

# Study of Annealing Effect on Dilute Nitride Alloys

DISSERTATION

zur Erlangung des akademischen Grades  
doctor rerum naturalium  
(Dr. rer. nat.)

eingereicht zum  
Fachbereich Physik der  
Freien Universität Berlin

von  
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eingereicht am: 18.11.2007  
Tag der mündlichen Prüfung: 12.12.2007

# Abstract

Annealing is an important fabrication process for devices based on the (In)GaAsN group of materials. This thesis studies two topics related to annealing of dilute nitrides:

1. The mechanism of structural changes during rapid thermal annealing at different temperatures on a set of GaAsN/GaAs MQWs; the structural and optical properties of the samples were studied by XRD, PL, TEM and Raman Spectroscopy. We found that the main mechanisms for structural change are different in different temperature ranges: at low temperatures ( $<750^{\circ}\text{C}$ ), the principal mechanism is the annihilation of point defects; at medium temperatures ( $\approx 750^{\circ}\text{C}$ ), a short-range ordered structure formed (the negative annealing stage); at high temperatures ( $>750^{\circ}\text{C}$ ), a low density of dislocations is formed by clustering of the residual defects.

2. The mechanism of atomic-dimensional structural changes during annealing of different durations of an InGaAsSbN/GaAs SQW was investigated by studying their In K-edge EXAFS spectra. In this study, firstly, the Sb and N atomic fraction ranges in the In first shell were determined. Secondly, a defect-complex-structure related feature was observed in the spectra. We propose that this complex is composed of an N-N dimer and an As-N pair. During annealing of medium duration, part of the defects was annihilated; but when the sample was annealed with a longer duration, a portion of the N-N dimers converted to In-As defects.

# Abbreviations

BAC .....	Band Anticrossing Model
BEEM .....	Ballistic Electron Emission Microscopy
CB .....	Conduction Band
CBE .....	Chemical Beam Epitaxy
DALA .....	Disordered Activated Longitudinal-Acoustic (phonons)
DFB .....	Distributed Feedback
DBR .....	Distributed Bragg Reflector
DF .....	Dark Field
DLTS .....	Deep-Level Transient Spectroscopy
DMH .....	Dimethyl Hydrazine
D-W .....	Debye-Waller
EXAFS .....	Extended X-ray Absorption Fine Structure
FTA .....	Fast Thermal Annealing
FWHM .....	Full Width at Half Maximum
FT .....	Fourier Transform
HRXDR .....	High-Resolution X-Ray Diffraction
INGAS .....	InGaAsSbN
LD .....	Laser Diode
LDA .....	Local Density Approximation
LO .....	Longitudinal-Optical (phonons)
LT-PL .....	Low-Temperature Photoluminescence
LVM .....	Local Vibrational Mode
MBE .....	Molecular Beam Epitaxy
MOCVD .....	Metal-Organic Chemical Vapor Deposition
MQW .....	Multi Quantum Well
MSRD .....	Mean Square Relative Displacement
PC .....	Photocapacitance
PL .....	Photoluminescence
PR .....	Photoreflectance
PTR .....	Photothermal Reflectance
QW .....	Quantum Well
RCS .....	Reduced Chi-Square
RF .....	Radio Frequency
RHEED .....	Reflection High-Energy Electron Diffraction
RS .....	Raman Scattering (Spectroscopy)
RT .....	Room Temperature
RTA .....	Rapid Thermal Annealing

SIMS .....	Secondary Ion Mass Spectrometry
SQW .....	Single Quantum Well
STA .....	Slow Thermal Annealing
$T_c$ .....	Critical Temperature
$T_{tran}$ .....	Transferring Temperature
TEM .....	Transmission Electron Microscopy
TMGa .....	Trimethyl Gallium
TO .....	Transverse-Optical (phonons)
T-PL .....	Temperature-dependent Photoluminescence
TR-PL .....	Time-Resolved Photoluminescence
UHV .....	Ultra High Vacuum
VCSEL .....	Vertical Cavity Surface Emitting Laser
XRD .....	X-Ray Diffraction

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