UNIVERSITI PUTRA MALAYSIA

DESIGN OF PIN DIODE DETECTOR

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By

NURUL AMZIAH BINTI MD YUNUS

**Thesis Submitted in Fulfilment of the Requirement for the
Degree of Master of Science in the Faculty of Engineering
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DEDICATION

TO MY FAMILY

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

DESIGN OF PIN DIODE DETECTOR

By

NURUL AMZIAH BINTI MD YUNUS

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Chairman: Mr. Rahman Wagiran

Faculty: Engineering

A good light detector is when it could convert all the photon to the electrical signal in high speed. The junction photodetector is the most common photodetection device. Nowadays, the known photodetectors are the PN diode, the PIN diode and the APD diode. At one time PN diodes were the most common detection device used in lightwave system. Now the PIN diodes become the most prevalent devices used in photodetector. The PIN diode is an acronym for positive-intrinsic-negative diode. It is a photodiode with a large neutrally doped intrinsic region sandwiched between p-doped and n-doped semiconducting regions. PIN diode is a unique device. It is a semiconductor device that operates as a variable resistor at RF and microwave frequencies and as a good detector in optical communication.

In this project, the homojunction PIN device, has been selected, which consists of GaAs material. GaAs is a good material in designing the optoelectronic infrared photodetector devices. To design an optimal PIN diode detector, a study of the variation intrinsic region widths, doping concentrations, reverse biasing voltages and the photon flux is carried out. By studying these variations, it has lead to the determination of the best possible design of the photodetector, to produce the maximum photocurrent at the output. To observe the optimization, the Medici Avant! is used as a device simulation software. This software is preferred because it is cheaper and faster technique to discover the properties and characteristic of PIN diode detector.

In Medici, a model of two-dimensional (2D) PIN diode for the electrical (without illumination) and optical (with illumination) was performed. In the simulation, the total thickness of the diode is originally set to be 3.0 μm length with the intrinsic region is 1.5 μm thick. In evaluating the PIN photodiode performance, a uniform optical generation is made to take place in a 1.5 μm thick region located in the middle of the intrinsic region. A light pulse with 1 ps duration was focused on the depletion region of the diode. Subsequently, details simulations were performed to find the I-V characteristics, the photocurrent response and the output pulse width of the GaAs PIN detector.

The results from the simulation qualitatively demonstrate that the PIN diode could be used as the photodetector. This is because it could produce high current at minimum intrinsic region width, optimally to 0.5 μm, with low-doped intrinsic region, which is 5E15 cm^{-3} and simultaneously at high reverse biasing voltage best to be 35 V and at large number of photon flux density, 5E21 $photon/sec/cm^{2}$.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan ijazah Master Sains.

REKABENTUK PENGESAN DIOD PIN

Oleh

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Pengesan cahaya yang baik ialah detektor yang dapat menukar semua foton kepada isyarat elektrik dengan pantas. Diod simpangan ialah peranti yang paling biasa digunakan sebagai pengesan cahaya. Pengesan yang dikenali ialah diod PN, diod PIN dan diod APD. Diod PN ialah diod yang paling biasa digunakan di dalam system gelombang cahaya suatu ketika dahulu. Kini diod PIN telah menjadi peranti yang paling popular yang digunakan di dalam pengesan diod. Diod PIN adalah ringkasan bagi diod positif-intrinsik-negatif. Suatu diodfoto PIN mempunyai kawasan intrinsik terdop neutral yang besar terletak di tengah-tengah kawasan semikonductor terdop-p dan terdop-n. Diod PIN adalah peranti yang unik. Ia merupakan peranti yang boleh beroperasi pada frekuensi RF dan gelombang mikro, dan ia juga adalah pengesan yang baik di dalam komunikasi optik.

Di dalam projek ini, peranti diod PIN homosimpangan dipilih, dan ia terdiri dari bahan GaAs. GaAs adalah bahan yang amat sesuai dalam merekabentuk peranti diodfoto inframerah optoelektronik. Untuk merekabentuk detektor diod PIN yang optimum, kajian ke atas pelbagai lebar lapisan intrinsik, kepadatan pendopan, voltan pincang dan fluk foton dijalankan. Dengan kajian ini, ia membawa kepada penetapan yang terbaik dalam merekabentuk fotodetektor untuk menghasilkan arus foto yang maksimum pada output. Medici Avant! adalah perisian peranti yang digunakan bagi memperlihatkan pengoptimuman tersebut. Perisian ini digunakan kerana ia murah dan merupakan teknik yang cepat untuk melihat sifat-sifat dan ciri-ciri pengesan diod PIN.

Di dalam Medici, model peranti dua-dimensi (2D) bagi kajian ciri-ciri elektrik (tanpa penggemerlapan) dan optik (dengan penggemerlapan) dilaksanakan. Dalam simulasi ini, jumlah ketebalan diod ditetapkan kepada 3.0 μm panjang dan kawasan terdop-rendah ialah setebal 1.5 μm. Untuk menilai pekerjaan diodfoto PIN, penjanaan optik yang seragam dipancarkan pada kawasan yang mempunyai ketebalan 1.5μm yang terletak di tengah-tengah lapisan intrinsik. Denyutan cahaya yang mempunyai tempoh 1ps difokuskan pada lapisan susutan diod. Kemudian, simulasi terperinci dihasilkan untuk mencari ciri-ciri I-V, sambutan arus foto dan lebar denyutan pada output bagi pengesan PIN GaAs.

Hasil dari simulasi menunjukkan bahawa diod PIN dapat diwakili sebagai pengesan foto. Ini adalah kerana ia dapat menghasilkan arus yang tinggi pada lapisan susutan yang minimum, 0.5 µm, dan terdop-rendah, 5E15 cm^{-3}, dan disamping itu ia dikenakan voltan pincang yang tinggi, 35 V dan kepadatan fluk foton yang tinggi, 5E21 $photon/sec/cm^2$.

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