Formation of vacancy clusters during copper diffusion in semiinsulating GaAs

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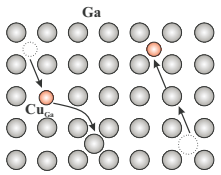
Introduction

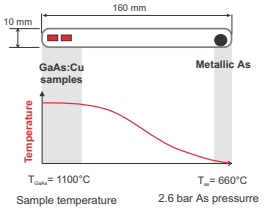
- Cu - most important impurity (contamination) in GaAs
- eletrically active as acceptor Cu_{Ga}^{2-}
- max. solubility: 6×10^{18} cm^{-3} at 1100°C [1]
- fast diffusion [1] via kick-out mechanism [2]



- This work: understanding diffusion process and related defects (vacancies) in more detail

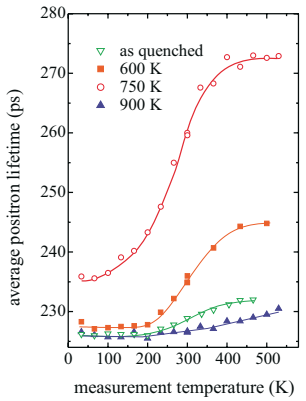
Experimental

- etching SI-GaAs with bromine-methanol and HCl
- covering by Cu with varying thickness (evaporation in UHV)

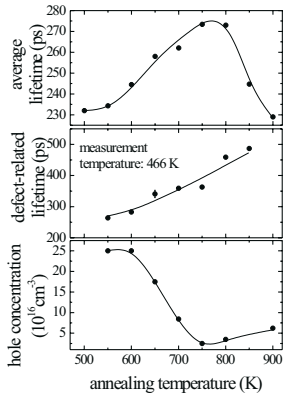


- annealing in two zone furnace
- quenching into water to room temperature (60 K/s)
- Hall and thermoprobe measurements
- PAS: Lifetime spectroscopy (FWHM = 240 ps)
- Doppler coincidence spectroscopy (Ge-Ge, 1.03 keV)
- Transmission electron microscopy (TEM)

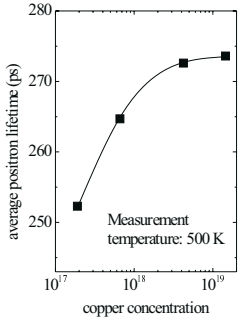
Positron lifetime measurements



Temperature-dependent measuremenst after annealing

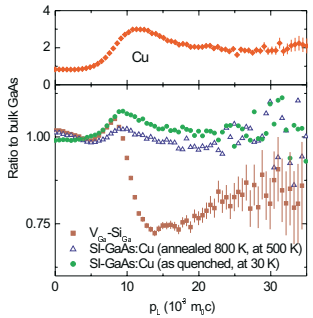


Behavior at high temperature (no influence from shallow traps)



Dependence on Cu concentration

Doppler coincidence measurements

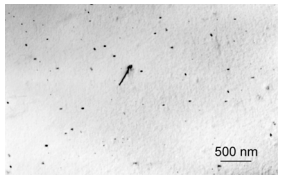


Normalized annihilation momentum distribution

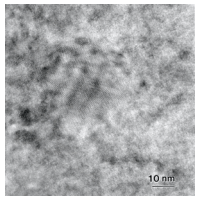
Shapes of GaAs:Cu similar to Cu but different from that of V_{Ga}-Si_{Ga}, high positron lifetime in annealed material
→ Cu neighbored to annihilation site

Annihilation next to Cu also in as-quenched material and lifetime < τ_{bulk}
→ direct idedntification of Cu as shallow positron trap?

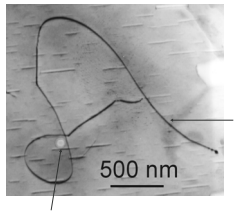
TEM investigations of structural defects



Bright-field image with small dislocation loops of interstitial type



High resolution image: Cu_6Ga_5 [3] or Cu_3As_2 [4]



perfect dislocation loop

vacancy cluster

• All images: [Cu]=6×10^{18} cm^{-3}, as quenched
• no further change during annealing
→ no direct influence of extended defects on positron trapping

Conclusions

- after Cu-indiffusion and quenching no vacancy-type defects are registered
- shallow traps are found which are directly related to Cu
- during annealing vacancy clusters grow and dissolve above 850 K
- vacancies and clusters are decorated with Cu
- Distance between possible annihilation centres seen in TEM is much longer than mean positron diffusion length so they have no influence on positron trapping

References

[1] R.N. Hall, J.H. Racette, J. Appl. Phys. 35 (1964) 379.
[2] F.C. Frank, D. Turnbull, Phys. Rev. 104 (1956) 617.
[3] R. Leon, P. Werner, K.M. Yu, M. Kaminska, E.R. Weber, Appl. Phys. A 61 (1995) 7.
[4] H. S. Leipner, R. F. Scholz, F. Syrowatka, J. Schreiber, P. Werner, Phil. Mag. A (1999) .

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