

---

# Contents

<b>List of Figures .....</b>	<b>i</b>
<b>List of Tables .....</b>	<b>iv</b>
<b>1 Introduction .....</b>	<b>1</b>
1.1 History	1
1.2 Elemental and Compound Semiconductors.....	2
1.3 Development of III-Nitrides .....	4
1.4 Basic Material Properties .....	5
1.5 Technological Applications.....	7
1.5.1 Optical Devices Based on III-Nitrides.....	7
1.5.2 Electronic Devices Based on III-Nitrides .....	9
1.6 Objectives of this work.....	11
<b>2 Theoretical background.....</b>	<b>13</b>
2.1 Crystal Structure.....	13
2.2 Atomic Bond Properties .....	15
2.3 Band Structure .....	16
2.3.1 Temperature Dependence .....	18
2.3.2 Pressure Dependence .....	18
2.4 Defects.....	19
2.4.1 Structural Defects .....	19
2.4.2 Point Defects.....	20
2.4.3 Thermodynamics of Defect Formation.....	21
2.4.4 Fermi Level in Equilibrium .....	23
2.4.5 Formation Energy of Charged Defects .....	23
<b>3 Experimental Methods.....</b>	<b>26</b>
3.1 Growth of III-Nitrides .....	26
3.1.1 AlN PVT .....	27

---

3.1.2 MBE.....	27
3.1.3 MOCVD.....	28
3.2 MOCVD Reactor System.....	28
3.2.1 Illumination System.....	30
3.3 Illumination Efficiency Considerations.....	32
3.4 Electrical Characterization .....	35
3.4.1 I-V Measurements.....	36
3.4.2 Hall Effect Measurements .....	36
3.4.3 Electrical Contacts .....	38
3.5 Optical Characterization.....	39
3.5.1 Photoluminescence Spectroscopy.....	40
3.5.2 Transmission Spectroscopy .....	41
3.6 Other Characterization Techniques .....	41
3.6.1 SEM .....	41
3.6.2 AFM.....	43
3.6.3 XRD .....	44
3.6.4 SIMS .....	44
<b>4 Conventional Point Defect Reduction in GaN.....</b>	<b>46</b>
4.1 Power electronic applications.....	46
4.2 Carbon in gallium nitride.....	50
4.3 Supersaturation.....	51
4.4 Growth of GaN films.....	52
4.4.1 Carbon Incorporation into GaN .....	54
4.4.2 Electronic Properties of GaN.....	61
4.4.3 Creation of high $\mu$ GaN epitaxial films .....	67
<b>5 Defect Quasi Fermi Level Control in n-GaN and AlGaN .....</b>	<b>75</b>
5.1 Formation Energy of Point Defects.....	76
5.2 Application of Defect Quasi Fermi Level Control during Growth .....	78

---

5.3	Intensity Dependence .....	80
5.4	Defect Quasi Fermi Level control of C <sub>N</sub> in the low concentration regime .....	87
5.5	Spatial control of defects .....	91
5.5.1	Comparison of above and below bandgap laser illumination in AlGaN .....	94
<b>6</b>	<b>Defect Quasi Fermi Level Control of Mg-Migration in GaN.....</b>	<b>97</b>
6.1	Significance of Mg for III-nitride devices.....	97
6.1.1	Significance of Mg memory effect for the development of power devices....	98
6.2	Review of Mg memory effect.....	100
6.3	Growth and Illumination Experiments .....	102
6.4	Control of Mg migration by Defect Quasi Fermi level control.....	105
6.5	Creation of insulation layers.....	109
<b>7</b>	<b>Conclusions and Future Work.....</b>	<b>113</b>
7.1	Summary and Conclusions .....	113
7.1.1	Optimization of Conventional Point Defect Reduction.....	113
7.1.2	Defect Quasi Fermi Level Control in n-type GaN and AlGaN .....	113
7.1.3	Defect Quasi Fermi Level Control of Mg Migration in GaN .....	114
7.2	Future Work.....	115
<b>8</b>	<b>References .....</b>	<b>117</b>
<b>9</b>	<b>Publications.....</b>	<b>125</b>
	<b>Acknowledgments .....</b>	<b>131</b>