The peculiarities of photoconductivity in the irradiated Si.

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The main aim of this presentation is to show what kind of properties it is possible to reveal in the samples,

AND TO STIMULATE YOUR INTERESTS to supply the samples for their investigation in our team

Non-equilibrium conductivity excited by the light pulse allows to investigate:

- The lifetime and trapping time (by the photoconductivity decay, and by its dependence on the additional background excitation)
- The spectrum of deep levels (by an extrinsic conductivity spectral dependence)
- The spectrum of trapping levels (by the thermally stimulated conductivity using the multi-heating measurement regime)

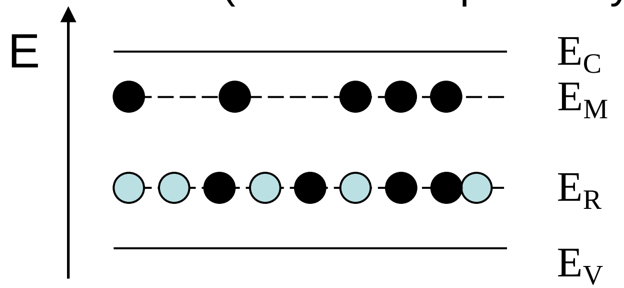
But also, the peculiarities of these phenomena (the deviations from a classical models) can be observed and were observed in the irradiated Si.

1st peculiarity
(related to TSC)

The classics:

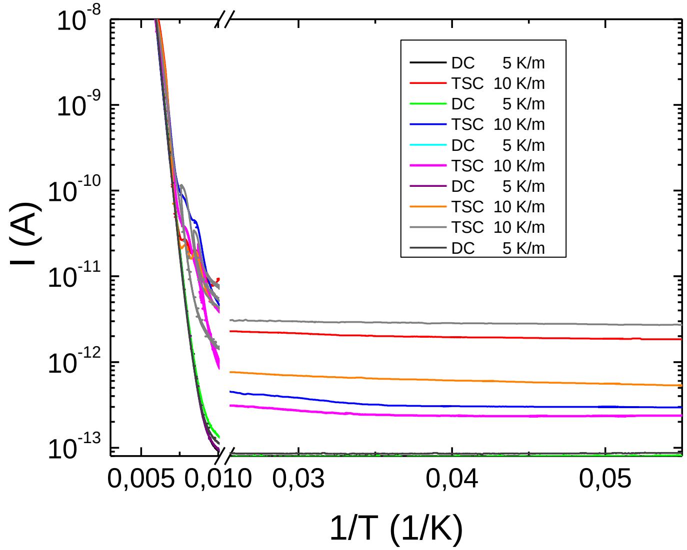
If the semiconductor is excited at low temperature and kept a certain time in the dark, the photoconductivity has to decay to very low value.

In n-type of semiconductor: the traps has to be filled by nonequilibrium electrons and correspondent holes are captured in the recombination centers (and hole traps it they exist)



What was observed:

The photoconductivity does not decay to a very low value.



The photoconductivity does not decay to a very low value.

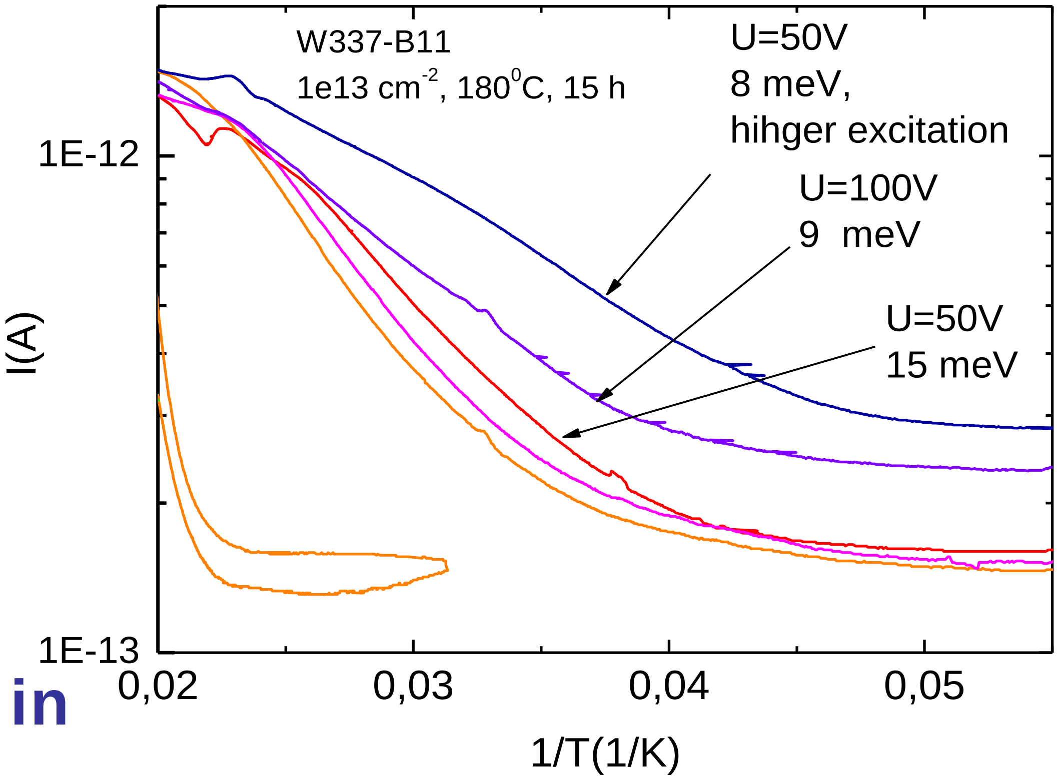
It means:

1) All traps are filled or part of them are surrounded by a barrier.
2) a bottom of conductivity band is modulated and the electrons and the holes in the recombination centers are separated by the barrier.

A control of proposal of inhomogeneity:

If there are **the modulation of the bottom of the conductivity band**, the barrier has to decrease if **a bias would be increased**, also, if the sample's **excitation would be higher**, the residual conductivity will be bigger, and the barriers has to be screened (the activation energy to decrease).

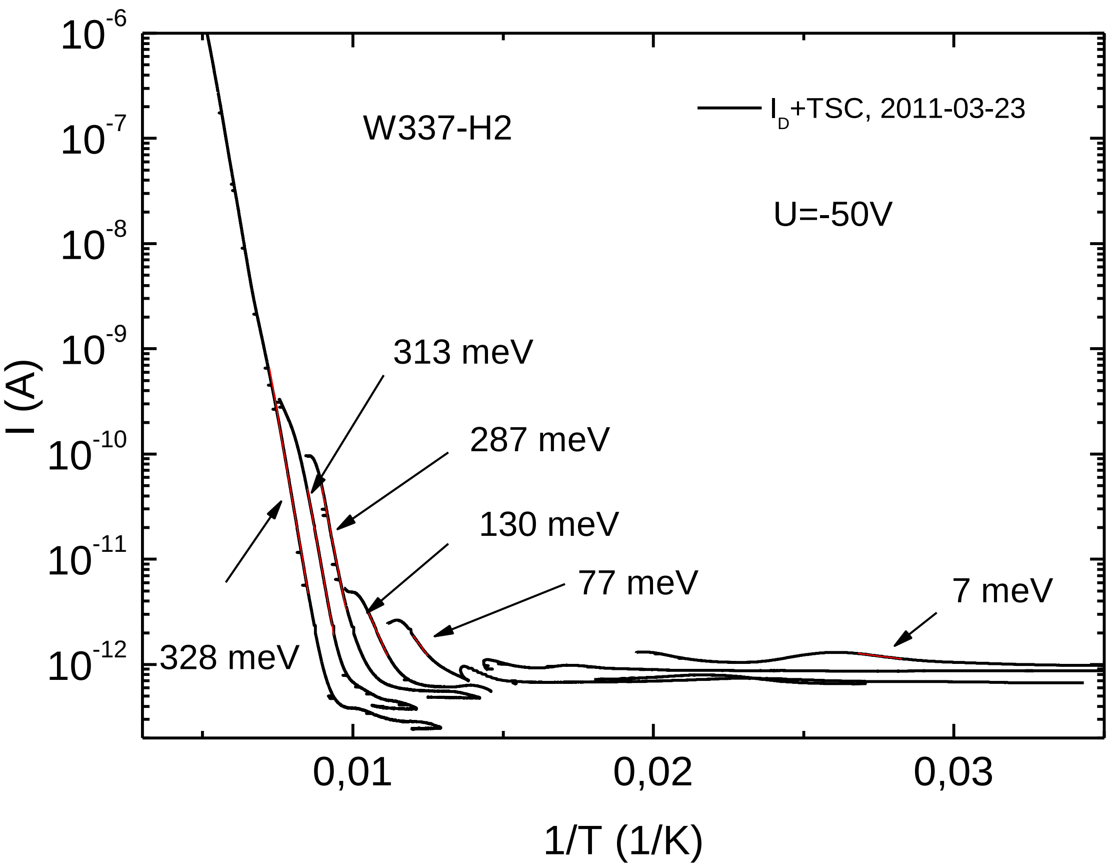
The results are shown on the figure:



The consequence:

it is necessary to take into account **the existing microinhomogeneity** in the analyze of other experiments **in irradiated Si.**

An example of multiple annealing TSC results



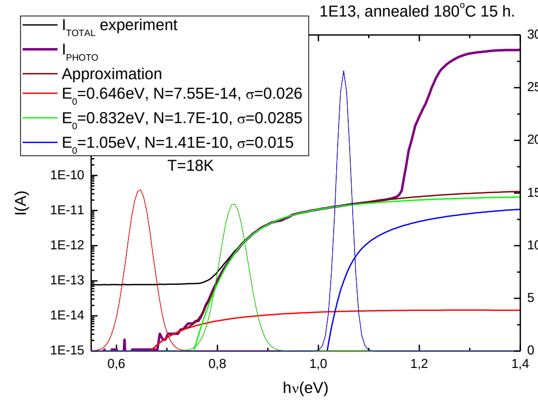
Extrinsic Photoconductivity (PC) spectrum

Classics:

in a case of deep local levels the fit to the deep level with a δ-potential model allow to measure activation energy of the center and determine a relative its concentration.

To exclude the effects related to electron-phonon interaction the measurements recommended to perform at low temperatures (< 77 K)

The PC time constant equal to the lifetime or corrected according the traps contribution

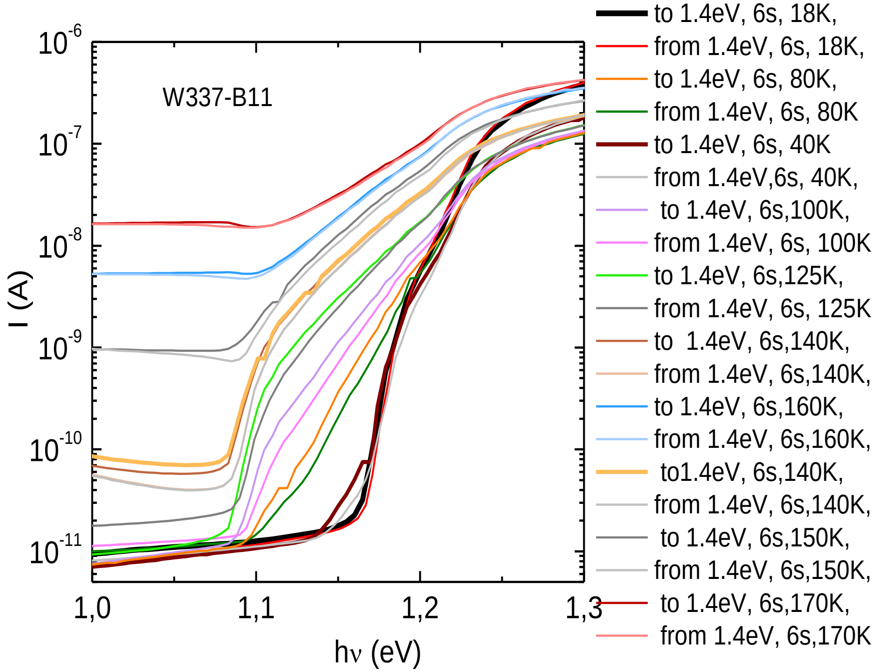


What is observed in the irradiated by hadrons Si:

1) The PC has long relaxation time;

2) Until a certain energy (≤0.8 eV) the "memory effect" is absent.

3) The additional photosensitivity band appears at higher T.



What can be concluded form this result?

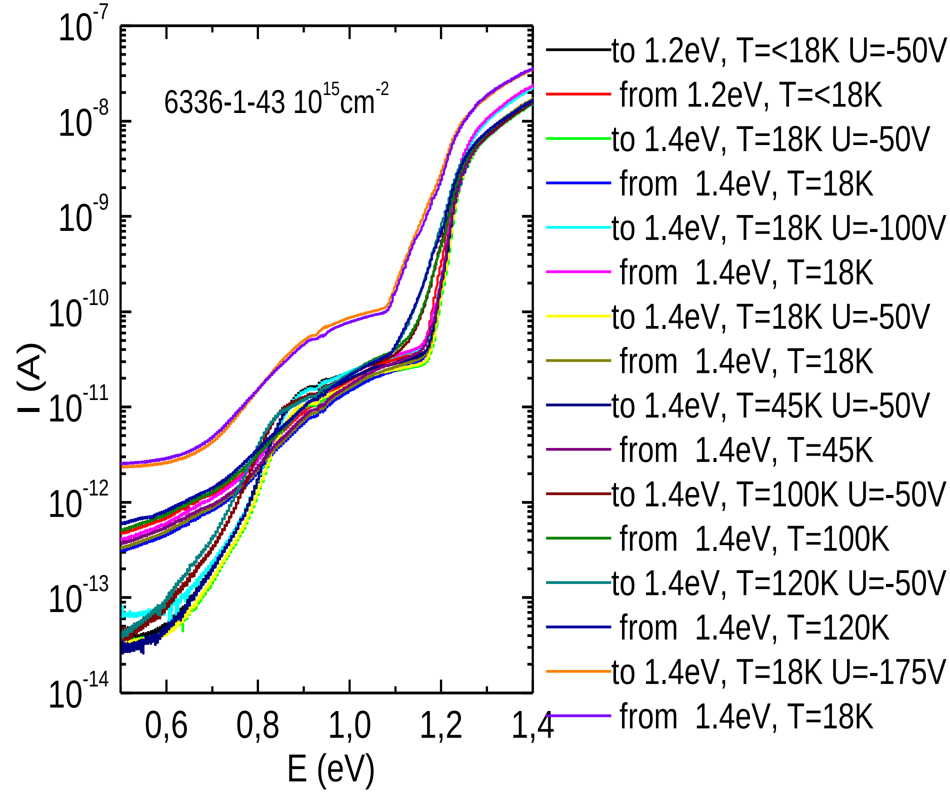
The light with energy < 0.8 eV excites the electrons from the deep centers that modulate the barriers around the recombination centers.

The electrons excited to the centers with activation energy E_C-E_M ~0.08-0.10 eV at higher T are released by thermal energy and the new PC band appears.

How to test it? To measure spectrum at high bias!

What does happened?

The "new" PC band appeared.



Both results confirmed the existence of the extended (macro) inhomogeneities in the irradiated Si (Its contribution depends on the bias)

What follows from the PC kinetics?

Classics:

Recombination via one type of recombination center (RC).

Most popular –SRH, but it valid ONLY when $N_R << n_0 + N_{CM}$

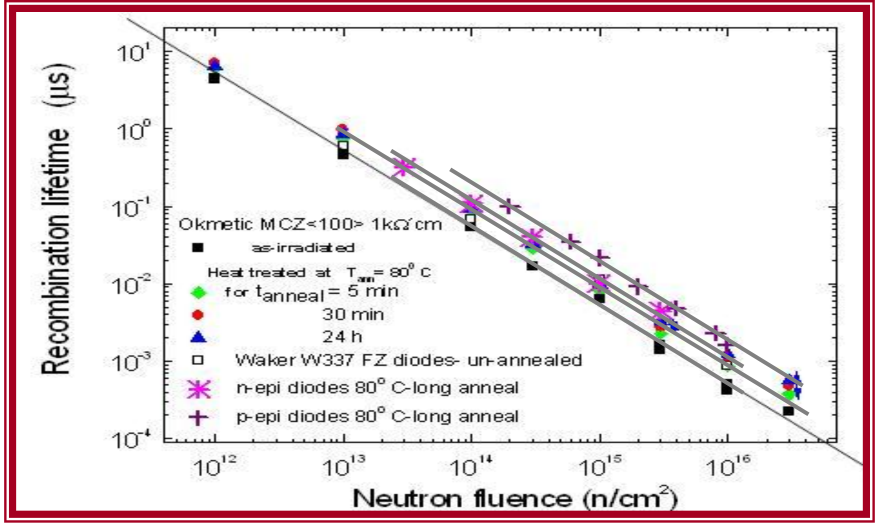
In other cases – theory of A.Rose.

Any fast trap or RC must be seen in the PC decay !!!

What was observed in the irradiated Si?

γ - irradiated Si – two components and trap contribution.

Hadron irradiated Si – the main recombination center (and small contribution of others)



What properties of the main center?

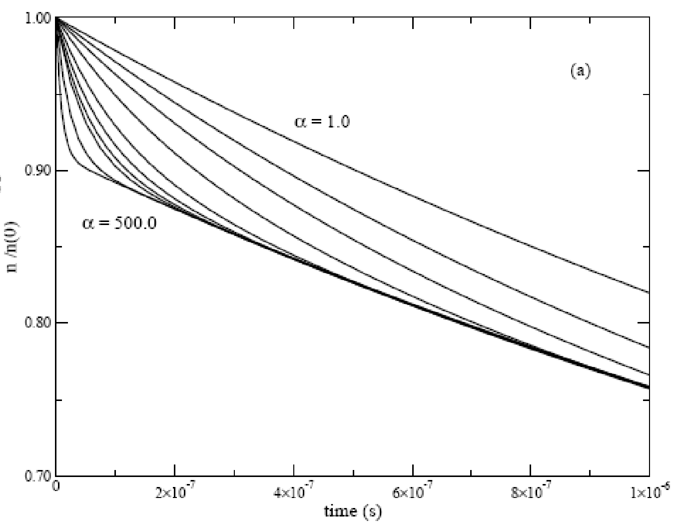
If the concentration of recombination center is > n_0, then the lifetime depends on the center filling, and appears a possibility to get its parameters:

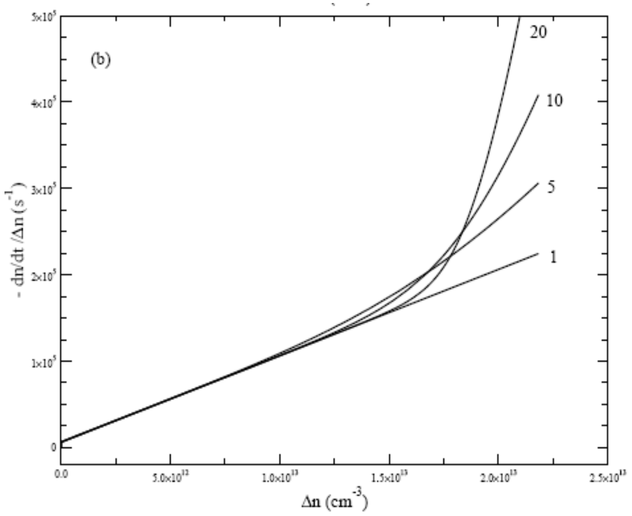
$$\frac{1}{\tau} = \gamma(P_{R0} + \Delta n)$$

($\sigma_{nM} = \gamma / v_{nT}$, cm^2, v_T – thermal velocity of electrons šiluminis elektronų greitis)

If there are two centers::

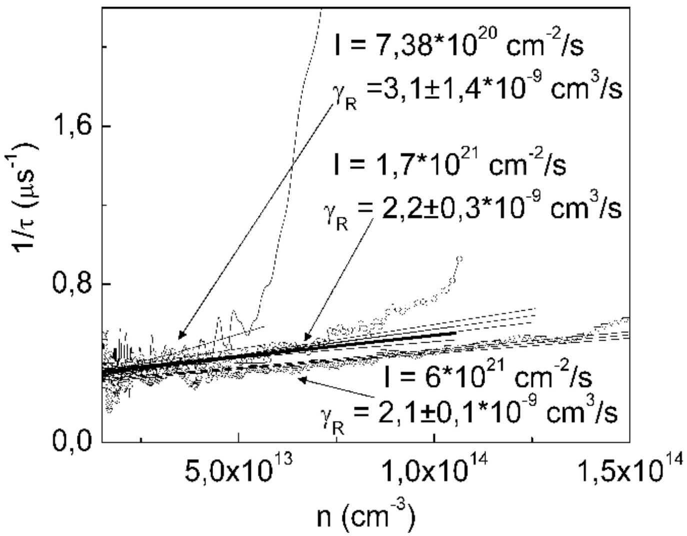
$$\frac{dn}{dt} = -\gamma_1 n p_1 - \gamma_2 n p_2$$
$$\frac{dp_1}{dt} = -\gamma_1 n p_1$$
$$\frac{dp_2}{dt} = -\gamma_2 n p_2$$
$$n = p_1 + p_2$$





Additional centers introduce fast component in PC kinetics due to the nonlinearity

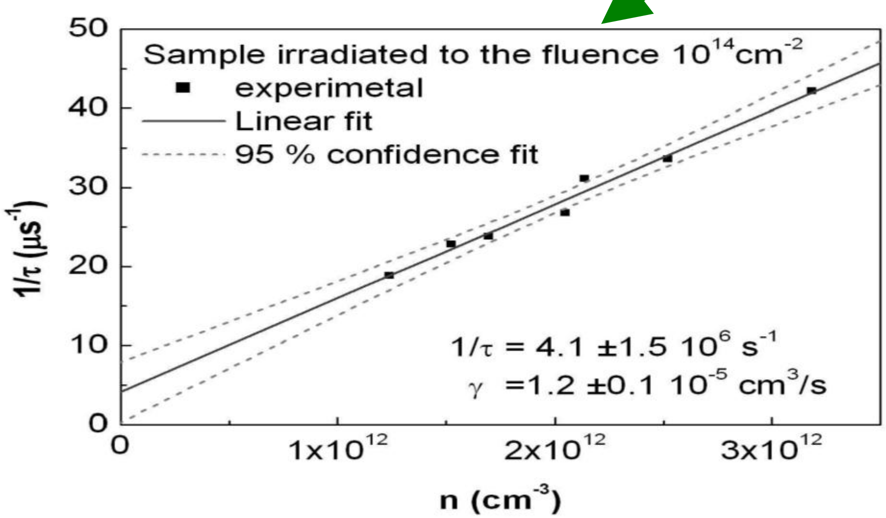
What does follows from PC decay?



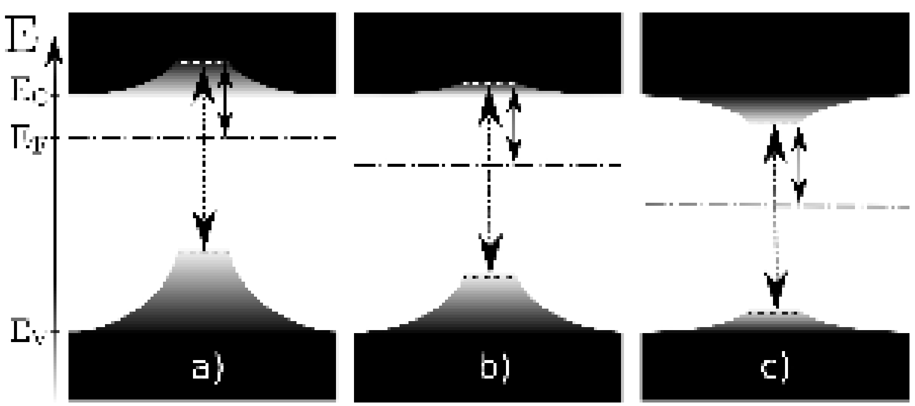
Fluence 10^{12} n/cm². The recombination centre capture coefficient, i.e., the capture cross-section corresponds to the neutral centre type, but a contribution of other centers also it is seen.

Fluence 10^{14} n/cm² and **more**: remains one type RC. Its capture coefficient increase in 630 times !!!). The capture cross-section 5.2 10^{-13} cm^{-2} corresponds to attractive centre type.

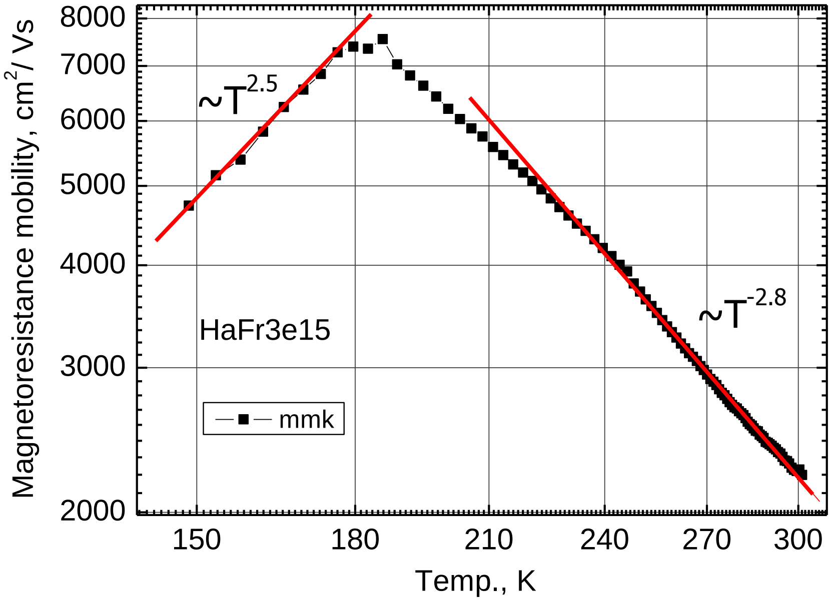
(It nearly corresponds to the RC extracted from the reverse current investigation by E.V. during ROSE collaboration)

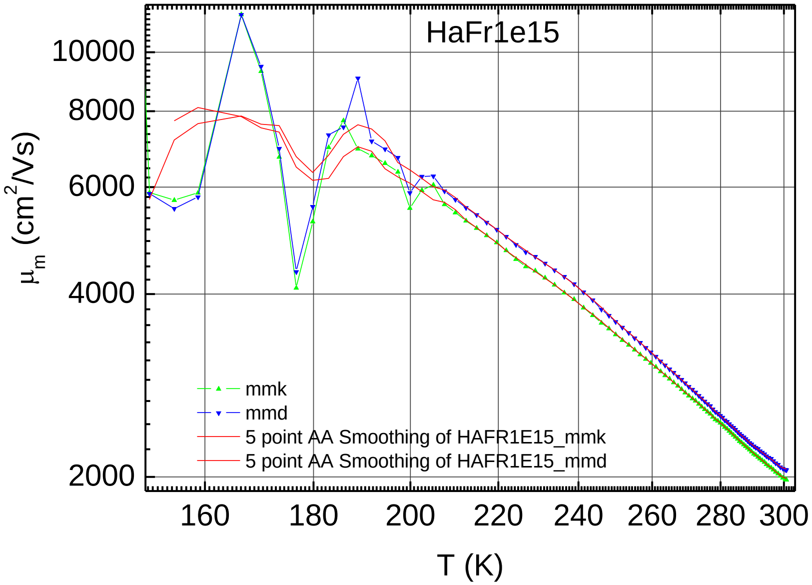


Model:



Last news from epi-diode investigation





It measured by magnetoresistance effect: $\mu_M=(r_M/B)\sqrt{[(\rho_B-\rho_0)/\rho_0]},$

Conclusions:

- Peculiarities of photoconductivity allows to reveal the microinhomogeneities role in the irradiated Si.
- If somebody is interested in the magnetoresistance mobility value, we wait of the samples.
  - (Best ones would be n*-n –n*, or p*-p-p* pads, but also p-i-n structures also interesting, especially highly irradiated)

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THANK YOU FOR YOUR ATTENTION!