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

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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

- 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.

\[ e_n = A \exp\left(-\frac{E}{kT}\right) \]

\[ c_n = n \sigma_n V_n \]

Deep states (ideal point defects)
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
- ?

- $V_r = -1$ V
- $V_p = 1.2$ V
- $t_p = 1$ ms
- $RW = 80$ s$^{-1}$

Defect concentration (x $10^{12}$ cm$^{-3}$) vs Temperature (K)
Germanium without equal

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

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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

1\textsuperscript{st} DLTS on ICP Ge

TIME PASSES

2\textsuperscript{nd} DLTS on “standard Ge

Brilliant result - nonsense

New defect - nice
First measurements

1\textsuperscript{st} DLTS on ICP Ge

TIME PASSES

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New defect - nice
**First measurements**

1\textsuperscript{st} DLTS on ICP Ge

TIME PASSES

2\textsuperscript{nd} DLTS on “standard Ge

Brilliant result - nonsense

New defect - nice
24 hours later…

Control – no defects

Measurements after defect evolution

Peak height $\propto$ 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

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