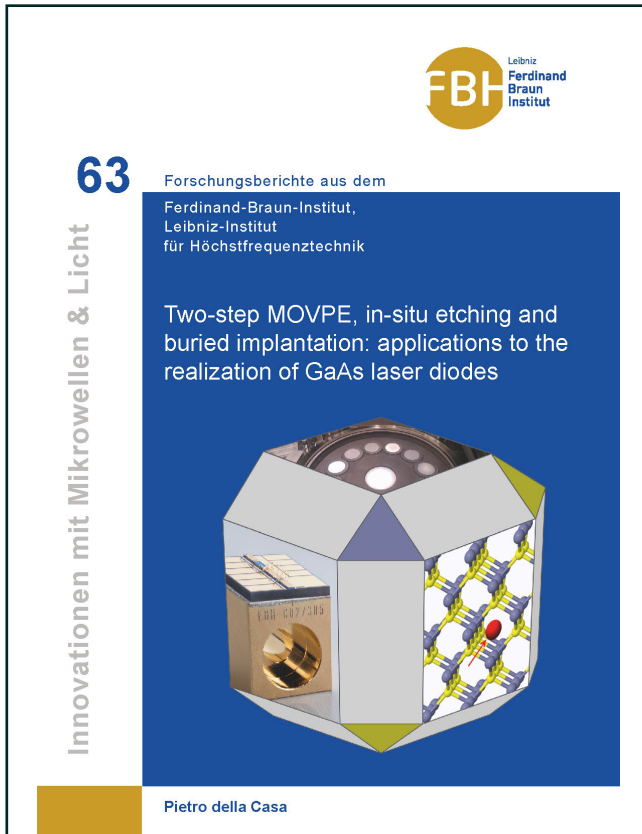




Pietro della Casa (Autor)

Two-step MOVPE, in-situ etching and buried implantation: applications to the realization of GaAs laser diodes



<https://cuvillier.de/de/shop/publications/8416>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,
Germany

Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>

Contents

1	Introduction	1
2	Zincblende III-V semiconductors	3
2.1	Chapter introduction	3
2.2	Zincblende crystal structure	3
2.3	Point defects in III-V semiconductors	6
2.4	III-V semiconductors and optoelectronics	7
3	MOVPE growth of III-V compounds	9
3.1	Introductory remarks on MOVPE technique	9
3.2	Planetary reactors AIX2400G3 and AIX2800G4	10
3.2.1	Reactor chamber	10
3.2.2	MOVPE gas mixing system and exhaust	13
3.3	Precursors selected for the experimental work	15
3.4	Dopants and impurities incorporation	16
3.4.1	Intrinsic/unintentional	16
3.4.2	Dopants from precursors	16
4	In-situ etching with CBr₄	17
4.1	Motivation for in-situ etching	17
4.2	Pre-existing research on in-situ etching	18
4.2.1	Chlorine compounds	18
4.2.2	CBr ₄	19
4.3	Investigation of CBr ₄ etching of GaAs	20
4.3.1	General experimental details	20
4.3.2	GaAs etching: surface morphology	23
4.3.3	GaAs etching: kinetics	29
4.4	Investigation of CBr ₄ etching of GaAs assisted with TMGa and TMAI	39
4.4.1	Experimental details	39
4.4.2	Assisted etching: kinetics	39
4.4.3	Assisted etching: morphology	44
4.5	CBr ₄ etching of AlGaAs and GaInP	46
4.5.1	AlGaAs	46
4.5.2	GaInP	47

4.6	Regrowth and interface contamination	47
5	SG-DBR tunable lasers	55
5.1	Chapter introduction	55
5.2	SG-DBR lasers	55
5.3	Thermally tuned SG-DBR lasers	57
5.3.1	Structure and process	57
5.3.2	MOVPE and intermediate pattern-definition process	62
5.3.3	Device results	66
5.4	Investigation of electronic tuning	68
6	Buried-mesa broad-area lasers	73
6.1	Chapter introduction	73
6.2	High-power lasers	73
6.2.1	Brightness and beam quality	74
6.2.2	Reliability and maximum output power	75
6.2.3	Design aspects	76
6.2.4	Strategies to introduce lateral confinement	77
6.3	Structure and process	77
6.3.1	The vertical structure	78
6.3.2	The process with two-step epitaxy	79
6.4	Results and discussion	82
6.4.1	Comparison of VS0 and VS2 vertical structures	82
6.4.2	Material characterization of the two-step epitaxy	87
6.4.3	Characterization of two-step epitaxy lasers: as-cleaved devices	89
6.4.4	Characterization of two-step epitaxy lasers: coated and mounted devices	91
6.4.5	Electrical overstress test	93
6.5	Chapter summary and conclusions	95
7	Lasers with buried implantation	97
7.1	Chapter introduction	97
7.2	Ion implantation	98
7.2.1	Interactions in the keV range and implantation profiles	98
7.2.2	Damage, damage removal, damage-isolation and doping	99
7.2.3	Oxygen in GaAs-AlGaAs	100
7.2.4	Silicon in GaAs-AlGaAs	101
7.2.5	Quantum-well intermixing effects of implantation	101

7.3	Device description and fabrication procedure	103
7.3.1	Vertical structure	103
7.3.2	Process with 2-step epitaxy and intermediate implantation	104
7.3.3	Device types	106
7.4	Material characterization	107
7.4.1	Residual implantation damage after regrowth	107
7.4.2	Electrical effects of the implantation	110
7.4.3	Surface morphology and regrowth interface	112
7.5	Characterization of as-cleaved devices	113
7.5.1	Comparison of 2-step and single-step growth	113
7.5.2	PI curves of LBI and STD lasers	114
7.5.3	Effects of implantation on I_{th} and leakage current	115
7.5.4	Effects of implantation on the slope efficiency	116
7.5.5	Effects of implantation on optical absorption	117
7.6	Characterization of coated and mounted devices	119
7.6.1	PI curves	119
7.6.2	Near-field and far-field	120
7.7	Step-stress tests	123
7.8	Chapter summary and conclusions	124
8	Summary and outlook	125
A1	Zinblende III-V semiconductors and related properties	129
A1.1	Appendix content	129
A1.2	Composition, bonding and related properties	129
A1.3	Crystal structure	131
A1.3.1	Zinblende and Wurtzite crystalline structures	131
A1.3.2	Zinblende crystal facets: thermodynamics and surface reconstructions	133
A1.4	Ternary and higher order compounds	135
A1.5	Epitaxial multilayers: mismatch, strain, relaxation	137
A1.6	Defects	139
A1.6.1	Point defects	139
A1.6.2	Electrical characteristics of point defects	139
A1.6.3	Structure of deep defects; an example: silicon DX center	140
A1.6.4	Extended defects	142
A1.7	Electronic structure and related properties	145
A1.7.1	Band structure of crystals	145

A1.7.2	Carrier statistics and semiconductors bands	146
A1.7.3	Interfaces and band offsets	151
A1.7.4	Band structure of III-V Zinblend semiconductors	153
A1.8	Carrier transport	157
A1.8.1	Semiclassical equations of motion – effective mass	157
A1.8.2	Intraband scattering and relaxation time	158
A1.9	Interband transitions	161
A1.9.1	Carrier populations away from equilibrium	161
A1.9.2	Non-radiative recombination at deep centers (SRH)	162
A1.9.3	Surface and interface recombination	163
A1.9.4	Auger	165
A1.9.5	Interband radiative transitions	167
A1.10	Optical properties in the transparency region	170
A2	Some general aspects of III-V MOVPE	173
A2.1	Different III-V epitaxy techniques	173
A2.2	General considerations about MOVPE reactors	174
A2.2.1	MOVPE reactor chamber and overall process: a simplified description	174
A2.2.2	Control of reagent flows	179
A2.3	Precursors for the growth of arsenides and phosphides	181
A2.3.1	General precursors requirements	181
A2.3.2	Molecular structure of the precursors and gas-phase diffusivity	181
A2.3.3	Pyrolysis of the precursors	182
A2.4	Surface processes	187
A2.4.1	Growth modes	187
A2.4.2	Surface chemistry and growth rate	189
A2.5	Stoichiometry, composition and impurity control in MOVPE	193
A2.5.1	V/III ratio, condensation phenomena and stoichiometry	193
A2.5.2	Composition control of multinary alloys	194
A2.5.3	Dopant and impurities incorporation	198
A3	Justification of the equations used in modeling the CBr₄+TMAI etch	204
A4	Model for the calculation of α_p in the implanted sections	207
	References	215