Study of vacancy-type defects after Cu diffusion in GaAs

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Introduction

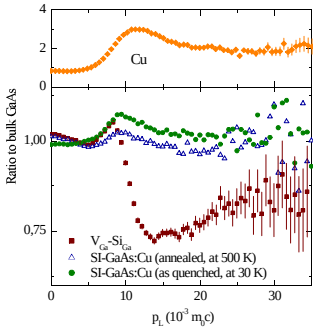
- Cu is one of the most common impurities in semiconductors
- rapidly diffuses via kick-out mechanism [1]
- high diffusion coefficient ($D=1.1\times10^{-5}$ cm^2 s^{-1}) [2]
- maximum solubility 7×10^{18} cm^{-3} at 1100° C [2]
- only small fraction is electrically active as Cu_{Ga}^{2-} acceptors after cooling to the room temperature, the inactive part forms Cu-Ga precipitates [3]
- during further annealing vacancy clusters neighboured by Cu atoms are formed and grow with increasing annealing temperature [4]
- this work: investigation of the process of copper in- and out-diffusion in SI GaAs

Experimental

Samples: **LEC grown SI GaAs covered by 30 nm of Cu under UHV conditions**

1. **Cu in-diffusion:** annealing in two-zone furnace at sample temperature 1100° C during 3h under different As vapor pressures (0.2-10 bar)
2. **Quenching:** 40 K/s in water to RT
3. **Post annealing:** isochronal annealing up to 900 K, then samples were slowly cooled to RT
4. **Detection of vacancy cluster:** Lifetime spectroscopy (fast-fast system, FWHM=240 ps), Doppler coincidence spectroscopy (Ge-Ge system, 1.03 keV), TEM, EDX

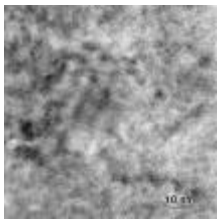
Doppler coincidence measurement



High-momentum part of the positron annihilation momentum distribution, normalized by taking the ratio to a GaAs:Zn reference

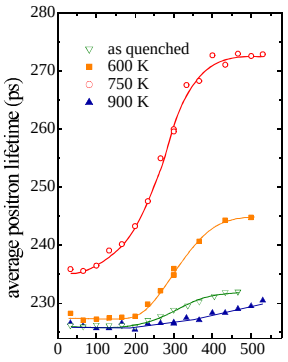
shapes of GaAs:Cu similar to Cu
→ Cu neighbored to annihilation site

TEM



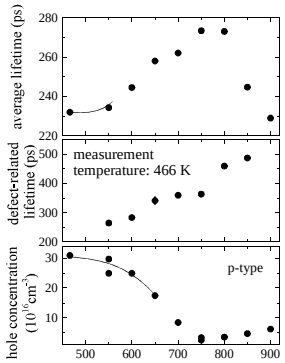
High resolution TEM:
- Cu_3Ga_4
- Cu_5As_2

Positron lifetime measurement

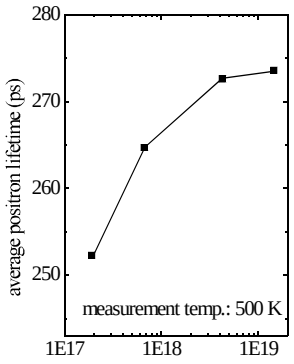


Temperature-dependent measurement after different annealing steps

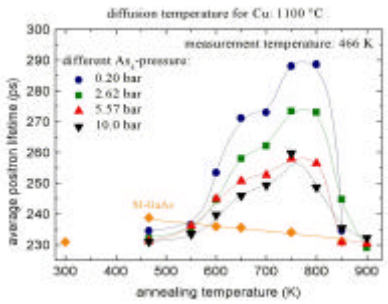
- presence of the shallow traps (Cu_{Ga}^{2-})
- formation of the vacancy clusters



- behaviour at high temperatures (no influence of shallow traps)
- growth of the vacancy clusters with the annealing temperature
- simultaneous decrease of the electrical activity of the Cu-acceptors

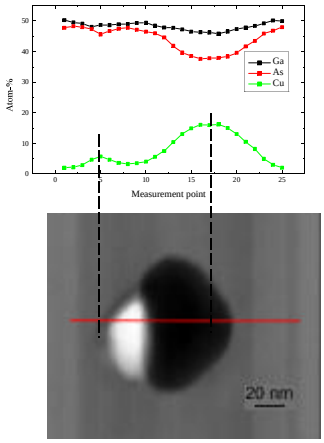


dependence on Cu concentration



- Variations of Cu in-diffusion with different As pressure

- higher As pressure ⇒ smaller number of vacancies in the cluster



EDX scan and high resolution TEM picture of the large vacancy cluster–Cu-Ga precipitate complex

Discussion

- After Cu in-diffusion large vacancy clusters with Cu rich shell and neighboured by Cu-Ga precipitates are formed, but there is almost no positron trapping.
- During annealing, copper atoms begin to out-diffuse from the Ga sublattice sites → vacancy cluster-Cu precipitates complexes are formed.
- These clusters grow with increasing annealing temperature. Above 850 K the vacancy signal disappears due to the large distance between them – higher than mean positron diffusion length.
- The formation of the clusters is influenced by the stoichiometry of the GaAs – with higher number of excess As the number of vacancy clusters decreases.

Literature

[1] F.C. Frank and D. Turnball, Phys. Rev. 104 (1956) 617
[2] R.N. Hall and J.H. Racette, J. Appl. Phys. 35 (1964) 379
[3] R. Leon, P. Werner, K.M. Yu, M. Kaminska, and E.R. Weber, Applied Physics A D61 (1995) 7
[4] R. Krause-Rehberg, K. Petters, J. Gebauer, Physica B 273-274 (1999) 714.

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