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Studies of defect centres in high-energy proton irradiated epitaxial silicon using HRPITS technique

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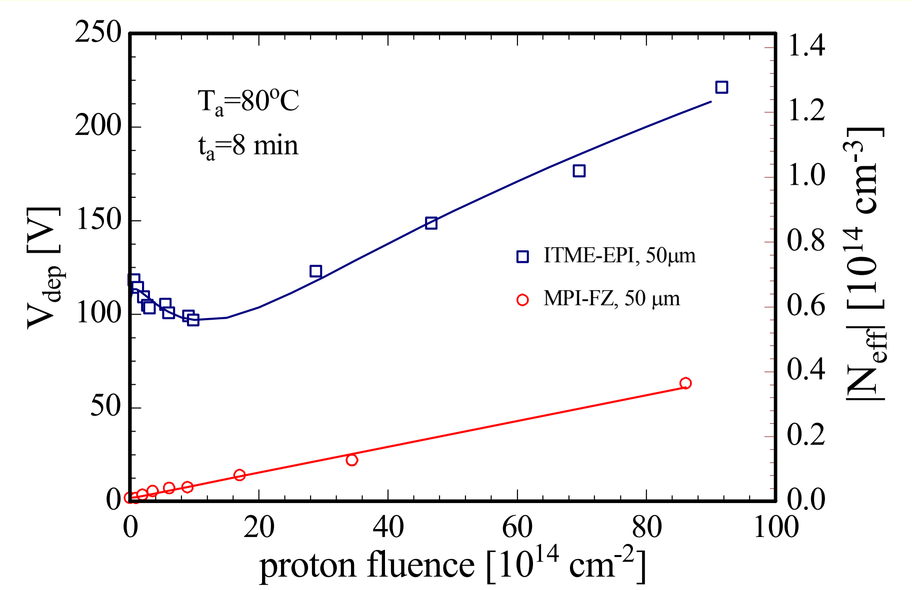
Plan of talk:

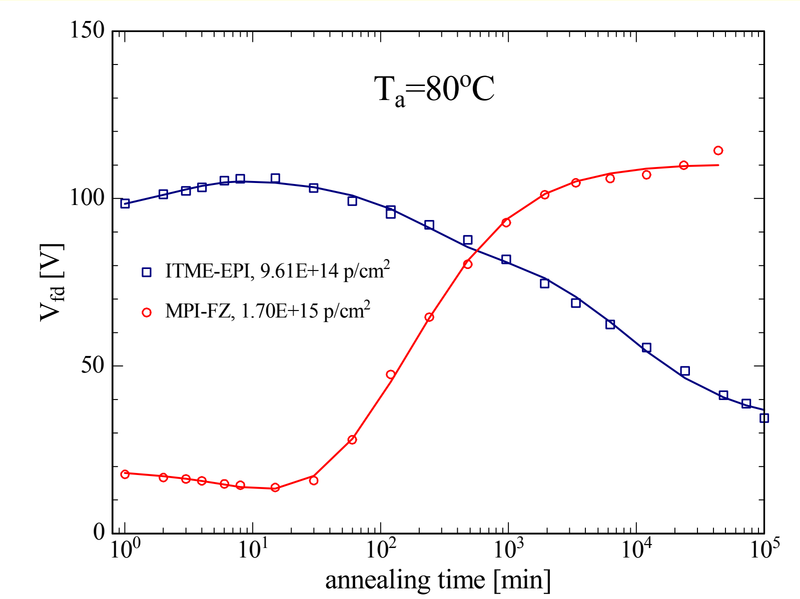
- **Background and motivation**
- **Experimental details**
- **Results of HRPITS measurements**
- **Conclusions**

Background

Epitaxial vs FZ thinned

(E. Fretwurst et al., 4th RD50 Workshop, http://rd50.web.cern.ch/rd50/4th-workshop)





- The depletion voltage of epitaxial detectors slightly decreases with increasing fluence from $1x10^{14}$ to $1x10^{15}$ cm^{-2}. This behaviour is opposite to that of thin detectors made from FZ Si
- For the fluences ranging from $2x10^{15}$ to $8x10^{15}$ cm^{-2} the depletion voltage rises with increasing fluence for the both types of detectors.

Epitaxial detector

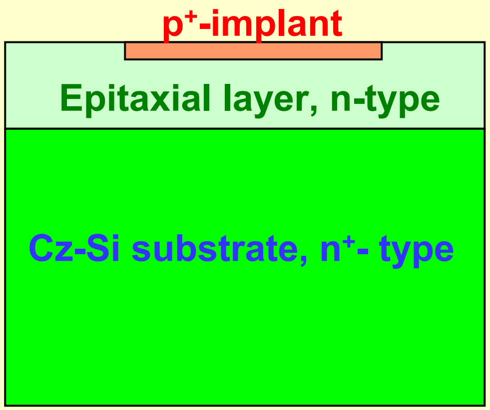
- For the short-term annealing the depletion voltage slightly increases with increasing the annealing time.
- For the long-term annealing the depletion voltage significantly decreases.

FZ thinned detector

- The short-term annealing results in a diminution of the depletion voltage.
- Long-term annealing causes its substantial increase.

Experimental details

50 µm epitaxial layer on CZ-Si substrate



Schematic of the sample structure

ITME: fabrication of epitaxial layer

CiS: device processing

1. Starting material: **low resistivity** (ρ<0.02 $\Omega\cdot$cm) **300 μm thick Czochralski** (Cz) **silicon substrate** doped by Sb donors.
2. A thin (**50 μm**) medium resistivity (**ρ=50 $\Omega\cdot$cm**), **epitaxial silicon layer** doped by P donors has been grown on the CZ substrate forming a simple n-n^+ structure.
3. p^+-n junction formed by **B implantation** on the epitaxial layer in a standard way using planar technology in order to obtain p^+-n-n^+ silicon detectors.
4. The detector active thickness is that of the epitaxial layer.

Experimental details

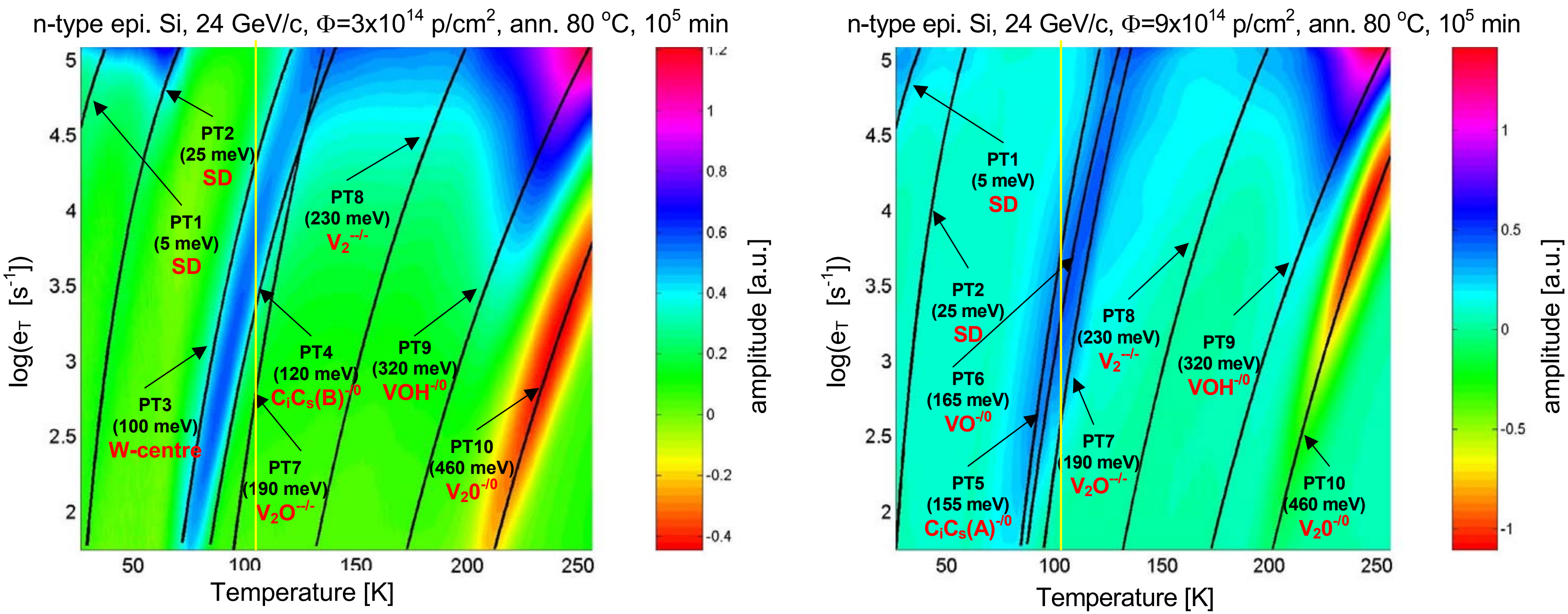
The parameters of the epitaxial silicon detectors used for the investigation of defect centres

Device	Sample A		Sample B	
Fluence [10^{14}cm^{-2}]	3.0		9.0	
Room temperature (295K)	V_{dep} [V]	N_{eff} [10^{13} cm^{-3}]	V_{dep} [V]	N_{eff} [10^{13} cm^{-3}]
Before irradiation	128.9	7.60	135.1	8.32
t_{anneal} = 0 min	96.0	5.66	91.5	5.63
$t_{anneal} \approx 1\text{x}10^5$ min	79.6	4.70	34.5	2.12

Charge carrier concentration at 100 K determined from current measurements:

- sample A - $5\text{x}10^7$ cm^{-3}
- sample B - $5\text{x}10^{11}$ cm^{-3}.

Results of HRPITS measurements

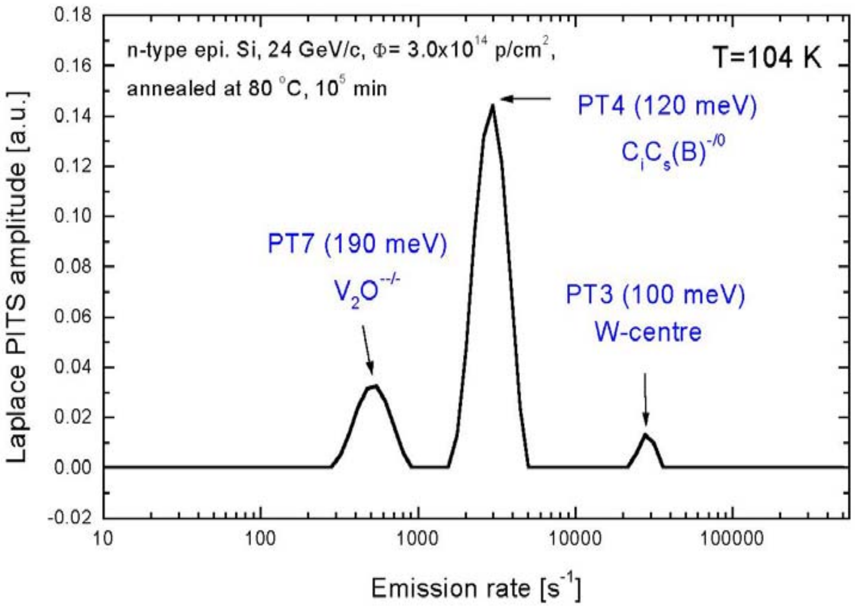


(a) (b)

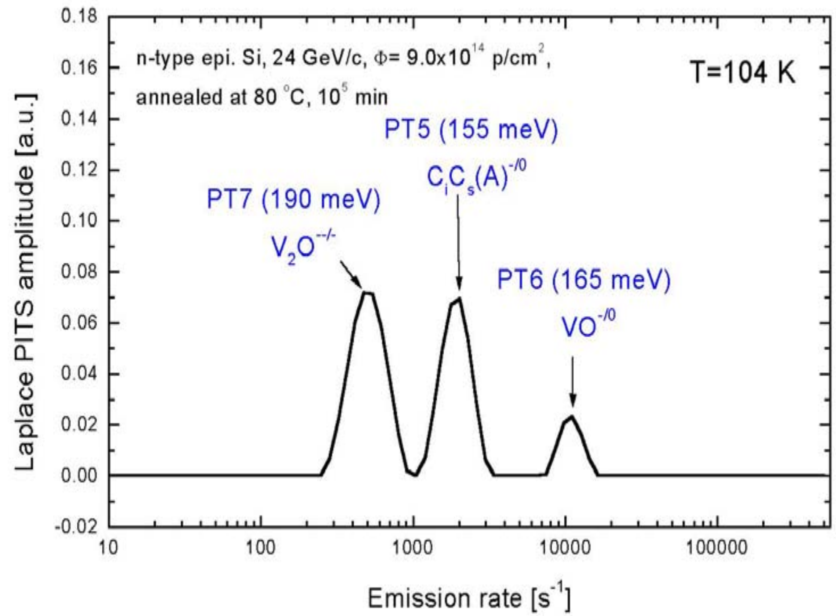
Experimental spectral fringes obtained by two-dimensional correlation procedure applied to the analysis of photocurrent decays for P-doped epitaxial Si irradiated with high-energy protons and annealed at 80 °C for 10^5 min. (a) Proton fluence 3×10^{14} cm^{-2}; (b) proton fluence 9×10^{14}cm^{-2}.

The solid lines illustrate the temperature dependences of emission rate for detected defect centres.

Results of Laplace PITS measurements



(a)



(b)

PITS spectra obtained by means of inverse Laplace transform applied the analysis of the photocurrent decay measured at 104 K for P-doped epitaxial Si irradiated with high-energy protons and annealed at 80 ^oC for 10^5 min. (a) Proton fluence $3x10^{14}$ cm^{-2}; (b) proton fluence $9x10^{14}cm^{-2}$.

Conclusions

- We have shown that the irradiation of the epitaxial silicon with the proton fluences of 3×10^{14} and 9×10^{14} cm^{-2} gives rise to the formation of shallow donors, divacancy $V_2^{--/-}$ and oxygen-related complexes such as $V_2O^{--/-}$, $VOH^{-/0}$ and $V_2O^{-/0}$.

- The irradiation with the fluence of 3×10^{14} cm^{-2} results in much stronger compensation of shallow donors with deep acceptors compared to the irradiation with the fluence of 9×10^{14} cm^{-2}.

Acknowledgement

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