Shallow levels analysis in n-type MCZ Si detectors after mixed irradiation

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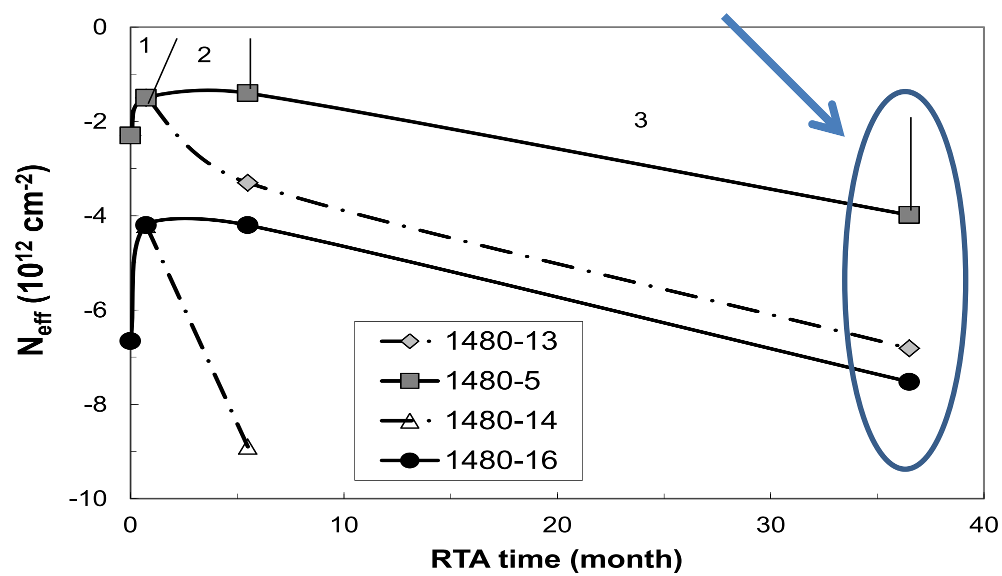
Motivation

- Neutron irradiation introduce a large number of deep acceptors, increased by reverse annealing.
- Gamma irradiation could compensate deep acceptor space charge enhancing shallow donor introduction [see talk Z. Li].
- TSC in the low T range to determine concentration of shallow donors in both neutrons and mixed (neutrons + gammas) irradiated samples.

Irradiated detectors

#	1480-5 (n+ϒ)	1480-13 (n)	1480-16 (2n+ϒ)
Si Material	n-type MCZ	n-type MCZ	n-type MCZ
n_{eq}/cm^2)	$1.5x10^{14}$	$1.5x10^{14}$	$3.0x10^{14}$
γ (Mrad)	500	0	500

N_{eff} data after irradiation and RT annealing of the three detectors, from [*]

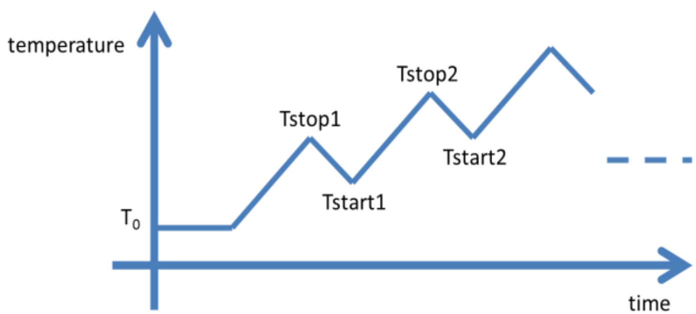


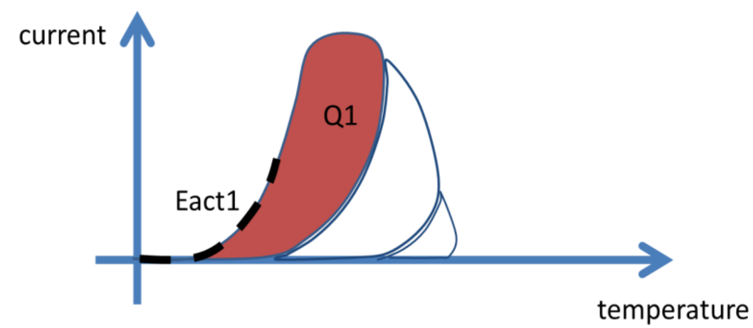
[*] Z. Li E. Verbitskaya, W. Chen, V. Eremin, R. Gul, J. Härkönen, M. Hoeferkamp, J. Kierstead, J. Metcalfe, S. Seidel, Complete suppression of reverse annealing of neutron radiation damage during active gamma irradiation in MCZ Si detectors, in press.

M. Bruzzi, R. Mori, M. Scaringella, Z. Li, Shallow levels analysis in n-type MCZ Si detectors after mixed irradiation, RD50 workshop, 05/30-06/01 Bari (Italy)

TSC Analysis

- TSC with optimized priming procedure [*]: 5min of pulsed IR in forward voltage (100V) at the lowest temperature and temperature scan in the ranges [5-80]K at low (0.05-0.1 K/s) heating rate with reverse voltage applied.
- Poole-Frenkel analysis to determine charge state of defects
- Decayed TSC to resolve composed TSC peaks (Saw tooth temperature scan with reverse voltage applied).

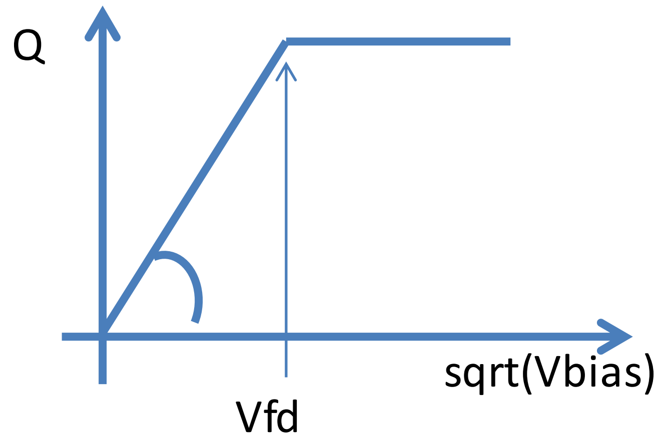




[*] M. Bruzzi , R. Mori, D. Menichelli, M. Scaringella, Optimization of the priming procedure for Thermally Stimulated Currents with heavily irradiated silicon detectors, Proceedings of Science PoS (2009)

Charge vs bias plot *

- To determine full depletion voltage and effective doping at low temperature:



- To evaluate trap concentration from the charge of the saturated peak

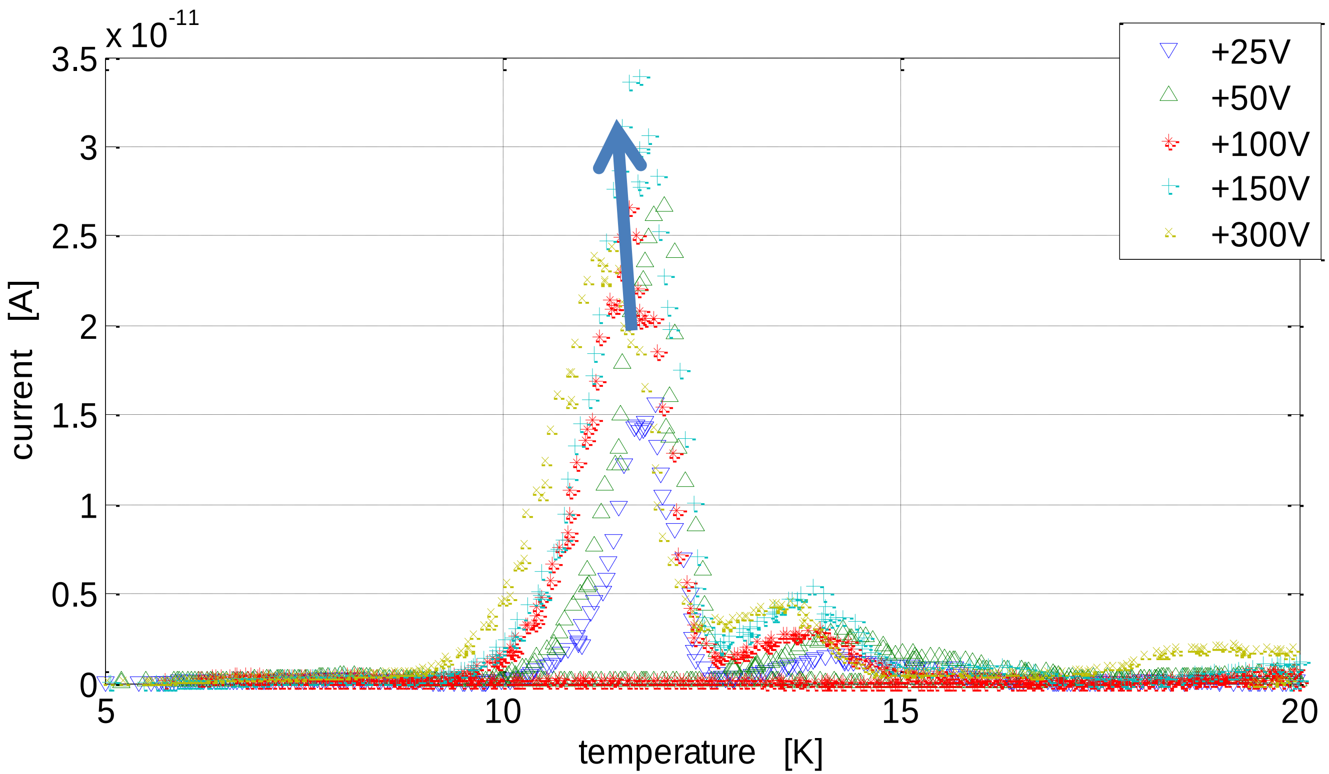
- To compare N_{eff} and N_t

[*] E. Borchi, M. Bruzzi, Z. Li S. Pirollo, J.Phys. D: App. Phys. 33, (2000) 299-304

Shallow Peaks in the 5-20K range

In the lowest temperature range we observe P and B emissions at approx. 12K and 14K.

Poole-Frenkel effect proofs their charge state after the emission.



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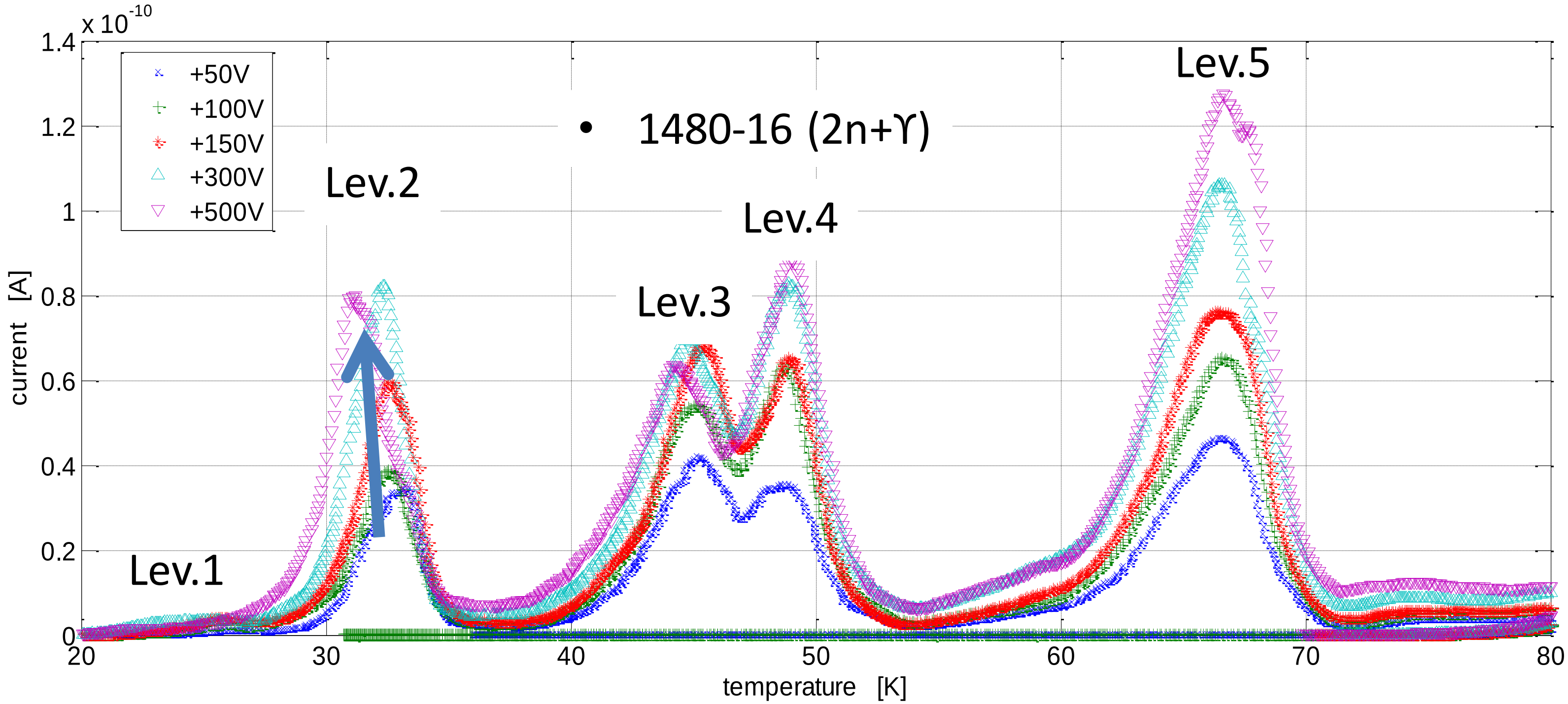
Shallow Peaks in the 20-80K range



Poole-Frenkel effect observed only on level at 30K: charged defect as in ref. [*]

[*] M. Bruzzi et al. NIM A 552 20-26 (2005)

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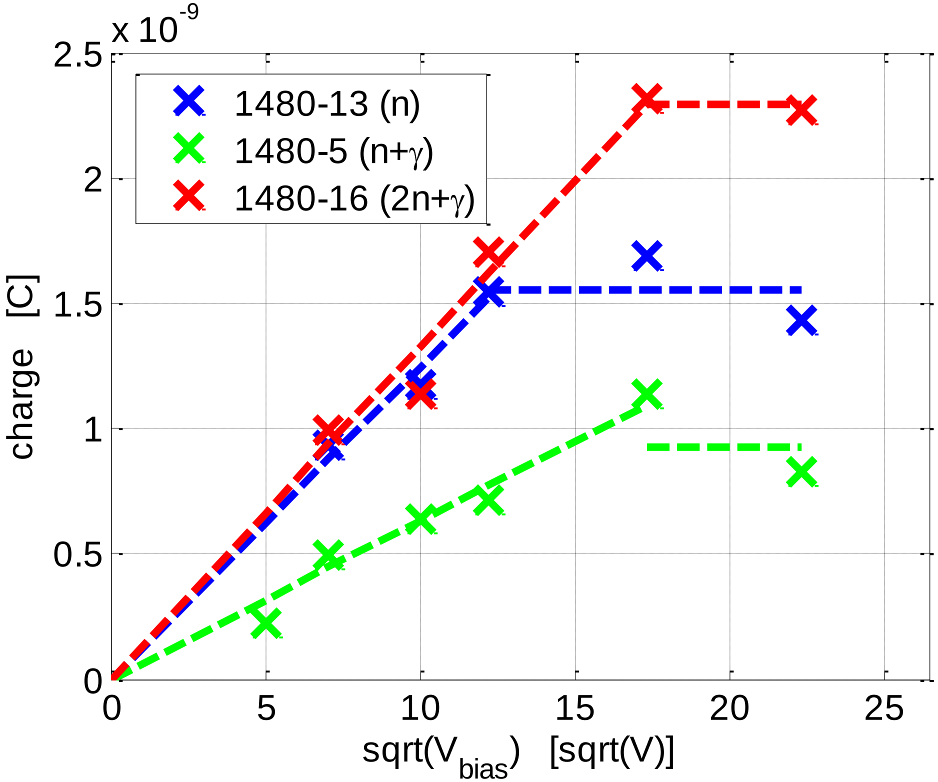
Charge of 30K peak vs V_{bias} to determine N_t



- N_{eff} increases with n fluence;
- N_t of peak at 30K increases with n fluence; it decreases with gamma dose for same n fluence.

Preliminary

Sample	Fluence N_{eq}/cm^2	Dose Mrad	V_{fd}[V]	N_{eff} [cm^{-3}]	N_t [cm^{-3}]
1480-13	1.5×10^{14}	0	157	1.3e12	9.9e11
1480-5	1.5×10^{14}	500	215	1.8e12	5.9e11
1480-16	3×10^{14}	500	300	2.6e12	1.5e12

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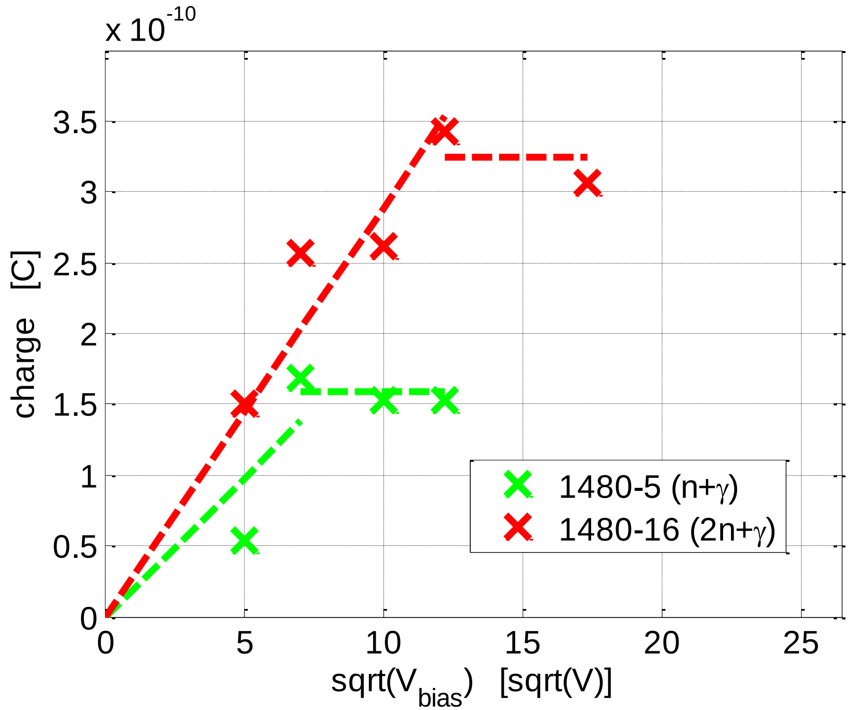
In progress:
Charge of 12K peak vs V_{bias} to determine N_t



-N_{eff} increases with n fluence;

-N_t of peak at 12K increases with n fluence

- 1480-13 still under test

Preliminary

Sample	f n_{eq}/cm^2	Dose MRad	V_{fd} [V]	N_{eff} [cm^{-3}]	N_t [cm^{-3}]
1480-5	$1.5x10^{14}$	500	66	5.7e11	1.0e11
1480-16	$3x10^{14}$	500	126	1.1e12	2.1e11

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Conclusions

We investigated a possible enhancement of radiation induced shallow donors due to gamma irradiation in neutron irradiated detectors → TSC have been performed in the range [5,80]K on neutron and mixed irradiated detectors.

We observed main radiation induced shallow donor candidates at 12K and 30K: their concentration after neutron irradiation increased. Work in progress: analysis of their dependence on gammas.

-N_{eff} in the low temperature range quite different to the one in the operative temperature.

- Need to look for positive space charge compensation also in the deep level range.