# INDEX

- **Abstract**: IX
- **Acknowledgement**: X

## 1. Introduction

1.1 Applications of Laser Diode: 1
1.2 Brief History of Laser Diode: 3
1.3 Background and Prerequisites: 4
   - 1.3.1 General Laser Theory: 4
   - 1.3.2 Diversities of Laser Systems: 8
   - 1.3.3 Lasing in Semiconductor: 9
     - 1.3.3.1 Gain Medium: 10
     - 1.3.3.2 Population Inversion: 11
     - 1.3.3.3 Resonator Cavity: 13
     - 1.3.3.4 Condition for Lasing: 13
   - 1.3.4 Operation of Laser Diode: 15
1.4 Laser Diode Structures: 17
   - 1.4.1 Homojunction Laser Structure: 17
   - 1.4.2 Double-Heterojunction Laser structure: 18
   - 1.4.3 QW Laser Diodes: 19
   - 1.4.4 Separate Confinement Heterostructure (SCH): 22
1.5 Thesis Overview: 23
1.6 Organization of Thesis: 26

## 2. Growth of Laser Diode Structure using MOVPE

2.1 Introduction: 30
2.2 Epitaxial Growth of Semiconductor Materials: 31
2.3 Epitaxial Growth Techniques: 35
   - 2.3.1 Liquid Phase Epitaxy: 35
   - 2.3.2 Molecular Beam Epitaxy: 36
   - 2.3.3 Vapor Phase Epitaxy: 37
2.3.3.1 Metal-Organic Vapor Phase Epitaxy

2.4 Growth of III-V Semiconductors using MOVPE
2.4.1 Chemical Reactions and Precursors
2.4.2 Growth Mechanism
2.4.3 Growth Regimes
2.4.4 Growth Rate
2.4.5 Doping of Semiconductors
2.4.5.1 Donors
2.4.5.2 Acceptors

2.5 Characterization Techniques
2.5.1 High-Resolution X-Ray Diffractometry
2.5.2 Photoluminescence Spectroscopy
2.5.3 Electrochemical Capacitance Voltage Profiling

2.6 Growth and Optimization of Laser Structure
2.6.1 Materials for High-Power Laser Diodes
2.6.1.1 The InGaP/InAlGaP Material System
2.6.1.2 The ZnCdSe Material System
2.6.1.3 The AlInGaN Material System
2.6.2 Experimental
2.6.3 Optimization of Different Layers
2.6.3.1 InAlP Cladding layer
2.6.3.2 InAlGaP Waveguide layer
2.6.3.3 InGaP QW Active Layer
2.6.4 Growth of a Complete Laser Structure

3. Device Processing for Laser Diodes
3.1 Various Laser Diode Geometries
3.1.1 Broad-Area Laser Diodes
3.1.2 Stripe Geometry Laser Diodes
3.1.2.1 Gain-Guided Stripe Geometry Laser Diodes
3.1.2.2 Index-Guided Stripe Geometry Laser Diode
3.2 Laser Diode Bars
3.3 Fabrication of Laser Diode Bar with Mesa-Stripe Geometry
3.4 Optimization of Various Steps in Laser Diode Processing
  3.4.1 Organic Cleaning
  3.4.2 Photolithography
    3.4.2.1 Photoresist Coating
    3.4.2.2 Chlorobenzene Soak
    3.4.2.3 Alignment
    3.4.2.4 Exposure
    3.4.2.5 Development
  3.4.3 Top Metal Contact Deposition
  3.4.4 Lift-off Process
  3.4.5 Rapid Thermal Annealing of Top Contact
  3.4.6 Etching
  3.4.7 Lapping & Polishing
  3.4.8 Bottom Metal Contact Deposition
  3.4.9 RTA of Bottom Contact
  3.4.10 Scribing
3.5 Detailed Process Layout
3.6 Testing of Laser Diode Bars

4. Optimization of Facet-Coating for Laser Diode
  4.1 Degradation of Laser Diodes
    4.1.1 COMD Mechanisms
  4.2 Facet Passivation for Laser Diode
  4.3 Optical Thin Films for Laser Diode Facets
    4.3.1 Anti-Reflection Coating
    4.3.2 High-Reflection Coating
    4.3.3 Materials for AR-HR Coatings
  4.4 Thin Film Deposition Technique
    4.4.1 Physical Vapor Deposition
      4.4.1.1 Electron Beam Evaporation Technique
  4.5 Optimization of Coating Conditions for Laser Diode

References
4.6 Experimental

4.7 Reflectivity Simulation

4.8 Optical Thin Film Characterizations
  4.8.1 Ex-situ Reflectivity Measurements
  4.8.2 In-situ Reflectivity Measurements
    4.8.2.1 Experimental Setup
    4.8.2.2 Results and Discussion
    4.8.2.3 Upgradation of In-situ Reflectivity Measurement

4.9 Optimization of AR-HR Coatings for Different Wavelengths
  4.9.1 650 nm
  4.9.2 820 nm
  4.9.3 850 nm
  4.9.4 890 nm
  4.9.5 950 nm
  4.9.6 1200 nm

4.10 Conclusion

References

5. Laser Diode Characterization: Setup and Automation

5.1 Overview of Laser Diode Characterizations
  5.1.1 L-I Characteristics
    5.1.1.1 Threshold Current
    5.1.1.2 Slope Efficiency
    5.1.1.3 External Differential Quantum Efficiency
    5.1.1.4 Kinks
  5.1.2 I-V Characteristics
  5.1.3 Spectral Response Measurement

5.2 Instruments for Laser Diode Characterization
  5.2.1 Current Driver
  5.2.2 Integrating Sphere
  5.2.3 Photodetector
  5.2.4 Lock-in Amplifier
  5.2.5 Temperature Controller
5.2.6 Monochromator 146
5.3 Automation of Characterization Facility 146
5.4 Virtual Instrumentation 147
5.4.1 Data Acquisition System 147
  5.4.1.1 The Personal Computer 148
  5.4.1.2 Transducers 148
  5.4.1.3 Signal Conditioning 148
  5.4.1.4 DAQ hardware 149
  5.4.1.5 Software 151
5.4.2 Communication Protocols 152
  5.4.2.1 Serial Communication 152
  5.4.2.2 Parallel Port Communication 153
  5.4.2.3 GPIB 153
5.4.3 Programming 154
5.5 Experimental Setups and VI Implementations 156
  5.5.1 L-I-V Characteristics and Spectral Response Measurement 156
  5.5.2 Characteristic Temperature Measurement 163
  5.5.3 Thermal Impedance Measurement 164
  5.5.4 Lifetime and Degradation Rate Measurement 168

References 172

6. Packaging and Testing of High-Power Laser diode Assembly 174
6.1 Die-Bonding 175
  6.1.1 Adhesive Bonding 175
  6.1.2 Soldering 176
    6.1.2.1 Eutectic Bonding 176
    6.1.2.2 Soft Soldering 177
  6.1.3 Solders Used for Die-bonding 178
    6.1.3.1 Silver (Ag) Epoxy 178
    6.1.3.2 Lead-Tin (Pb-Sn) Paste 178
    6.1.3.3 Indium (In) Preform 179
    6.1.3.4 Gold-Tin (Au-Sn) Preform 179