CHARACTERIZATION OF SILICON ON INSULATOR (SOI) MOSFET USING TCAD TOOLS

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This report is submitted in partial fulfilment of the requirements for the Bachelor of Electronic Engineering (Computer Engineering) with Honors

Faculty of Electronics and Computer Engineering

Universiti Teknikal Malaysia Melaka

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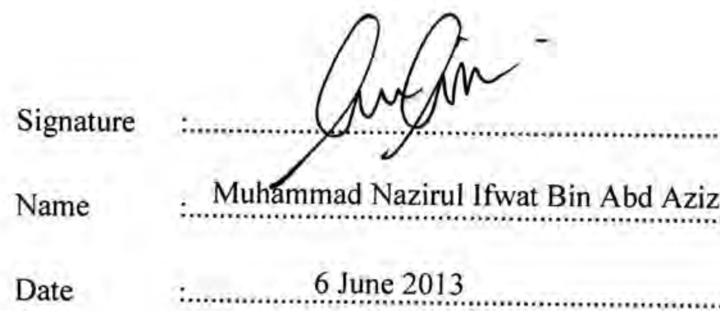

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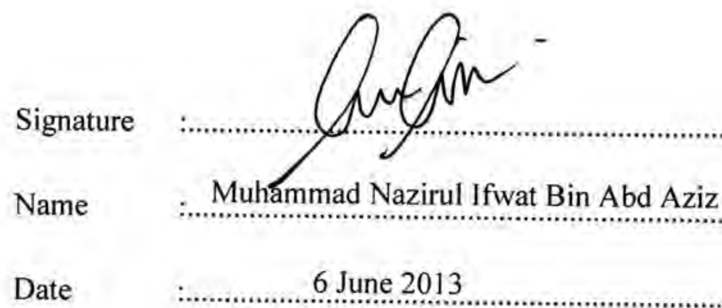

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Dedicated to my beloved family especially my parents, supervisor, lecturers, all my friends.

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ABSTRACT

Thisproject present the result of process and device semulation using silvaco TCAD tools to develop Silicon on insulator (SOI) MOSFET. The aim for this project is to analyze the electrical characteristic of SOI MOSFET and the effect of Buried oxide layer (BOX) with the variation of thickness. The result obtained show that as the electrical characteristic of SOI MOSFET greatly increase with the presence of BOX layer. This SOI MOSFET has higher Drive current (ION), lower Leakage current and lower Subthreshold Swing (S_S).With this increasing perfomance, the switching speed for this MOSET device increase and it has lower power consumption as the ratio of I_{ON}/I_{OFF} is larger. For information, the larger the ratio, the lower the power consumption.This project also analyze the effect of oxide layer thickness toward the electrical characteristic and the result shown that the thickness of oxide layer increase will decrease the perfomance of device. The best thickness is 100nm thickness layer but if its to thick then the Finfet technology need to be used as prevention because when the thickness become too smal it will also decrease the perfomance.Finfet refer as one of the types of multigate transistor. The term FinFET is to describe a nonplanar, double-gate transistor built on an SOI substrate.

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ABSTRAK

Projek ini membentangkan hasil daripada proses dan peranti semulation menggunakan alat-alat silvaco TCAD untuk membangunkan Silikon pada penebat (SOI) MOSFET . Tujuan projek ini adalah untuk menganalisis ciri elektrik MOSFET SOI dan kesan dikebumikan lapisan oksida (BOX) dengan perubahan ketebalan . Keputusan yang diperolehi menunjukkan bahawa ciri elektrik SOI MOSFET sangat meningkatkan dengan kehadiran lapisan BOX. Ini MOSFET SOI mempunyai arus yang lebih tinggi Drive (ION), lebih rendah Kebocoran Swing Subthreshold semasa dan lebih rendah (SS) . Dengan Prestasi ini yang semakin meningkat, kelajuan pensuisan untuk ini peningkatan peranti MOSET dan ia mempunyai penggunaan kuasa lebih rendah sebagai nisbah ION / IOFF adalah lebih besar . Untuk pengetahuan, lebih besar nisbah , lebih rendah penggunaan kuasa. Projek ini juga menganalisis kesan oksida ketebalan lapisan ke arah ciri elektrik dan hasilnya menunjukkan bahawa ketebalan oksida lapisan peningkatan akan mengurangkan Prestasi peranti . Ketebalan terbaik adalah 100nm lapisan tebal tetapi jika untuk tebal maka teknologi Finfet yang perlu digunakan sebagai pencegahan kerana apabila ketebalan menjadi terlalu smal ia juga akan mengurangkan perfomance.Finfet rujuk sebagai salah satu jenis transistor multigate . FinFET adalah untuk menggambarkan tak satah , dua pintu transistor dibina di atas substrat SOI .

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LIST OF ABBREAVIATIONS

SOI		Silicon on Insulator
MOSFET	-	Metal-Oxide Semiconductor Field Effect Transistor
DIBL		Drain induced Barrier Lowering
ITRS		International Technology Roadmap Semiconductor
SIO_2		Silicon Dioxide
TCAD		Techonology Computer Aided System
SNR		Signal to Noise Ratio
nm		Nanometer
NMOS		N-Channel MOSFET
PMOS		P- Chanel MOSGET

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LIST OF SYMBOLS

I_D	-	Drain Current
I_{OFF}	-	Off-state Leakage Current
V_{DS}	-	Drain to source Voltage
V_G	-	Gate Voltage
V_{GS}	-	Gate to source Voltage
V_{TH}	-	Threshold Voltage
I_{ON}	-	Drive current
S_S	-	Subthreshold Swing
S/N	-	Signal to noise

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The Metal-Oxide Semiconductor Field Effect Transistor (MOSFET) is a device that widely used in industry, especially digital circuit, microprocessor and memory circuit industry. This MOSFET is used as a switch or to amplify the electronic signal. In one integrated circuit (IC), they will be a lot the number of MOSFET because of his small size characteristic thus simply make it another advantage of this device to the electronic industry in the world [3]. MOSFET technology is well-known in the industry. This technology has been used a lot and has been around for many years starting from early 60-70s. There have been a lot of gains in the performance of the MOSFET device since their creation with the size keeps decrease with improving years [1].

The cost and size are the main attribute of MOSFETS devices. Since the technology is well established thus make the fabrication process of this device have experienced decreased of cost. With the advantage of smaller physical shape than the others' technologies, thus allowing more devices in silicon wafer in fabrication makes MOSFET devices mainly used in the creation of Complementary Metal Oxide Semiconductor (CMOS) logic chips because of its cheap cost. Now MOSFET technologies have become the heart of every computer. An enhancement-type NMOS

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transistor was used during this course of this project. Figure 1.1 shows the basic structure of MOSFET device.

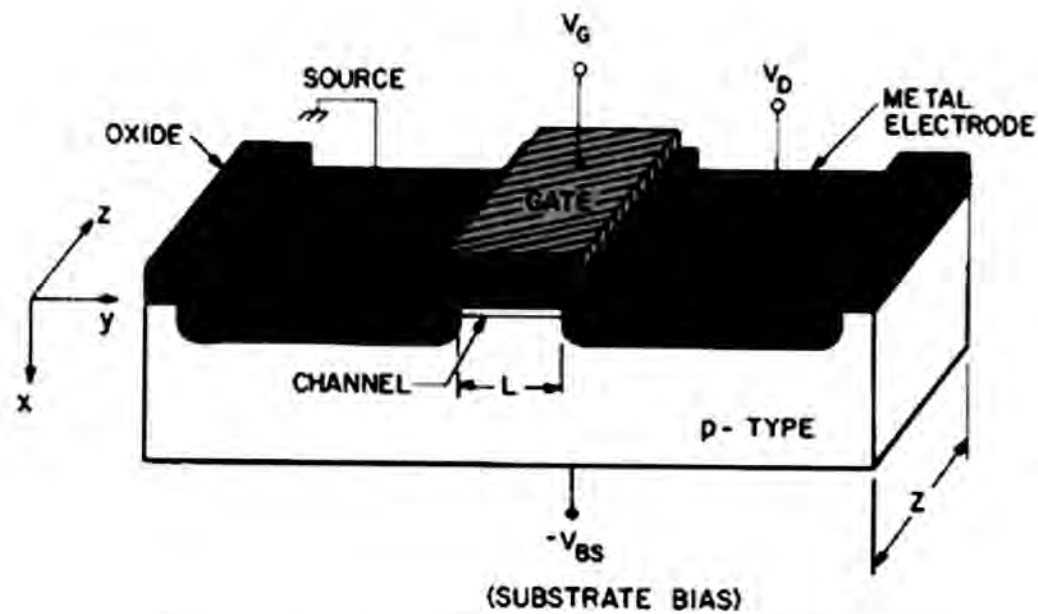

Figure 1.1: The basic structure of the MOSFET device [2].

Silicon-On-Insulator (SOI) devices are new technology that recently popular. Although the technology has been around since 1960's, this SOI less popular of before and lately become popular because of the expense associated with producing the devices. SOI is the advancement of standard MOSFET technologies that improve in their characterizations. The main difference between SOI MOSFET and regular MOSFET is the inclusion of an insulating layer. SOI devices are created from a thin layer of silicon placed on top of a layer of insulating [1].

The purpose of this research is to design and analyze the electrical characterization of Silicon-On-Insulator (SOI) Metal-Oxide-Semiconductor Field Effect transistor (MOSFET) performance using Technology Computer-Aided Design (TCAD) tools. TCAD tool is a program that's been made to allow the creation, fabrication, and simulation of semiconductor devices. This TCAD tool is used for designing various

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applications for semiconductor device. Silicon-On-Insulator (SOI) device is a silicon-based device built upon an insulating substrate [3].

Substrate for this SOI can be ranged from a rate material such as ruby, diamond and sapphire to common materials that largely been used in the semiconductor industry that is silicon dioxide. The SOI design that is being applied in this research was SOI MOSFET design, using silicon dioxide for the dielectric. The structure of SOI MOSFET is no different from a regular MOSFET design, but the difference is the existence of a thick layer of insulating material under the depletion region that gives a slightly different value of electrical value in this design thus improve its characteristic value. During this research, Silvaco's TCAD tools were used to create simulations of the device. These simulations provided a great deal of opportunities to examine the issue of various parameters on the overall device performance. Throughout the years, the operation of each simulated device gradually been improved and until an optimal device, configuration was produced for the particular applications.

The primary advantage of SOI performance over conventional bulk CMOS is more often than not from lower average threshold-voltage due to transient floating body (FB) operation and lower junction capacitance. SOI MOSFET has two types, which is the partial depleted and fully depleted SOI MOSFET. Nowadays, the partially depleted (PD) instead of fully depleted (FD) SOI becomes the desirable choice for mainstream digital applications, due to the easy manufacturing, better controlling of short channel effect, large design window for the threshold voltage and lower self-heating effect.

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1.2 Objectives of the project

There are three main objectives of this research:

i) To create an initial SOI-MOSFET device design.

ii) To analyze the characterization of SOI MOSFET.

iii) To compare the electrical characteristic between SOI MOSFET and conventional bulk MOSFET.

1.3 Problem statement

In the material universe, before certain MOSFET device, proceed with the fabrication process the SILVACO TCAD tools (virtually fabrication tools) will be used to design it at the 1st hand. This will make the cost of production been minimized effectively. In current MOSFET devices, there is physical limitation, which is the short channel effect that is found in conventional MOSFETS as the gate length is further downsized. There are also a few problems in device performance for such an example, switching effect, which came from the higher leakage current (I_{OFF}) [3]. Besides that because of the high-power usage and low speed characteristic of conventional circuit MOSFET must be improved to a new level so that this device can improve and be a lot more useful for future. Hence, the new device concept that has more improved than conventional MOSFET is introduced. That device calls Silicon-On-Insulator (SOI) MOSFET. To prove that statement, research has been conducted to analyze the characteristic of SOI MOSFET.

1.4 Scope of the project

This research mainly focused on designing the device structure and determined the characterization of Silicon - On - Insulator (SOI) MOSFET. Besides that, this project was conducted by using Silvaco's TCAD tool. The Silvaco's TCAD simulation tool is

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