Native point defects in non-stoichiometric GaAs doped with beryllium

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Introduction

Non-stoichiometric GaAs - grown by MBE at low temperatures (LT-GaAs)

- unique properties (subtilt carrier recombination, semi-insulating behavior after annealing)
- incorporation of excess As in form of native point defects (As+ and VAs-) [1,2]
- instability during annealing restricted applications so far
- recent doping with Be improves thermal stability of point defects in LT-GaAs [3]
- goal of present work: understanding the influence of Be doping on native, incorporation and annealing behavior of native point defects in LT-GaAs:Be

Experimental details

Samples - MBE grown LT-GaAs (200-300°C), Beam equivalent pressure (BEP) 20 (arsenic-rich conditions), growth rate 1 µm/h, Be doping up to 10^19 cm^-3

Methods - Near infrared absorption (NIRA), to detect As+ and VAs-
- Magnetic circular dichroism of absorption (MCDA), to detect As+ and VAs- (Be:Zn, Fe:Al)
- Positron annihilation spectroscopy (PAS), to detect vacancy defects

Absorption spectroscopy of As+ and VAs-

Calibration - MCDA of semi-insulating bulk GaAs

- typical features of As+ spectrum [4]
- correlation of MCDA intensity at 0.94 eV with As+ density (determined by EPR, [5])
- calibration of MCDA signal for our setup

Ga Vacancies

Detection of VAs- by positron annihilation

- 5 parameter from PAS is a measure of vacancy defects [7]
- Increase of 5 above reference value shows positive trapping at vacancy defects
- Defects are identified as Ga vacancies, the same defect as in undoped LT-GaAs [8]

Absorption spectroscopy of As+ and VAs-

MCDA of As+:

- undoped LT-GaAs - spectrum deviates around 1.2 eV [1]
- As+ in LT-GaAs was believed to be different from that in bulk GaAs
- MCDA spectra in LT-GaAs:Be show features typical for As+:
  - Be doping concentration dependent density of As+ (through compensation)
  - As+ in LT-GaAs:Be is not significant different from As+ in bulk GaAs, especially, evidence for complexes with Be

Correlation [VAs-] - [As+] in as grown LT-GaAs:Be

- in undoped LT-GaAs concentration of As+ is determined by VAs- concentration
- doping with Be increases As+ concentration
- for comparison [As+] and [VAs-] are simultaneously determined
- universal relationship between total [As+] and [VAs-] independent of particular doping or growth conditions
- Be doping has no influence on incorporation of native point defects in LT-GaAs

Summary

- native point defects investigated in LT-GaAs:Be
- As+ and VAs- detected by MCDA/NIRA and PAS
- VAs- has same properties as in undoped LT-GaAs
- Detailed investigation of MCDA/NIRA spectra shows that As+ defects are similar to that in bulk GaAs, previous discrepancies regarding the spectral shape of the MCDA signal in LT-GaAs are mainly explained by simultaneous detection of As+ and VAs- signals
- Concentration of all native point defects (As+ and VAs-) in LT-GaAs is not influenced by Be doping - defect concentrations are kinetically dictated by growth conditions as in undoped LT-GaAs
- No evidence for defect complexes containing Be as origin of the thermal stability
- VAs- anneals parallel to As+ thermal stability of LT-GaAs:Be is not related to incorporation of point defects or early annealing of VAs-
- most likely explanation for thermal stability is stress compensation, i.e. small Be atoms compensate the lattice strain caused by As+ atoms

Literature