# Contents

I. Cover page
II. Dedication
III. Abstract
IV. Author’s declaration
V. Certificate from supervisor
VI. Thesis Examiner’s Certificate
VII. Acknowledgement
VIII. Table of contents
  A. List of tables
  B. List of figures
  C. Glossary of abbreviations
  D. List of symbols
  E. List of publications

1. Chapter-1: General Introduction (1.1-1.16)
   1.1 General perspective 1.2
   1.2 Motivation 1.4
   1.3 Present State-of-Art 1.4
   1.4 Aims and Objectives 1.6
   1.5 Original contribution made by thesis 1.6
   1.6 Outline and scope of the thesis 1.7
   1.7 List of References 1.12

   2.1 Introduction 2.3
   2.2 Fundamentals of optical waveguide 2.4
      2.2.1 Wave equation in symmetric slab waveguide 2.6
      2.2.2 Planar waveguides and the modes 2.8
         2.2.2.1 Guided modes 2.11
         2.2.2.2 Radiation and leaky modes 2.16
      2.2.3 Introduction to Numerical methods for approximate modal analysis 2.18
         2.2.3.1 Effective Index Method (EIM) 2.18
         2.2.3.2 Finite Element Method (FEM) 2.20
         2.2.3.3 Finite Difference Time Domain (FDTD) Method 2.22
         2.2.3.4 Beam Propagation Method (BPM) 2.23
   2.3 Optical sensor and its Classification 2.25
      2.3.1 Fiber Optic (FO) sensors and classification 2.26
         2.3.1.1 Intensity Based Fiber Optic Sensor 2.29
         2.3.1.2 Wavelength Modulated Fiber Optic Sensors 2.30
2.3.1.3 Phase Modulated Fiber Optics Sensors 2.32
2.3.1.4 Polarization Modulated Fiber Optic Sensors 2.33
2.3.2 Integrated Optical Waveguide Sensors 2.34
   2.3.2.1 Integrated Optical Interferometers 2.35
   2.3.2.2 Grating-Coupler Sensors 2.36
   2.3.2.3 Evanescent-Wave and Surface Plasmon Resonance Sensors 2.37
2.3.3 Basic Principle: Optical Planar Waveguide Sensors 2.41
   2.3.3.1 Integrated Optic Planar Waveguide 2.42
       Sensor Effect
2.3.4 Comparison between fiber optic sensor and integrated optical planar waveguide sensor 2.51
2.3.5 Requirement of IO planar waveguide sensors 2.51
2.4 Performance parameters of optical sensors 2.52
   2.4.1 Sensor Sensitivity 2.52
   2.4.2 Limit of Detection (LOD) 2.52
   2.4.3 Limit of Quantization (LOQ) 2.53
   2.4.4 Selectivity or Specificity 2.53
   2.4.5 Sample Volume 2.53
2.5 Review on planar waveguide materials and fabrication technologies 2.53
2.6 Optical planar waveguide sensor and applications-a review study 2.59
   2.6.1 Refractometric optical sensing and petroleum fuel adulteration
      2.6.1.1 Causes of petroleum adulteration 2.74
      2.6.1.2 Impacts due to petroleum adulteration 2.75
      2.6.1.3 Petroleum adulteration detection as reported by earlier authors 2.76
      2.6.1.4 Status of petroleum adulteration in Indian context 2.78
   2.6.2 Integrated optical waveguide sensor as detection element for lab on a chip sensing application
      2.6.2.1 Non-invasive sensing approach for Measurement of glucose concentration 2.83
      2.6.2.2 Significance of sensing glucose 2.84
      2.6.2.3 Glucose concentration in human physiological fluids -blood 2.85
      2.6.2.4 Challenges of glucose sensors and motivation of planar waveguide sensor with Lab-on-chip for glucose concentration measurement 2.88
2.7 Conclusion 2.90
2.8 List of References 2.91

3. Chapter-3: Theoretical modeling, design and development of integrated planar waveguide optical sensor (3.1-3.64)

3.1 Introduction 3.3
3.2 Proposed waveguide structure for sensor 3.3
3.2.1 Solution of the wave equation for planar waveguide sensor 3.6
3.2.2 Waveguide Sensitivity 3.12
3.2.3 Power propagation in the structure 3.17

3.3 Design of the proposed sensor structure 3.19
3.3.1 Estimation of sample volume 3.21

3.4 Fabrication of the designed sensor 3.21
3.4.1 Fabrication processes 3.22
3.4.1.1 Preparation of Wafer for Fabrication 3.22
3.4.1.2 Deposition of Silica (SiO₂) Layer as Lower Cladding 3.27
3.4.1.3 Deposition of Silicon Oxynitride (SiON) as Guiding Layer 3.38
3.4.1.4 Preparation of Mask 3.43
3.4.1.5 Annealing 3.44
3.4.1.6 Transfer of Pattern on Guiding Layer 3.45
3.4.1.7 Spin Coating of Photoresist 3.46
3.4.1.8 Photolithography 3.47
3.4.1.9 Mask cleaning 3.50
3.4.1.10 Alignment and Exposure 3.50
3.4.1.11 Development and Post Baking 3.50
3.4.1.12 Metallization 3.50
3.4.1.13 Lift-off Technique 3.52
3.4.1.14 Reactive Ion Etching 3.53
3.4.1.15 Wet Etching/RIE of Metallization (Cr) layer 3.56

3.5 Experimental set up for sensing application 3.57
3.5.1 Measurements 3.57
3.5.2 Results and Characterization 3.58

3.6 Conclusion 3.61
3.7 List of References 3.62

4. Chapter-4: Integrated optic waveguide sensor for detecting 
adulteration in petroleum based products (4.1-4.18)

4.1 Introduction 4.2
4.2 Design of the waveguide sensor for adulteration applications 4.3
4.2.1 Sensitivity response 4.5
4.2.2 Limit of Detection (LOD) 4.6
4.2.3 Estimation of sample volume 4.6
4.2.4 Estimation of detection time 4.7
4.2.5 Material and methods 4.7
4.2.5.1 Procurement of petroleum product samples 4.7
4.2.5.2 Preparation of samples 4.7
4.2.5.3 Design parameters 4.8
4.3 Experimental results and Discussion 4.8
4.4 Performance comparison 4.15
4.5 Conclusion 4.16
5. Chapter-5: Integrating Optical waveguide Sensor with Lab-on-a-Chip Device Platform for detecting glucose concentration in blood plasma

5.1 Introduction

5.2 Sensing Concept and Design
5.2.1 Lab-on-a-Chip
5.2.2 Design of sensor with interfacing capillary tube
5.2.3 Sensitivity
5.2.4 Limit of Detection (LOD)
5.2.5 Estimation of detection time
5.2.6 Estimation of sample volume

5.3 Fabrication of waveguide sensor

5.4 Experiment for the diabetic study
5.4.1 Preparation of the rat model
5.4.1.1 Induction of Experimental Diabetes
5.4.1.2 Fixation of doses for induction of diabetes
5.4.2 Assessment of Diabetes and Hyperglycemia

5.5 Measurement Setup
5.5.1 Rapid testing of blood plasma glucose level of rat and our proposed technique

5.6 Comparison between the existing techniques and our proposed technique

5.7 Conclusion

5.8 List of References

6. Chapter-6: Conclusion & Future Scope

6.1 Conclusion

6.2 Future Scope