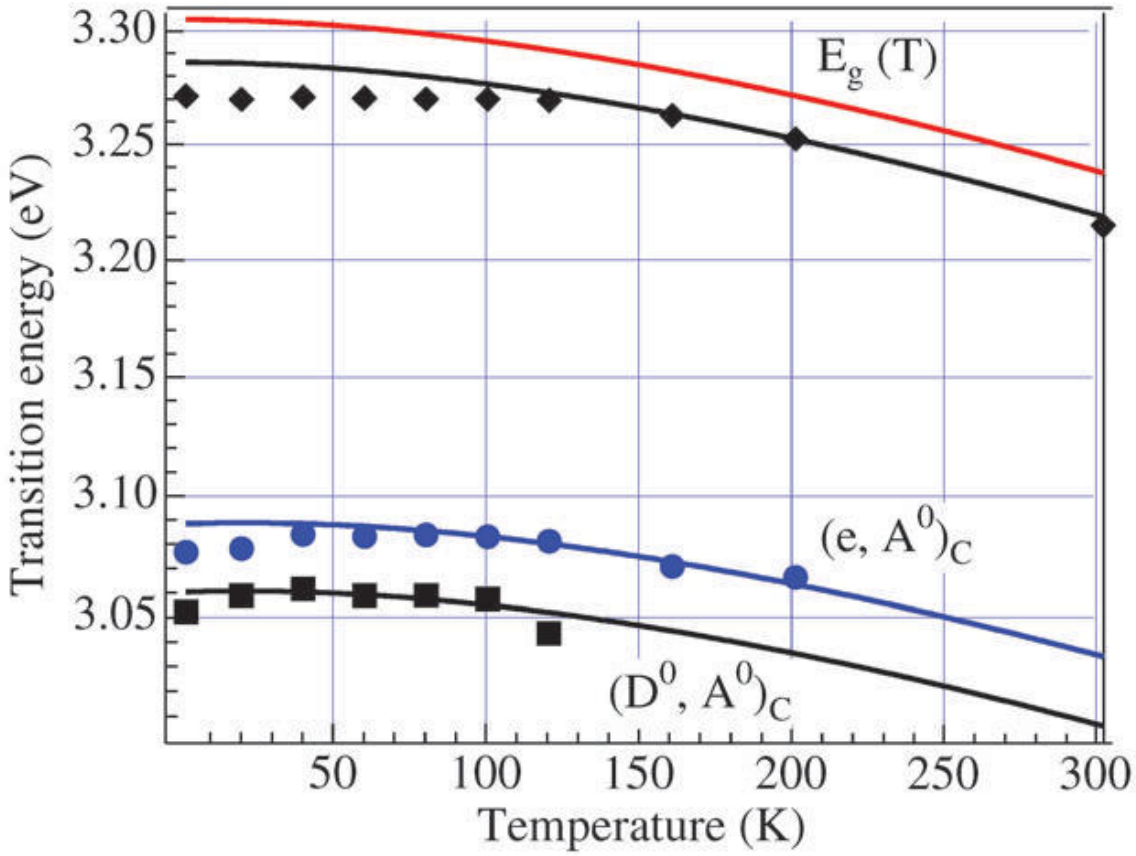
Ulrich Köhler

A Study of Growth and Doping of cubic Group III Nitride Structures



Cuvillier Verlag Göttingen

A Study of Growth and Doping of cubic Group III Nitride Structures

Dem Department Physik
der Universität Paderborn
zur Erlangung des akademischen Grades eines

Doktors der Naturwissenschaften

vorgelegte

Dissertation

von

Ulrich Köhler

Paderborn, April 2003

Abstract

Current commercially available advanced optoelectronic devices made from group III Nitrides are based on material exhibiting hexagonal crystal structure. Magnesium is in use as p–type dopant, and Silicon as donor element. Quantum structures make use of ternary and quaternary compositional alloys, $Al_xIn_yGa_{1-x-y}N$, where the Aluminum and Indium mole fractions x and y, respectively, allow a precise tailoring of the electronic and structural properties.

Group III Nitrides with cubic crystal symmetry are considered as alternatives because of potentially more favourable material properties. In the course of this thesis work, cubic III Nitrides have been examined in closer detail. Molecular Beam Epitaxy was used to grow GaN and AlN epitaxial films as well as $Al_xGa_{1-x}N$/GaN heterostructures and quantum structures. Furthermore, cubic Aluminum Nitride was grown both on c–GaN and directly on Gallium Arsenide substrates, thus demonstrating the possibility of direct AlN low temperature nucleation.

The first part of this thesis is concerned with the properties of Carbon as an alternative acceptor in cubic Gallium Nitride. To this purpose Carbon doping sources were constructed and calibrated. By means of temperature–dependent luminescence and Hall measurements the thermal activation energy of Carbon was determined as $E_A = 215meV$. Additionally, excitation–dependent photoluminescence revealed the existence of a Carbon–related deep center. The effect of the incorporation of Carbon in c–GaN was calculated. The experimental results were reproduced by assuming a self–compensation of the Carbon acceptor by a Carbon interstitial. This behaviour explains electrical and optical incorporation–dependent trends.

The second part deals with $Al_xGa_{1-x}N$ structures. Electrical measurements revealed p–type conductivity of as–grown samples. $Al_xGa_{1-x}N$/GaN multi quantum wells were grown and characterized optically and structurally. The energetic positions of the optical QW transitions as a function of well width and barrier Aluminum content were successfully modelled using effective mass theory.

Contents

List of Figures

List of Tables

List of abbrevations

AFM	*Atomic Force Microscope/Microscopy*
BEP	*Beam Equivalent Pressure*
CL	*Cathodoluminescence*
cw	*Continuous Wave*
DFT	*Density Functional Theory*
DOS	*Density of States*
EDX	*Energy Dispersive X–Ray Analysis*
EL	*Electroluminescence*
ELOG	*Epitaxial Lateral Overgrowth*
FWHM	*Full Width at Half Maximum*
HRXRD	*High–Resolution X–Ray Diffraction*
HVPE	*Halide Vapour Phase Epitaxy*
IR	*Infrared*
LD	*Laser Diode*
LDA	*Linear Density Approximation*
LED	*Light Emitting Diode*
LT	*Low Temperature*
MBE	*Molecular Beam Epitaxy*
MOCVD	*Metal–Organic Chemical Vapour Deposition*
MOVPE	*Metal–Organic Vapour Phase Epitaxy*
MQW	*Multi Quantum Well*
PBN	*Pyrolytic Boron Nitride*
PG	*Pyrolytic Graphite*
PL	*Photoluminescence*
PMT	*Photomultiplier Tube*
QMS	*Quadrupole Mass Spectrometer*
QW	*Quantum Well*
rf	*Radio Frequency*
RHEED	*Reflection High Energy Electron Diffraction*
RSM	*Reciprocal Space Map*
RT	*Room Temperature*
SEM	*Scanning Electron Microscope/Microscopy*
SIMS	*Secondary Ion Mass Spectometry*
SL	*Superlattice*
STM	*Scanning Tunneling Microscope/Microscopy*
TEM	*Transmission Electron Microscope/Microscopy*
UHV	*Ultra–High Vacuum*
UV	*Ultraviolet*
VT	*Variable Temperature*
XRD	*X–Ray Diffraction*