

Contents

1	Introduction	1
1.1	Objectives of the dissertation	2
1.2	Outline of the dissertation	3
2	Device Physics / Theoretical basis	5
2.1	Theory of the Gunn effect	5
2.1.1	History	5
2.1.2	The transferred-electron effect and the domain formation	6
2.1.3	Domain Dynamics	11
2.1.4	The small signal behaviour of a transferred-electron device	14
2.2	Gunn diode with hot electron injectors	18
2.2.1	Metal semiconductor Schottky contact injector	18
2.2.2	Graded gap injector	21
2.2.3	Resonant tunneling injector	23
2.3	Gunn diode based oscillators	26
2.3.1	Theory of two-port networks	26
2.3.2	Negative differential conductance oscillators	31
2.3.3	Gunn oscillation modes	31
2.4	The thermal behaviour of a Gunn diode	36
2.4.1	Analytical solution of the simplified static heat transfer problem	36
2.4.2	Finite elemente simulations of the temperature distributions in a Gunn diode	38
3	III-V compound semiconductor material systems	43
3.1	Group-III/As and group-III/N material systems	43
3.1.1	GaAs, AlAs	44
3.1.2	GaN, AlN	45
3.2	GaAs, AlAs grown by MBE	46
3.3	GaAs Gunn diode structures	47
3.3.1	Graded Gap injector GaAs Gunn diodes	47
3.3.2	Resonant tunneling injector GaAs Gunn diodes	48
3.4	GaN grown by MOVPE	50
3.5	GaN Gunn diode structures	50

4 Experimental Methods	53
4.1 Atomic Force Microscope (AFM)	53
4.2 Scanning Electron Microscope (SEM)	55
4.3 Hall measurements	55
4.4 Capacitance-Voltage measurements	58
4.5 TLM and CLM	59
4.6 Short pulse DC measurements	61
4.7 S-parameters measurements	61
4.7.1 Network Analyzer Measurement systems	61
4.7.2 Displaying data: Smith Chart	64
5 Technology	67
5.1 Mesa etching	67
5.1.1 ECR-RIE of GaAs/AlGaAs mesa.	68
5.1.2 ECR-RIE of GaN mesa	70
5.1.3 GaN nanocolumns: a topdown approach.	70
5.2 Ohmic contacts	72
5.3 Electrical isolation of the single Gunn diodes	73
5.4 Polyimide planarization / passivation	74
5.5 Deposition of the bond-pads and of the oscillator passive elements	75
5.6 Air-bridge interconnection (optional step).	76
6 Experimental results and discussion	81
6.1 Gunn diode direct current behavior	81
6.1.1 Contacts	81
6.1.2 I-V characteristics of graded gap injector GaAs Gunn diodes	83
6.1.3 Temperature dependant DC modelling of graded gap injector GaAs Gunn diodes	85
6.1.4 I-V characteristics of resonant tunnelling injector GaAs Gunn diodes	87
6.1.5 I-V characteristics of GaN Gunn diodes	88
6.1.6 100 ns pulse measurements: heat effects evidences	89
6.2 Gunn diode high frequency behaviour	91
6.2.1 Impedance measurements up to 50MHz	91
6.2.2 High frequencies investigations of GaAs Gunn diodes	93
6.2.3 Drift velocity computation and operation mode classification	96
6.2.4 Estimation of the Γ and L-valley occupation	100
6.2.5 Temperature dependance of the drift velocity	101
6.3 Gunn diode based oscillators	102
6.3.1 The Gunn diode cavity oscillator	102
6.3.2 The planar low pass filter	103
6.3.3 The planar resonant circuit	105
6.3.4 The monolithic integrated voltage-controlled Gunn oscillator	109
7 Conclusions	113

8 Zusammenfassung	115
A Mask layout	119
B Properties of semiconductors and table of elements	123
C Process parameters	125
C.1 Cleaning process	125
C.2 Lithography processes	127
C.3 Wet-chemical etching processes	131
C.4 Plasma-etching processes	133
C.5 Metallization processes	134
List of Figures	137
List of Tables	140
Bibliography	142
Acknowledgement	149