Declaration
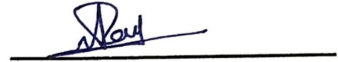
I, **Arpita Roy**, hereby declare that the present thesis, entitled **"Fabrication and Characterization of the 2D Tungsten Disulfide (WS$_2$) Field Effect Transistor"**, is the record of research work done by me under the supervision of Dr. Biplob Mondal, Associate Professor, Department of Electronics and Communication Engineering, Tezpur University, Tezpur. The contents of the thesis represent my original works that have not been previously submitted for any Degree/Diploma/Certificate in any other University or Institutions of Higher Education.

This thesis is being submitted to Tezpur University for the Degree of Doctor of Philosophy in Electronics and Communication Engineering.

Place: Tezpur University, Tezpur

Date: 04/07/2025

(Arpita Roy)

Certificate

This is to certify that the thesis entitled, "**Fabrication and Characterization of the 2D Tungsten Disulfide (WS$_2$) Field Effect Transistor**", submitted to the School of Engineering, Tezpur University in partial fulfillment for the award of the degree of Doctor of Philosophy in Electronics and Communication Engineering is a record of research work carried out by **Ms. Arpita Roy** under my supervision and guidance.

All help received by her from various sources have been duly acknowledged.

No part of this thesis has been submitted elsewhere for award of any other degree.

04/07/25

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Certificate of the External Examiner

This is to certify that the thesis entitled **"Fabrication and the Characterization of the 2D Tungsten Disulfide (WS$_2$) Field Effect Transistor"** submitted by **Ms. Arpita Roy** Department of Electronics & Communication Engineering, School of Engineering, Tezpur University in partial fulfilment for the award of the degree of Doctor of Philosophy in Electronics & Communication Engineering has been examined by us on_____ and found to be satisfactory.

The committee recommends for the award of the degree of Doctor of Philosophy.

Supervisor   **External Examiner**

(Dr. Biplob Mondal)   (   )

Date:_____   **Date:**_____

Acknowledgment

Arpita Roy

Dedicated to my

Parents…….

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Nomenclature

Abbreviations:

Si	Silicon
SiO$_2$	Silicon Dioxide
MOSFET	Metal Oxide Field-Effect Transistors
M-S	Metal-Semiconductor
FET	Field-Effect Transistors
SOI	Silicon-On-Insulator
1D	One-Dimensional
2D	Two Dimensional
NW	Nanowire
NT	Nanotube
CNT	Carbon Nanotube
CNR	Carbon Nanoribbon
SWNT	Single-Wall Nanotube
MWNT	Multiwall Nanotube
NR	Nanoribbon
NRO	Nanorod
BP	Black Phosphorus
TMD	Transition Metal Dichalcogenide
GAA	Gate-All-Around
Au	Gold
ZnO	Zinc Oxide
TiO2	Titanium Dioxide
GaN	Gallium Nitride
vdW	Van-der Waals
CVD	Chemical Vapor Deposition
X	Chalcogen
Mo	Molybdenum
W	Tungsten

S	Sulfur
Se	Selenide
Ti	Titanium
WS_2	Tungsten Disulfide
MoS_2	Molybdenum Disulfide
$MoSe_2$	Molybdenum Diselenide
WSe2	Tungsten Diselenide
MoTe2	Molybdenum Ditelluride
PL	Photoluminescence
UV-Vis	UV-Visible
XRD	X-Ray Diffraction
FESEM	Field Emission Scanning Electron Microscopy
AFM	Atomic Force Microscopy
HRTEM	High Resolution Transmission Electron Microscopy
EDX	Energy-Dispersive X-ray
SBH	Schottky Barrier Height
I-V	Current-Voltage
LPE	Liquid-Phase Exfoliation
Cl	Chlorine
DFT	Density Functional Theory
DOS	Density of States
OT	Octahedral
CBM	Conduction Band Minimum
VBM	Valence Band Maximum
SOC	Spin-Orbit Coupling
C	Carbon
TTF	Tetrathiafulvalene
TCNQ	Tetracyanoquinodimethane
HOMO	Highest Occupied Molecular Orbital
LUMO	Lowest Unoccupied Molecular Orbital
NMP	N-Methyl-2-Pyrrolidone
DMF	N-Dimethylformamide

ACE	Acetone
DI	Deionized
EtOH	Ethanol
IPA	Isopropyl Alcohol
PVD	Physical Vapor Deposition
MBE	Molecular Beam Epitaxy
VDWE	Van-der Waals Epitaxy
PLD	Pulsed Laser Deposition
EBE	Electron Beam Evaporation
O_2	Oxygen
TB-WS_2	Twisted Bilayer-Tungsten Disulfide
Ar	Argon
PMMA	Poly (Methyl Methacrylate)
$K_2S_2O_8$	Potassium Persulfate
NaOH	Sodium Hydroxide
Na_2SO_4	Sodium Sulfate
PDMS	Polydimethylsiloxane
PET	Poly(Ethylene Terephthalate)
ALD	Atomic Layer Deposition
Al_2O_3	Aluminum Dioxide
HfO_2	Hafnium Dioxide
OH	Hydroxyl
V	Vanadium
$(RhCpCp*)_2$	Pentamethylrhodocene Dimer
P_2O_5	Phosphorous Pentoxide
Na	Sodium
LiF	Lithium fluoride
TEA	Triethylamine
PPh3	Triphenylphosphine
$AuCl_3$	Gold Chloride
BV	Benzyl Viologen
Li^+	lithium-Ion

Cu	Copper
h-BN	Hexagonal Boron Nitride
ITO	Indium Tin Oxide
MeOH	Methanol
$(NH_4)2CO_3$	Ammonium Carbonate
CHP	Cyclohexylpyrrolidone
PEG	Polyethylene Glycol
HMT	Hexamethylenetetramine
SC	Sodium Cholate
CTAB	Cetyltrimethylammonium Bromide
SDBS	Sodium Dodecyl Benzene Sulfonate
FWHM	Full Width Half Maximum
SAED	Selected Area Electron Diffraction
MIGS	Metal-Induced Gap States
FLP	Fermi Level Pinning
Ge	Germanium
MIS	Metal-Insulator-Semiconductor
Kl	Potassium Iodide
Fe	Iron
DCE	1,2-Dichloroethane
GUI	Graphical User Interface
QE	QUANTUM-ESPRESSO
RT	Room Temperature
VB	Valence Band
CB	Conduction Band
TLM	Transmission Line Model
EOT	Equivalent Oxide Thickness
FL	Few-Layer
HF	Hydrofluoric Acid
N_2	Nitrogen
Al	Aluminium

Symbols:

Λ	Intermediate point
A_{1g}	out-of-plane
E_{2g}^1	in-plane
N	Nanosheet Thickness
λ_A	A Exciton
A^o	Exciton
A^-	Trion
c	Lattice Constant
d	Interplanar Spacing
E_g	Bandgap
E_F	Fermi level
E_{CNL}	Charge Neutrality
R_{SB}	Schottky Barrier Resistance
R_{IL}	Interlayer Resistance
R_{Ch}	Channel Resistance
R_T	Total Resistance
R_{SD}	Series Resistance
R_{Sh}	Sheet Resistance
ρ_C	Contact Resistivity
L_T	Transfer Length
Φ	Work Function
Φ_S	Semiconductor Work Function
Φ_M	Metal Work Function
χ_s	Electron Affinity
Φ_B	Schottky Barrier
I_0	Saturation Current
k	Boltzmann Constant
T	Temperature
e	Charge of an Electron
A	Contact Area

A^*	Richardson Constant
V_{gs}	Gate-Source Voltages
I_{ds}	Drain Source Current
V_{ds}	Drain Source Voltage
I_{max}	Maximum Current
I_{min}	Minimum Current
I_{on}	On Current
L	Channel Length
W	Channel Width
μ_{FE}	Field Effect Mobility
μ_0	Intrinsic Mobility
g_m	Transconductance
V_{th}	Threshold Voltage
SBH	Schottky Barrier Height
I_{ON}/I_{OFF}	Current ON OFF Ratio
E_{F_M}	Metal Fermi Level
E_{F_S}	Semiconductor Fermi Level
E_{VAC}	Vacuum Level
R_C	Contact Resistance
n_s	Carrier Concentration
C_{ox}	Oxide Capacitance
C_{it}	Interface-Trap Capacitance
SS	Subthreshold Slope
D_{it}	Interface Trap Density
θ	Mobility Attenuation Coefficient