V International Symposium on strong Nonlinear Vibronic and Electronic Interactions in Solids

- Institute of Physics, University of Tartu, Estonia
- Max Planck Institute for Solid State Research, Stuttgart,
- Brandenburg University of Technology, Cottbus, Germany
- European Union - Regional Development Fund

The introduction of subthreshold induced defects in germanium by above threshold radiation exposure

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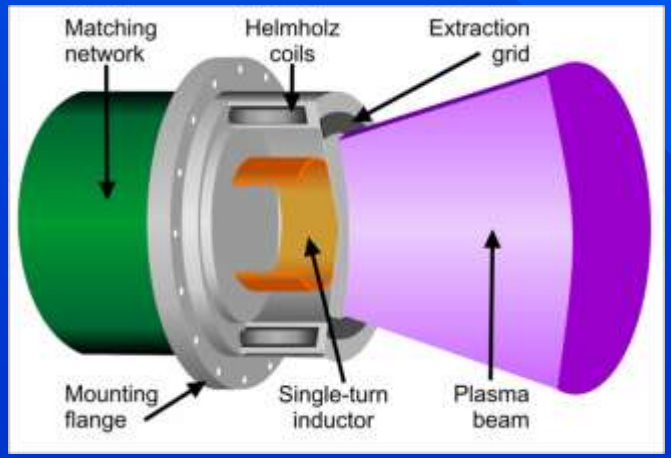
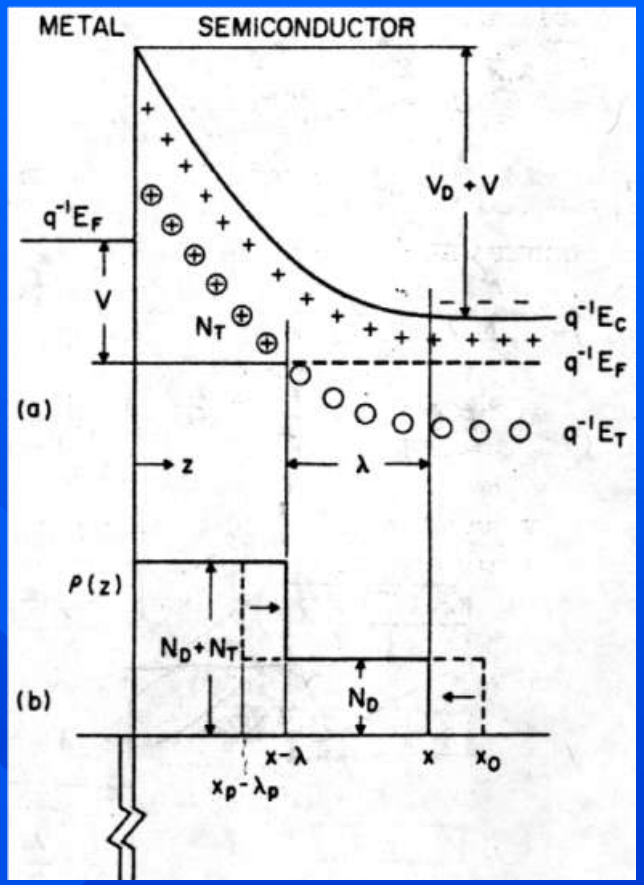
Outline

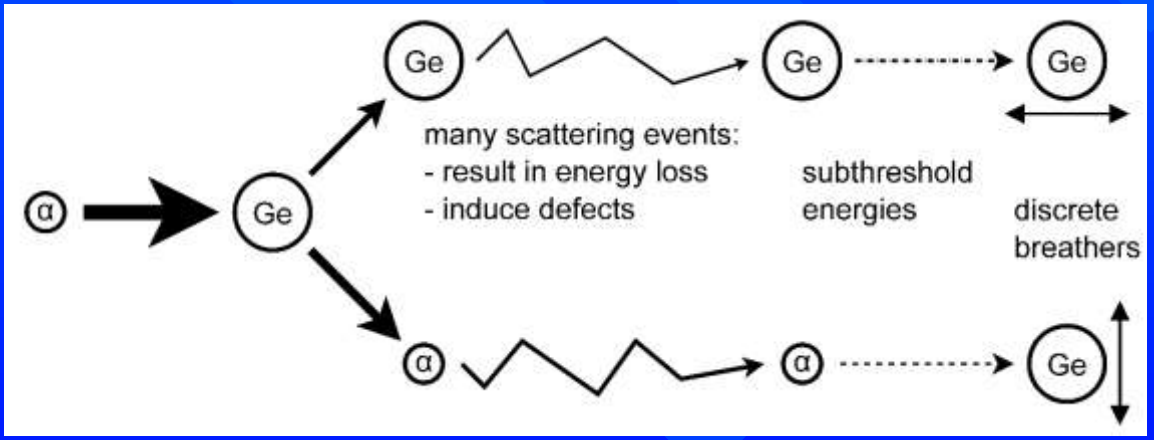
- Subthreshold damage?
- Building blocks:
  - Experimental lab – crystal
  - Introducing defects
  - Measuring of defects
- An experiment – alpha irradiation
- Results - discussion





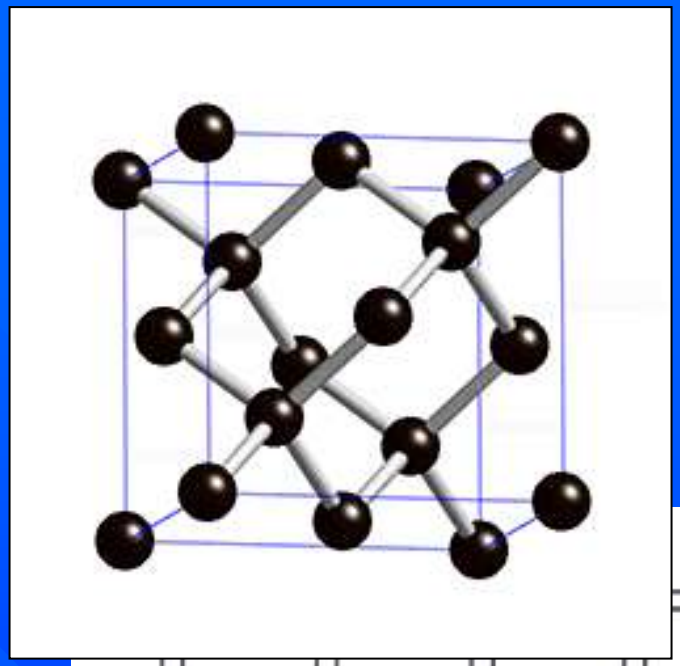
Concept & Motivation

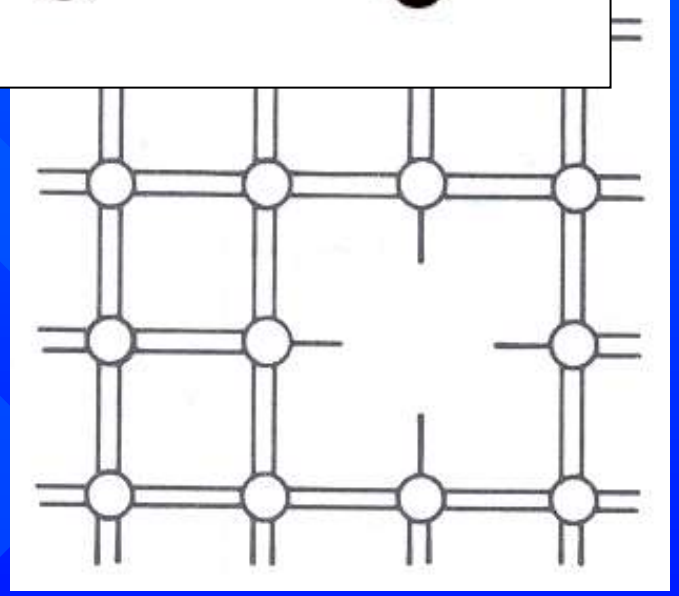
- High energy particle - damage
- Radiation induced defects – Cause?
- All defects created by ion solid interactions?
- Qualify then quantify



Our experimental space

- Pure single crystal – Germanium
- Low impurities – not measurable
- Only 1 to 2 μm
- Temperature above 0K – defects
- Simplest defect - vacancy





Dominant defects

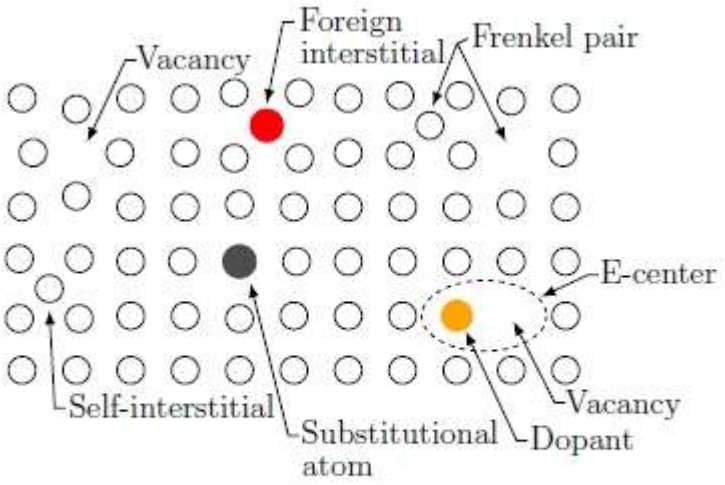
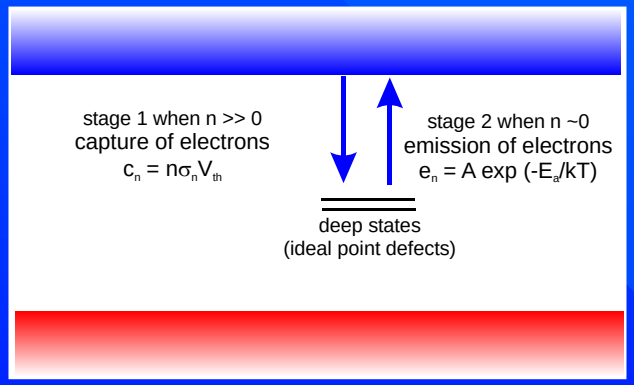


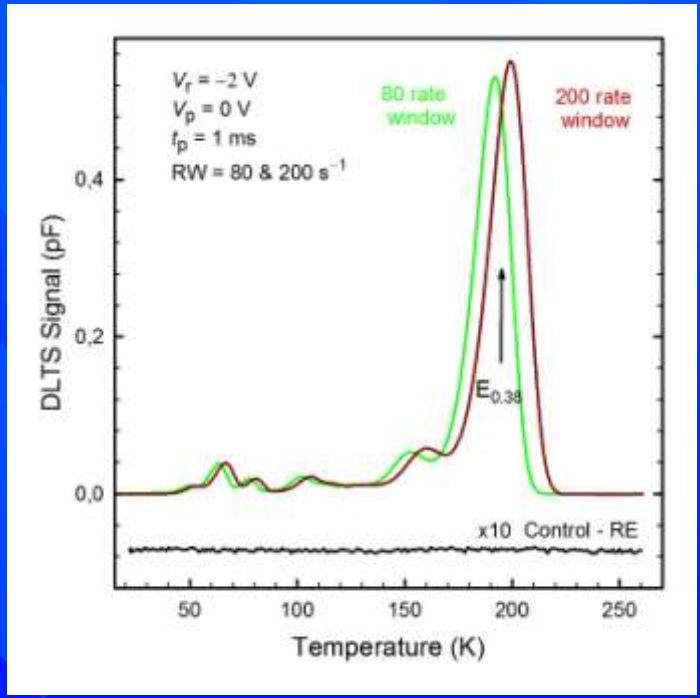
Figure 1: Types of point defects.

- Antimony – substitutional position
- E-center – vacancy – Sb complex

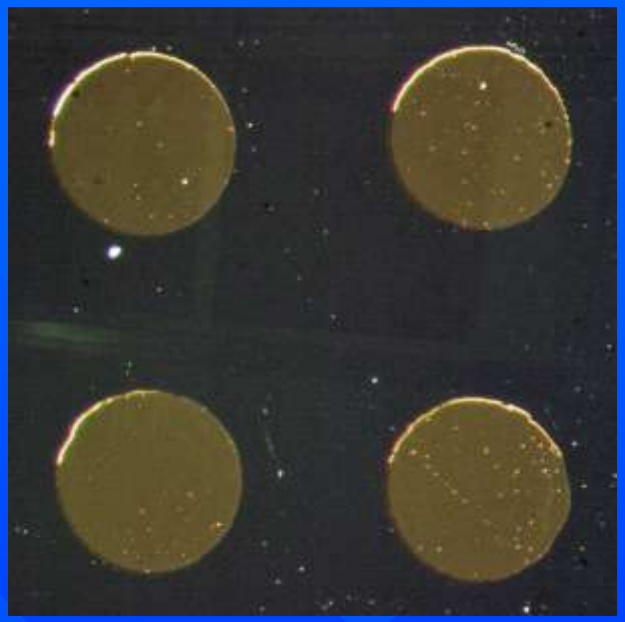
Defect detection - DLTS

- Classic Deep Level Transient Spectroscopy (DLTS)
- By monitoring the change of emission rate with temperature an activation energy is obtained.
- By observing the capture rate a cross section can be obtained.



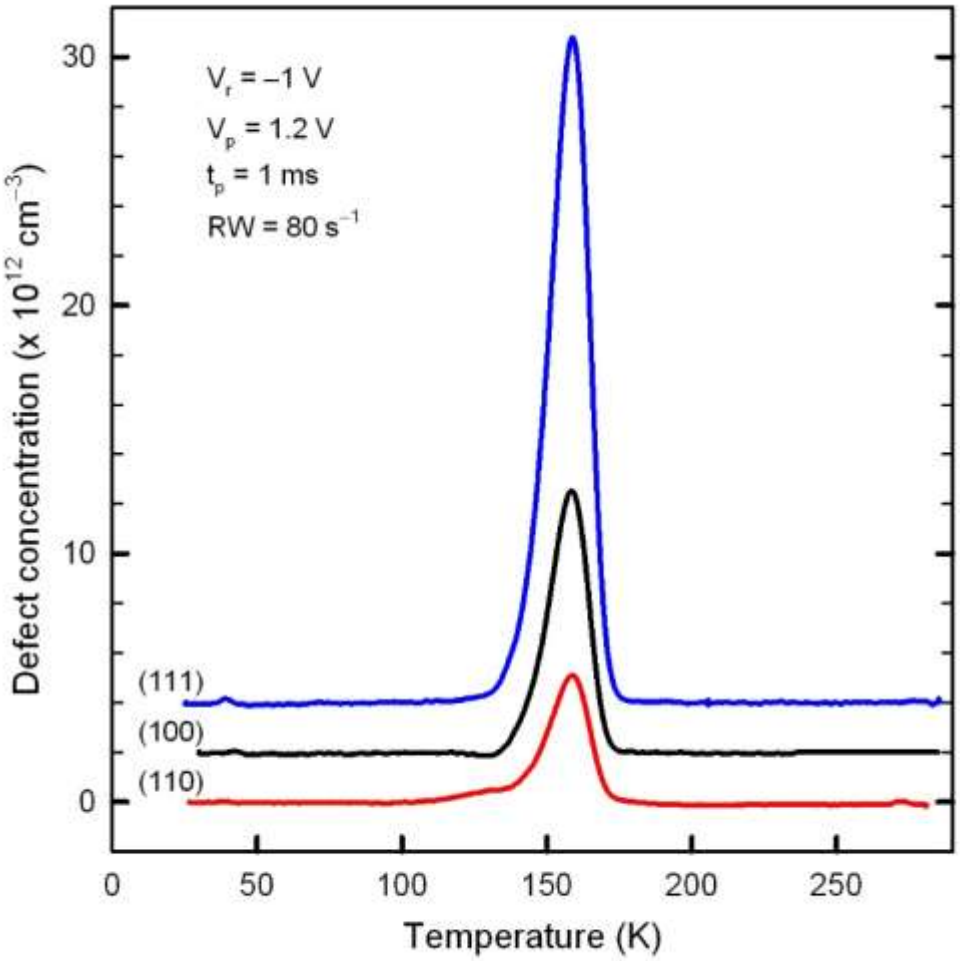


The experiment



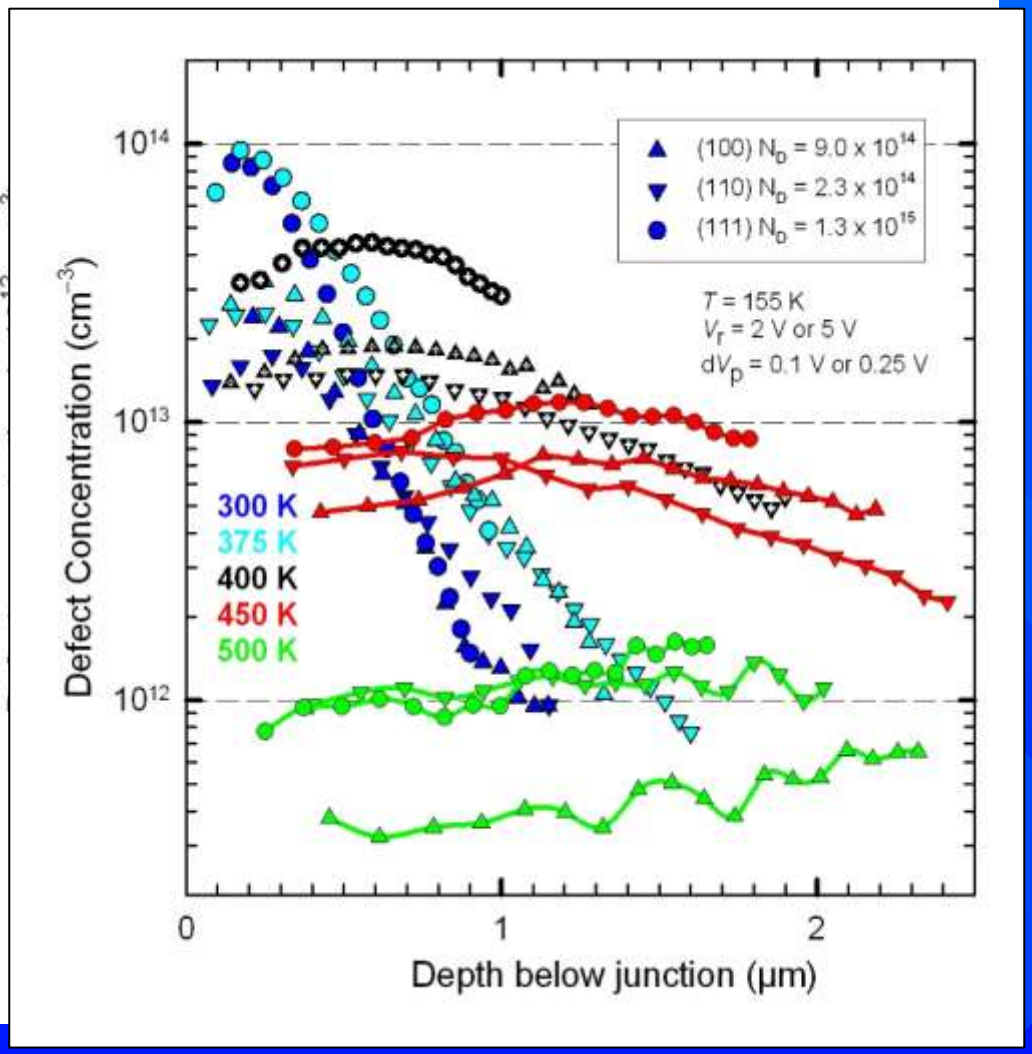
- Special Ge – no subthreshold defects
- Control – standard Ge
- Evaporate Au SBDs – no defects
- Alpha irradiation through metal
- DLTS to observe defects introduced (after alphas)

Germanium without equal



- 15 eV to ICP - $E_{0.31}$ introduced
- Anneal with high T
- No subthreshold defects possible
- No $E_{0.31}$ possible
- ?

Germanium without equal

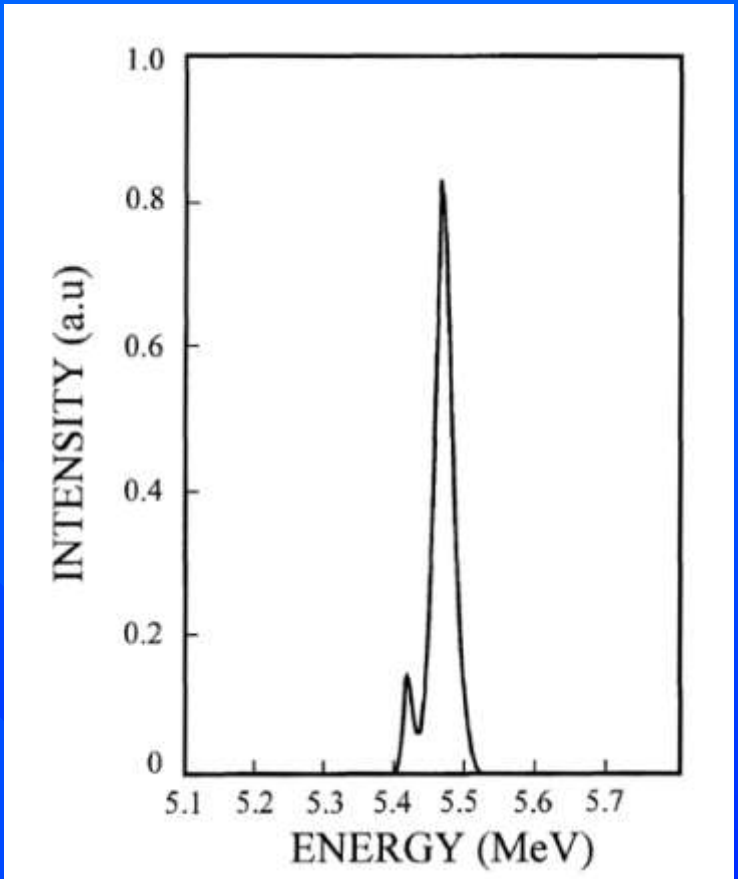


- 15 eV to ICP - $E_{0.31}$ introduced
- Anneal with high T
- No subthreshold defects possible
- No $E_{0.31}$ possible
- ?

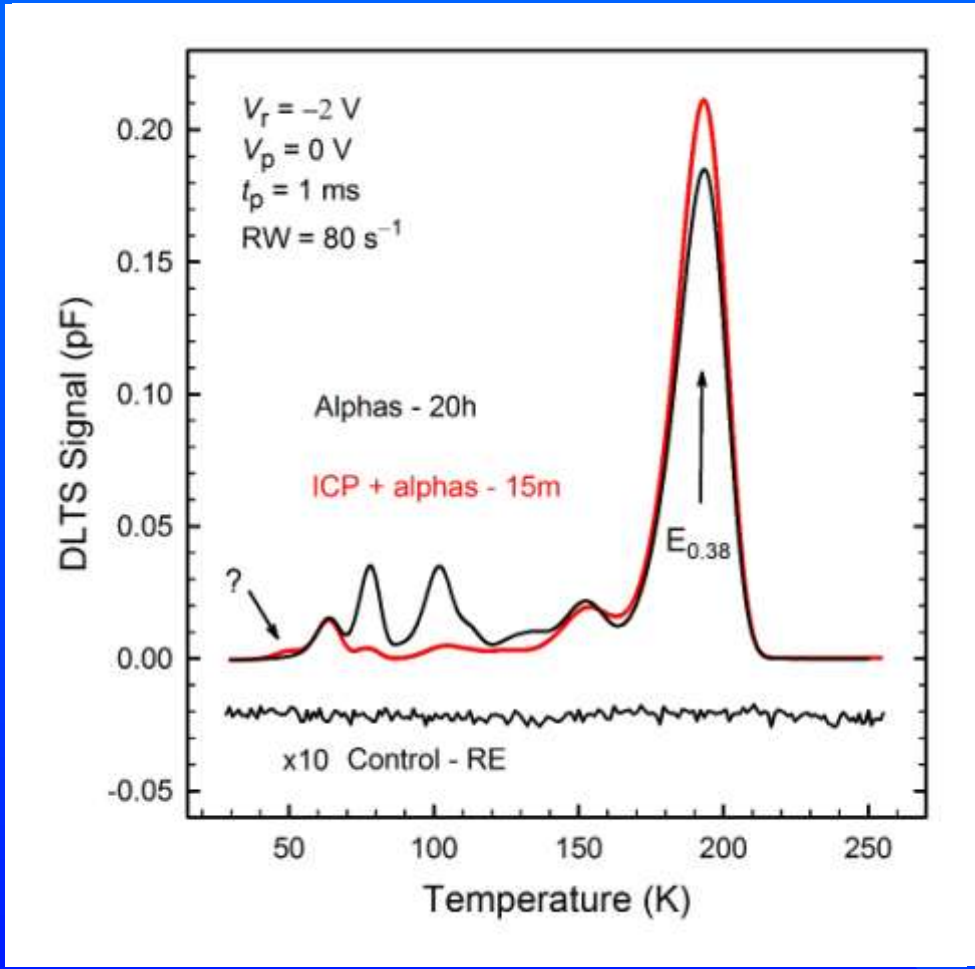
Alpha source

- Americium foil
- Sharp energy peak – 5.4 MeV
- Alpha irradiation through metal
- 30 minute exposure
- 25 µm end of range –

  2 µm measurement
- DLTS to observe defects introduced



First measurements



1st DLTS on ICP Ge

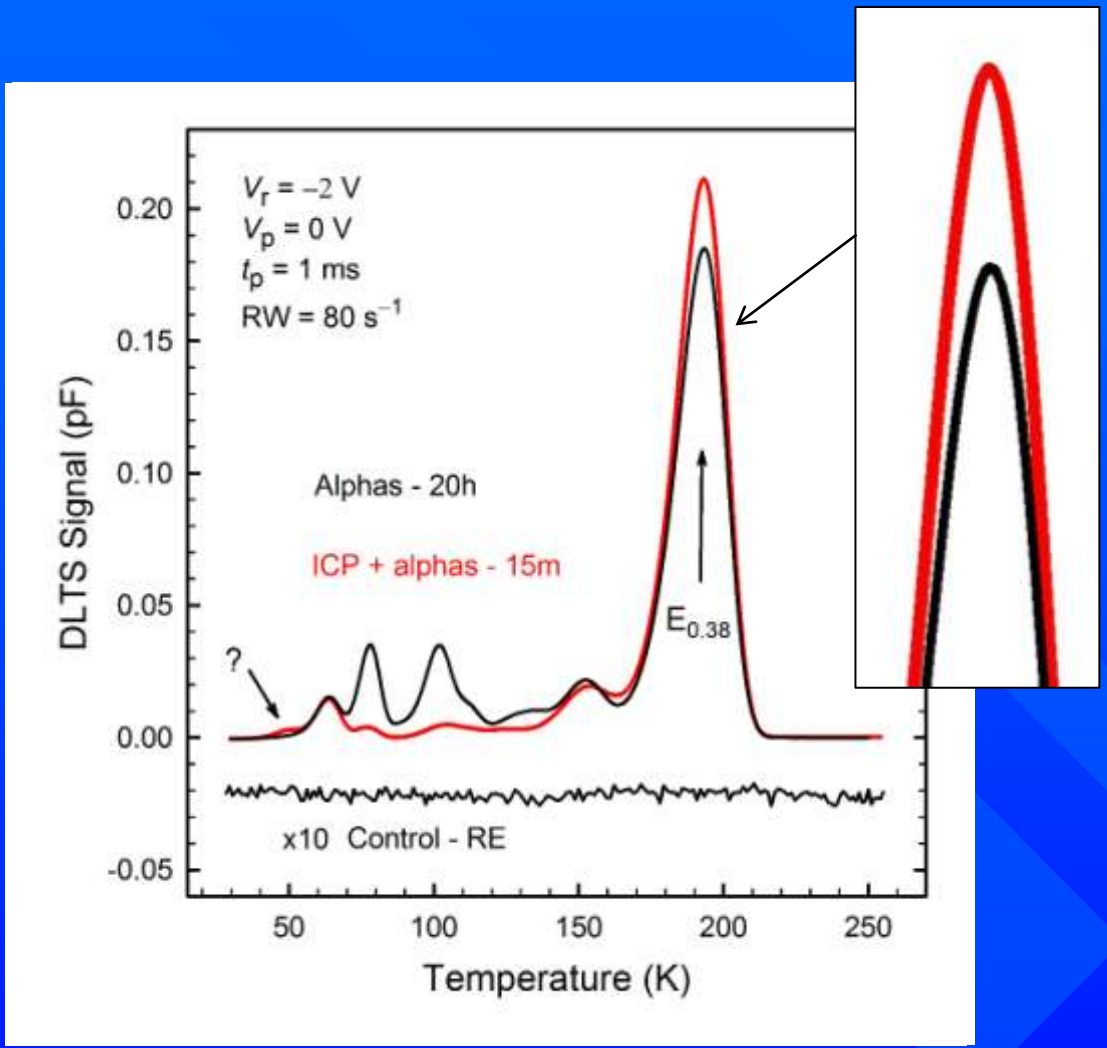
TIME PASSES

2nd DLTS on “standard Ge

Brilliant result - nonsense

New defect - nice

First measurements



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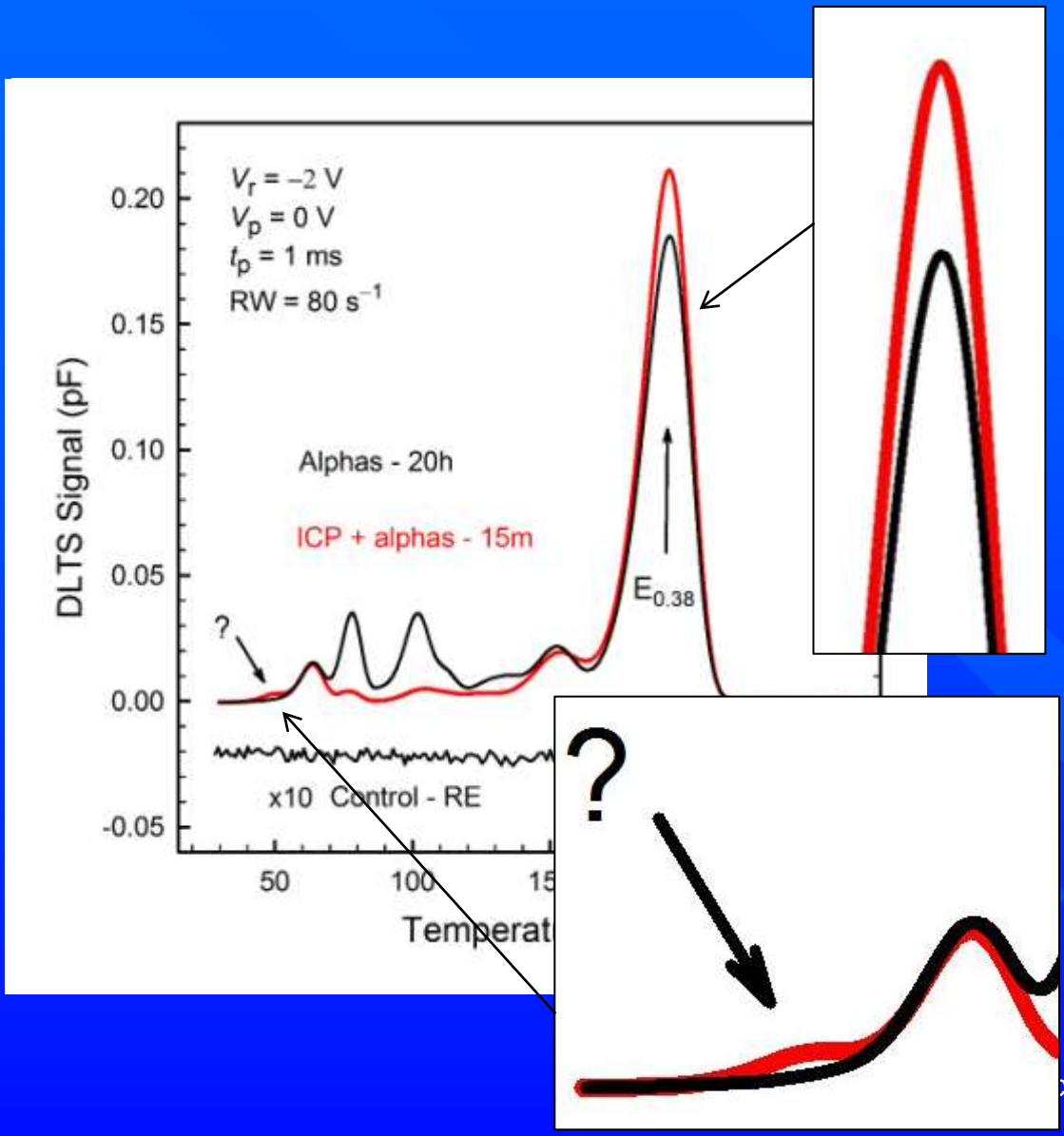


1st DLTS on ICP Ge

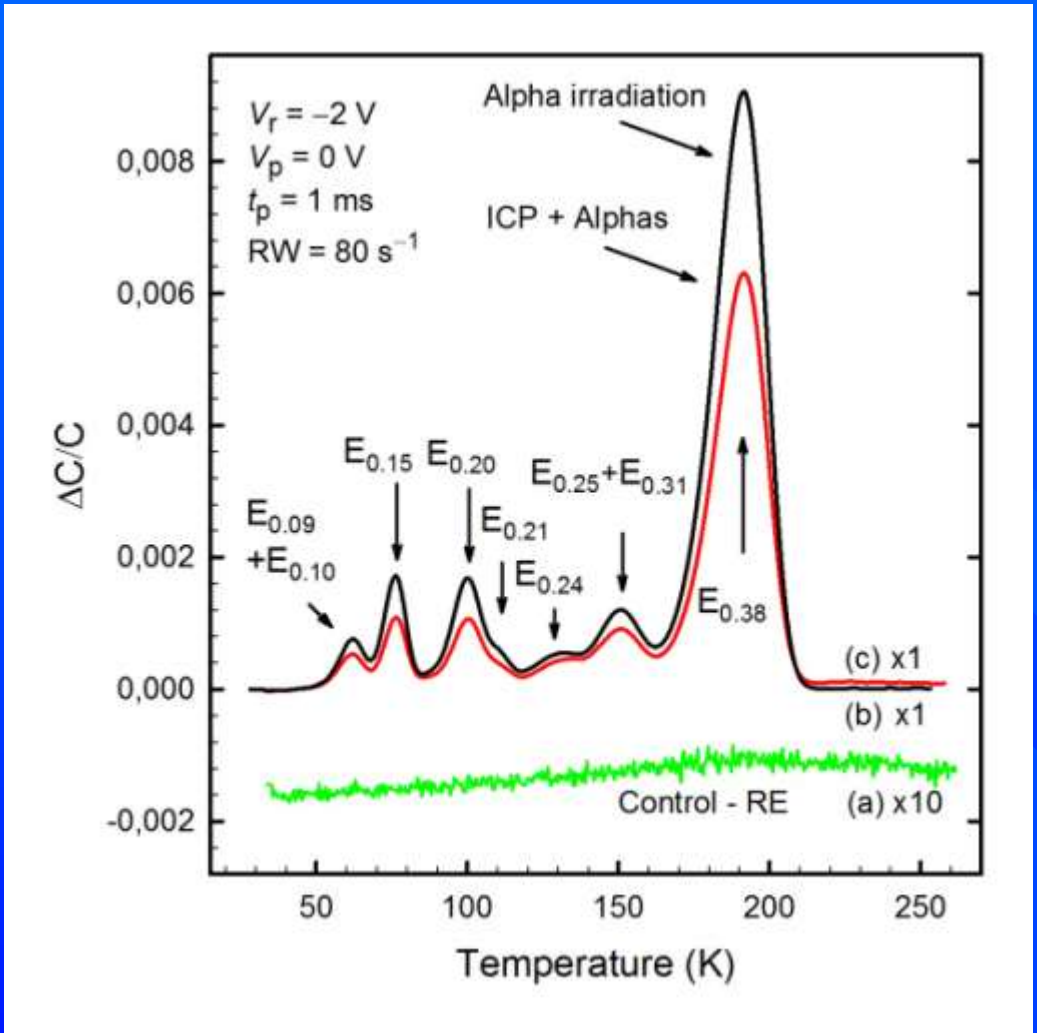
TIME PASSES

2nd DLTS on “standard Ge

Brilliant result - nonsense

New defect - nice

24 hours later…

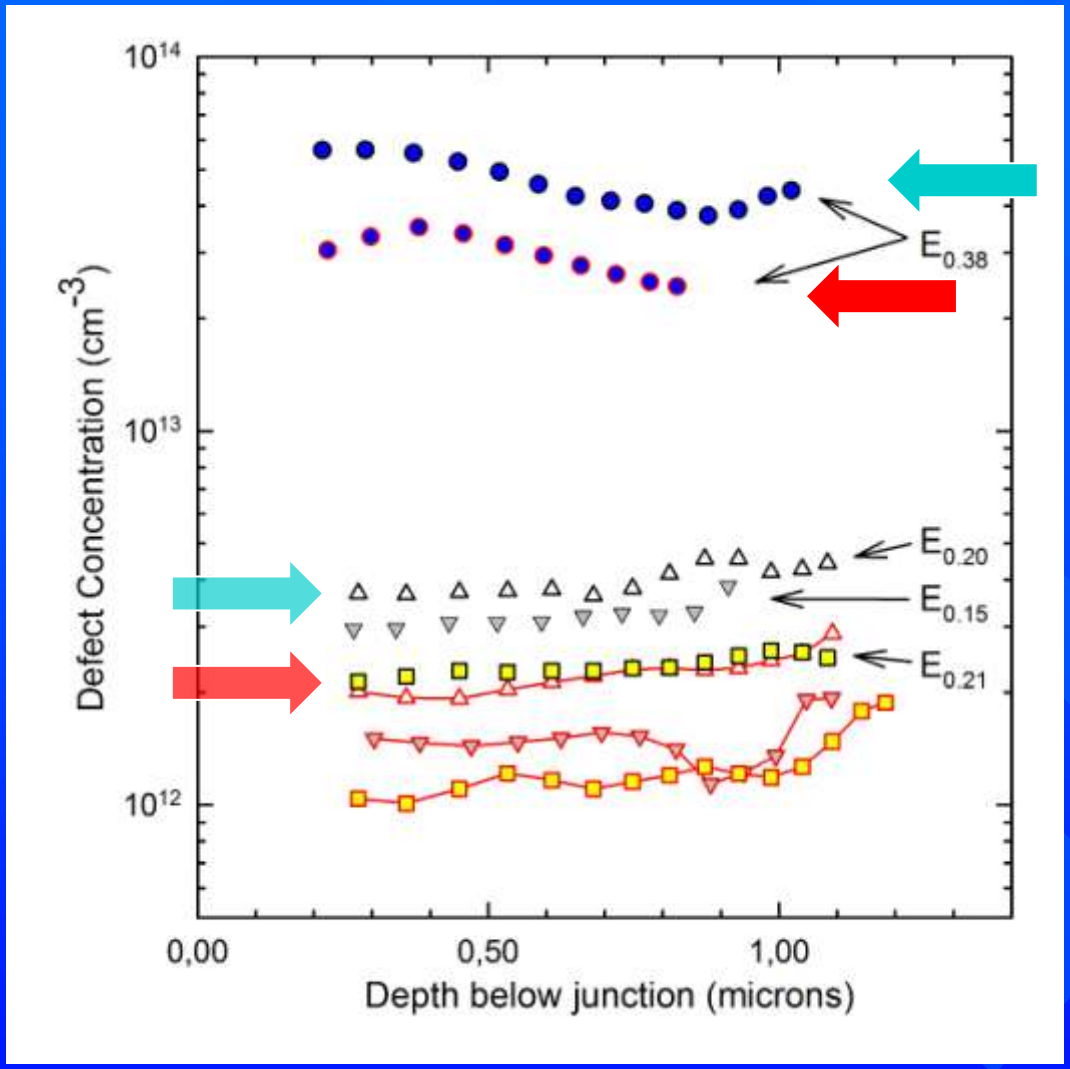


Control – no defects

Measurements after defect evolution

Peak height ∝ defect concentration

Depth profiles - Compare

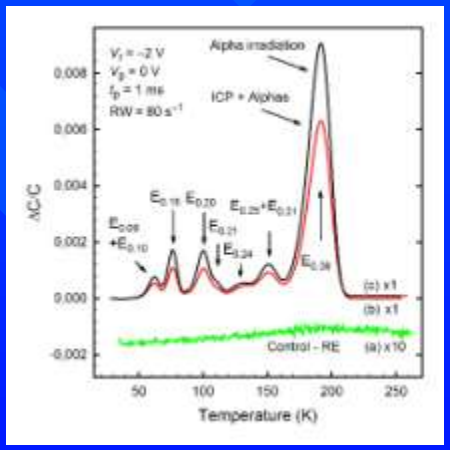


E-center – 30% less

$E_{0.15}$ – -50%

$E_{0.20}$ - -50%

$E_{0.21}$ (metastable)



Discussion - conclusions

- 1. Subthreshold effects – substantial part of radiation damage
- 2. Defects involved – also observed after EBE (1.3 eV)
- 3. How was the energy transferred? ILMs?
  - Stationary ILM possible in Ge and Si – MD
  - Energy packets MUST move – defect sites isolated

- Novel interaction with crystal – Highest purity!

Thank you

Acknowledgements

- Organizers of this Symposium
- My colleagues, Archilla & Auret
- South African NRF – Financial assistance
- You, for your attention