DESIGN AND FABRICATION OF QUANTUM DOT SINGLE-ELECTRON TRANSISTORS USING SCANNING ELECTRON MICROSCOPY-BASED ELECTRON-BEAM NANOLITHOGRPHY

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UNIVERSITI MALAYSIA PERLIS
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by

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A thesis submitted
In fulfillment of the requirements for the degree of
Doctor of Philosophy

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UNIVERSITI MALAYSIA PERLIS

2009

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Date of birth	:	November 20th, 1974
Title	:	Design and Fabrication of Quantum Dot Single-Electron Transistors using Scanning Electron Microscopy-based Electron-Beam Nanolithography
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DEDICATION

Al-Fatihah to my dad, Allahyarham Madnasri, may Allah S.W.T. bless you. Special dedication to may mum, Marwati, and my wife, Noor Aini Habibah, thanks for the support and the pray. Al-Fatihah is also to my children (Muhhammad Noordien and Shafa Noor Aulia). May Allah S.W.T. bless all of us, amien. Thank you.

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LIST OF ABBREVIATIONS

ACB	automatic contrast brightness
Acc. Voltage	accelerating voltage
aF	atto farad
AFM	atomic force microscope
APC	automatic pressure control
BE detector	backscattered electron detector
BOE	buffered oxide etch
BOX	buried oxide
CAD	computer aided design
CB effect	coulomb blockade effect
CBE	chemical beam epitaxy
CIF	caltex intermediate format
CMOS	complementary metal-oxide-silicon
CNT	carbon nano tube
CVD	chemical vapor deposition
DC bias	direct current bias
DXF	drawing exchange format
E-beam	electron-beam
E-beam lithography	electron-beam lithography
ECR	electron cyclotron-resonance
EDAX	energy dispersive absorption X-ray
EDX	energy dispersive X-ray
FETs	field effect transistors
GUI	graphic user interface
GDSII Editor	graphic display system II editor
HMDS	hexamethyldisilazane
IBAD	ion beam assisted deposition
ICP	inductively coupled plasma
IPPCM	in-plane point-contact metal
IPA	isopropyl alcohol
JQP	josephson quasi particle

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LPCVD	low pressure chemical vapor deposition
LSI	large scale integration
MBE	molecular beam epitaxy
MIBK	methyl-isobutyl ketone
MOSFET	metal-oxide-semiconductor field effect transistor
MOCVD	metal oxide chemical vapor deposition
MTJ structures	multiple-tunnel junction structures
OL	objective lens
PAC	photoactive compound
Padox	pattern dependent oxidation
Pasidox	pattern single dot dependent oxidation
PC	personal computer
PCD Beam Blanker	pico-ammeter detector beam blanker
PECVD	plasma enhanced chemical vapor deposition
PLAD	pulsed laser ablation deposition
PMMA	poly methyl methacrylate
Pt	platinum
PVD	physical vapor deposition
QD, QDs	quantum dot, quantum dots
RF power	radio frequency power
RIE	reactive ion etching
RMS	root mean square
RTA	rapid thermal annealing
RTP	rapid thermal processing
QDCA	quantum dot cellular automata
SC1	standard cleaning 1
SECO method	step edge cut off method
SEM	scanning electron microscope
SET	single-electron transistor
SFM	scanning force microscopy
STM	surface tunneling microscopy
SiO_2	silicon dioxide

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SOI	silicon on insulator
VLSI	very large scale integration
V-PADOX	vertical-pattern dependent oxidation
WD	working distance
WDS analysis	wavelength dispersive spectrometer analysis

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LIST OF SYMBOLS

Quantity	Symbol	Unit	
Energy	E	Joule	J
Coulomb energy (charging energy)	E_C	electron volt	eV
Frequency	ω	Hertz	Hz
Lateral radius of quantum dot	a	nanometer	nm
Effective mass of electron	m_e	kilogram	kg
Electron elementary charge	e	Coulomb	C
Density of energy states	$D(E)$	$\text{Joule}^{-1}\text{meter}^{-3}$	$J^{-1}m^{-3}$
Capacitance	C	Farad	F
Capacitance of gate	C_g	Farad	F
Capacitance of middle junction	C_m	Farad	F
Total capacitances of islands	C_Σ	Farad	F
Capacitance of dot	C_{dot}	Farad	F
Electrostatic potential	V	volt	V
Voltage of gate	V_g	volt	V
Tunneling rate of electron	Γ	Hertz	Hz
Angle between corresponding spin moments	β	degree	°
Absolute temperature	T	Kelvin	K
Electric current	I	ampere	A
Beam current	I_{beam}	microampere	μA
Time of electron tunneling through	τ_t	second	s

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