# 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 Raghuwanshi*
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

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*Vivek Raghuwanshi*
PhD Student

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# List of Symbols

| *Symbol* | *Description* |
|---|---|
| $A$ | Effective Device Area |
| $B$ | Temperature Dependent Dispersion Parameter |
| $C_i$ or $C_{ox}$ | Capacitance Density |
| $D_{it}$ | Interface Trap Density |
| e or q | Electronic Charge |
| $E$ | Electric Field |
| $E_F$ | Fermi Energy Level |
| $E_C$ | Conduction Band |
| $E_G$ | Energy Band Gap |
| $H$ | Planks constant |
| $I_{DS}$ | Drain Current |
| $I_{DS}(t)$ | Drain Current at time t |
| $I_{DS}(t)$ | Drain Current at time 0 |
| $I_{photo}$ | Drain Current under Illuminated State |
| $I_{dark}$ | Drain Current under Dark State |
| $I_{ON}$ | Maximum ON-State Current |
| $I_{OFF}$ | Minimum OFF-State Current |
| $K$ | Boltzmann's Constant |
| $L$ | Length of Transistor Channel |
| m | Slope of Square-root of Drain Current |
| $R_{bend}$ | Bending Radius |
| $\mu$ | Field Effect Mobility |
| V | Drift Velocity |
| $T$ | Absolute Temperature |
| t | Transfer Integral |
| $\tau$ | Relaxation Time |
| $t_{sub}$ | Thickness of the Substrate |
| $V_{GS}$ | Gate to Source Voltage |
| $V_{DS}$ | Drain to Source Voltage |
| $V_{TH}$ | Threshold Voltage |
| $V_{TO}$ | Initial Threshold Voltage |
| $\Delta V_T$ | Shift in Threshold Voltage |
| $W$ | Width of Transistor Channel |
| X | Electron Affnity |
| $\lambda$ | Wavelength of Light Source Used |
| $\lambda_{peak}$ | Peak Wavelength in the Emission Spectrum of the Light Source Used |
| $\mu_{max}$ | Maximum Mobility |
| $\mu_{sat}$ | Saturation Mobility |
| $\mu_{avg}$ | Average Mobility |
| $\Phi_m$ | Metal Work Function |

## List of Abbreviations

| *Abbreviation* | *Full form* |
|---|---|
| Au | Gold |
| Ag | Silver |
| AFM | Atomic Force Microscopy |
| ALD | Atomic Layer Deposition |
| AMOLED | Active Matrix Organic Light Emmiting Diode |
| BAMS | Bar-Assited 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-*b*:2',3'-*f*]thieno[3,2-*b*]thiophene |
| DPP-CN | 2,2′-[(2,5-dihexadecyl-3,6-dioxo-2,3,5,6-tetrahydropyrrolo[3,4-c]pyrrole-1,4diylidene)dithiene-5,2-diylidene]dimalononitrile |
| DPP6T | Diketopyrrolopyrrrole-sexithiophene |
| DPTTA | meso-diphenyl tetrathia[22]annulene[2,1,2,1] |
| F16 CuPc | hexadecafl uorocopperphthalocyanine |
| F8T2 | Poly(9,9-dioctylfluorene-alt-bithiophene) |
| FWHM | Full Width At Half Maximum |
| $HfO_2$ | Hafnium dioxide |
| HOMO | Highest Occupied Molecular Orbital |
| HPCPS | Polysiloxane-poly(vinyl alchohol) |
| 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-2yl(thieno[3,2-b]thiophene) |
| PDI8CN2 | |
| 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 napthalate |
| 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(α-methylstyrene) |
| PTCDI-$C_{13}H_{27}$ | N,N′-ditridecyl-3,4,9,10-perylenetetracarboxylic diimide |
| PQT-12 | Poly(3,3‴-didodecylquaterthiophene) |
| PVC | Poly (vinly cinnamate) |
| PVN | Poly(2-vinylnapthalene) |
| RFID | Radio Frequency Identification |
| SAM | Self Assembled Monolayer |
| Si | Silicon |
| $SiO_2$ | 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 |
| $TiO_2$ | Titanium dioxide |
| TIPS-pentacene | 6,13-Bis(triisopropylsilylethynyl)pentacene |
| TIPS-pen. | TIPS-pentacene |
| UV | Ultra-Violet |
| XRD | X-ray Diffraction |
| $ZrO_2$ | Zirconium dioxide |