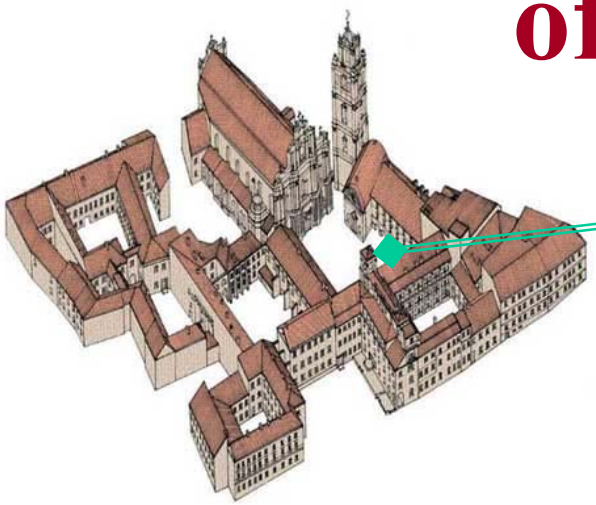
Properties of irradiated SI-GaN and activation-modification of defects in SiC



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Outline:

1. GaN samples properties after x-ray irradiation (~600 Mrad of 10 keV x-rays at IC facility) and neutron irradiation (5.10^{14} cm^{-2} Flux of fast neutrons (E > 100 keV) up to 5E12 $n/cm^2/s$ at Ljubljana facility)
2. Detector performance when observing alpha particles detection.
3. Electric properties.
4. Conclusion concerning GaN

5. Non-equilibrium conductivity in SiC crystals.
6. Non-equilibrium defects in SiC crystals.

Alpha pulse (Am^{241}) height spectra calibration for 2 μm GaN

The SRIM [J.F. Zeigler, J.P. Biersack, IBM-Research, YH, NY, USA, 1996] code was used to calculate the Bragg curve for 5.48 MeV α particles in GaN.

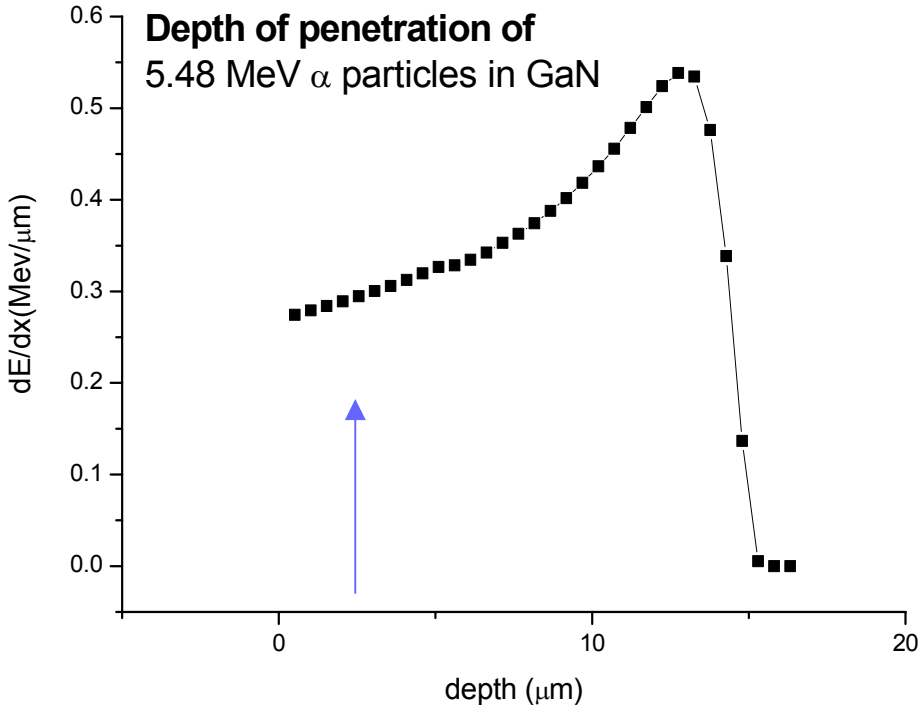
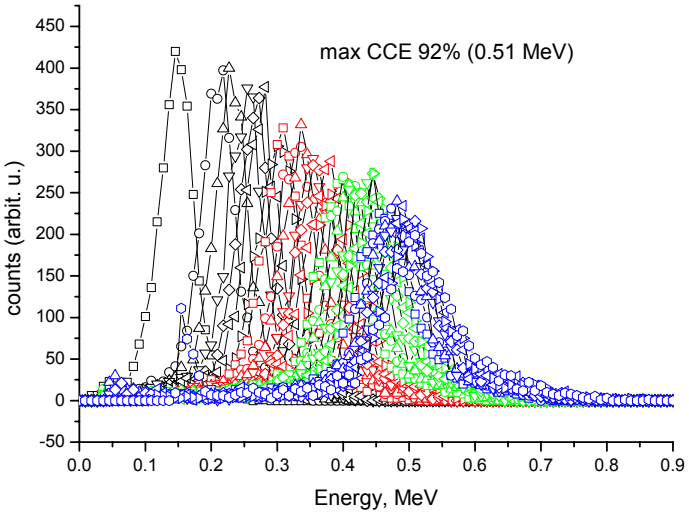
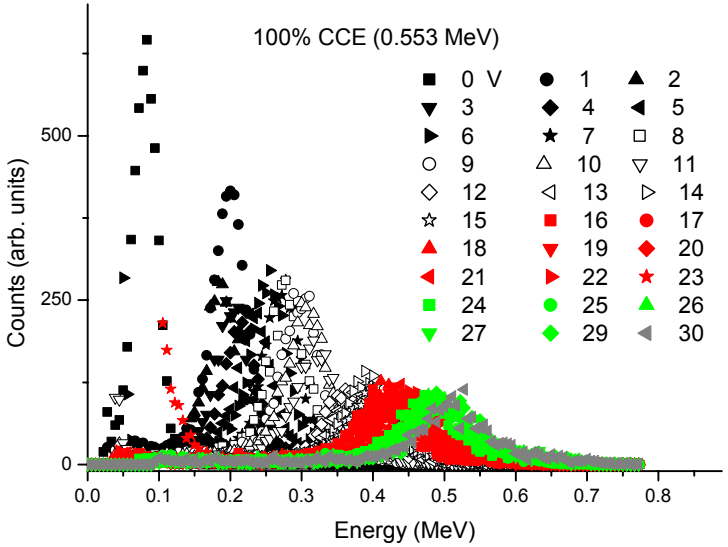


Figure: Energy loss curve for α particles in GaN

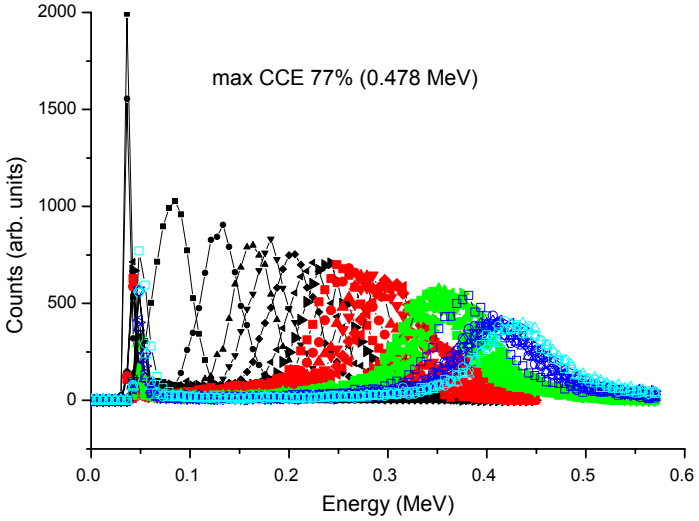
To calculate the amount of energy deposited in the 2 μm the curve was integrated to get the total energy deposited. Measured alpha spectra were converted to energy using a calibration scale based on a Si surface barrier diode assumed to have 100% CCE. This takes into account the different electron/hole pair creation energy 3.6 eV in Si and 8.9 eV in GaN. CCE was calculated as a ratio of the energy detected and the calculated energy deposited in the detecting layer.

α detection in GaN





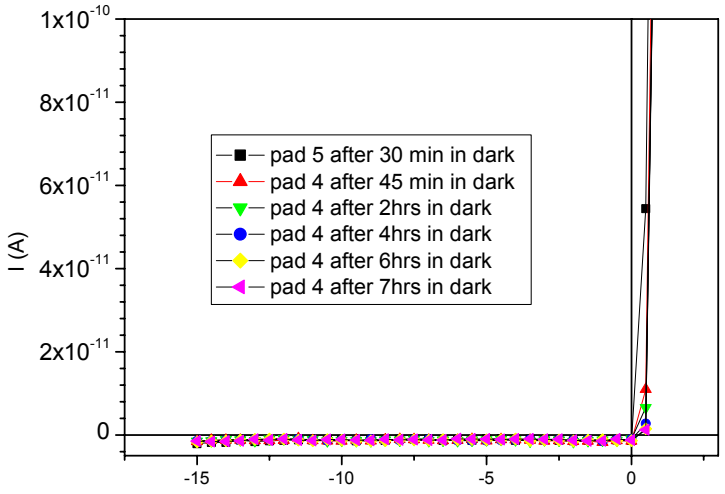
Non-irradiated



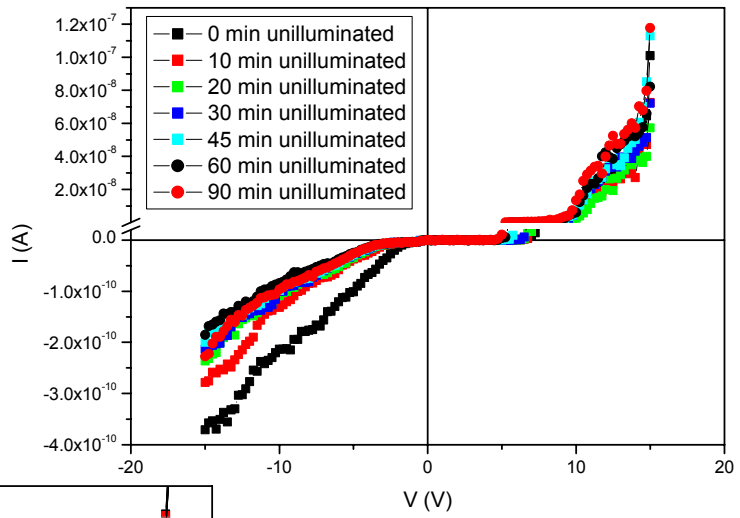
Irradiated by **X- rays**

Irradiated by **neutrons**

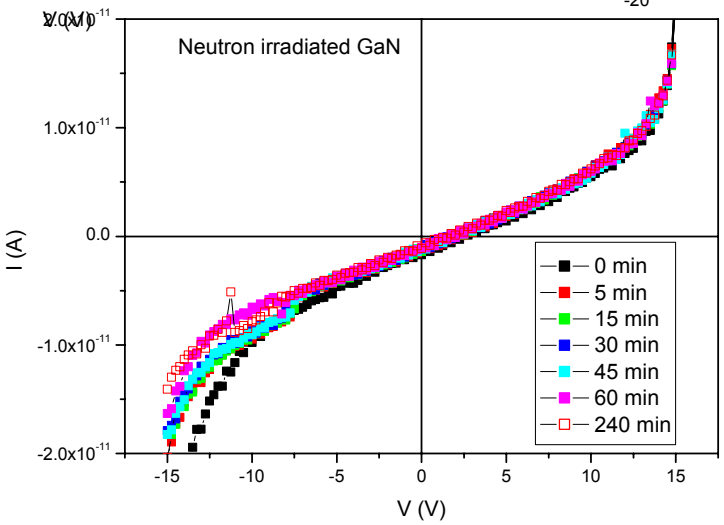
GaN I-V



Non-irradiated

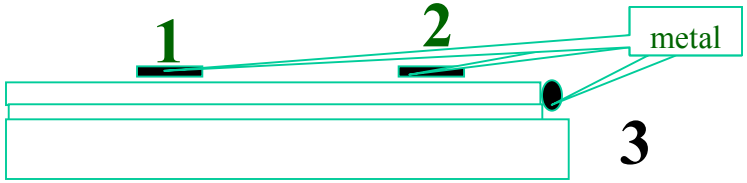


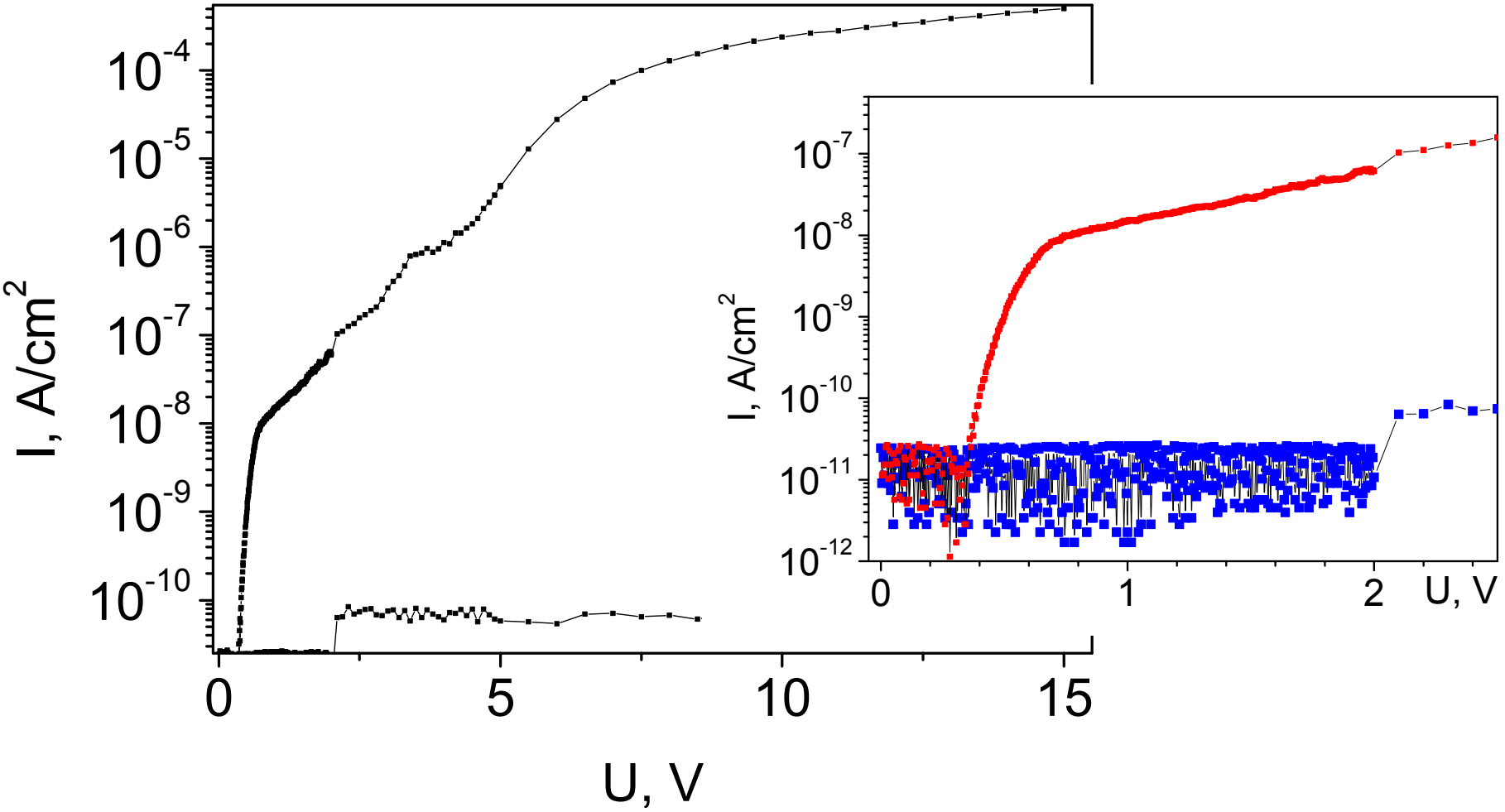
Irradiated by **X- rays**



Irradiated by **neutrons**

The sample was biased between the contacts “1” and “3” for I-V and between “1” and “2” for c.c.e.

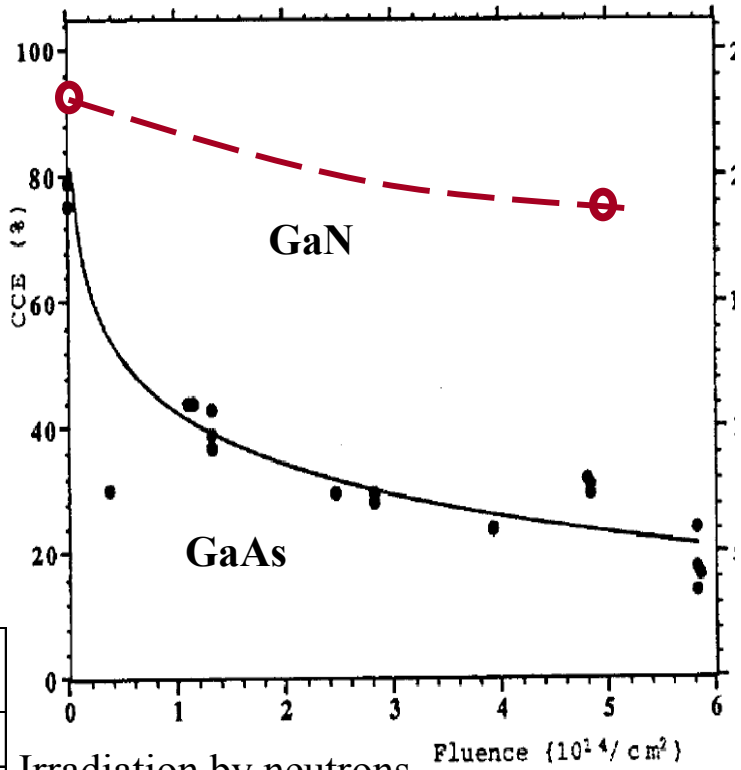




Conclusions for GaN

1.

SI- GaN	Energy /fluence	c.c.e.
nonirradiated		**92 %**
Irradiated by X-rays	10 keV / 600 Mrad	**100 %**
Irradiated by neutrons	> 100 keV / 5 10^{14} cm^{-2}	**77 %**



Irradiation by neutrons

2. A main actuality: to grow a thick SI-GaN !!!

SiC

Remarks:

1. Material is promising but has a complicated structure of defects.
2. The traditional characteristics seems can fit to a model of simple semiconductor but a few peculiarities can be mentioned and are in contrary to classical material (polarisation effects, …).

Aim of further presentation is to pay attention on :

1. the peculiarities of the simple non-equilibrium conductivity effects;
2. The modification of defects stimulated by recombination of carriers.

Effects

Photo-current dependence on temperature:

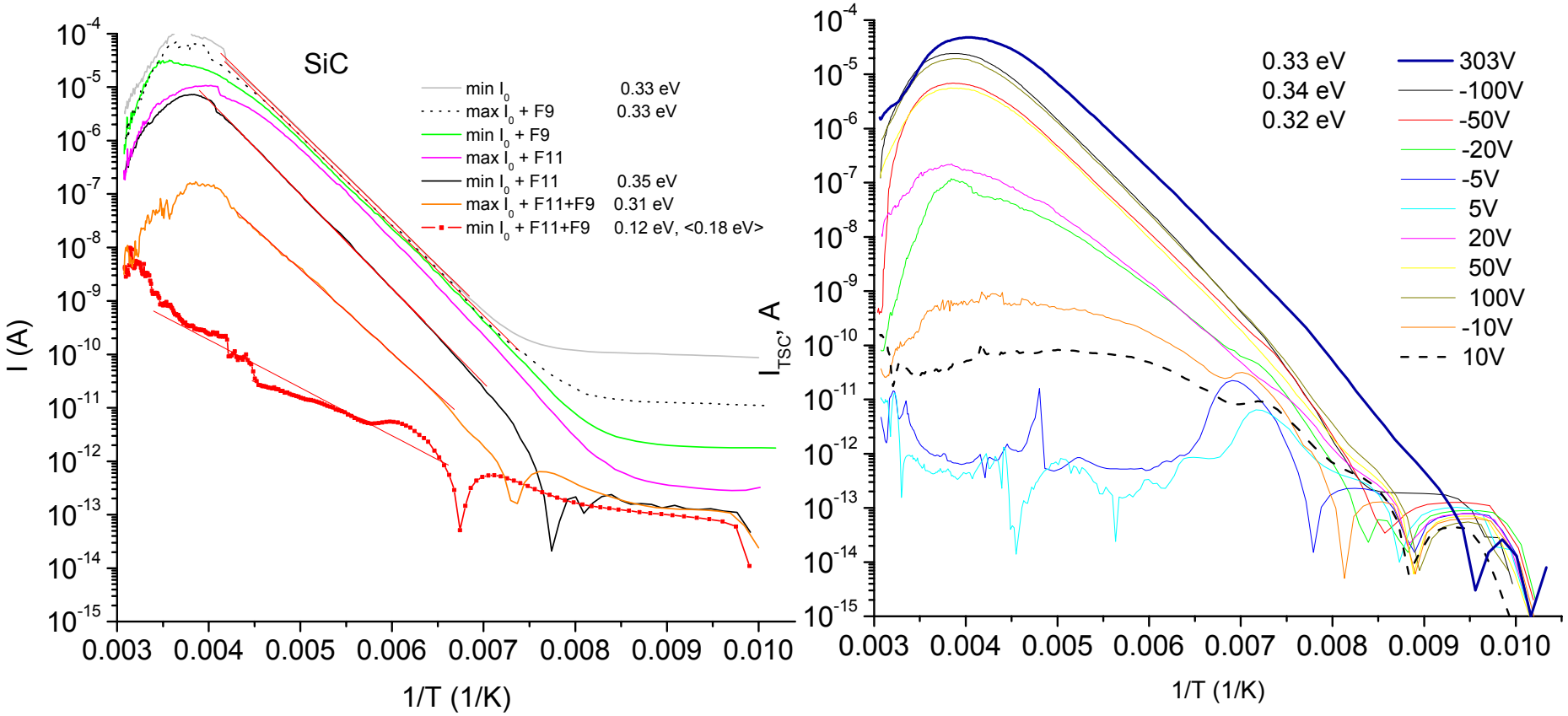
carrier concentration is constant, on temperature depend their mobility (slightly) and lifetime **(if exist a competition between the recombination centres or "works" SRH model, a change can be significant)**

Thermally stimulated conductivity:

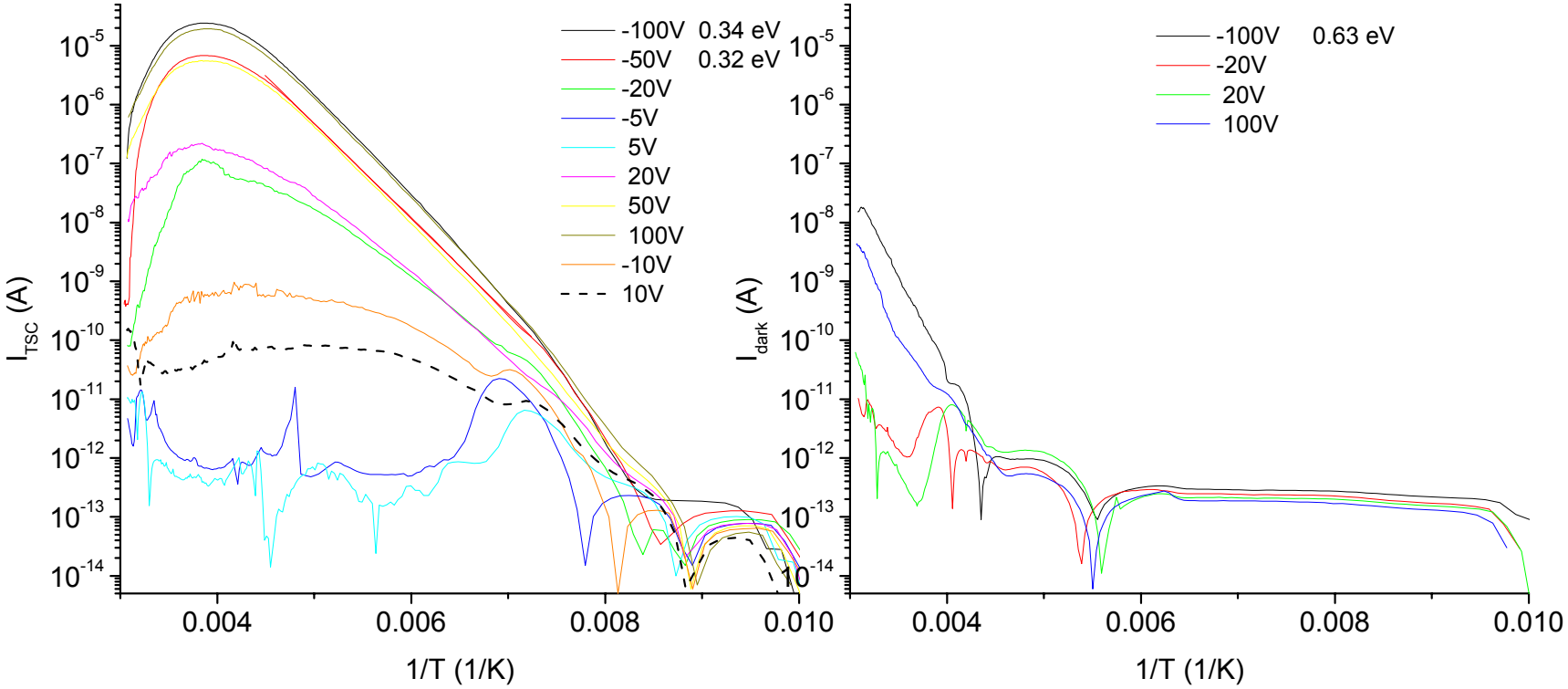
carrier concentration depends on thermal activation and recombination.

But in a "normal" SiC the polarisation effects and different deviations from the classical models were observed that follows:

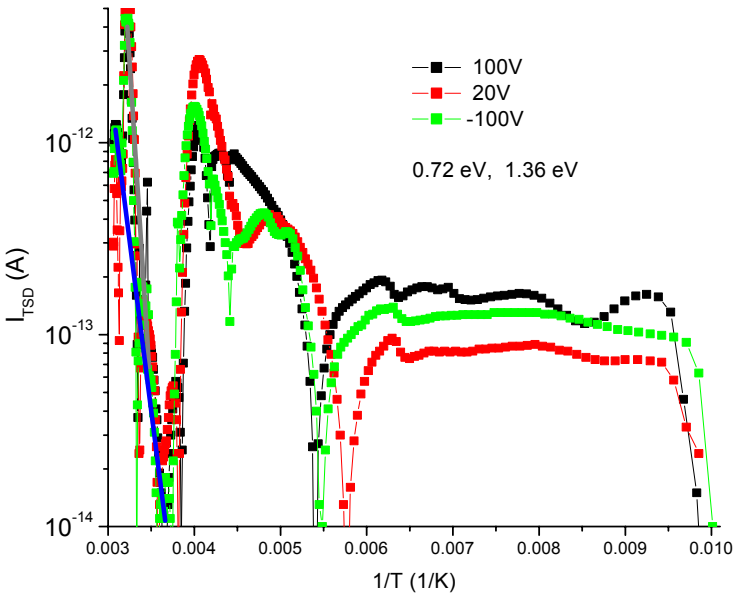
I_{photo} & TSC in SiC

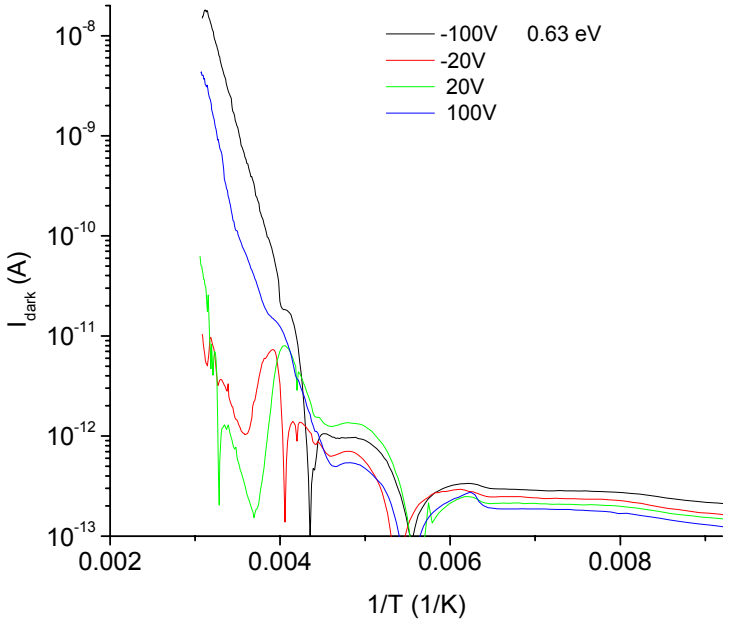


Thermally stimulated and dark current dependencies on temperature



TS Depolarisation Current and I_{dark}





Proposition:

all these peculiarities are related with a crystal micro-inhomogeneity, and the microinhomogeneities cause a percolation conductivity possibilities and a great role of drift barriers.

A related problem: DEGRADATION PHENOMENON

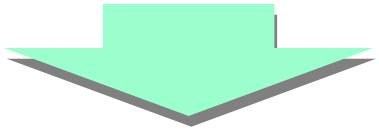
Questions: Why and how does a degradation is going?

Some answers gave the investigations of 4H-SiC diodes but effects can be existing after irradiation by highly ionizing particle

Advanced methods were used in Stockholm

Investigation of defects by OPTICAL METHODS:

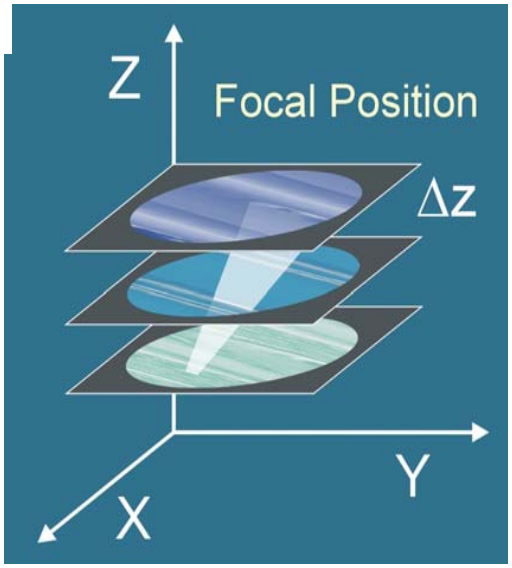
Optical microscopy with:

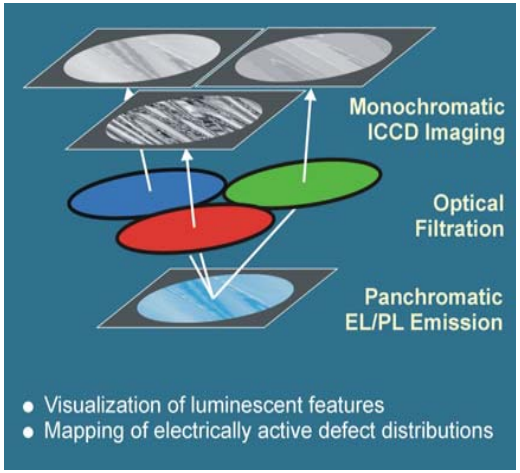


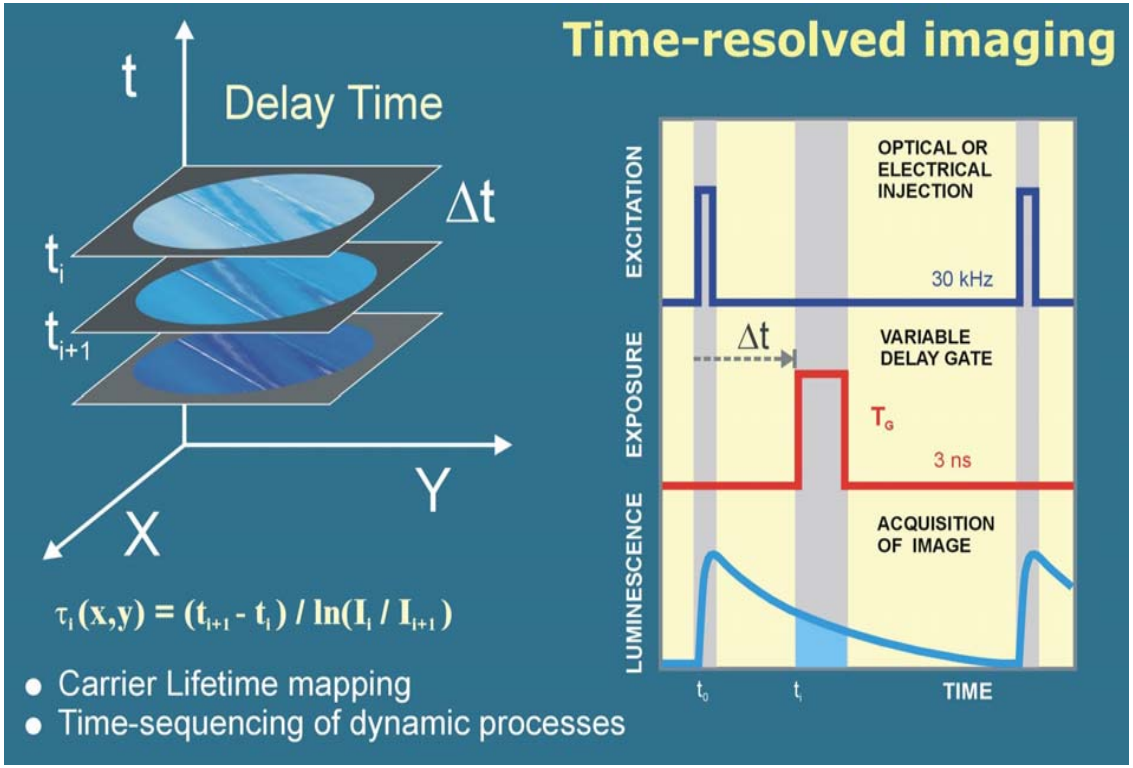
- **Spatial**
- **Spectral**
- **Time-resolved**

characterization of SiC material and operating devices

Experimental

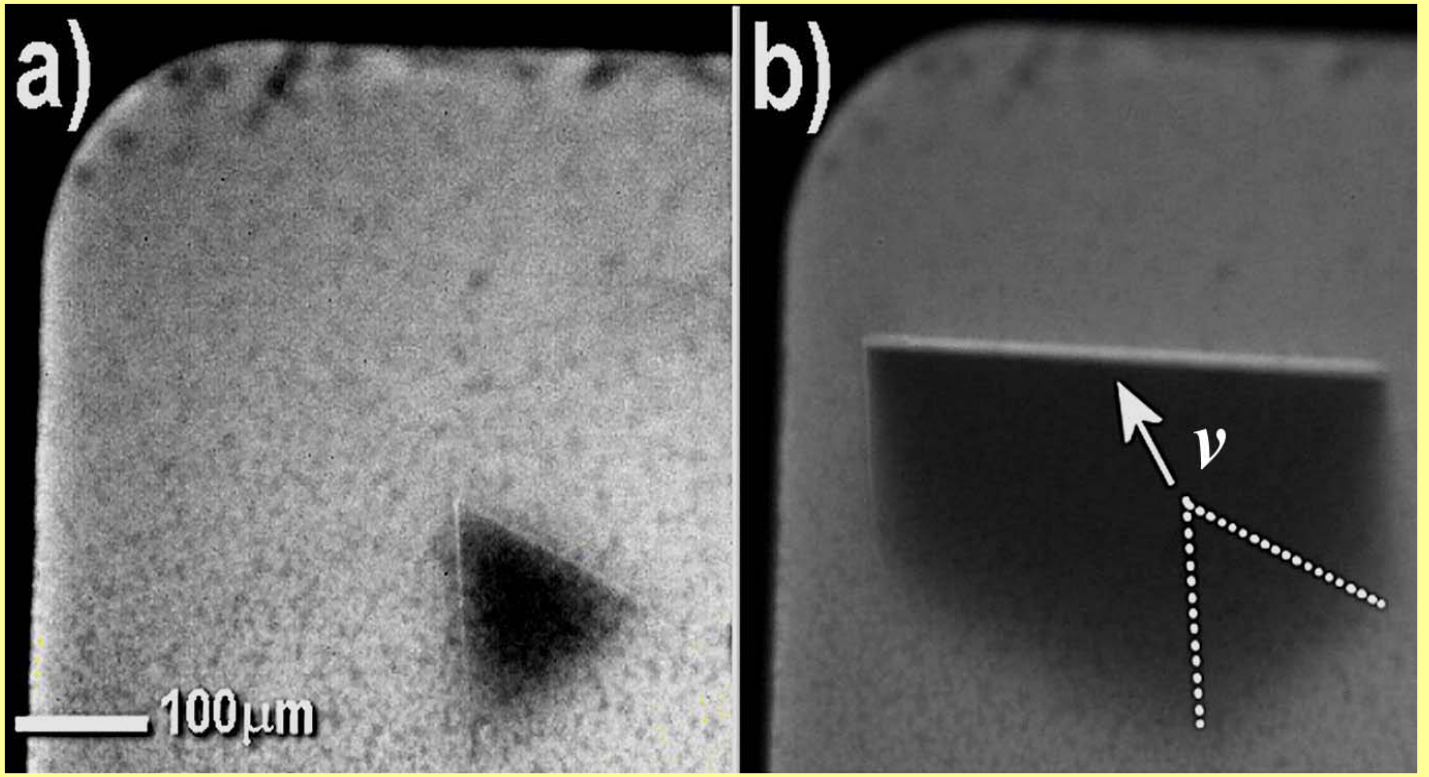






Degradation phenomenon

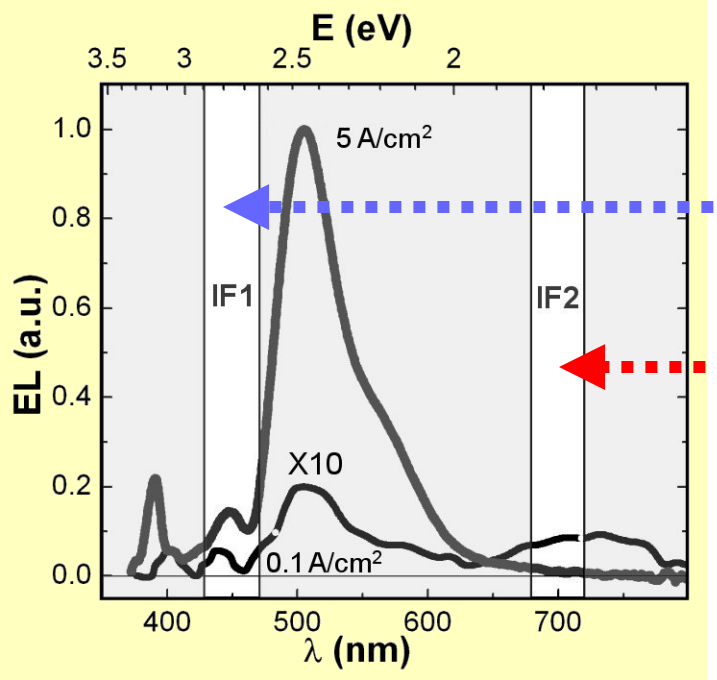
Preliminary Observations

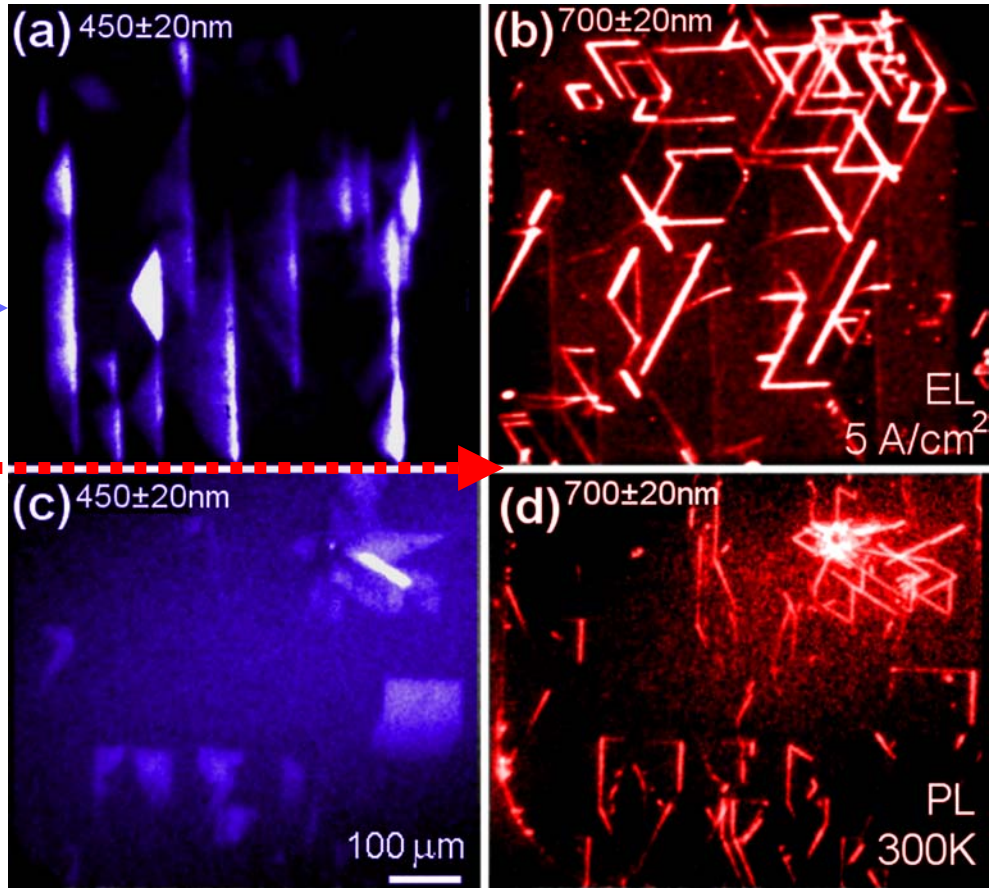


Rapid motion (v>50 mm/s) of partial dislocations (a) and formation of an extended SF defect (b)

Defect visualization

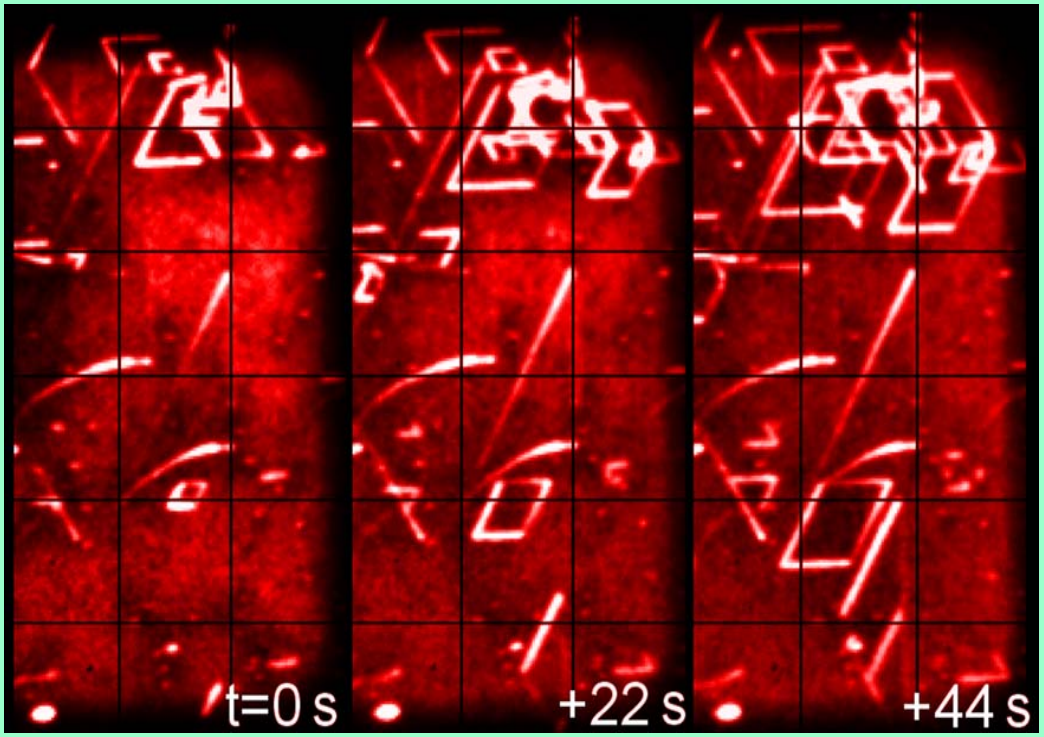
Spectrally selective EL/PL





- Stacking faults (SF)
- Bounding partial dislocations
- Screw and Edge threading dislocations

SEQUENTIAL IMAGING



- Tracking of individual dislocation partials
- Assessment of glide velocity versus T and J

Instead of conclusions:

1. Next steps:

I. Analyze of inhomogeneities and degradation process (including recombination enhanced phenomena) and possible situations in irradiated material .

II. Analyse of different non-equilibrium effects, including the recombination at a level of excitation similar to existing in a track of ionizing particle

2. Future of SiC: Defect engineering

- "Solution hardening" by *x*-dopant (e.g., Te in GaAs) ?
- Pinning of dislocations by extra impurities (e.g., +H "hydrogenation") ?
- Novel SiC material growth schemes: alternative planes, sandwiches ?

A main conclusion:

we depend on a success of GaN and SiC crystal growers !

Thank you for your attention !