DESIGN AND ANALYSIS OF CMOS PIN-PHOTODIODE FOR OPTO-FLUIDIC DETECTOR

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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This project is gratefully dedicated to my father and mother

To my beloved family

To my respected lecturer / supervisor

And to all my friends

For their support, advice, patience and understanding

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ABSTRACT

This paper is about to design and analyzes PIN Photodiode. The PIN Photodiode was design and analysis in by using Silvaco TCAD Tools. The width of intrinsic layer had been varied with two different values which are 2.4mμ x 8mμ and 2mμ x 8mμ. The size of intrinsic layer will affect the depletion region of each Photodiode. To see the difference, the IV characteristics for each photodiode have been analyzed and the results show that each of PIN photodiode with a different active area gives different IV characteristics.

ABSTRAK

Kertas kerja ini adalah untuk merekabentuk dan menganalisa PIN fotodiod. PIN Fotodiod di reka bentuk dan di analisis dengan menggunakan Silvaco TCAD Tools. Lebar lapisan intrinsik telah diubah dengan dua nilai yang berbeza iaitu 2.4mμ 8mμ x dan 2mμ x 8mμ. Saiz lapisan intrinsik akan mempengaruhi setiap kawasan susut fotodiod. Untuk melihat perbezaannya, ciri-ciri IV untuk setiap Fotodiod telah dianalisis dan keputusan menunjukkan bahawa setiap PIN fotodiod dengan kawasan aktif yang berbeza memberikan IV ciri-ciri yang berbeza.

TABLE OF CONTENT

4 METHODOLOGY

5 RESULT AND DISCUSSIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CMOS	-	Analysis of Variance
TCAD	-	Technology Computer-Aided Design
IV	-	Current Voltage
RF	-	Radio Frequency
GUI	-	Graphical User Interface
EDA	-	Electronic Design Automation
1D	-	1 Dimension
2D	-	2 Dimension
Conmob	-	Concentration Dependent Mobility
Fldmob	-	Field Dependent Mobility
Auger	-	Auger Recombination
Bgn	-	Band Gap Narrowing
AC	-	Alternating Current
DC	-	Direct Current
FYP	-	Final Year Project

CHAPTER 1

INTRODUCTION

This project is about to design and analyzes PIN Photodiode by using SILVACO TCAD tools software. By using DECKBUILD, the design of PIN Photodiode can be designed by using appropriate coding and compared with datasheet established by other company in order to meet the specifications by designing the structure. To get the IV characteristics, TONYPLOT is used to display the breakdown graph of PIN Photodiode. The environment of the study is systematically elaborated in this chapter. This chapter also outlined the objectives and scope of the research

1.1 Project Overview

The PIN photodiode is a special case of the PN junction photodiode, in which a large intrinsic or lightly doped N semiconductor area is inserted in between the P region and N region. This is different from the PN photodiode in that the intrinsic region is much larger than that in PN diode.

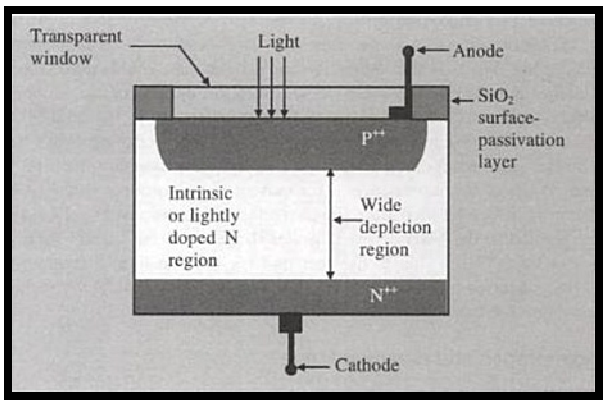

Figure 1.0: PIN Photodiode [1]

It is a well known fact that in any PN diode, the depletion region extends more into the lightly-dope N region than into the heavily doped P region. This is because, in the heavily doped region, the number of free charge carriers available for conduction is quite large compared to that in the lightly doped region [1]. In a normal operation a reverse-bias voltage is applied across the device so that no free electrons or holes exist in the intrinsic region.

Electrons in semiconductor materials are allowed to reside in only two specific energy bands. The two allowed band are separated by a forbidden region called energy gap. The energy difference between the top and bottom bands is referred to as the band gap energy [2]. In a generic photodiode, light enters the devise through a thin layer whose absorption typically causes the light intensity to exponentially drop with penetration depth.

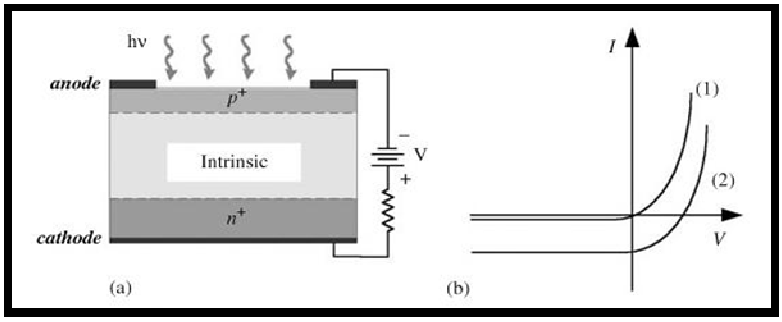

Figure 1.1: a) PIN photodiode operated in reverse bias, hv is the energy of radiation, V is the bias, and RL is the local load resistance. b) IV characteristics for a pin photodiode (1) with no light (2) with light [2]

For enhanced performance it is often necessary for the device to have a shallow junction followed by a wide depletion region where most of the photon absorption and Electron Hole generation should take place. The magnitude of the generated current is proportional to the intensity of the incident light. It can be used as a photon detector by operating it in the third quadrant of its electrical current voltage (I-V) characteristics [3].

The PIN photodiode when forward biased by a direct current it can pass RF signals without distortion, down to some minimum frequency set by the lifetime of the carriers, holes and electrons, in the intrinsic region. As the forward current is reduced, the resistance to the flow of the RF signal is increased, but it does not vary over a half cycle of the signal frequency. As the direct current is reduced to zero, the resistance rises towards infinity, when the diode is reverse biased only a very small amount of RF current can flow, via the diode's reverse capacitance [4].

PIN photodiode is usually functioning by applying a reverse-bias voltage. The magnitude of the reverse-bias voltage depends on the photodiode purpose, but naturally is less than a few volts. While no light is incident on the photodiode, a current is still produced. This current is called the dark current [5].

1.2 Problem Statements

In this project we target to design PIN photodiode with different size with a different sensitivity. A market survey that been done shows that there are a lot of PIN photodiode but it there have been a gap where there are a lack of PIN photodiode with less detection and sensitivity.

1.3 Objectives

The objectives of this project are to:

a) To study the theory behind PIN photodiode
b) To design and analysis PIN Photodiode
c) To determine IV Characteristic of PIN Photodiode

1.4 Scope of Works

This project is based on Integrated Circuit (IC) Design which is using PIN Photodiode. This project is using SILVACO TCAD tool software to get the designs, layouts and results.

a) DECKBUILD is an interactive runtime and input file development environment within which all SILVACO'S TCAD and several other EDA products can run. DECKBUILD has numerous simulator specific and general debugger style tools, such as powerful extract statements, GUI based process file input, line by line runtime execution and intuitive input file syntactical error messages. DECKBUILD contains an extensive library of hundreds of pre-run examples decks which cover many technologies and materials, and also allow the user to rapidly become highly productive.

b) TONYPLOT is a powerful tool designed to visualize TCAD 1D and 2D structures produced by SILVACO TCAD simulators. TONYPLOT provides visualization and graphic features such as pan, zoom, views, labels and multiple plot support. TONYPLOT also provides many TCAD specific visualization functions such as HP4154 emulation, 1D cut lines from 2D structures, animation of markers to show vector flow, integration of log or 1D data files and fully customizable TCAD specific colours and styles

1.5 Project Methodology

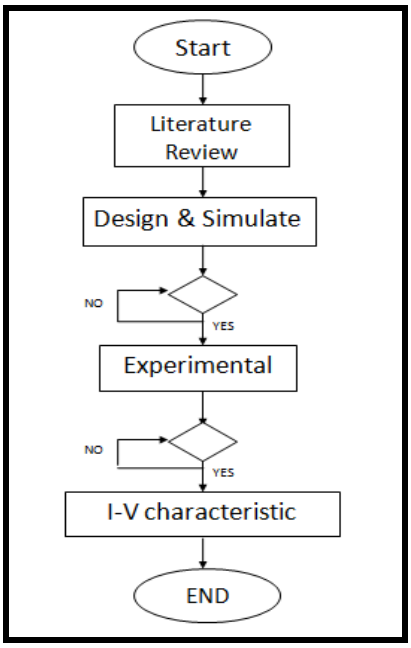

Figure 1.2: Project Methodology

In the beginning of the project, a literature review needs to be done as we want to familiar with the project. In the literature review, needs to cover up about the PIN Photodiode and SILVACO TCAD tools software so that easy to start the design of the photodiode. The schematics are then design by using DECKBUILD.

To make a design in the DECKBUILD, just create a coding to get it. In the coding, the size and shape needs to be specified so that the right design will be produce. Then, click the RUN button and the tools will create the design and produce

the results which are IV Characteristics. If the results are not satisfied with the expected one, change the coding and run it again until get the expected one.

1.6 Project Outline

Chapter I We divided our thesis into several chapters. In Chapter 1 the background research of this project were studied.

Chapter 2 examines about the literature review of this project on designing PIN Photodiode and its performance characteristic which is IV Characteristics.

Chapter 3 Explain about SILVACO TCAD and ATLAS

Chapter 4 summarizes the methodology of this project. In this chapter, we explain how the project has been done.

Chapter 5 presents the results and explain about the discussions of IV Characteristics of the PIN Photodiode by using SILVACO TCAD tools software. The discussion is about the finding and observation from the layout design.

Chapter 6 clarifies the conclusion and some improvement for this project. The improvement of this project is clearly explained in this chapter.

1.7 Simulation

The simulations were performed using SILVACO ATLAS. SILVACO ATLAS is a TCAD product which is physics based modelling system. This allows SILVACO to predict device performance based upon equations which describe the physics within the structure of the device.