DESIGN, FABRICATION AND CHARACTERIZATION OF CMOS ISFET FOR pH MEASUREMENTS

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UNIVERSITI MALAYSIA PERLIS
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DESIGN, FABRICATION AND CHARACTERIZATION OF CMOS ISFET FOR pH MEASUREMENTS

by

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A thesis submitted
in fulfillment of the requirements for the degree of
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School of Microelectronic Engineering
UNIVERSITI MALAYSIA PERLIS

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APPROVAL AND DECLARATION SHEET

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List of Abbreviations

Al	Aluminium
Al_2O_3	Aluminium Oxide
Ag/AgCl	Argentum/ Argentum Chloride (Silver/Silver Chloride)
BSC	Back sided contact
BOE	Buffered Oxide Etch
Ca^{2+}	Calcium ion
ChemFET	Chemically modified field effect transistor
CMOS	Complementary Metal Oxide Semiconductor
CAD	Computer Aided Design
I-V	Current-Voltage
DIW	Deionised Water
DUT	Device Under Test
DC	Direct Current
FET	Field Effect Transistor
FIA	Flow injection analysis
HDL	Hardware Description Language
H^+	Hydrogen ion
IGFET	Insulated Gate Field Effect Transistor
ISE	Ion sensitive electrode
ISFET	Ion Sensitive Field Effect Transistor
K^+	Kalium ion
Hg	Mercury
Hg_2Cl_2	Mercury Chloride

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MIS	Metal Insulator Semiconductor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MNOS	Metal-nitride-oxide-semiconductor
MFCL	Micro Fabrication Cleanroom Laboratory
µTAS	Micro total analysis system
Na^+	Natrium ion
NMOS	N-channel MOSFET
O_2	Oxygen (gas)
PMOS	P-channel MOSFET
PVD	Physical Vapour Deposition
PECVD	Plasma Enhanced Chemical Vapour Deposition
pCO_2	Power of carbon dioxide
pH	Power of hydrogen
PCB	Printed Circuit Board
QC	Quality control
RE	Reference Electrode
rpm	Revolution per minute
SCE	Saturated Calomel Electrode
SCS	Semiconductor Characterization System
SPA	Semiconductor Parameter Analyzer
Si	Silicon
SiO_2	Silicon dioxide or Silicon oxide or Oxide
Si_3N_4	Silicon Nitride
SPICE	Simulation Program With Integrated Circuit Emphasis
SnO_2	Stanum oxide

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Ta_2O_5	Tantalum penoxide
TCAD	Technology Computer Aided Design
TAT	Turn around time
VHDL-AMS	Very-High-Speed-Integrated-Circuit Hardware Description Language (VHDL)-Analog and Mixed Signal (AMS)

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List of Symbols

Symbol	Description	Unit
I_D	Drain current	A
V_D	Drain voltage	V
V_G	Gate voltage	V
V_{TH}	Threshold Voltage	V
b	Width of Area	μm
L	Length of Area	μm
μ_n	Electron mobility in a channel	
C_0	Oxide capacitance per unit area	F/m^2
V_{DSAT}	Drain voltage at saturation	V

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[1] U. Hashim and S. F. Chin, "Simulation of NMOS in Standard CMOS Process using Synopsys' TSUPREM-4 and MEDICI," in *Malaysian Technical Universities Conference on Engineering and Technology (MUCET)*, Universiti Teknologi Tun Hussein Onn, 2006, pp. 36-39.

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[9] U. Hashim, S. F. Chin, and S. Sakrani, "Application of Synopsys' Taurus TCAD in Developing CMOS Fabrication Process Modules," *International Journal of Nanoelectronics and Materials,* vol. 2, pp. 1-10, 2009.

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List of Awards

1. Research and Innovation Awards 2009 **Gold** Medalist
2. BioInno Awards 2009 **Silver** Medalist
3. PECIPTA 2009 **Silver** Medalist
4. Malaysia Invention and Innovation Awards 2009 **Silver** Medalist
5. BioInno Awards 2008 **Bronze** Medalist
6. Research and Innovation Awards 2008 **Bronze** Medalist

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REKABENTUK, FABRIKASI DAN PENCIRIAN CMOS ISFET UNTUK PENGUKURAN pH

ABSTRAK

Transistor Kesan Medan Sensitif terhadap Ion atau lebih dikenali sebagai Ion Sensitive Field Effect Transistor (ISFET) ialah penderia pH jenis potentiometrik yang mudah diadaptasikan pada applikasi kimia, bio-kimia dan bio-perubatan. Operasi ISFET ini berdasarkan penyerapan cas daripada larutan ujikaji pada antaramuka pepejal-elektrolit yang terletak di get ISFET. Hasilnya, voltan ambang ISFET dimodulasikan. Tesis ini menggambarkan rekabentuk, simulasi, fabrikasi dan pencirian ISFET untuk ukuran pH suatu larutan. Simulasi ISFET dijalankan terlebih dahulu dengan menggunakan perisian simulasi TCAD TSUPREM4 dan MEDICI. Fabrikasi ISFET dijalankan di dalam Makmal Bilik Bersih di Universiti Malaysia Perlis dengan meggunakan teknologi fabrikasi CMOS. Fabrikasi ini dapat dicapai oleh kerana kesesuaian teknologi antara ISFET dan CMOS. Silikon nitrida digunakan sebagai membran sensitive ion dan ia dilapiskan pada permukaan get dengan menggunakan teknik pemendapan wap kimia peningkatan plasma (PECVD). Sejumlah enam acuan direkabentuk dan digunakan dalam fabrikasi ini. ISFET yang difabrikasi bertujuan mengukur pH suatu larutan. Satu sistem pencirian semikonduktor yang terdiri daripada alat pengukur wafer mikro dan alat analisa parameter digunakan untuk mendapatkan pencirian yang jitu tentang ISFET. Bagi tujuan analisa ISFET dalam larutan, satu elektrod rujukan Argentum/Argentum Klorida dan tiga sample larutan penampan dengan pH 4, pH 7 dan pH 10 masing-masing digunakan semasa eksperimen dilakukan. Kepekaan ISFET yang diukur ialah 40mV/pH bagi ISFET jenis n dan 30mV/pH bagi ISFET jenis p. Hasil yang diperolehi menunjukkan CMOS ISFET yang difabrikasi di makmal berfungsi seperti yang dijangkakan.

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