Investigation of carrier lifetime temperature variations in the proton irradiated silicon by MWA transients

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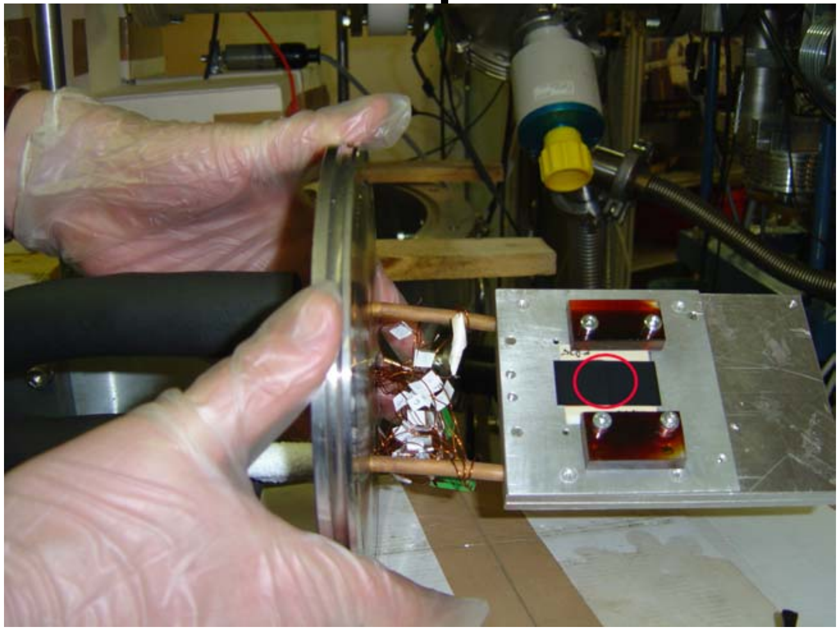
Problem

Role of oxygenation in modification of the recombination characteristics in proton irradiated silicon

Outline

- proton irradiated samples – fabricated in Helsinki
- RT characteristics: lateral, intensity, irradiation fluence, initial//irradiated
- lifetime temperature variations,-comparison of Helsinki&Hamburg samples
- possible recombination flow redistribution processes and simulated characteristics

Initial material and proton irradiated Si samples



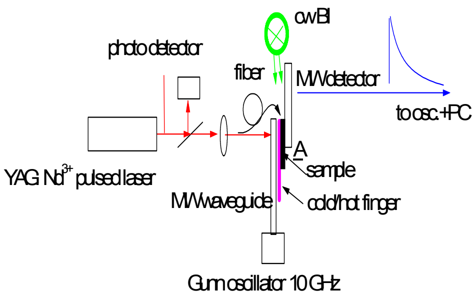
Helsinki Si pieces. There is a picture of irradiation arrangement. Two pieces (e.g. samples #5 and #6) were irradiated at the same time.

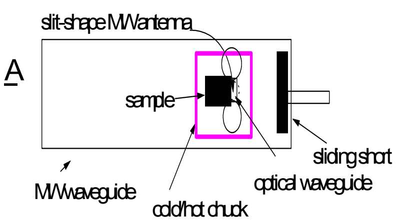
In the picture, it is marked with red approximately the proton beam spot, when one side of the sample is more irradiated with given dose. **The beam spot has a radius of about 2,5cm.** The non-irradiated pieces are passivated with thermally grown SiO_2 (at 1100^0C), so the surface recombination velocity should be lower in the latter samples.

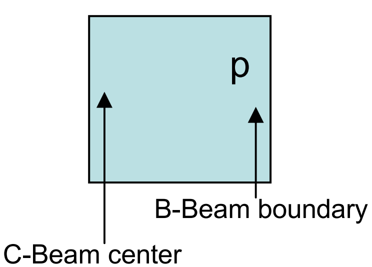
ID #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Fluence	0	0	0	0	5e12	5e12	5e12	5e12	1e13	1e13	1e13	1e13
Type of Si	p	p	n	n	p	p	n	n	p	p	n	n
TD treatment	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Proton energy					10	10	10	10	10	10	10	10

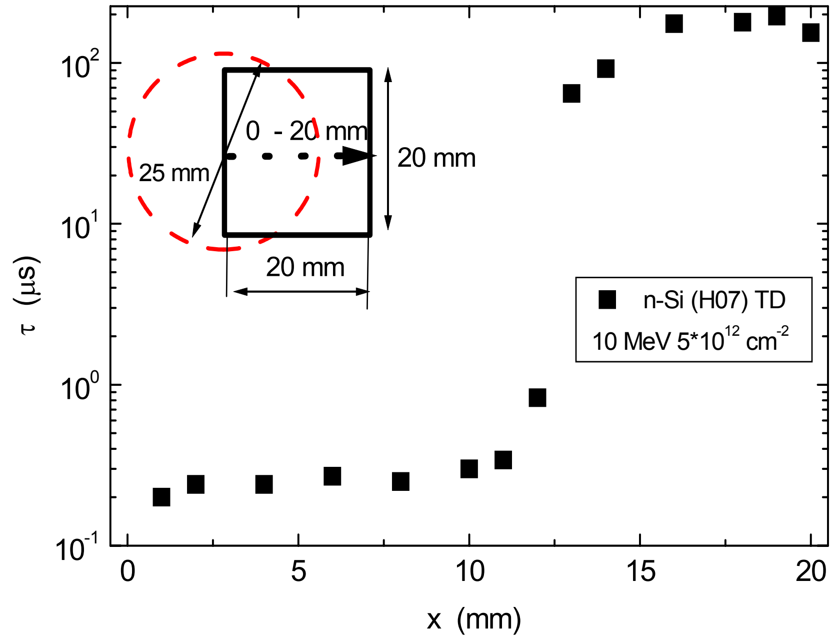
ID #	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Fluence	9e12	9e12	9e12	9e12	2e13	2e13	2e13	2e13
Type of Si	p	p	n	n	p	p	n	n
TD treatment	Yes	No	Yes	No	Yes	No	Yes	No
Proton energy	50	50	50	50	50	50	50	50

Lateral lifetime variation due to irradiation geometry with proton beam spot of 25 mm





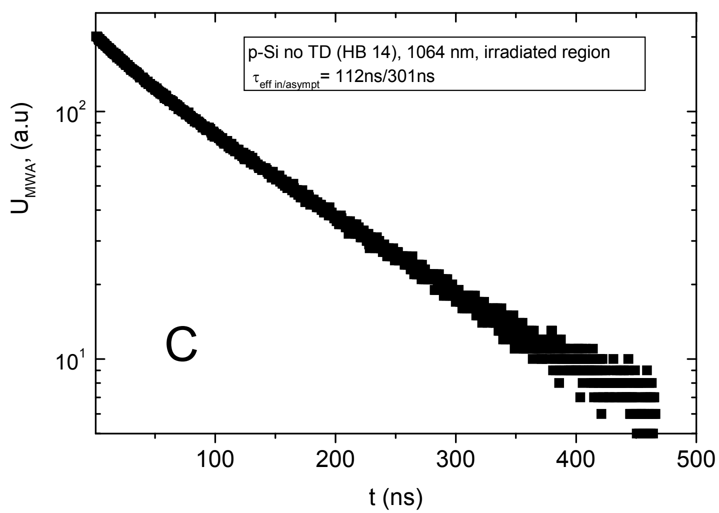


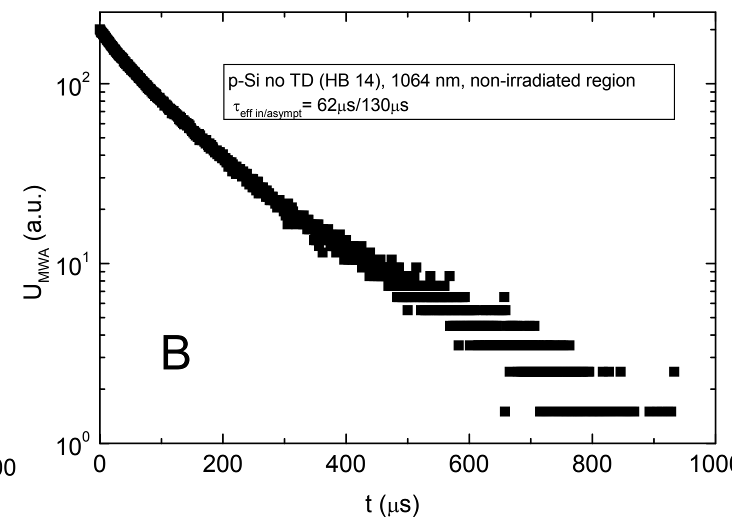


Short mono-exponential decay in the irradiated area

Two-componential decay with trapping effect in the non-irradiated area

Strong increase of lifetime at boundary of irradiated and non-irradiated areas



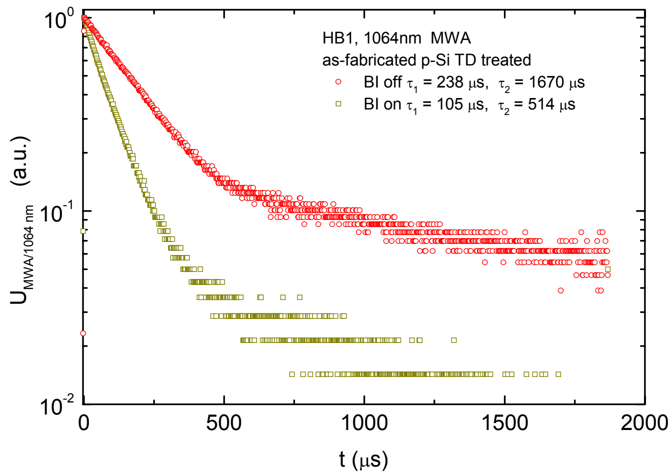


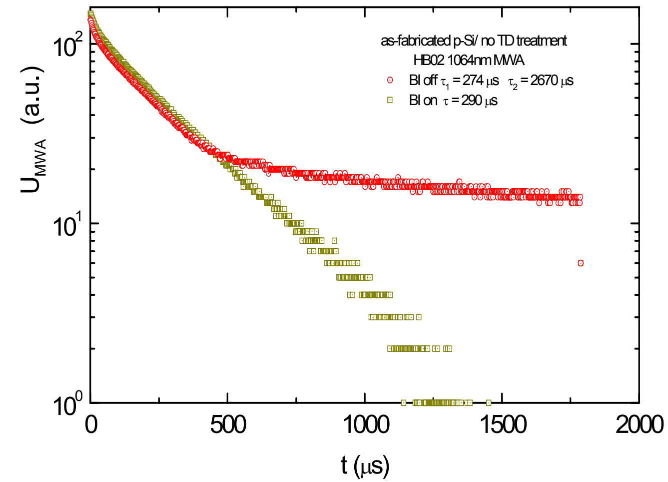
Recombination-trapping in the initial material

TD treated

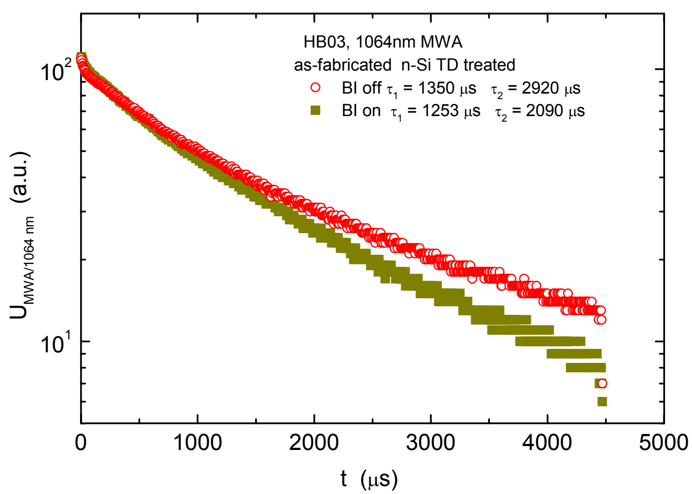
no TD treatment

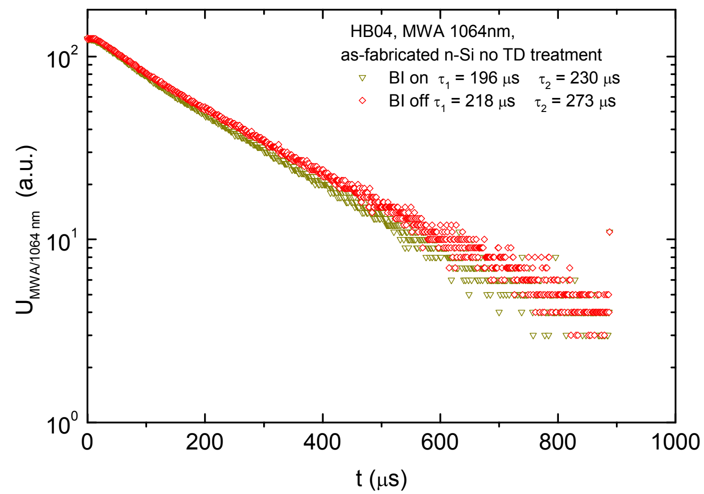
p-Si



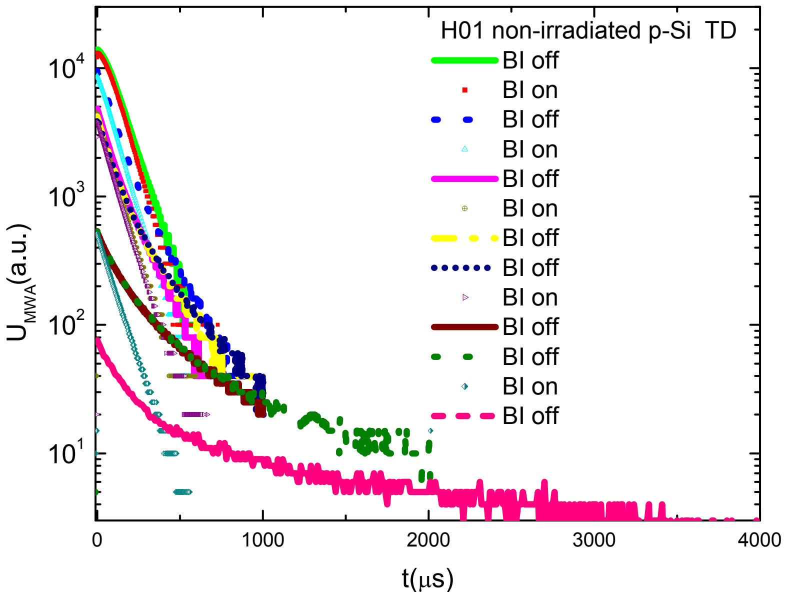


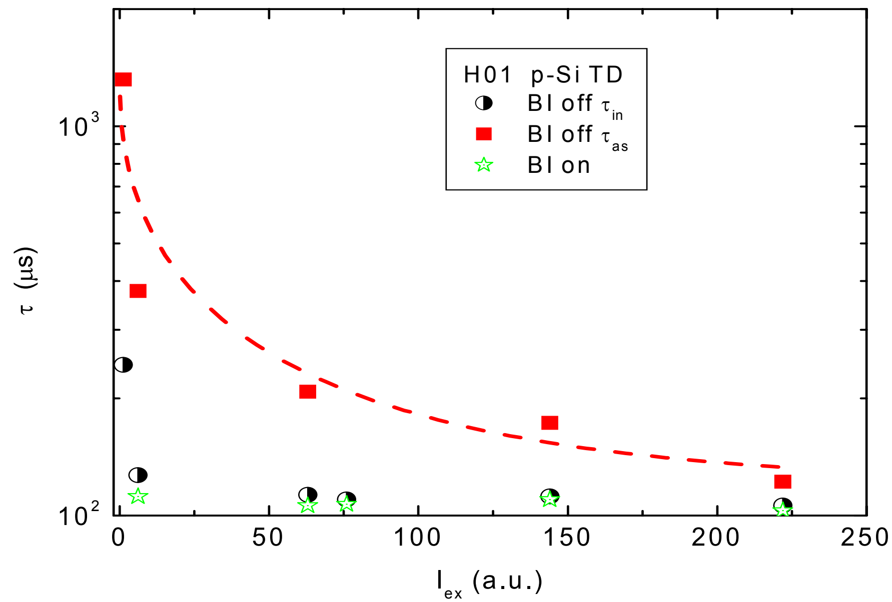
n-Si

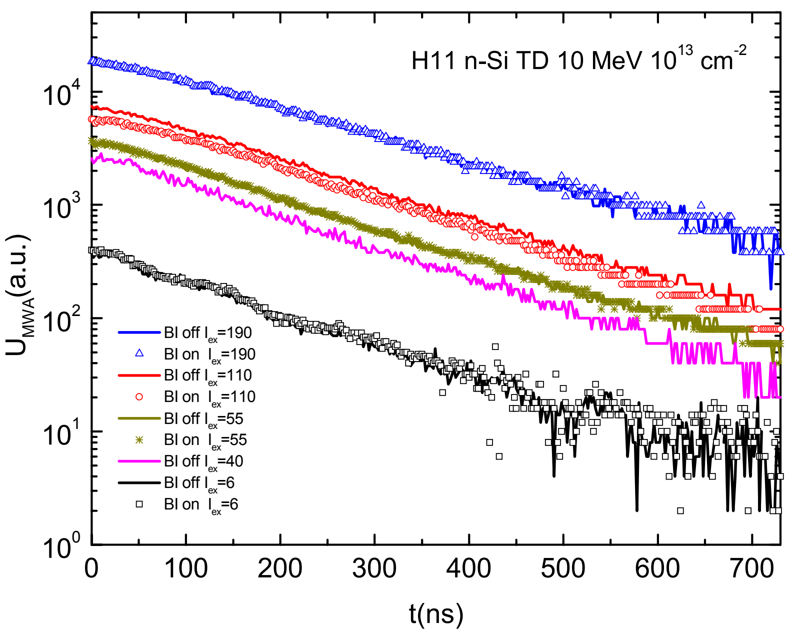




Decay variation with excitation intensity in the initial and irradiated samples at RT

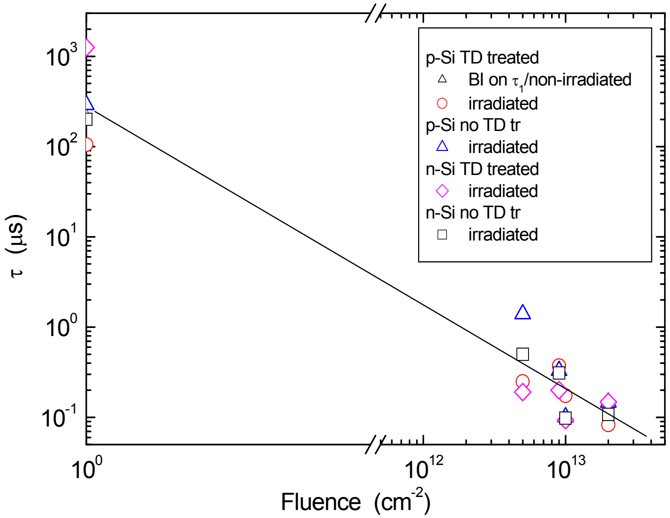


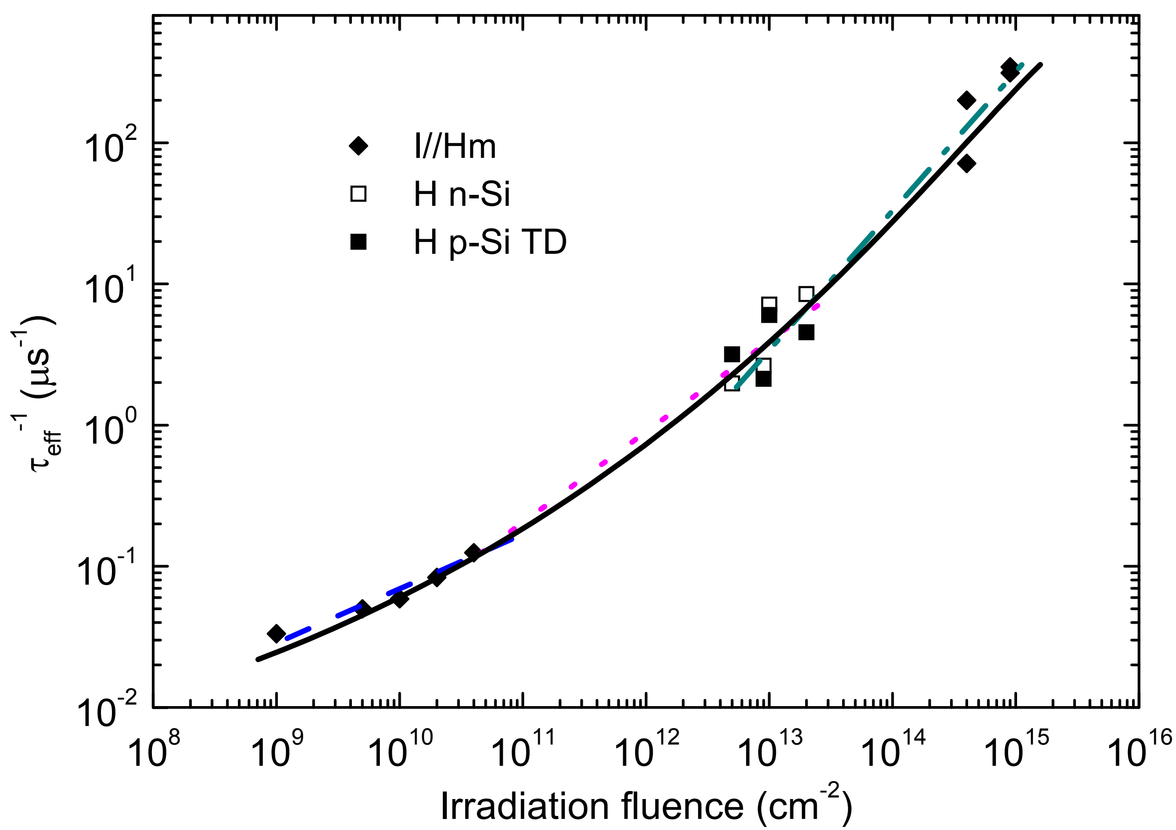


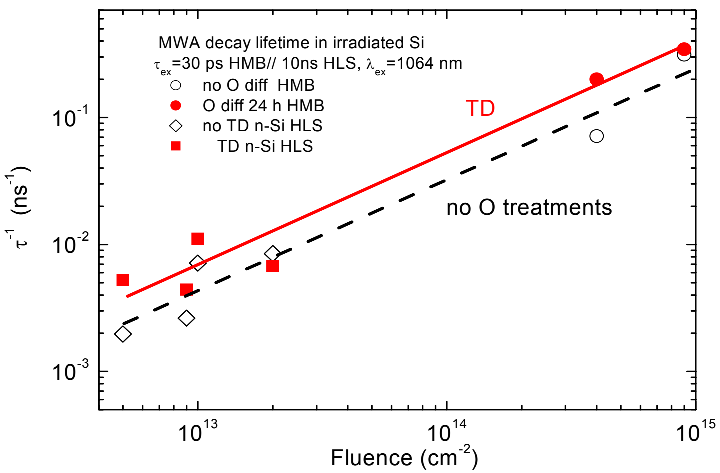


- Trapping is inherent for initial material and decreases with excitation
- No significant trapping at RT in the irradiated samples

Reciprocal lifetime vs. protons irradiation fluence at RT

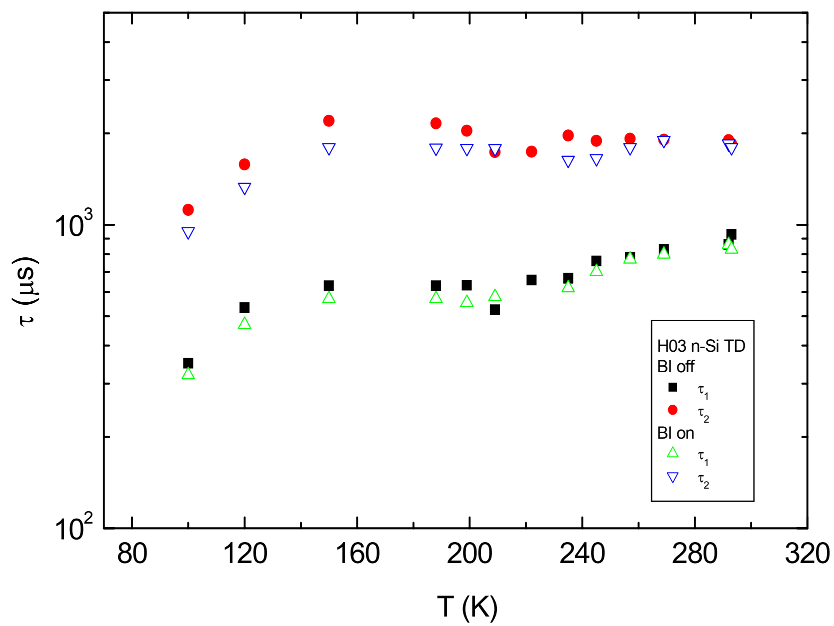


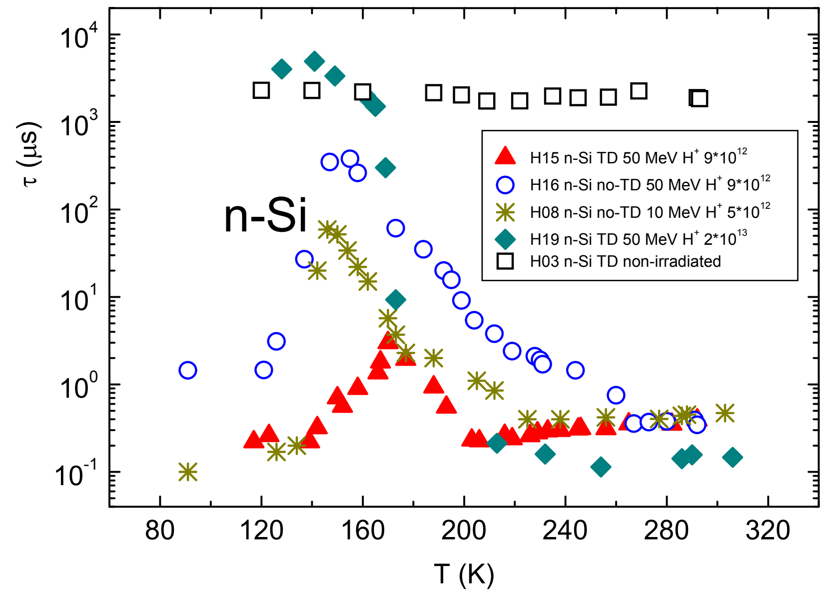


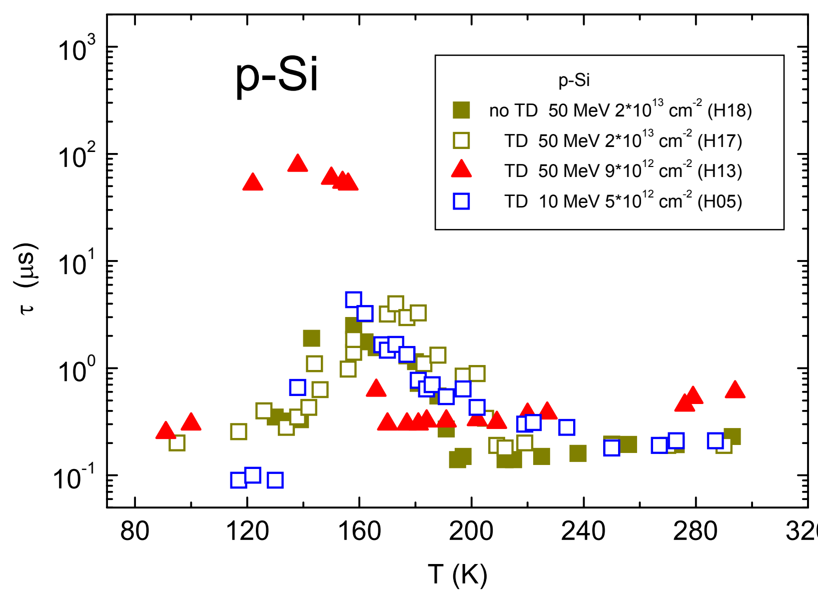


Effective lifetime dependence on temperature in the initial material and in the irradiated samples

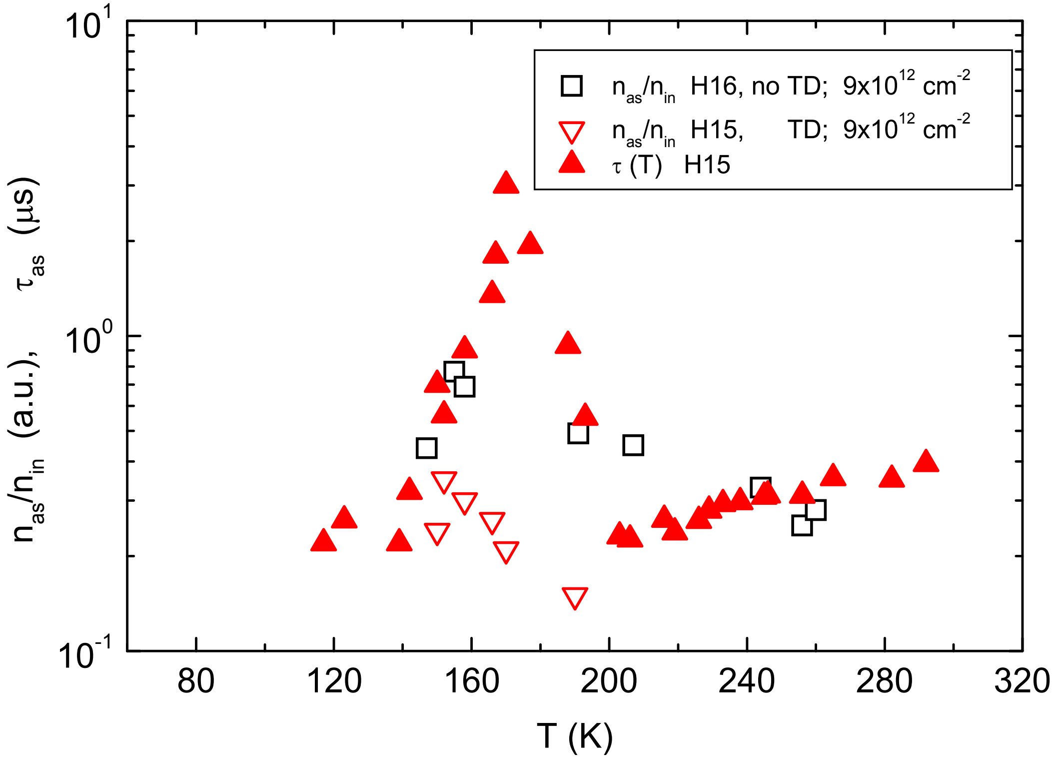
Initial material





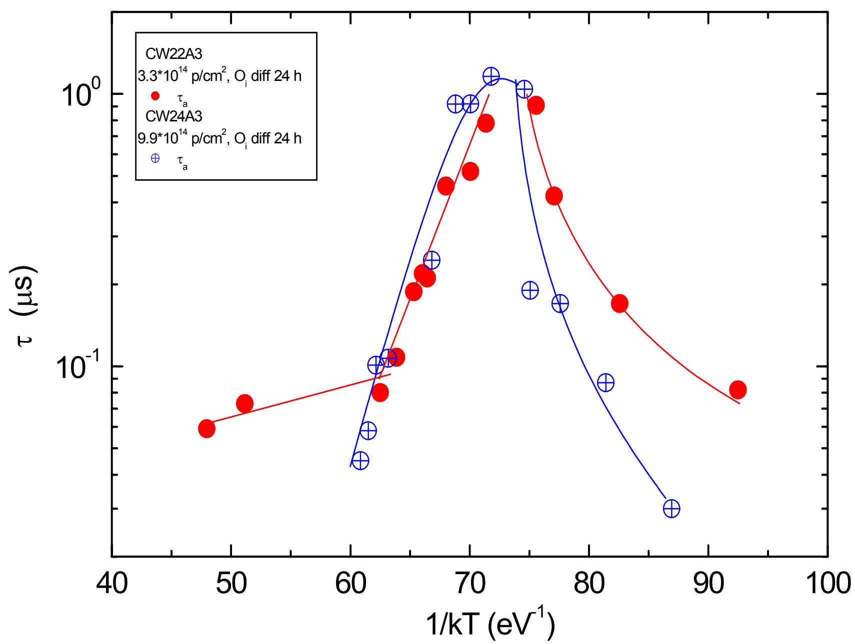


Variation of the partial decay amplitudes

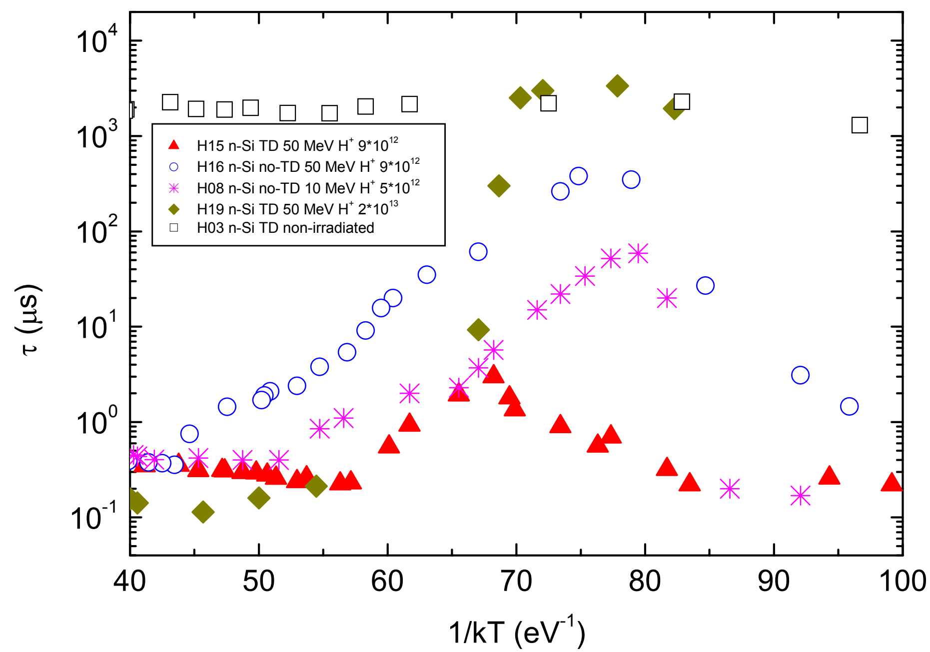


Correlation between lifetime vs. kT plots in the proton irradiated samples fabricated in Hamburg and Helsinki

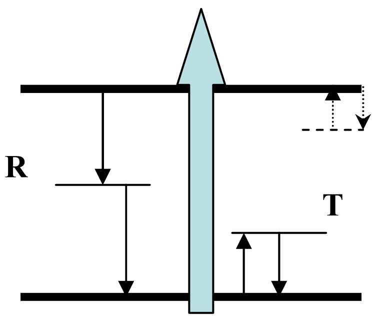
Hamburg



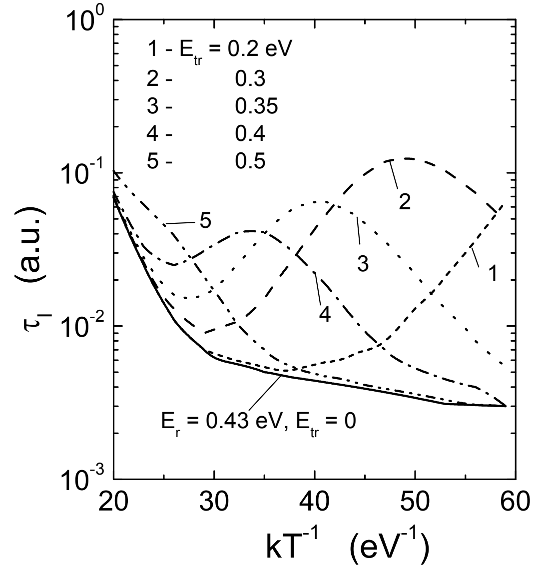
Helsinki

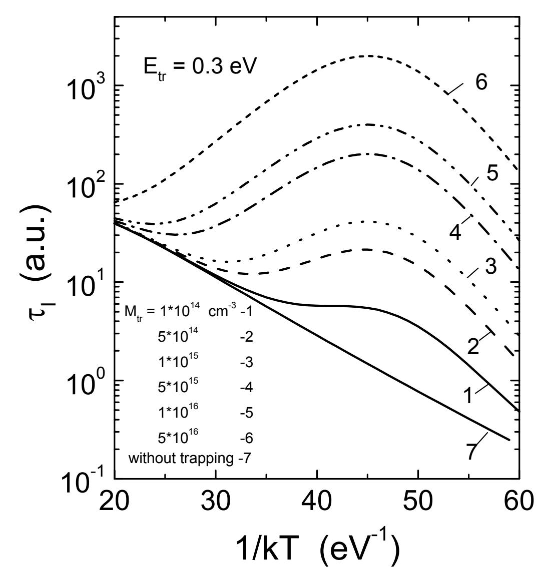


Possible trapping processes and characteristics



Trap filling effects





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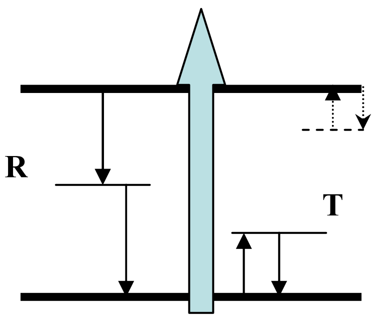

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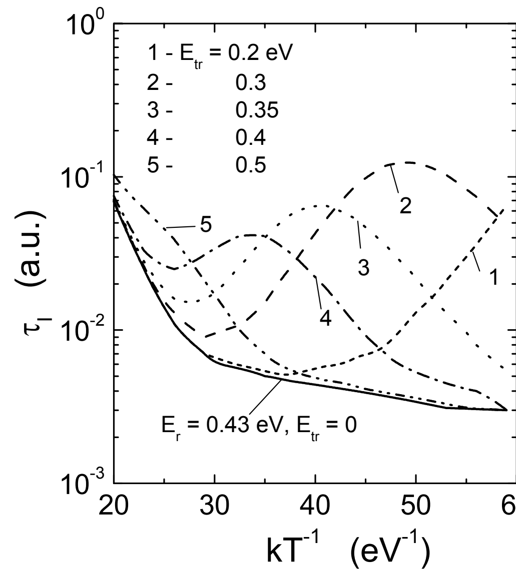
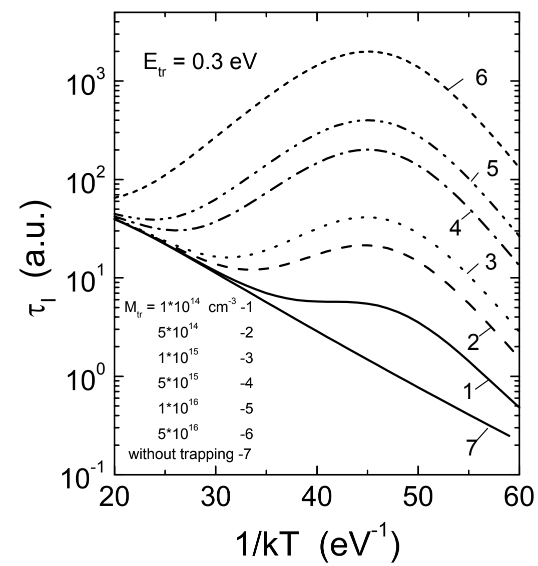
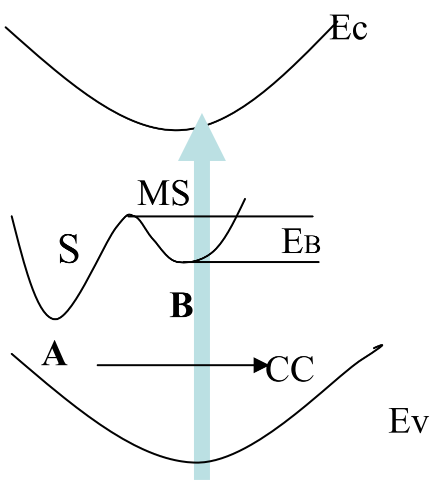
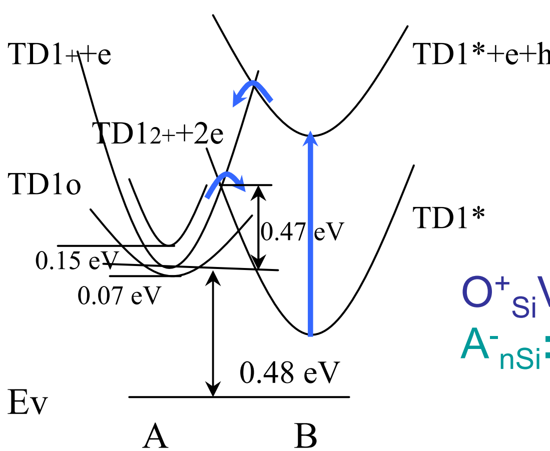




Metastable centres TD,V-O, etc.



TD Si



$\Rightarrow$ TD

$O_i + V_{Si} \rightarrow O_{Si} \rightarrow + V_{nnSi} \Rightarrow O^+_{Si} V^-_{nSi}$

$O^+_{Si} V^-_{nSi} \rightarrow O^{2+}_{Si} V^-_{nSi} + e^- \Rightarrow O^{2+}_{Si} A^-_{nSi} + e^-$

A^-_{nSi}: **irr V_{Si}; Cu_{Si}; Al_{Si}** $\Rightarrow O^{2+}_{Si} A_1{}^-_{nSi} A_2{}^-_{nSi}$

Methodological summary

The decay of photoconductivity excited by short light pulse enables one to distinguish the slow trapping and recombination processes.

The determined lifetime values in proton irradiated Cz Si for fluences in the range of 5×10^{12} - 2×10^{13} cm^{-2} fits into the earlier revealed lifetime fluence dependency, but an existence of the dominant defect type change still requires further, the **more detail** examination of this lifetime vs. fluence characteristic.

The trapping effect is observable in the temperature range of 240- 120 K for these proton irradiated samples, but **application of the simple recombination-trapping model** is complicated due to the quite abrupt lifetime changes in its temperature dependency.

Technological potential

The temperature dependent trapping effect is inherent for all the irradiated samples, irrespective of TD treatment $\rightarrow$ is dominant the interaction between oxygen and the radiation defects in TD transformations?
The post-irradiation history of lifetime variations would enable to reveal these TD transformations.

The MWA photo-response decay controller, the "τ-meter", allows a non-invasive monitoring of the trapping -recombination processes.

Thank you for your attention