

## MASTER'S THESIS

### Tunable wavelength from porous silicon-based devices

To, Wai Keung

*Date of Award:*  
2009

[Link to publication](#)

#### **General rights**

Copyright and intellectual property rights for the publications made accessible in HKBU Scholars are retained by the authors and/or other copyright owners. In addition to the restrictions prescribed by the Copyright Ordinance of Hong Kong, all users and readers must also observe the following terms of use:

- Users may download and print one copy of any publication from HKBU Scholars for the purpose of private study or research
- Users cannot further distribute the material or use it for any profit-making activity or commercial gain
- To share publications in HKBU Scholars with others, users are welcome to freely distribute the permanent URL assigned to the publication

Tunable Wavelength from Porous Silicon-based Devices

TO Wai Keung

A thesis submitted in partial fulfillment of the requirements

for the degree of

Master of Philosophy

Principal Supervisor: Prof. CHEAH Kok Wai

Hong Kong Baptist University

December 2009

## **Abstract**

Two approaches were taken to fabricate wavelength tunable devices based on porous silicon. One was to control emission energy of erbium/ytterbium dependent on porous silicon by using a microcavity through fabricating multi-layer porous silicon beneath the doped layer.

Erbium/ytterbium doped porous silicon was found to emit efficiently from ultraviolet to near infrared [1]. The aim was to continue the previous research on erbium/ytterbium doped porous silicon. However, p-type silicon wafers were used to fabricate porous silicon instead of n-type silicon wafer. The reason was that multi-layer porous silicon can only be fabricated in p-type silicon and the porosity of the p-type porous silicon was more easily controlled than that in n-type porous silicon. This is a benefit in making microcavity.

Another was to have an enhancement and narrowing on a particular wavelength with the ability of tuning in porous silicon microcavity. The target wavelength can be adjusted without any change in the material used. This work can be divided into two parts. First part is to enhance and narrow a particular wavelength. Second part is to make the sample with the ability of wavelength selection.

To achieve the first part, microcavity is applied. Hence, patterned etching was applied to fabricate multi-layers for porous silicon distributed Bragg reflector as porous silicon was used. For the latter one, we did with the Bragg reflector. By controlling the etching current, the reflector produced was patterned. The high reflection wavelengths could be shifted by about 25nm.

## Table of Contents

Declaration.....	i
Abstract.....	ii
Acknowledgements.....	iii
Table of Contents .....	iv
List of Tables.....	vi
List of Figures.....	vii
Chapter 1 Introduction and Thesis Outline.....	1
Chapter 2 Theory .....	4
2.1 Formation of Porous Silicon.....	4
2.2 Electric Field of Ring Electrode .....	8
2.3 Porous Silicon Distributed Bragg Reflector .....	10
2.4 Microcavity in Porous Silicon .....	16
2.5 Photoluminescence of Erbium and Ytterbium.....	19
2.5.1 Enhancement of Emission of 1540 nm.....	20
2.5.2 Up-conversion.....	21
Chapter 3 Sample Fabrication.....	24
3.1 Fabrication of Porous Silicon.....	24
3.1.1 Etching .....	25
3.1.2 Annealing .....	27
3.2 Thin Film Deposition.....	28
3.3 Doping of Erbium and Ytterbium .....	29
Chapter 4 Measurements.....	32
4.1 Reflectivity.....	32
4.2 Photoluminescence .....	35
4.3 Ellipsometry.....	37
4.4 Field Emission Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) Analysis .....	38
Chapter 5 Simulation .....	40
5.1 Electric Field of Platinum Ring Electrode.....	40
5.2 Characteristic Matrix .....	40
5.2.1 Porosity of Porous Silicon .....	41
5.2.2 Distributed Bragg Reflector (DBR).....	42
5.2.3 Microcavity.....	45
5.2.3.1 Cavity Layer: Alq <sub>3</sub> and Top Metal Layer.....	46
5.3 Tunable Microcavity .....	50
Chapter 6 Results and Discussion.....	54

6.1 Etching .....	54
6.2 Comparison of Simulation and Experimental Results .....	56
6.2.1 Reflectance of Porous Silicon Multi-Layer .....	56
6.2.2 Bragg Reflector of Porous Silicon .....	61
6.2.3 Microcavity .....	66
6.2.4 Photoluminescence .....	68
6.3 Erbium/Ytterbium Doped p-type Porous Silicon.....	72
6.3.1 Doping of Erbium and Ytterbium .....	72
6.3.2 Photoluminescence .....	79
6.4 Additional Study .....	81
Chapter 7 Conclusion and Future Work.....	83
Reference .....	84
Curriculum Vitae.....	87