Photoresponse spectrum in differently irradiated and annealed Si

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Outline:

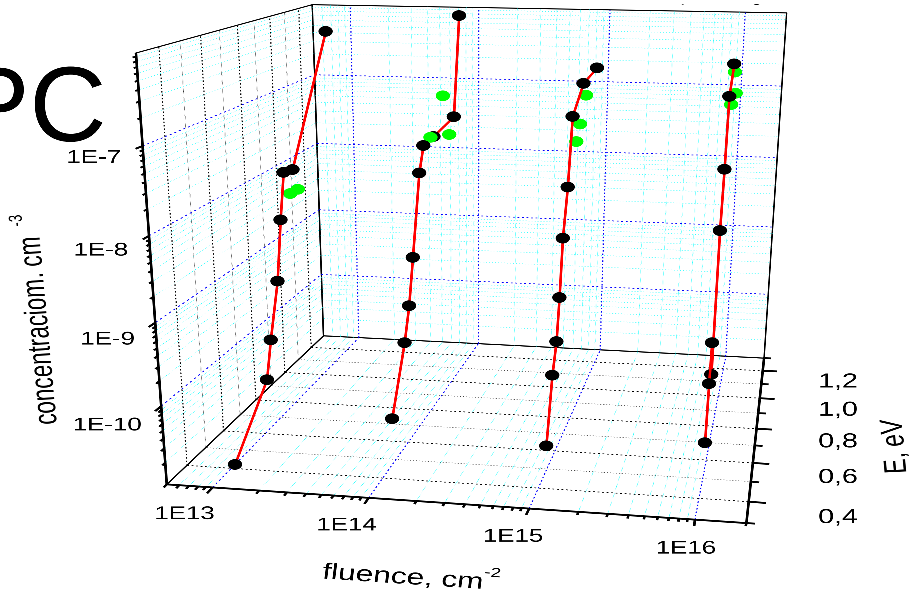
- Photoconductivity spectra in differently irradiated and annealed (according the WODEAN plan) samples
- Model of photoconductivity (the cluster properties included)

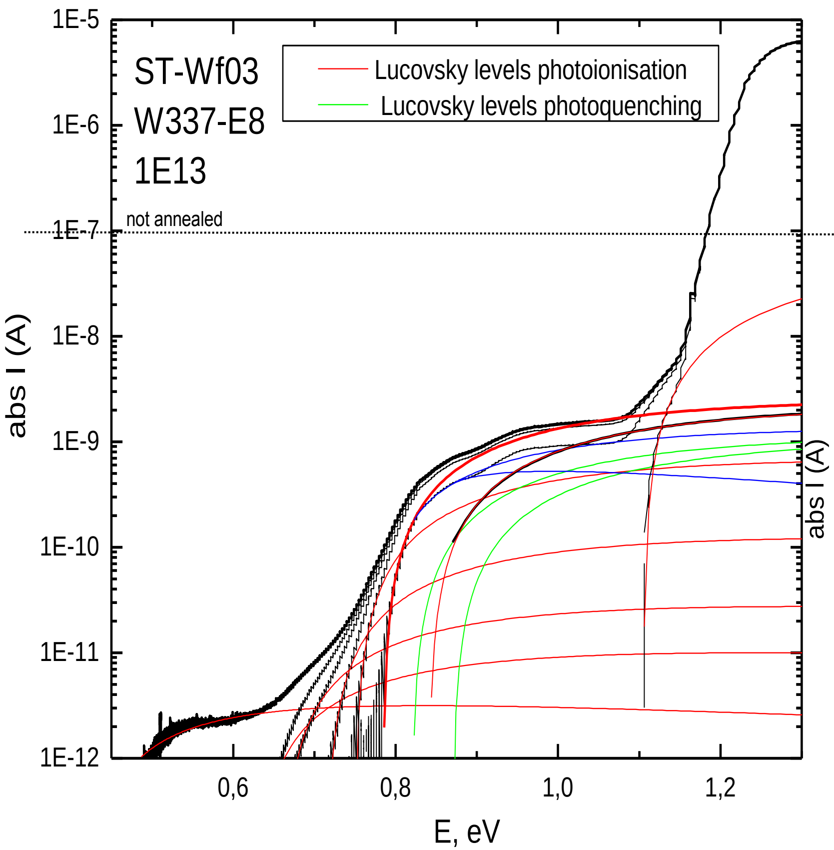
Photoconductivity spectrum gives information:

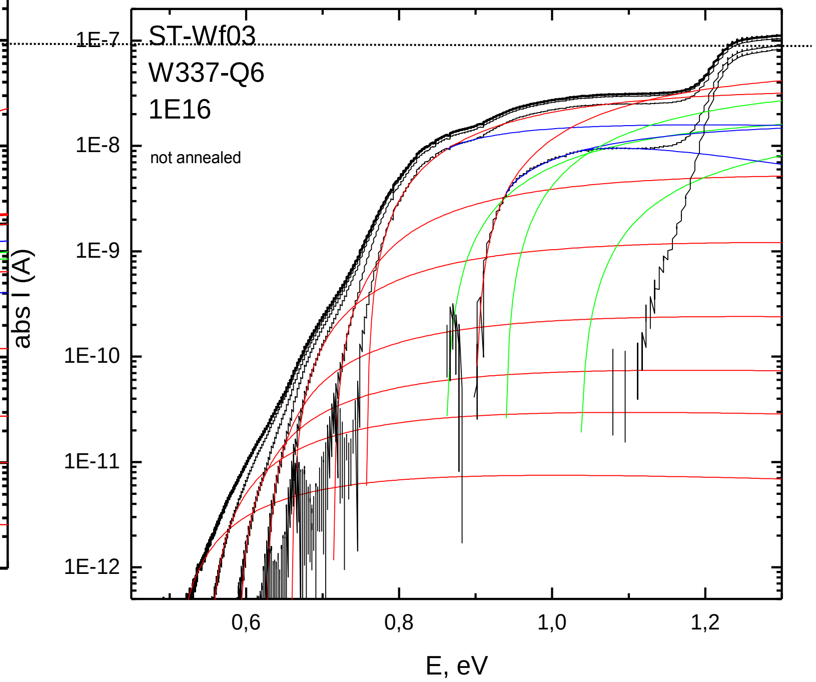
- Constant excitation:
  - Intrinsic region – the signal related to the free carrier lifetime, i.e. recombination efficiency.
  - Extrinsic region – the signal gives information about the deep levels
- Pulse excitation (40 fs) (microwave measurement)
  - Photo-ionization rate
  - Recombination (capture) time constant

Non-annealed PC

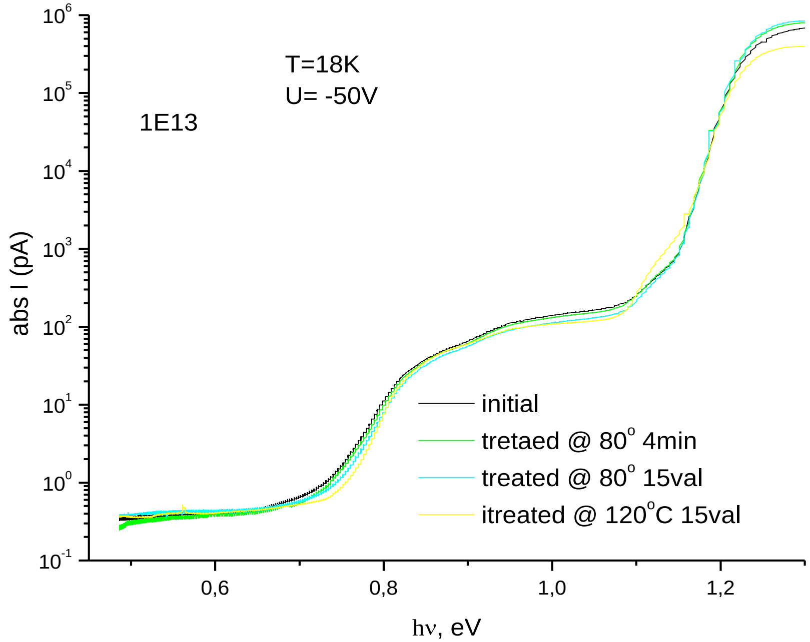
Most surprising: non-monotonous change the contribution of different deep levels: it is an evidence of the random processes in defect generation

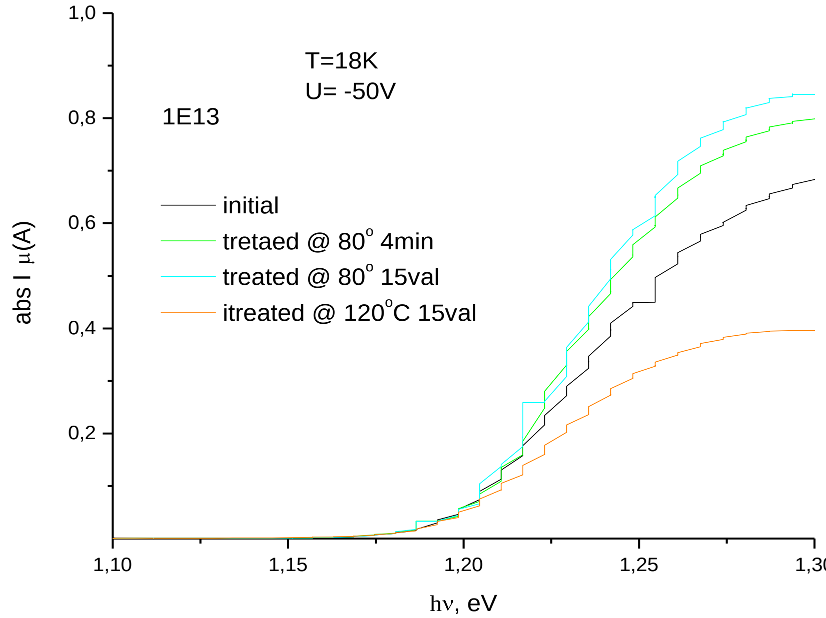


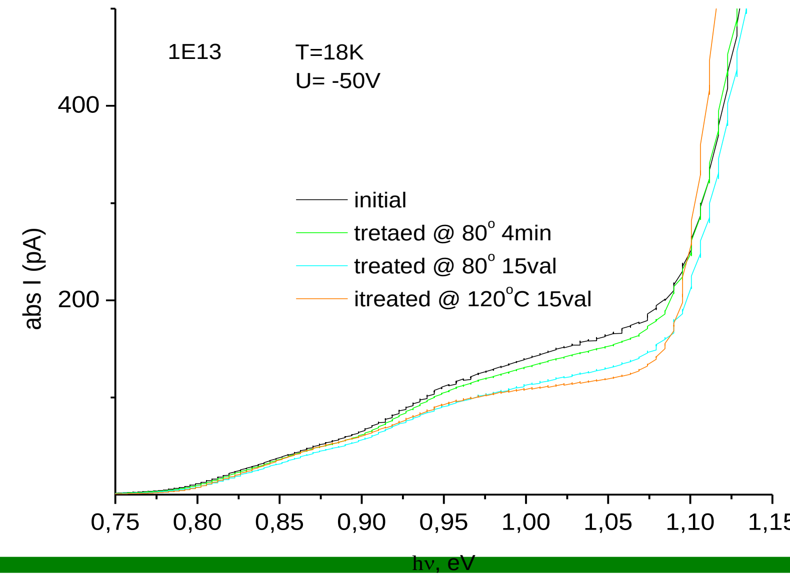




1e13 cm^{-2}

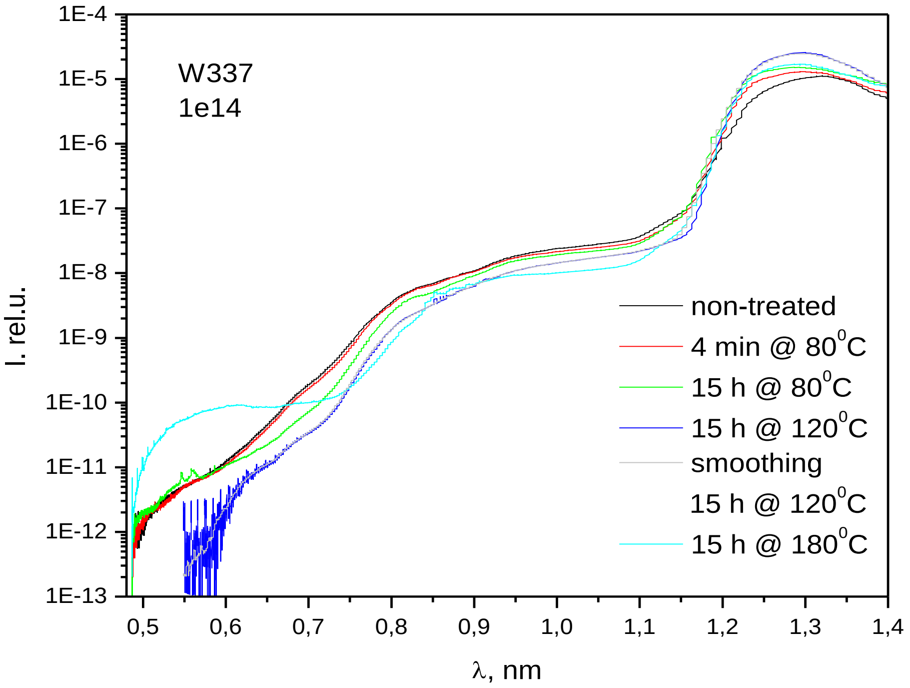


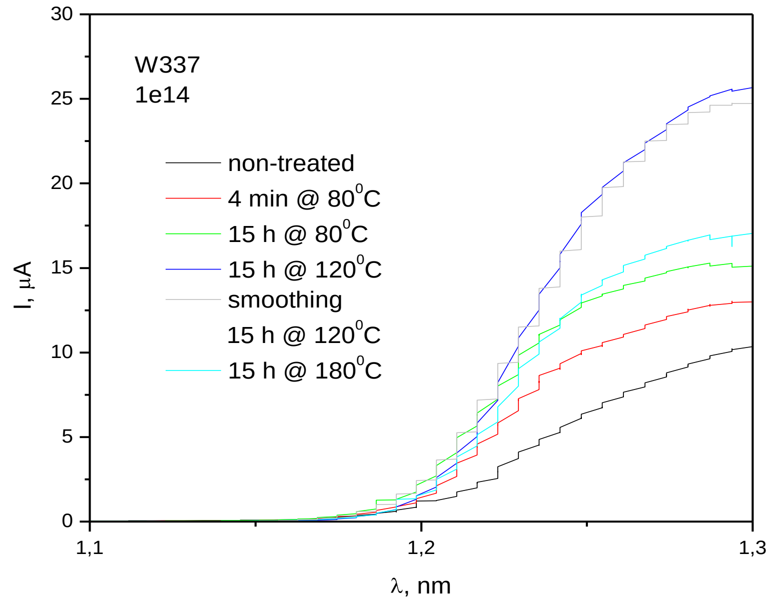


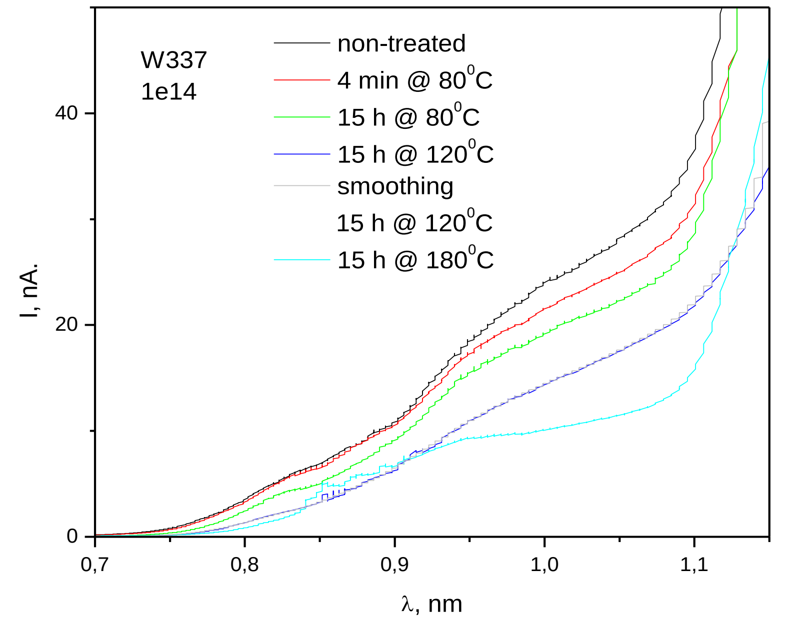


1) Annealing influences the lifetime (at the beginning the increase, later – decrease)
2) Annealing decrease the level at the valence band concentration (ΔE_{opt}~0.9 eV)

1e14 cm^{-2}

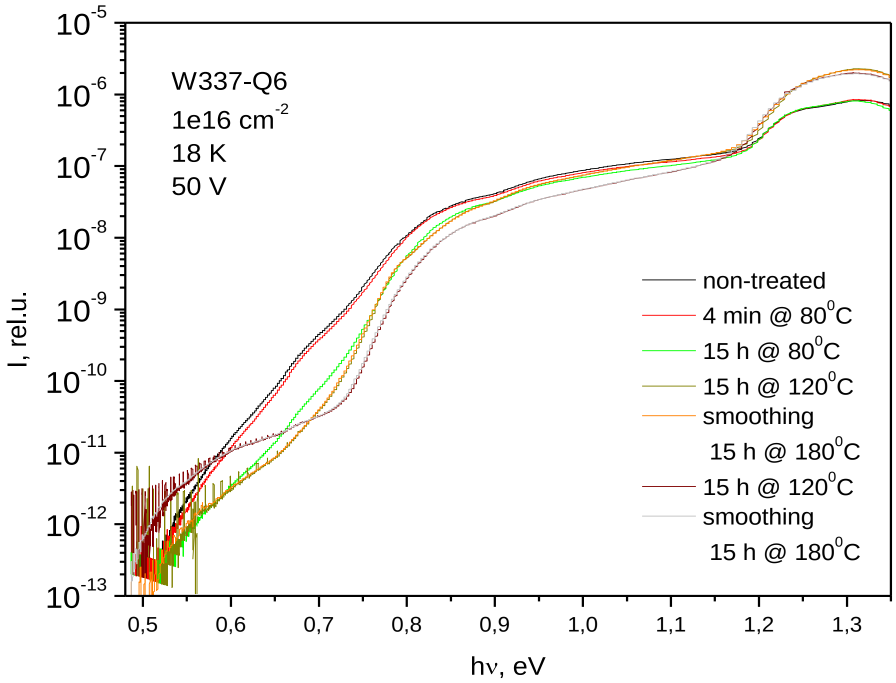


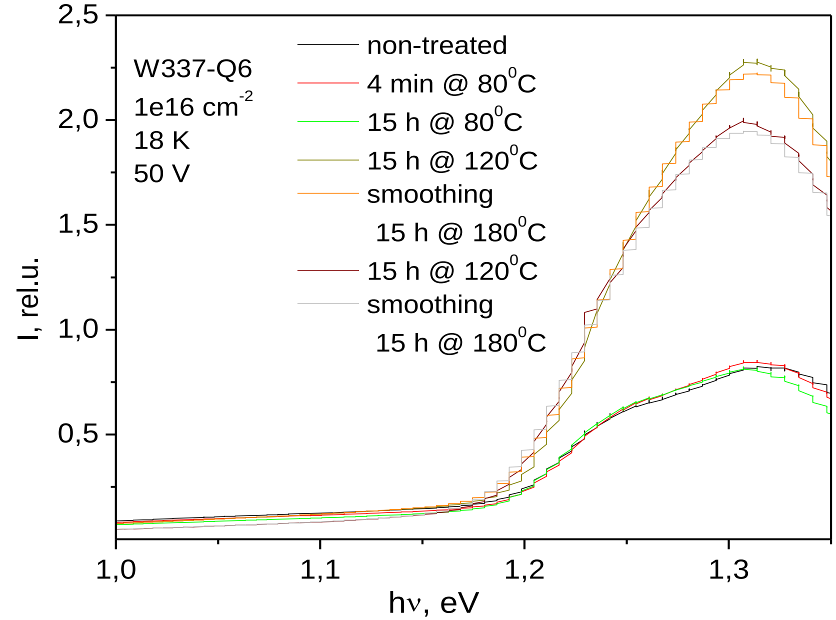


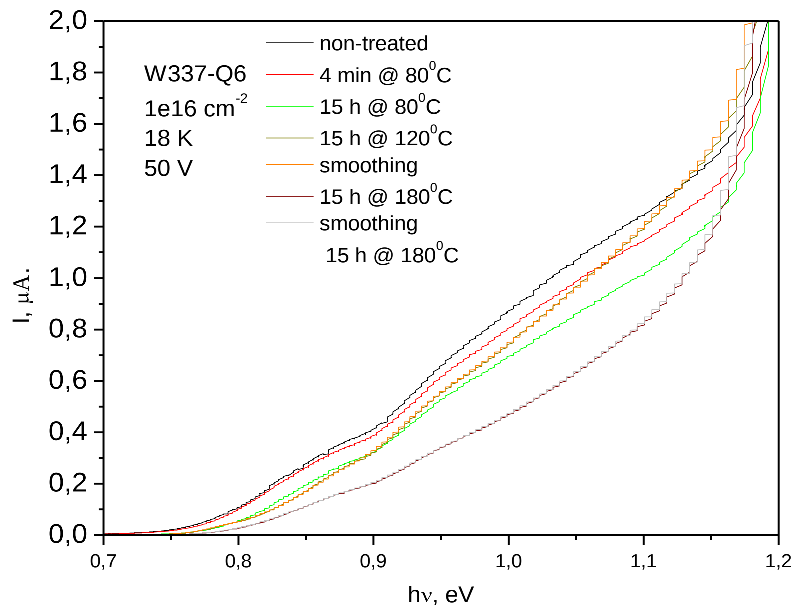


1) Annealing influences the lifetime (at the beginning the increase, later – decrease)
2) Annealing decrease the the level at the valence band concentration (ΔE_{opt}~0.9 eV), but at higher T – the defect system reconstruction

1e16 cm^{-2}





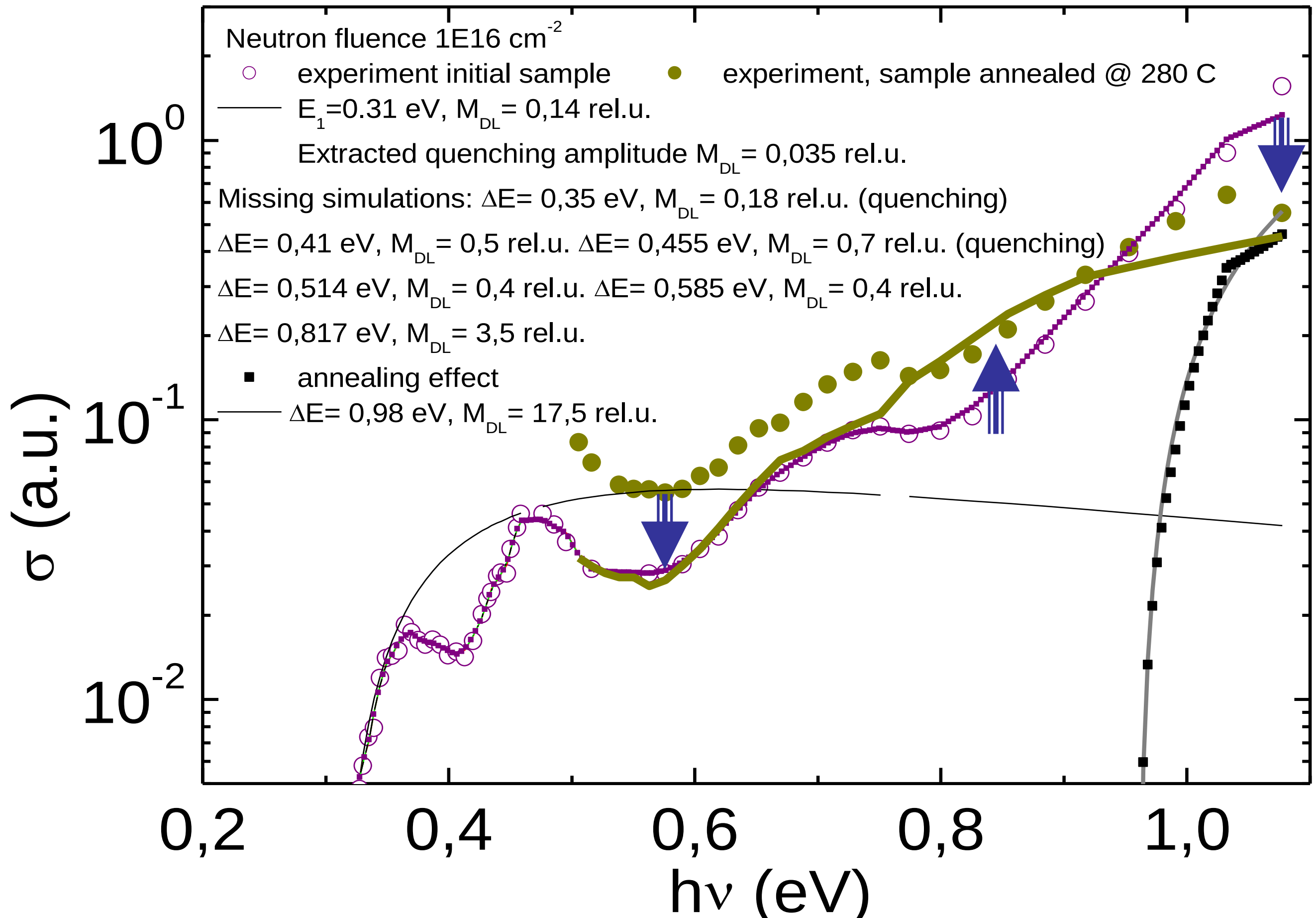


Annealing increase the lifetime
Annealing caused the complicate influence on deep level concentration

40 fs pulse excitation, RT

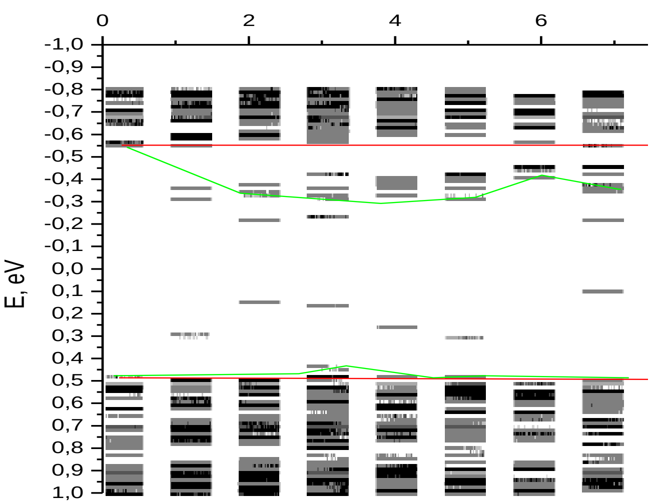
The difference of dc 18 K and pulse @ RT: more shallow levels are observed
the quenching is more significant.

Annealing reduced quenching by 0.41 eV and the contribution of most deep levels (probably disorder origin), but enhanced level at 0.82 eV.

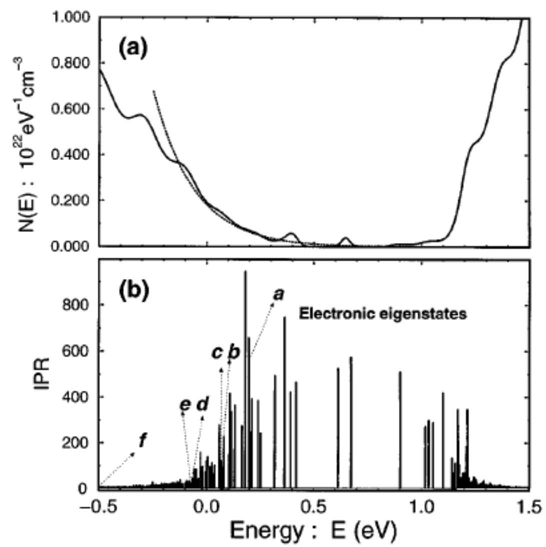


All results can be understood by the cluster transform model:

1) the kick off by neutron Si atom creates the vacancy-interstitials cluster (Huhtinen – track consisting vacancies and Si disorder).
2) the generation-recombination induced phonons and low temperature annealing leads to the cluster reconstruction to the different vacancy clusters and the gettering of other defects.

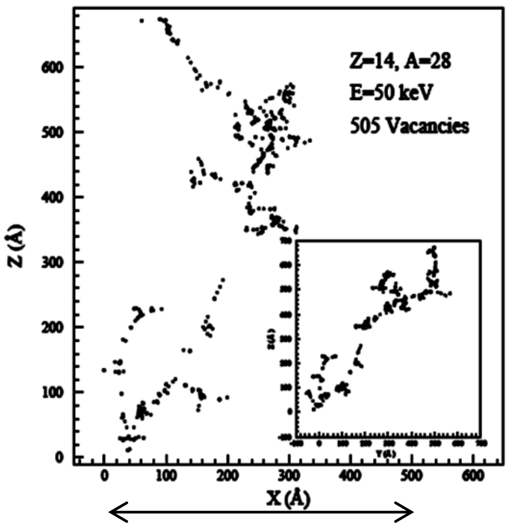


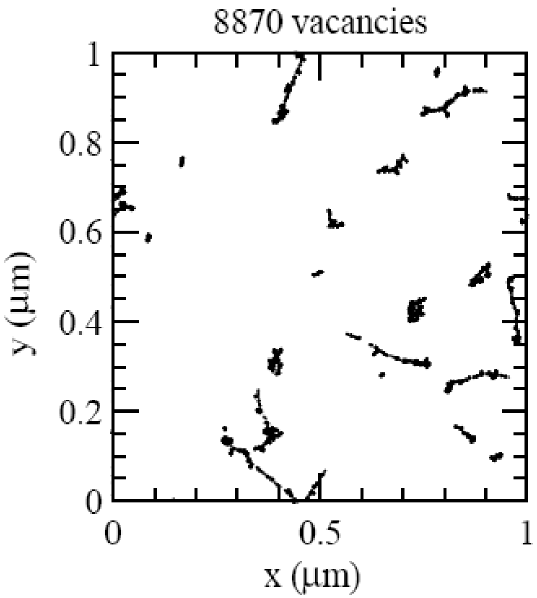
J.L. Hastings, S.K. Estreicher, P.A. Fedders. Vacancy aggregates in silicon. Phys. Rev. B, Vol. 56 (16), p. 10215-10220 (1997).



J. Dong, D. A. Drabold. Atomistic Structure of Band-Tail States in a-Si. Phys. Rev. Lett. Vol. 80 (9) p. 1928-1931 (1998). The valence tail is primarily due to structural disorder, while the conduction tail is much more sensitive to temperature and originates in thermal disorder.

Simulation review:



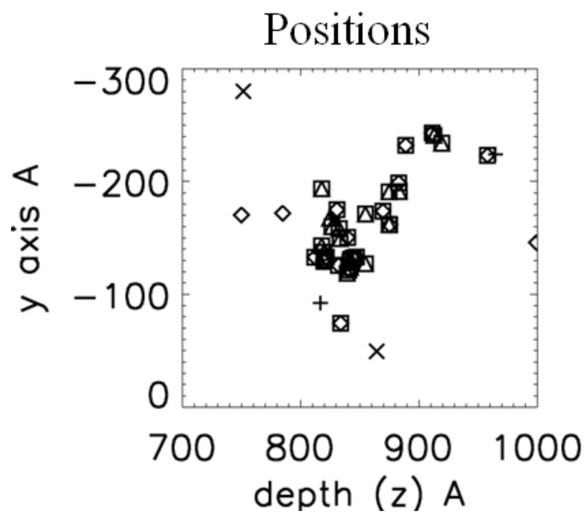


0.05 μm

After random walk (Time nano- to milli-seconds)

I (X) V (+) I_2 (♦) V_2 (Δ)

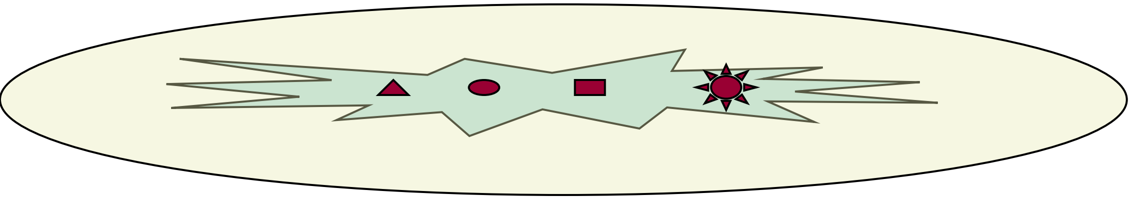
I-clusters (♦) and V-clusters (Δ) in squares



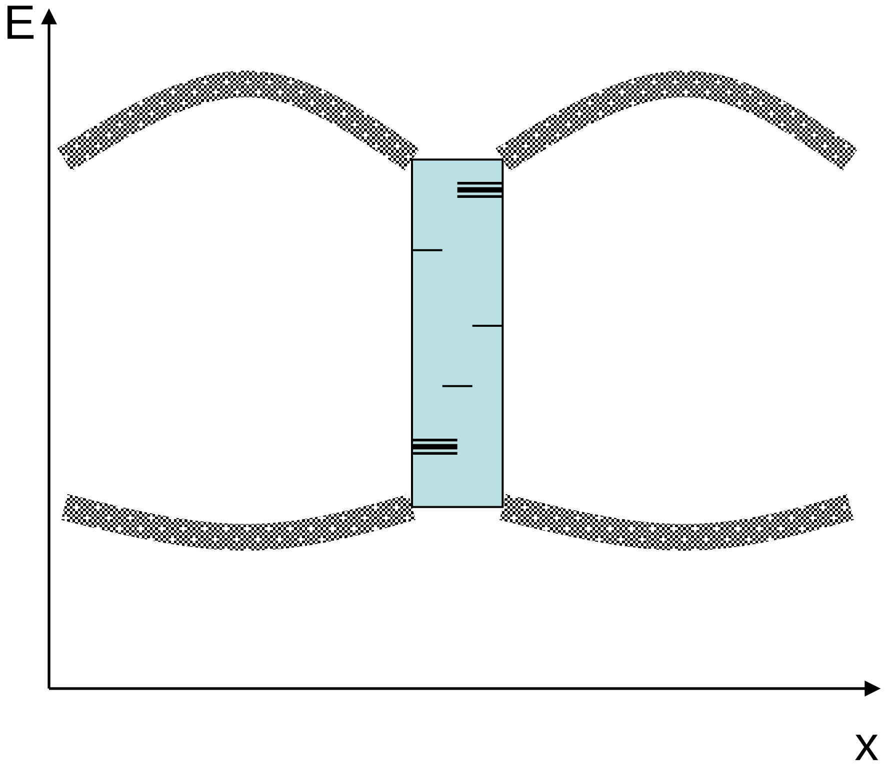
Initial distribution of vacancies produced by 1 MeV neutron in Si, a – a result of kick of Si atom, and b – if a fluence was 10^{14} cm^{-2}, according M.Huhtinen. NIMA 491 (2002) 194–215

G.Davies, presentation at the WODEAN workshop in Bucharest: **reconstructions inside 100 nm size volume** (all inside the Debye sphere)

Photo-ionization of the cluster



Different deep levels onside the volume surrounded by a single potential barrier.



Annealing change the compensation in the bulk, i.e., barrier,
and
the structure (i.e., properties) of deep levels inside the cluster.

Conclusion 1:

The talk of Gordon Davies in Bucharest demonstrated that the main transforms during self-annealing and different treatment are going inside the cluster where different random processes happens.

Our results show that by photoconductivity a the changes in the deep level system can be controlled.

The positive and negative contribution on the photoconductivity allow to recognize the levels that influence the carrier capture by the cluster.

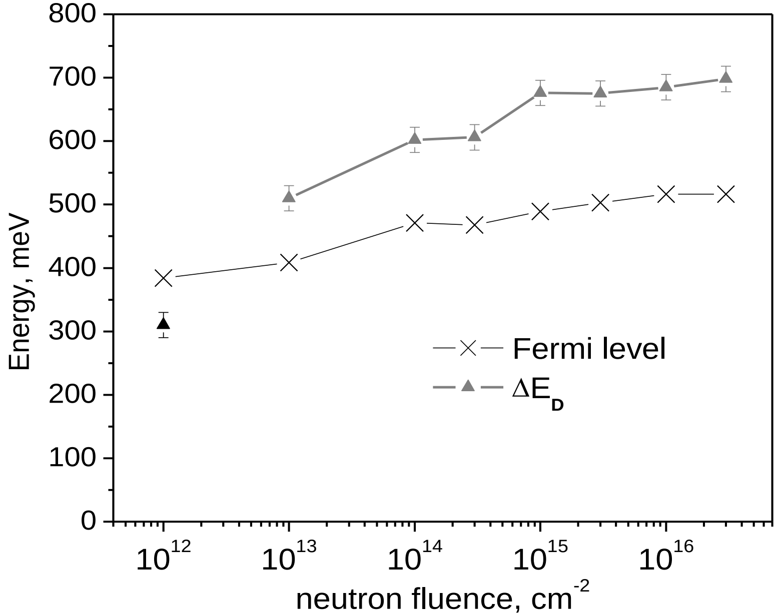
Conclusion 2:

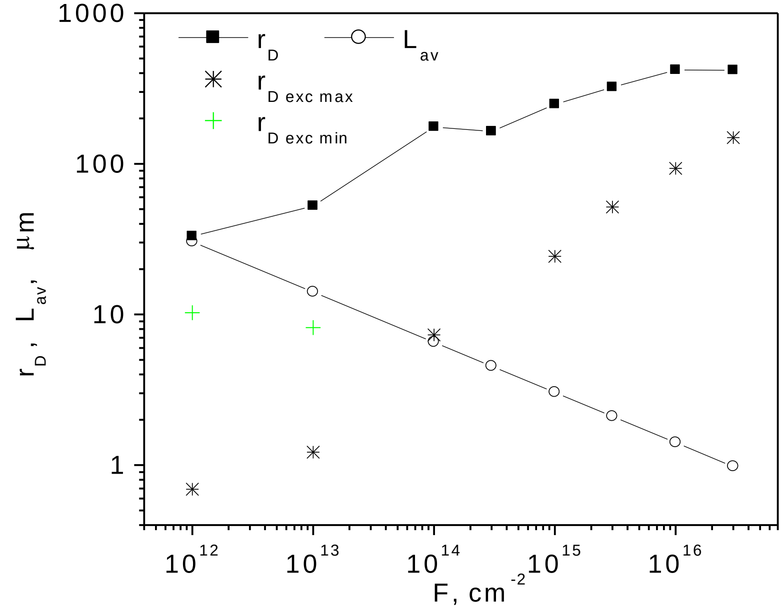
Irradiation and low T annealing effect demonstrate:

- Extrinsic photoconductivity reveals a few deep levels that are directly related to the irradiation.
- Low T annealing allows to propose the random transforms in the defect system

Thanks for Your attention !

The comparison of the acting quantities confirming the model





1) Fermi level location determined from the free carrier concentration (proposing the existence of the conductivity channels, the error related to the indefinite of the volume participating in the percolation)
2) Local level energy is determined from the temperature dependence of the free carrier concentration.
3) The Debye radius is evaluated neglecting the ionized defects between the clusters. (If it would be included, the overlap would be less)
4) The cluster separation distance evaluated using the approximation of linear dependence of the cluster concentration on the fluence.

Other series samples