Simulation of SiC radiation sensors

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PPE – Detector Development Group

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  - no screw dislocations included
- Defects added to the simulation
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Introduction

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- Many SiC radiations detectors made
- Different types of SiC material
- Defects characterised – limited number of parameters reported in each paper
- Some radiation tests preformed
- Want to try to understand if SiC should be more radiation hard from IV, V_{fd} and CCE view point

Medici simulator

- Medici simulator
  - Models 2D distribution of potential and carrier concentrations in a device
  - Can predict electrical characteristics for an arbitrary bias condition
- Solves

Poisson's Equation and Continuity Equation

$$\varepsilon\nabla^2\phi = -q\left(p - n + N_D^+ - N_A^-\right) - \rho_s$$

$$\frac{\delta n}{\delta t} = \frac{1}{q}\nabla J_n - U_n \qquad \frac{\delta p}{\delta t} = -\frac{1}{q}\nabla J_p - U_p$$

electrons holes

Material Modelling

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PARAMETER	VALUE
Bandgap at 300K (eV)	3.23
Energy / e-h pair (eV)	4.4
Atomic numbers	12 and 14
Electron lifetime (μs)	0.1
Hole lifetime (μs)	1
Permittivity	9.7
Affinity (V)	3.5
Electron effective mass	0.28
Hole effective mass	4.2
Electron sat. velocity (cm/s)	1.743×10^7
Hole sat. velocity (cm/s)	1.5×10^7

Field dependent mobility model used

Defects included in SiC

Defect	Energy (eV)	Conc (cm^{-3})	τ_{elec} (s)
Defect:	E_c-0.40	2.1×10^{13}	4.5×10^{-9}
Vanadium:	E_c-0.98	2×10^{15}	6.67×10^{-7}
$Z_{1/2}$:	E_c-0.66	3×10^{16}	1.42×10^{-10}

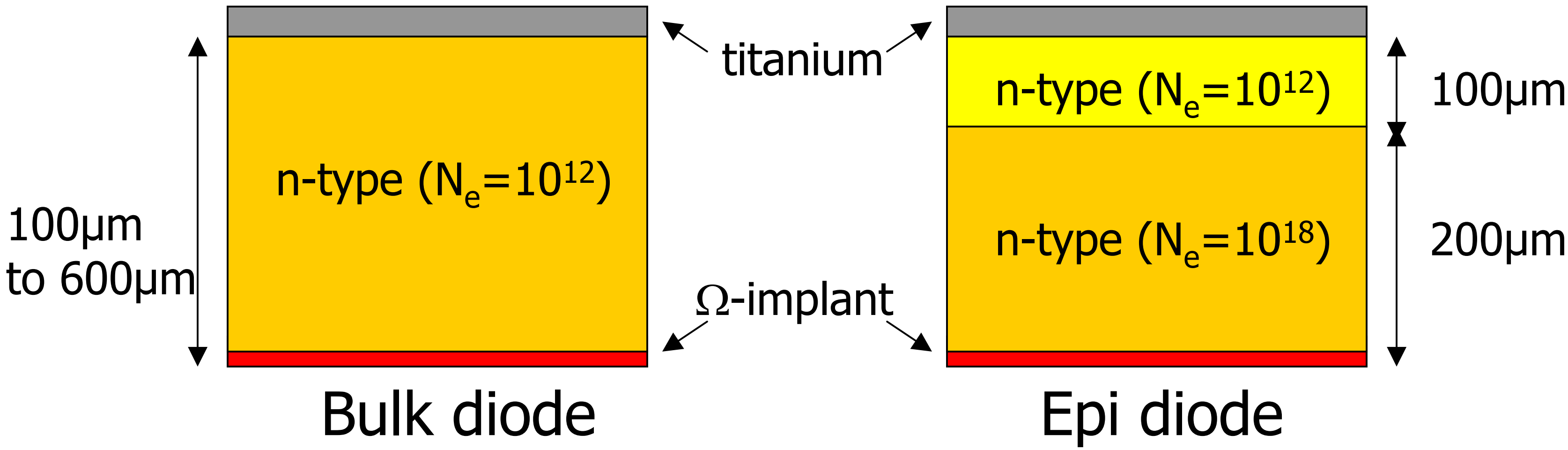
- No Macroscopic defects added, i.e. Screw defects/dislocations
- Concentration of $Z_{1/2}$ varies due to irradiation

  Range 3×10^{16} to $3 \times 10^{20} cm^{-3}$ simulated

- Models
  - Shockley-Read-Hall
  - Impact ionisation
  - Trap assisted and band-to-band tunnelling

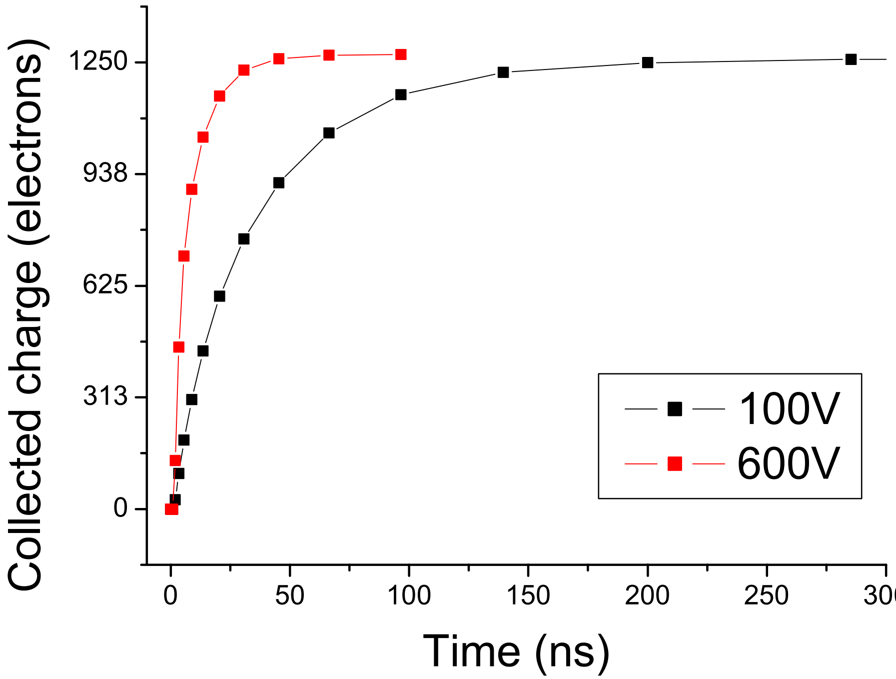
Diode description

- Bulk diode and Epitaxial diode
  - Simple Schottky diode 300μm wide
  - Front contact
    - Ti contact: Work function 4.4V
  - Back contact
    - 1μm thick n^+ with $1x10^{20}$ doping
  - Thicknesses – 100μm-600μm



Results – pre-irradiation

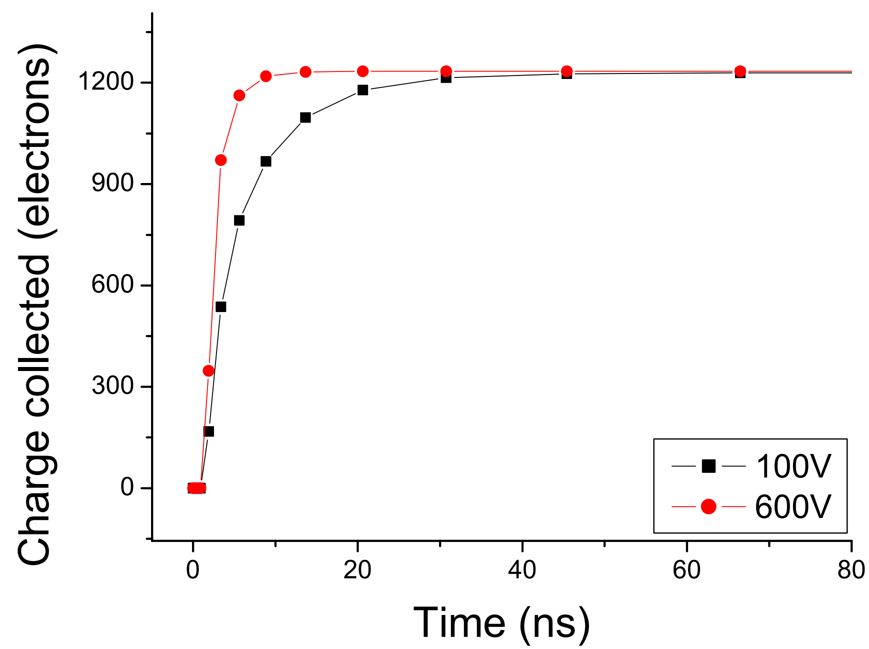
- Charge collected from 300μm bulk diode
  - 1250 e/h pairs deposited in centre of device
- 100% CCE observed
- $\tau_{\text{coll } 95\%}$
  - 116ns @100V
  - 24.8ns @600V



Q collected at Ω contact (elecs)

Results – pre-irradiation

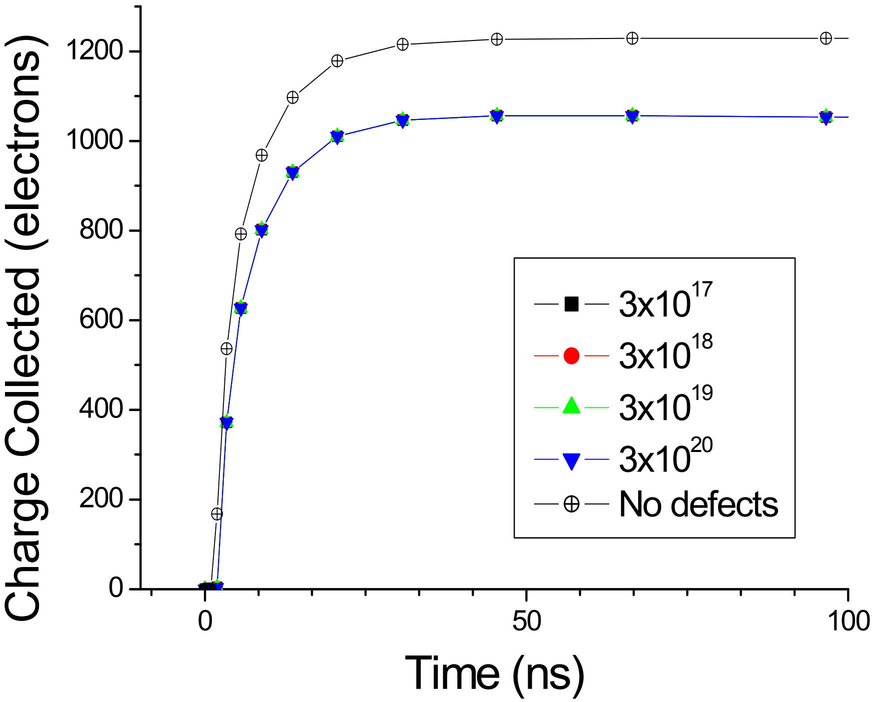
- Charge collected from 100μm bulk diode
  - 1250 e/h pairs deposited in centre of device
- 100% CCE observed
- $\tau_{coll\ 95\%}$
  - 22.5ns @100V
  - 7.0ns @600V



Q collected at Ω contact (elecs)

Results – with defects

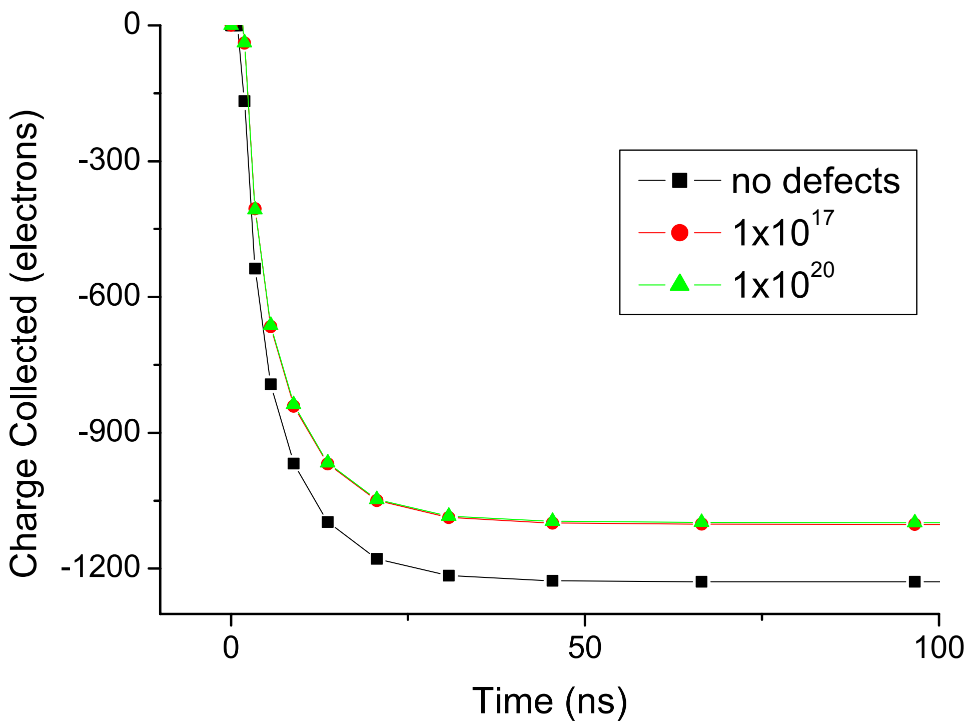
- Increasing conc. $Z_{1/2}$ defect added
- CCE
  - Initially reduced to 85%
  - Stable with further $[Z_{1/2}]$
- τ_{coll} 95%
  - Pre-defects = 22.5ns
  - Post defects =20ns



Q collected at Schottky contact (holes)

Epitaxial SiC – 100μm @100V

- No defects
  - Q_{coll} = 98% (1230e)
  - $\tau_{coll\ 95\%}$ = 19ns
- Z1/2 defects
  - Q_{coll} = 88% (1100e)
  - $\tau_{coll\ 95\%}$ =21ns
  - No difference for $[Z_{1/2}]=10^{17}$ and $10^{20} cm^{-3}$



Conclusions

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- 1st attempt to simulated SiC detectors
- Bulk and epitaxial style devices work well
- 300um Bulk @600V
  - 100% CCE
  - τ_{coll} ~ 25ns
- Epitaxial 100um @100V
  - 98% CCE
  - $\tau_{coll} < 20$ns
- Defects initially reduce CCE
  - No further reduction observed for higher [Z1/2]
- More data and more complexity required