Study of vacancy-type defects after post-growth annealing of undoped GaAs

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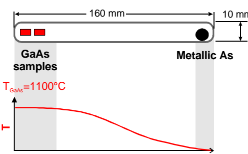
Introduction

- SI GaAs — one of the most common materials for semiconductor devices
- Point defects determine the electrical and optical properties of semiconductors
- The density of point defects is dependent on the stoichiometry deviation [1]
- This work: investigation of undoped SI GaAs after post-growth annealing under different As pressure (0.2-5.57 bar) by means of positron annihilation

Experimental

Sample: LEC grown undoped SI GaAs

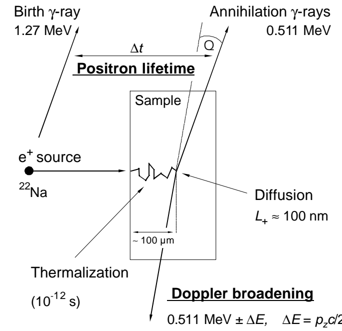
- **Etching:** 30 µm in brommethanol solution before and after annealing
- **Annealing in two-zone furnace:** time 2 hours, sample temperature = 1100° C, As pressures = 0.2..5.57 bar



- **Quenching:** in water to room temperature (40 K/s)
- **Positron lifetime measurements:** FWHM = 240 ps
- **Annealing in vacuum:** temperature range up to 900 K, then samples were cooled down slowly

Method

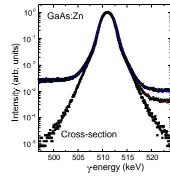
Positron lifetime spectroscopy



Positrons can be trapped in open-volume crystal defects. Annihilation parameters (lifetime, Doppler broadening) are dependent on the electron density and momentum distribution in the defect.

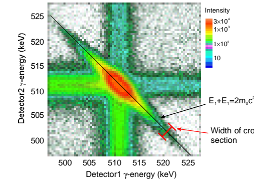
Positron lifetime is measured as time difference between a γ quantum from the β^+ decay and only one of the two annihilation 511-keV γ quanta.

Doppler broadening coincidence spectroscopy



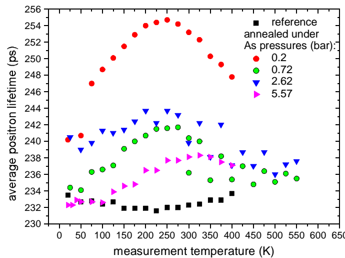
By conventional Doppler measurements only one γ-quant is registered

Background reduction in Doppler spectrum using coincidence measurements by simultaneous registration of two γ-quanta

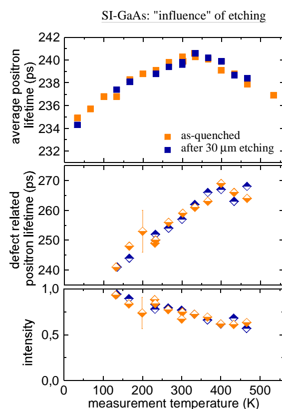


Two-dimensional Doppler coincidence spectrum

Results after post-growth annealing

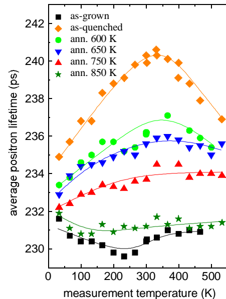


- average lifetime is distinctly higher than for reference sample - evidence of the open-volume defects
- typical dependence for presence of negative vacancies and shallow traps [2]
- negative dependence of the average lifetime on the As pressure during the annealing

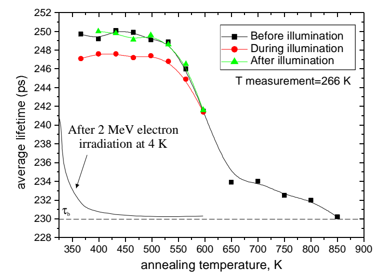


- results before and after etching are the same → we "see" the bulk properties not surface
- defect-related lifetime points to a monovacancy type defect

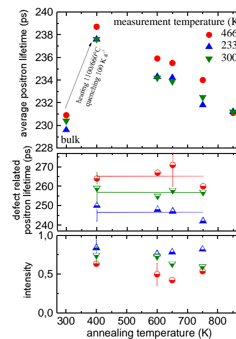
Defect annealing



annealing behaviour of SI GaAs after heat treatment under As pressure of 2.62 bar
- after 850 K annealing step the defect signal disappears



the same annealing procedure for sample heated under 0.2 bar of As pressure
- annealing stage at 550-650 K
- after annealing at 850 K defect disappears
- defect is obviously different from those after electron irradiation [3]
- illumination has some effect but no metastability



annealing of the defect measured at different temperatures
- the same defect is observed after each annealing step

Discussion

- untreated material → no positron trapping observed
- after annealing → presence of shallow traps and negative vacancies
- negative dependence of average positron lifetime on As_4 vapor pressure is observed
- the defect differs from that after electron irradiation

Literature

[1] Ulrich M. Goesele and Teh. Y. Tan, MRS Bulletin 10, 42 (1991).
[2] J. Gebauer and M. Lausmann et al., Phys. Rev. B 60, 1464 (1999).
[3] A. Polity, F. Rudolf, C. Nagel, S. Eichler, and R. Krause-Rehberg, Phys. Rev. B 55, 10467 (1997).

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