and 600 °C deposited BST based OFETs.	62
5.1	Summary of the electrical parameters for Type 1 and Type 2 OFETs	77
6.1	Summary of the electrical parameters for the fabricated paper OFETs.	89

## List of Symbols

<i>Symbol</i>	<i>Description</i>
<b>A</b>	Effective Device Area
<b>B</b>	Temperature Dependent Dispersion Parameter
<b>C<sub>i</sub> or C<sub>ox</sub></b>	Capacitance Density
<b>D<sub>it</sub></b>	Interface Trap Density
<b>e or q</b>	Electronic Charge
<b>E</b>	Electric Field
<b>E<sub>F</sub></b>	Fermi Energy Level
<b>E<sub>c</sub></b>	Conduction Band
<b>E<sub>G</sub></b>	Energy Band Gap
<b>H</b>	Planks constant
<b>I<sub>DS</sub></b>	Drain Current
<b>I<sub>DS(t)</sub></b>	Drain Current at time t
<b>I<sub>DS(t)</sub></b>	Drain Current at time o
<b>I<sub>photo</sub></b>	Drain Current under Illuminated State
<b>I<sub>dark</sub></b>	Drain Current under Dark State
<b>I<sub>ON</sub></b>	Maximum ON-State Current
<b>I<sub>OFF</sub></b>	Minimum OFF-State Current
<b>K</b>	Boltzmann's Constant
<b>L</b>	Length of Transistor Channel
<b>m</b>	Slope of Square-root of Drain Current
<b>R<sub>bend</sub></b>	Bending Radius
<b>μ</b>	Field Effect Mobility
<b>V</b>	Drift Velocity
<b>T</b>	Absolute Temperature
<b>t</b>	Transfer Integral
<b>τ</b>	Relaxation Time
<b>t<sub>sub</sub></b>	Thickness of the Substrate
<b>V<sub>GS</sub></b>	Gate to Source Voltage
<b>V<sub>DS</sub></b>	Drain to Source Voltage
<b>V<sub>TH</sub></b>	Threshold Voltage
<b>V<sub>TO</sub></b>	Initial Threshold Voltage
<b>ΔV<sub>T</sub></b>	Shift in Threshold Voltage
<b>W</b>	Width of Transistor Channel
<b>X</b>	Electron Affnity
<b>λ</b>	Wavelength of Light Source Used
<b>λ<sub>peak</sub></b>	Peak Wavelength in the Emission Spectrum of the Light Source Used
<b>μ<sub>max</sub></b>	Maximum Mobility
<b>μ<sub>sat</sub></b>	Saturation Mobility
<b>μ<sub>avg</sub></b>	Average Mobility
<b>Φ<sub>m</sub></b>	Metal Work Function

## List of Abbreviations

<i>Abbreviation</i>	<i>Full form</i>
Au	Gold
Ag	Silver
AFM	Atomic Force Microscopy
ALD	Atomic Layer Deposition
AMOLED	Active Matrix Organic Light Emitting Diode
BAMS	Bar-Assisted Meniscus Shearing
BGTC	Bottom Gate Top Contact
BGBC	Bottom Gate Bottom Contact
BST	Barium Strontium Titanate
Cap.	Capacitance Density
CMOS	Complementary Metal Oxide Semiconductor
C-V	Capacitance-Voltage
Cu-PC	Copper(II) phthalocyanine
C8-BTBT	2,7-Dioctyl[1]benzothieno[3,2-b][1]benzothiophene
DiF-TES-ADT	2,8-Difluoro-5,11-bis(triethylsilylethynyl)anthradithiophene
DNTT	Dinaphtho[2,3- <i>b</i> :2',3'- <i>f</i> ]thieno[3,2- <i>b</i> ]thiophene
DPP-CN	2,2'-[(2,5-dihexadecyl-3,6-dioxo-2,3,5,6-tetrahydropyrrolo[3,4- <i>c</i> ]pyrrole-1,4-diylidene)dithiene-5,2-diylidene]dimalononitrile
DPP6T	Diketopyrrolopyrrole-sexithiophene
DPTTA	meso-diphenyl tetrathia[22]annulene[2,1,2,1]
F16 CuPc	hexadecafluorocopperphthalocyanine
F8T2	Poly(9,9-dioctylfluorene-alt-bithiophene)
FWHM	Full Width At Half Maximum
HfO <sub>2</sub>	Hafnium dioxide
HOMO	Highest Occupied Molecular Orbital
HPCPS	Polysiloxane-poly(vinyl alcohol)
ICCN	Ionic Conductive Cellulose Nanopapers
I-V	Current-Voltage
ITO	Indium Tin Oxide
KITE	Keithley Interactive Test Environment
LCD	Liquid Crystal Display
LUMO	Lowest Unoccupied Molecular Orbital
MIS	Metal Insulator Semiconductor
MOSFET	Metal Oxide Field-Effect Transistor
MEH-PPV	Poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene]
NTCDI-F15	N, N-dipentadecafluorooctyl-1,4,5,8-naphthalene tetracarboxylic diimide
ODPA	octadecylphosphonic acid
OFET	Organic Field-Effect Transistor
OTFT	Organic Thin Film Transistor
OLED	Organic Light Emitting Diode
OSC	Organic Semiconductor
PAA	polyacrylic acid
PBTTT-C14	poly(2,5-bis(3-tetradecylthiophen-2-yl)(thieno[3,2- <i>b</i> ]thiophene)
PD18CN2	
PIDT-BT	Poly(indacenodithiophene-co-benzothiadiazole)
PLAA	Poly(L-lactic acid)
PS	Polystyrene
PVA	Polyvinyl alcohol

PVP	Poly(4-vinylphenol)
P(VDF-TrFE)	Poly(vinylidene fluoride-trifluoroethylene)
PEN	Polyethylene naphthalate
PES	Polyestersulfone
PET	Polyethylene Terephthalate
PGMEA	Propylene Glycol Monomethyl Ether Acetate
P3HT	Poly(3-hexylthiophene-2,5-diyl)
PSS	poly(4-styrene sulphonic acid)
PTAA	Poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine]
PMMA	Poly(methylmethacrylate)
P-Ams	Poly( $\alpha$ -methylstyrene)
PTCDI-C <sub>13</sub> H <sub>27</sub>	N,N'-ditridecyl-3,4,9,10-perylenetetracarboxylic diimide
PQT-12	Poly(3,3''-didodecylquaterthiophene)
PVC	Poly (vinly cinnamate)
PVN	Poly(2-vinylnaphthalene)
RFID	Radio Frequency Identification
SAM	Self Assembled Monolayer
Si	Silicon
SiO <sub>2</sub>	Silicon dioxide
SEM	Scanning Electron Microscopy
SCS	Semiconductor Characterization System
SMU	Source Measuring Unit
SS	Sub-threshold Slope
STO	Strontium titanate
SVA	Solvent Vapor Annealing
TCNQ	Tetracyanoquinodimethane
TDMAH	Tetrakis(dimethylamino)hafnium
TES-ADT	5,11-Bis(triethylsilylethynyl)anthradithiophene
TFTs	Thin Film Transistors
TGTC	Top Gate Top Contact
TGBC	Top Gate Bottom Contact
TiO <sub>2</sub>	Titanium dioxide
TIPS-pentacene	6,13-Bis(triisopropylsilylethynyl)pentacene
TIPS-pen.	TIPS-pentacene
UV	Ultra-Violet
XRD	X-ray Diffraction
ZrO <sub>2</sub>	Zirconium dioxide



