Investigation of fluence–dependent lifetime variations in proton and neutron highly irradiated Si

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Outline

- Motivation
- Fluence and heat-treatment dependent lifetime variations
- Characteristics of lifetime cross-sectional profiles
- Summary

Motivation of investigation

- Direct measurements of recombination lifetime:
  - MWR transients,
  - combined investigations of MWR and DG,
  - comparison between neutron and proton irradiated materials
- Control of possible anneal of defects and of behavior of the capture centers
- Cross-sectional scans within wafer depth

Measurement techniques and instruments

Microwave probed photoconductivity (MW-PCD)

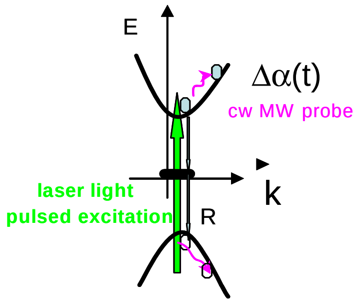
in MW reflection mode (MWR)

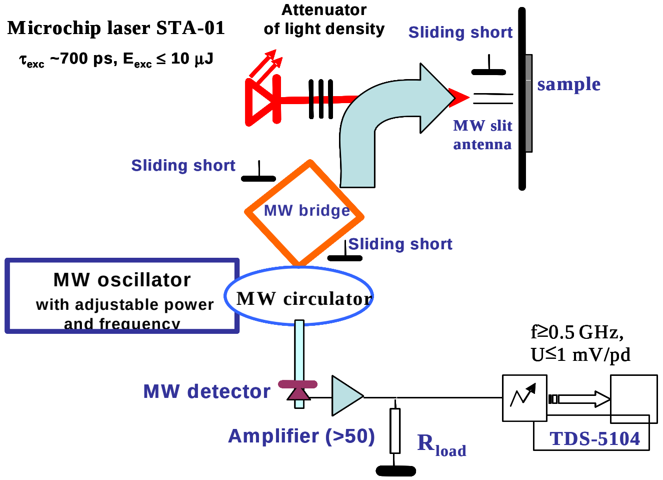
MWR $\lambda > 100 \mu m \Rightarrow \alpha_0 = (4\pi / c \sqrt{\varepsilon}) \sigma_{dc}$,

transient:

$$\Delta\alpha(t) \propto \Delta\,\sigma(t) \propto \mu_{FC}\, n_{exFC}\,(t)$$

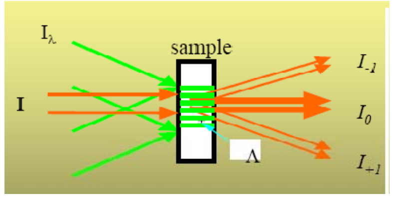
E.Gaubas. Lith. J. Phys., 43 (2003) 145.



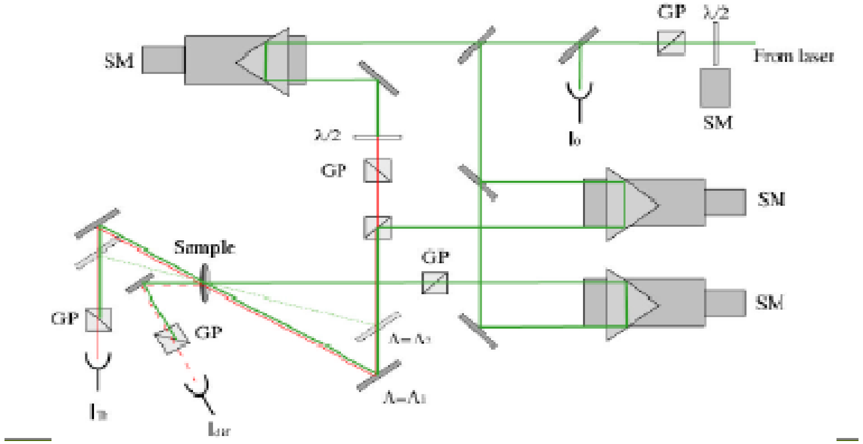


The microwave probed photoconductivity (MW-PCD) technique is based on the direct measurements of the carrier decay transients by employing MW absorption by excess free carriers. Carriers are photoexcited by 1062 nm light generated by pulsed (700 ps) laser and probed by 22 GHz cw microwave probe.

Dynamic gratings (DG)

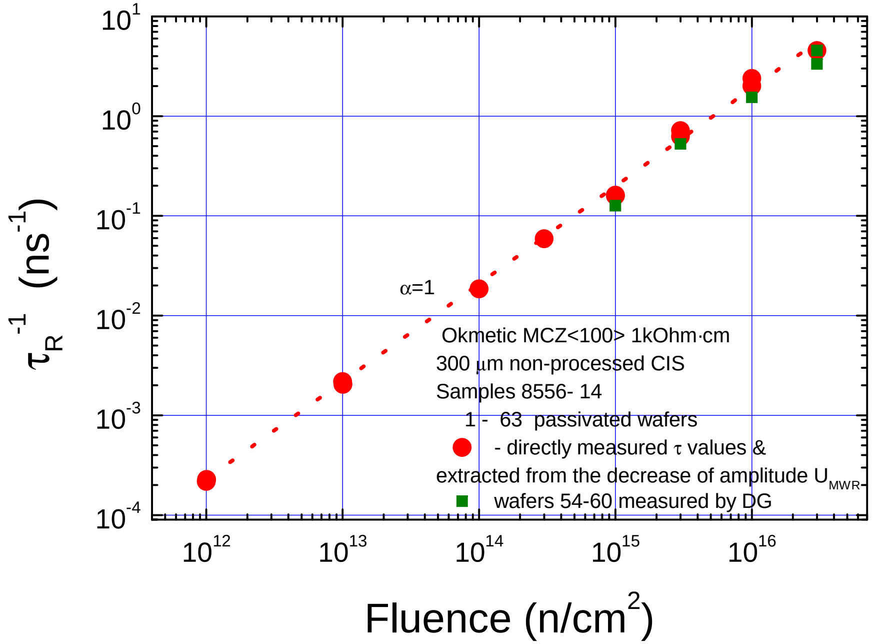


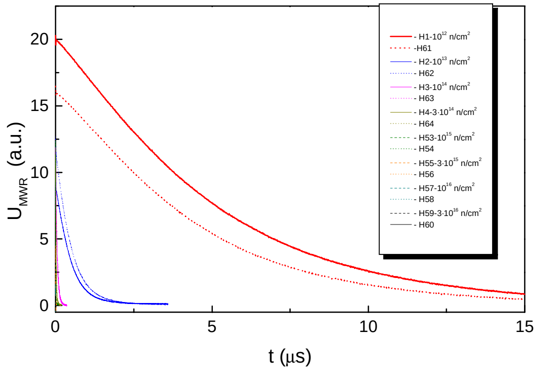
K.Jarasiunas, J.Vaitkus, E.Gaubas, et al. IEEE Journ. QE, QE-22, (1986) 1298.



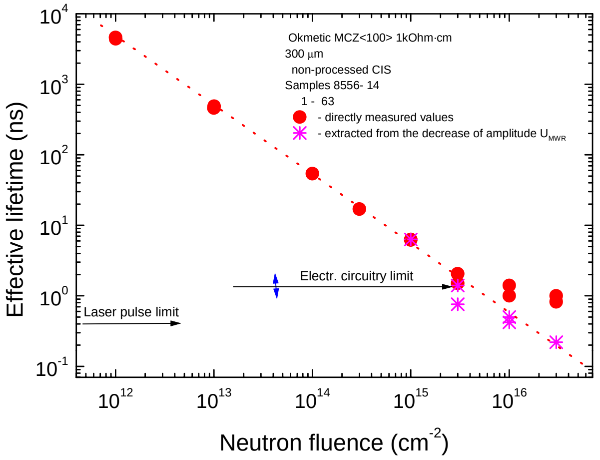
Diffraction efficiency ($\eta = I_{-1}/I_0$) on light induced dynamic grating is a measure $\eta \propto (\Delta N)^2$ of excess carrier density, while its variations in time $\eta(t) \propto \exp(-2t/\tau_G)$ by changing a grating spacing (Λ) enable one to evaluate directly the parameters of grating erase $1/\tau_G = 1/\tau_R + 1/\tau_D$ through carrier recombination (τ_R) and diffusion $\tau_D = \Lambda^2/(4\pi^2 D)$ with D as a carrier diffusion coefficient.

Direct measurements of recombination lifetime by MWR

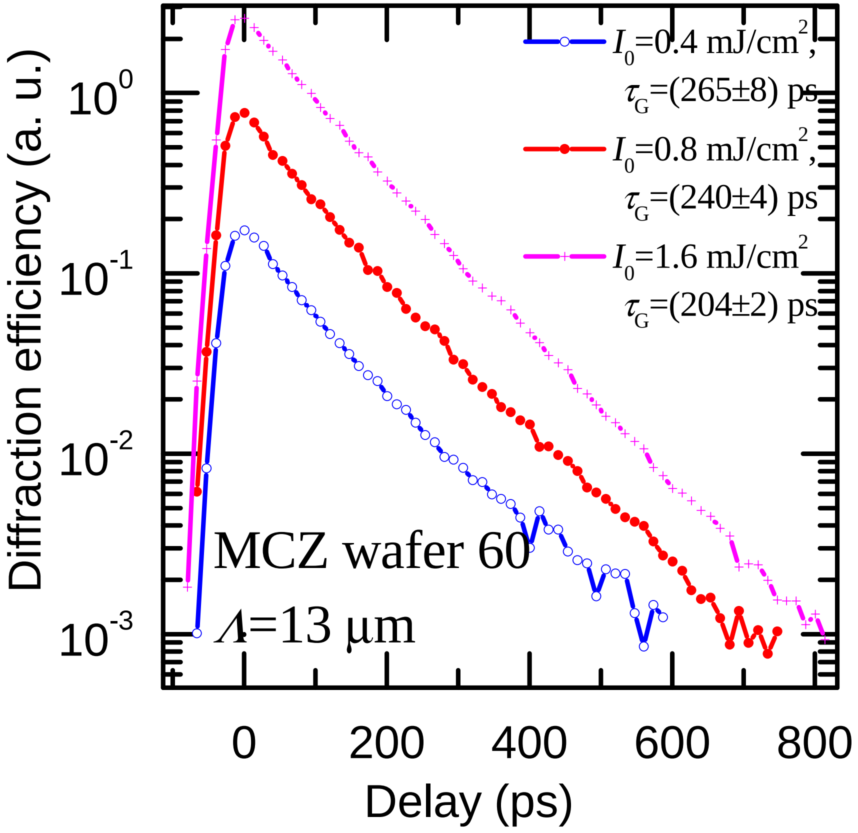




- $\tau_R \Leftarrow \Delta t|_{U\sim\ \exp(-1)}$
- $\tau_R \Leftarrow g_{exc}\tau_{Rs}/g_{exc}\tau_{RL}\ (U_{MWRs<2\ ns}/U_{MWRL>5\ ns})$



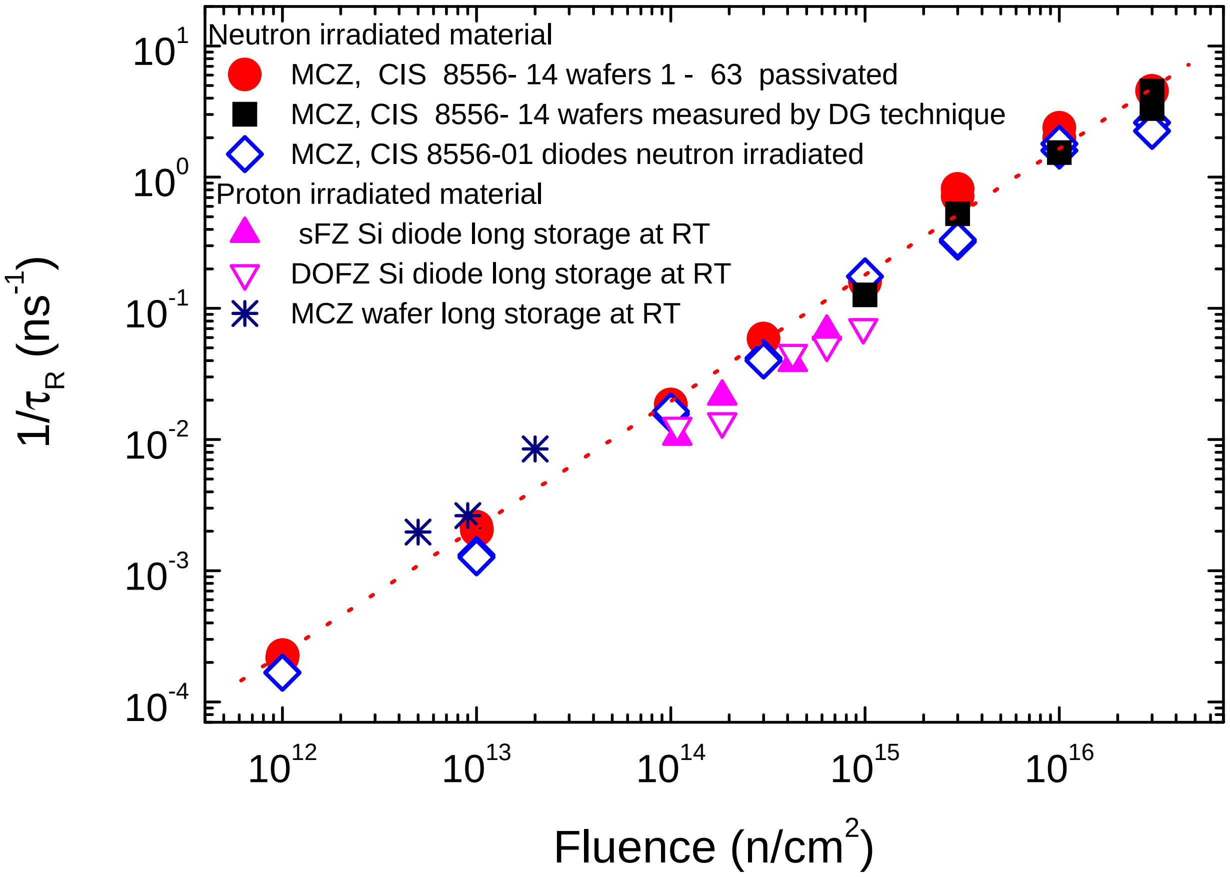
Direct measurements of recombination lifetime by DG



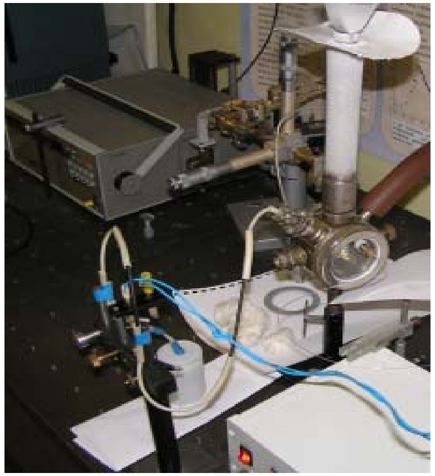
$3{\cdot}10^{16}$ n/cm^2

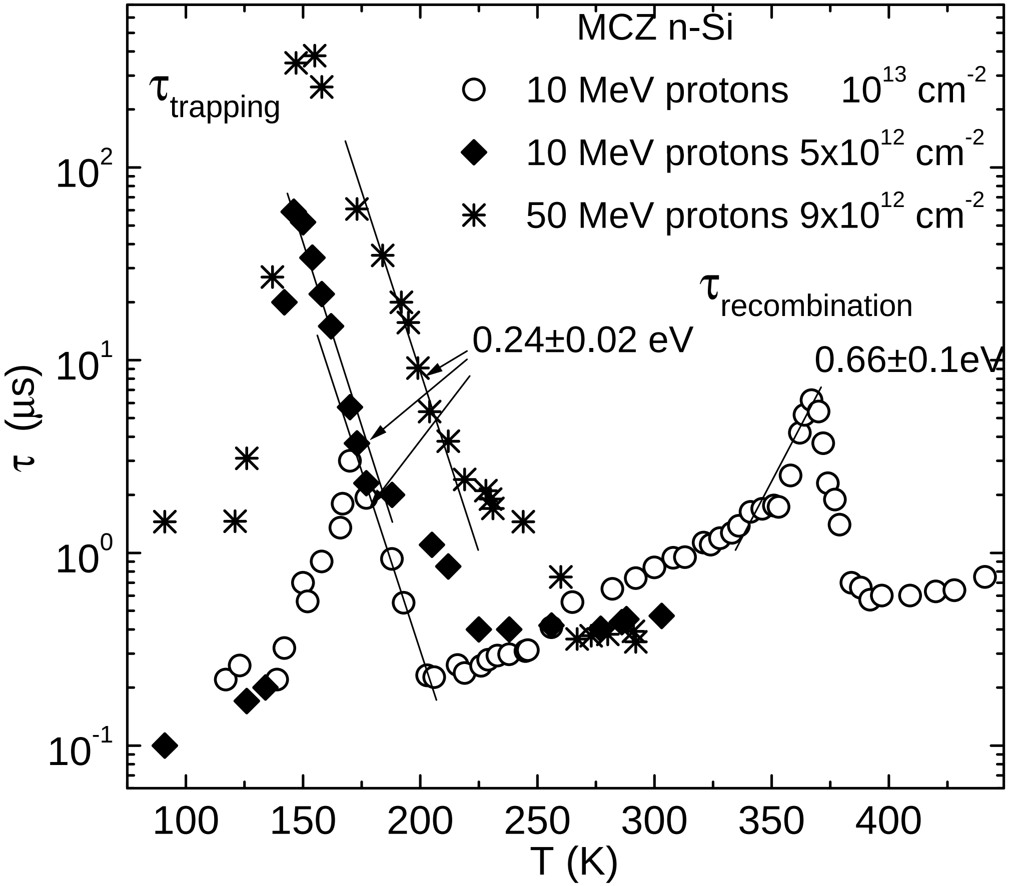
D (cm^2/s)	τ_R (ps)
15.4±0.4	220±3

Recombination lifetime in wafer and diode samples of various technology irradiated by neutrons and protons

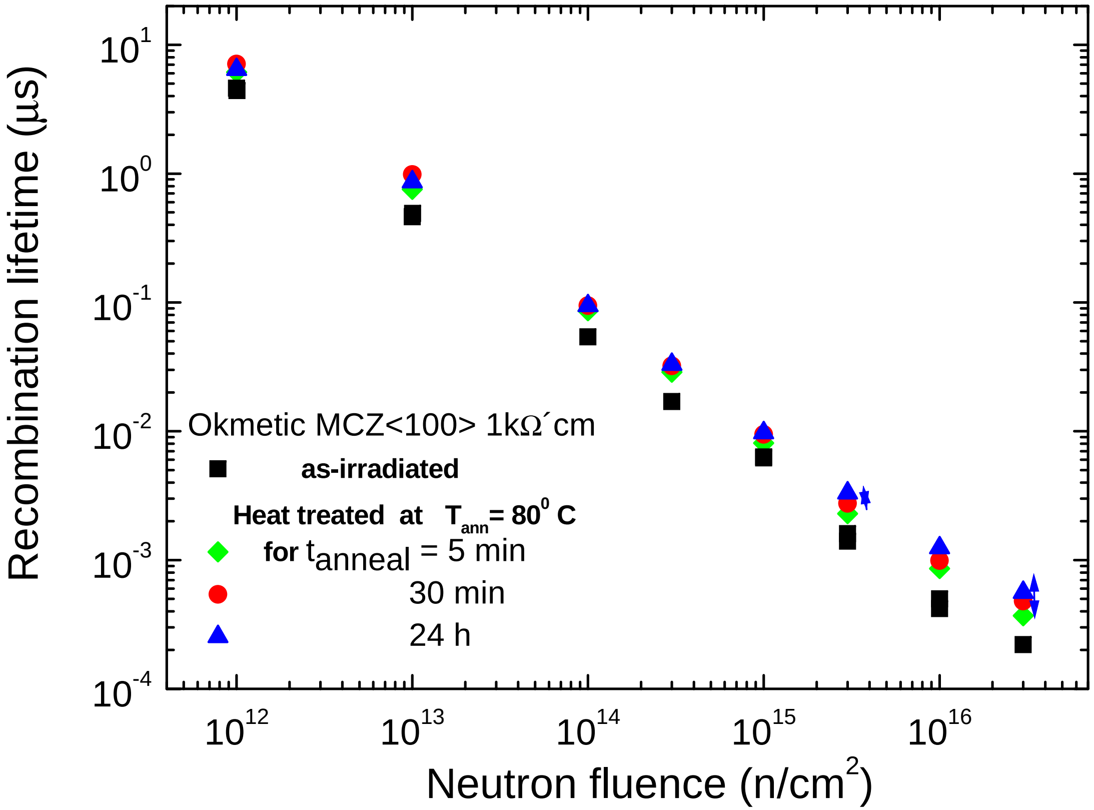


Temperature variations of recombination and trapping lifetime in MCZ Si irradiated by protons



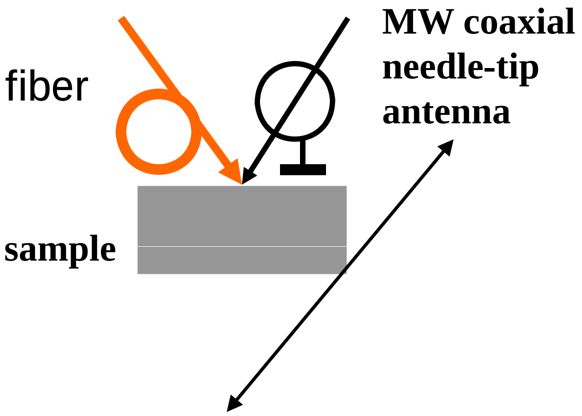


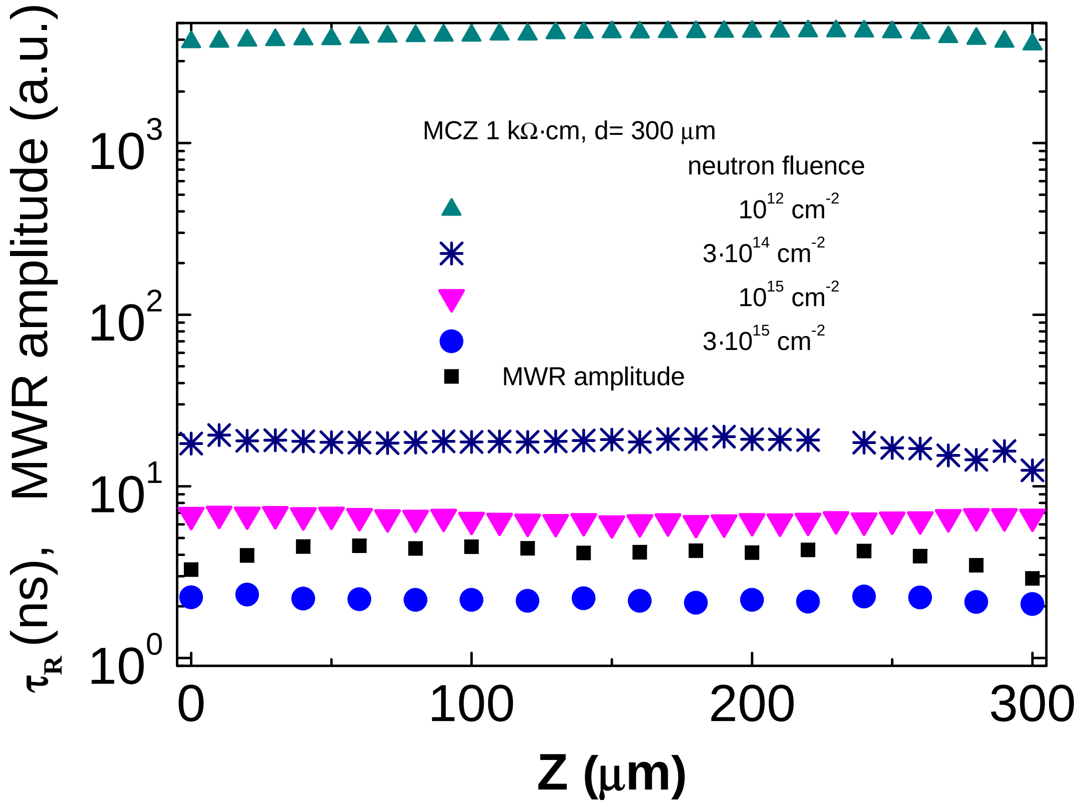
Lifetime under heat treatments at 80C for 5 min, 30 min and 24 h



Lifetime variation with neutron irradiation fluence in MCZ Si wafers for the as-received and heat treated material

Cross-sectional scans within wafer depth





SUMMARY

- ***Lifetime decreases nearly linearily from few μs to about of 200 ps with enhancement of neutron irradiation fluence ranging from 10^{12} to $3\cdot10^{16}$ n/cm^2, as measured directly by exploiting microwave probed photoconductivity transients and verified by dynamic grating technique.***

- ***Lifetime values are nearly the same for wafer and diode samples in neutron irradiated material for as received samples.***

- ***Values o f recombination lifetime are close for neutron and proton irradiated samples for materials of various technology***

- ***Behavior of dominant capture centers varies with temperature***

- ***Small increase of lifetime values under annealing can be implied in neutron irradiated material***

- ***Lifetime values are nearly invariable within wafer thickness, as determined from the lifetime cross-sectional scans within wafer depth.***

Thank You for attention !