การผลิตและศึกษาผลตอบสนองทางสเปกตรัมของโฟโตไดโอด GaAs/GaAlAs ที่มีช่องว่างพลังงานเป็นขั้นบันได

นายภควัฒน์ วิเศษละคร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมไฟฟ้า ภาควิชาวิศวกรรมไฟฟ้า
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2546

ISBN 974-17-3469-17

FABRICATION AND STUDY ON SPECTRAL RESPONSE OF GaAs/GaAlAs STAIRCASE BAND GAP PHOTODIODES

Mr. Pakhawat Wisetlakhorn

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering in Electrical Engineering

Department of Electrical Engineering
Faculty of Engineering
Chulalongkorn University

Academic Year 2003
ISBN 974-17-3469-7

Thesis Title	Fabrication and study on spectral response of GaAs/GaAlAs staircase band gap photodiodes
By	Mr. Pakhawat Wisetlakhorn
Field of study	Electrical Engineering
Thesis Advisor	Associate Professor Choompol Antarasena, Dr.-Ing.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of Faculty of Engineering
(Professor Somsak Panyakeow, D.Eng.)

THESIS COMMITTEE

.... Chairman
(Professor Somsak Panyakeow, D.Eng.)

.... Thesis Advisor
(Associate Professor Choompol Antarasena, Dr.-Ing.)

.... Member
(Associate Professor Montri Sawadsaringkarn, Dr.-Ing.)

.... Member
(Assistant Professor Somchai Ratanathammaphan, D.Eng.)

##4370655021: MAJOR ELECTRICAL ENGINEERING
KEYWORD: GaAs/GaAlAs, PHOTODIODE, STAIRCASE BAND GAP, WINDOW EFFECT, SPECTRAL RESPONSE, LIQUID PHASE EPITAXY (LPE), MOLECULAR BEAM EPITAXY (MBE), Zn DIFFUSION

PAKHAWAT WISETLAKHORN: FABRICATION AND STUDY ON SPECTRAL RESPONSE OF GaAs/GaAlAs STAIRCASE BAND GAP PHOTODIODES.
THESIS ADVISOR: ASSOC. PROF. CHOOMPOL ANTARASENA, Dr.-Ing.
90 pp. ISBN 974-17-3469-7.

This thesis is a study of the role of staircase bandgap structure on the spectral response of GaAs/GaAlAs photodiodes. Two structures have been designed: type A staircase bandgap structure which converges the bandgap energy of active layer from that of $Ga_{0.6}Al_{0.4}As$ (P^+) window layer to that of GaAs (n^+) substrate and type B staircase bandgap structure which diverges the bandgap energy of active layer from that of GaAs (n^-) underneath $Ga_{0.6}Al_{0.4}As$ (P^+) window layer to that of $Ga_{0.6}Al_{0.4}As$ (N^-) near to GaAs (n^+) substrate. These two structures were compared with the structure of GaAs (n^-) constant bandgap active layer. From the calculation point of view, the constant bandgap structure has the carrier generation occurs very close to the p-n junction where the high recombination rate exists. Moreover, there is no quasi electric field produced within active region, therefore, the quantum efficiency is not high. While type A staircase bandgap structure generates the carriers far distance from the junction, thus the recombination would not much effect as well as the electrons would drift very nearly toward the n-side. In addition, the quasi electric fields were produced within the active region due to the band edge gradients especially for conduction band. As a result, electron multiplication can be gained. In case of type B staircase bandgap structure, the carrier generation happens near the junction as the one of constant bandgap. Anyway, this structure is over than the constant bandgap structure that the quasi electric field can be produced in active region and especially for hole, consequently, hole multiplication can be gained. The quasi electric field of conduction band and valence band can be separately adjusted by either the thickness of $Ga_{1-x}Al_xAs$ (N^-) active layer or doping aspect. For the sake of this, the staircase bandgap structure can be applied to the Separate Absorption and Multiplication Avalanche Photodiode (SAM APD) to minimize the excess avalanche noise.

As for the experiment, we have fabricated 3 structures namely structure I, structure II and structure III. Structure I and II were grown by Liquid Phase Epitaxy (LPE) while the structure III which its pn junction was formed by Zn diffusion was grown by Molecular Beam Epitaxy (MBE). However, all experimental structures are the type A staircase bandgap. From the experimental point of view, all structures have the short wavelength spectral responses expand more broader than those of theoretical calculation because of the diffusion current. In addition, their spectral responses of active region were fluctuated due to the recombinations around each interface of active layer. As for the case of structure III, the spectral response between 400 and 750 nm depended upon the junction depth. The deeper the junction is, the lower the spectral response at short wavelengths exhibits.

Department Electrical Engineering	Student's signature..........................
Field of Study Electrical Engineering	Advisor's signature..........................
Academic year 2003	Co-advisor's signature..........................

ACKNOWLEDGEMENT

This research has been done at the Semiconductor Device Research Laboratory (SDRL), Department of Electrical Engineering, Faculty of Engineering, Chulalongkorn University under the supervision of Associate Professor Dr. Choompol Antarasena.

The author gratefully acknowledges Associate Professor Dr. Choompol Antarasena for proving the opportunity to do this research in the laboratory with valuable guidance.

The author wishes to make deep acknowledgement to the member of the thesis committee: Professor Dr. Somsak Panyakeow, Associate Professor Dr. Montri Sawadsaringkarn, Assistant Professor Dr. Somchai Ratanathamphan and Associate Professor Dr. Choompol Antarasena for every useful discussions and guidance.

Particular thanks are due to Dr. Arporn Teeramongkonradsame for good recommendations, Mr. Supachok Thainoi for technical assistances and Miss Yuparwadee Deesirapipat as well as Miss Duangporn Chatweerachaikit for discussions.

In addition, the author would like to give special thanks to his parents and his sister for warm encouragement.

This work reported here was supported by SDRL Research Fund.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

LIST OF FIGURES

Figures Page

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

Tables Page