Properties of 12 µm thick epitaxial GaN irradiated up to 10^{16} cm^{2} by 24 GeV protons

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If is GaN promising for high energy physics on a third year of analyze?

1. **Positive sides**:
   a) high density and high voltage breakdown semiconductor,
   b) chemically quite passive,
   c) fast developing technology,
   d) rather good radiation hardness: C.C.E. = ~ 30 % in irradiated up to 1.15 10^{16} protons/cm^{-2} (*James Grant talk*.)

2. **Negative sides**:
   a) high scale applications in optoelectronics – no interest of crystal growers to perform material processing research;
   b) Today semi-insulating crystal growth technology induces the various structural defects, mostly related with the growth conditions.

Remark. A test: how long did it take an improvement of Si, SiC and other ionizing partcle detector semiconductors?

Then once more: If is GaN promising for high energy physics on third year of analyse?

Correction of the question:

a) For which experiment the promises foreseen?

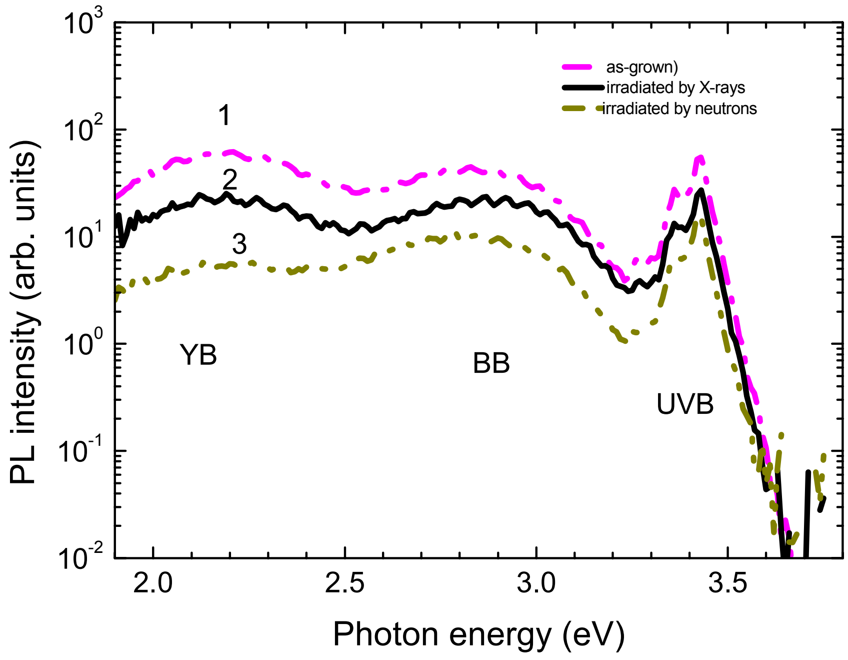
Answer (probably realistic): many doubts if to discuss a nearest upgrade of LHC experiments (previous slide, p.2a), maybe for the special detectors.

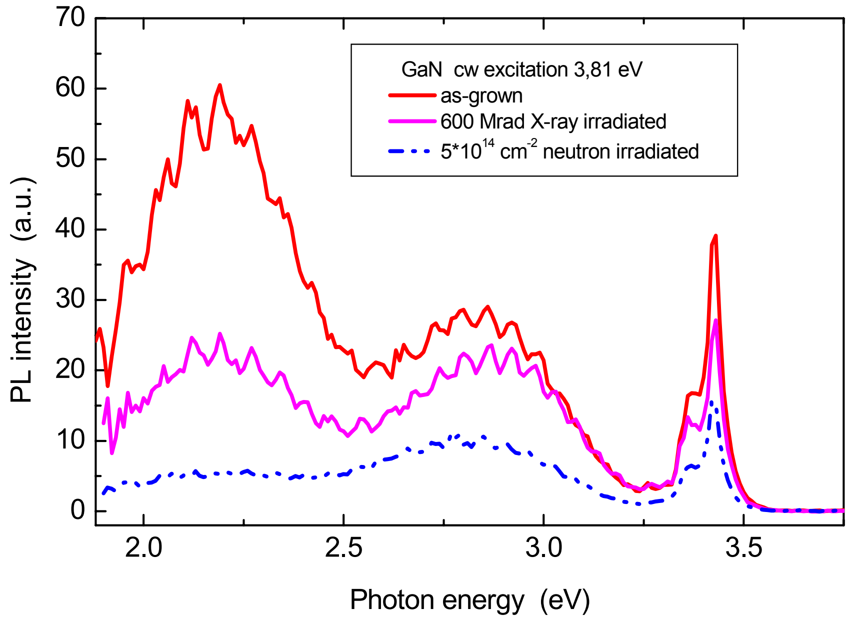
Answer (too optimistic): there are the predictions to improve the crystal structure by modified growth technique and the SI-GaN could became cost effective and have improved properties.

It is more attractive to be too optimistic, but this talk presents the current status in the investigation of irradiated epi-layers of thicker GaN tha it was done before:

- Luminescence spectra
- Electrical properties;
- Non-equilibrium photoconductivity

Photoluminescence
("thin" samples)

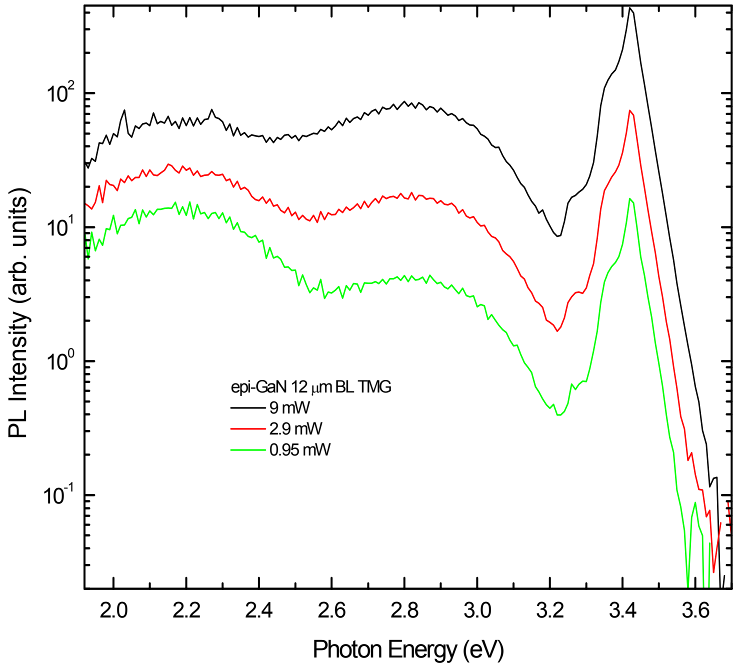


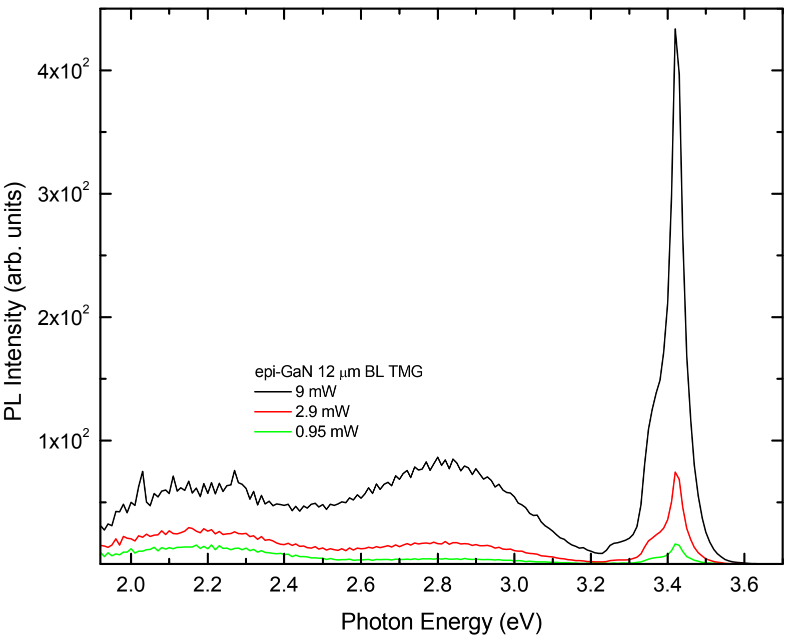


The native defects concentration estimated in* 2.5 μm thick layer *from the luminescence spectra dynamics with the excitation density:

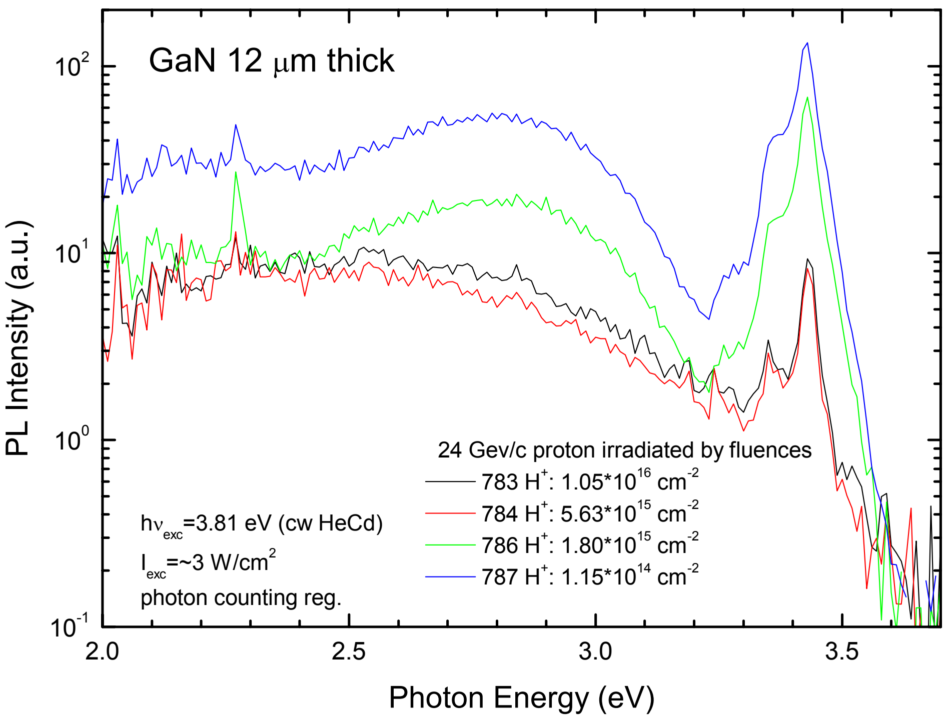
"yellow" trap (point defects V_{Ga}) : $N_Y < 10^{15}$ cm^{-3}, "blue" levels (dislocation-related): $N_B \geq 10^{18}$ cm^{-3}.

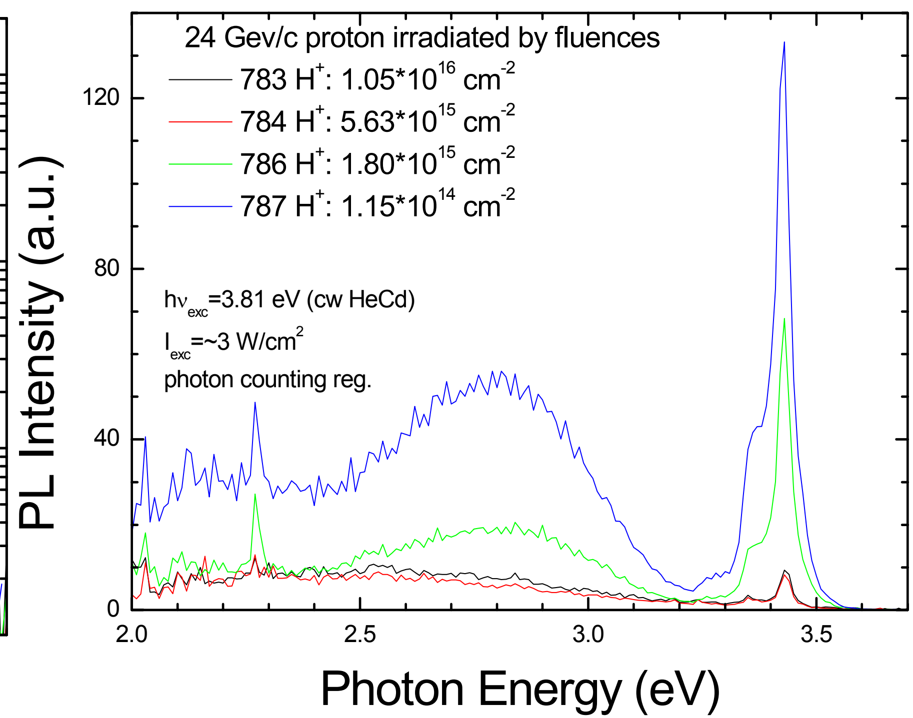
12 μm MOCVD BL GaN



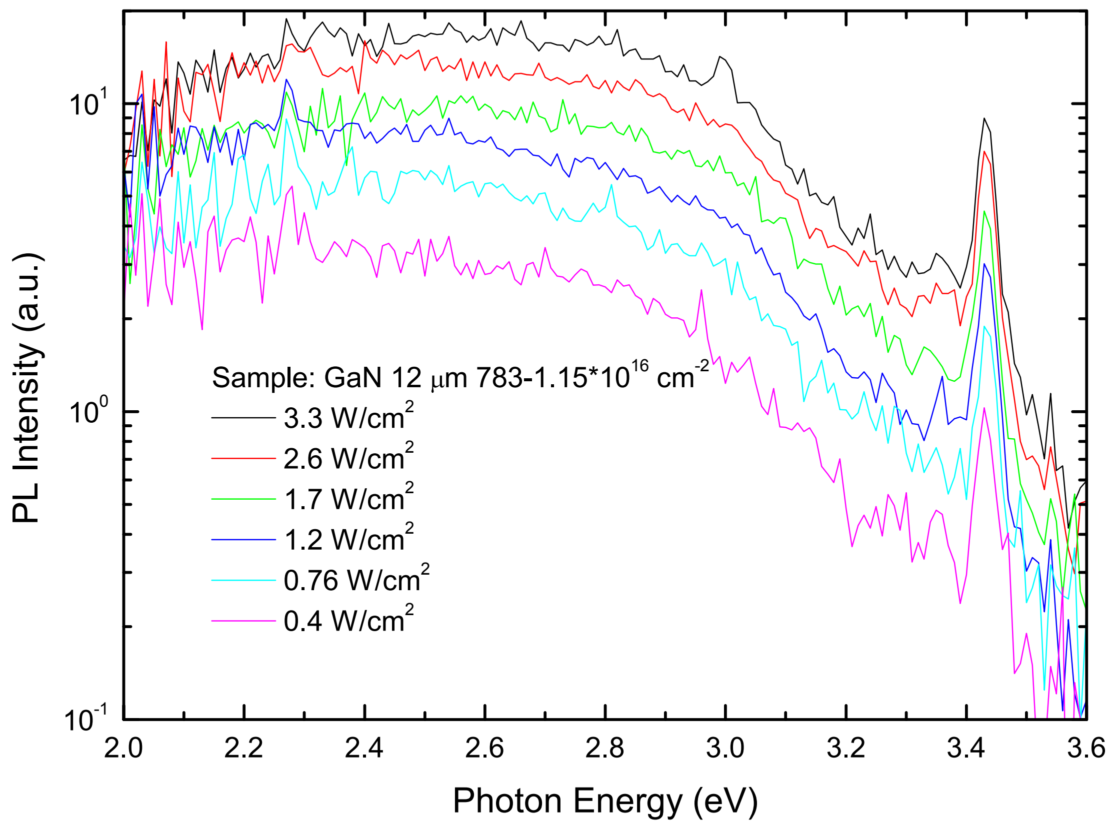


Irradiated 12 μm thick GaN



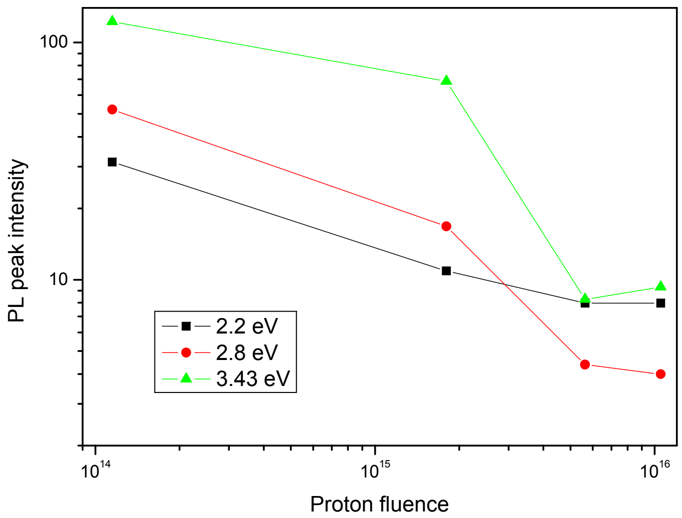


PL Intensity dependence

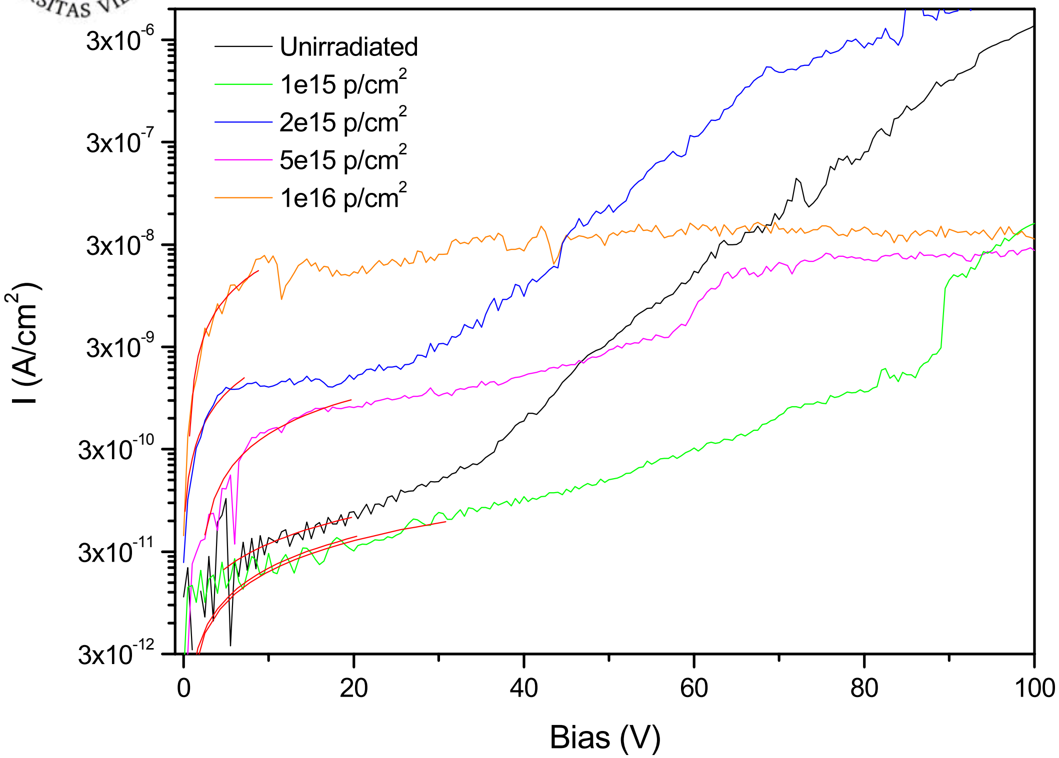


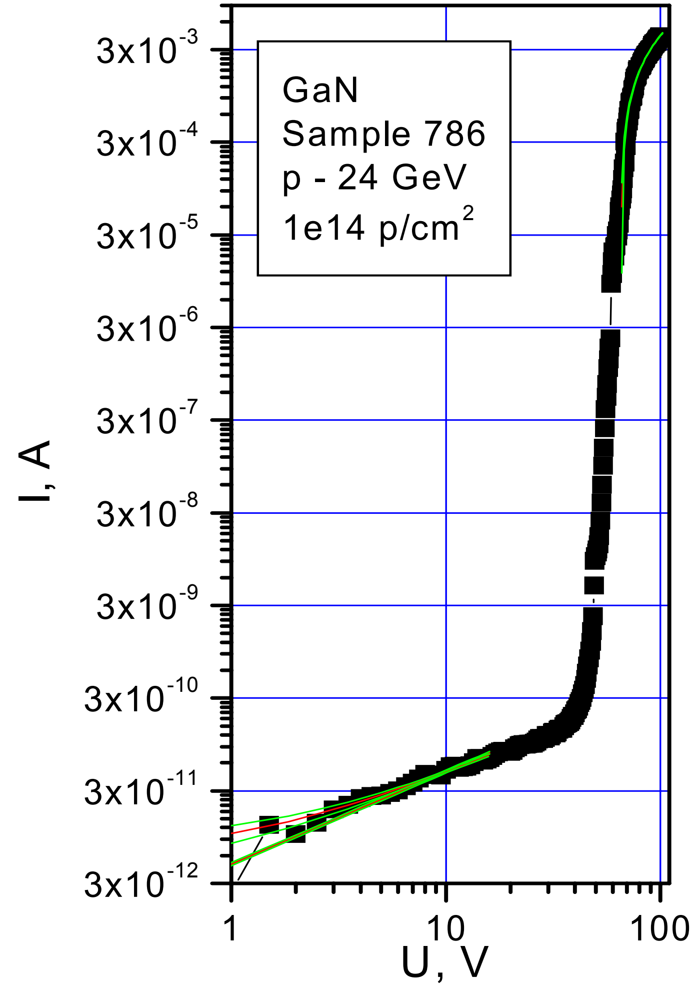
Conclusions from photoluminescence (PL) spectra

- Increase of epi-layer thickness from 2.5 μm → 12 μm - improves the epi-layer quality;
- Irradiation introduces non-radiative centre of recombination, because all PL bands intensity decrease
- Irradiation effect gradually depend on fluence



I-V





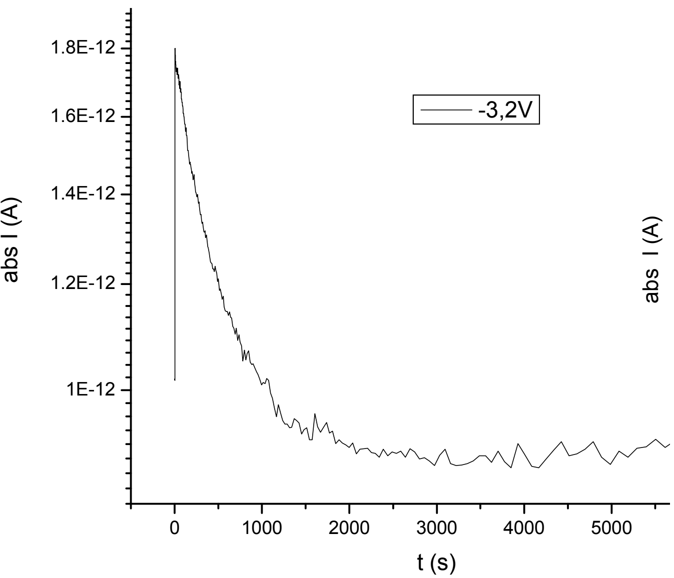
At low bias dark current liner depend on bias – *the red lines linear dependence fit.*

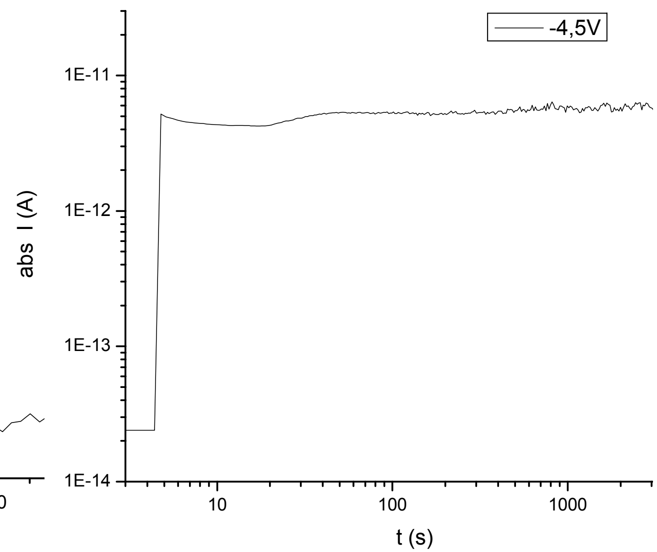
Space charge limited current characteristics was observed in the sample irradiated up to 1e14 p/cm2

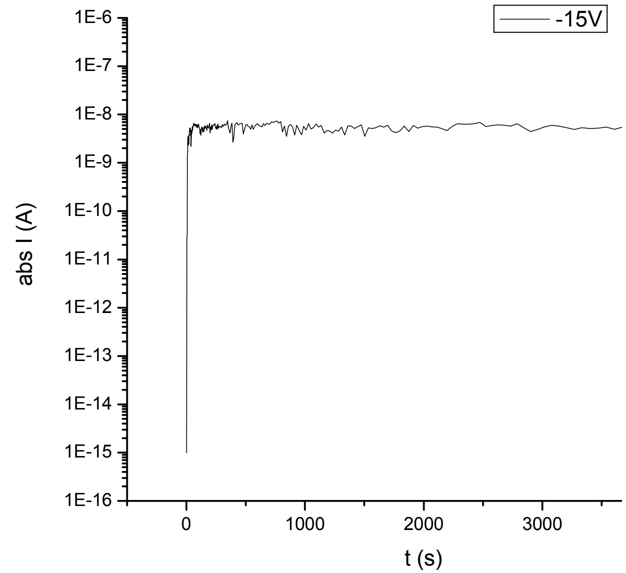
Main conclusion: irradiation induce defects in the contact region and in the bulk. The microingomogeneities in the contact region and redistribution of electric field due to the defects in the bulk cause complicated change of I-V shape

I(t) in the Sample irradiated up to fluence 5.63 10^{15} cm^{-2})

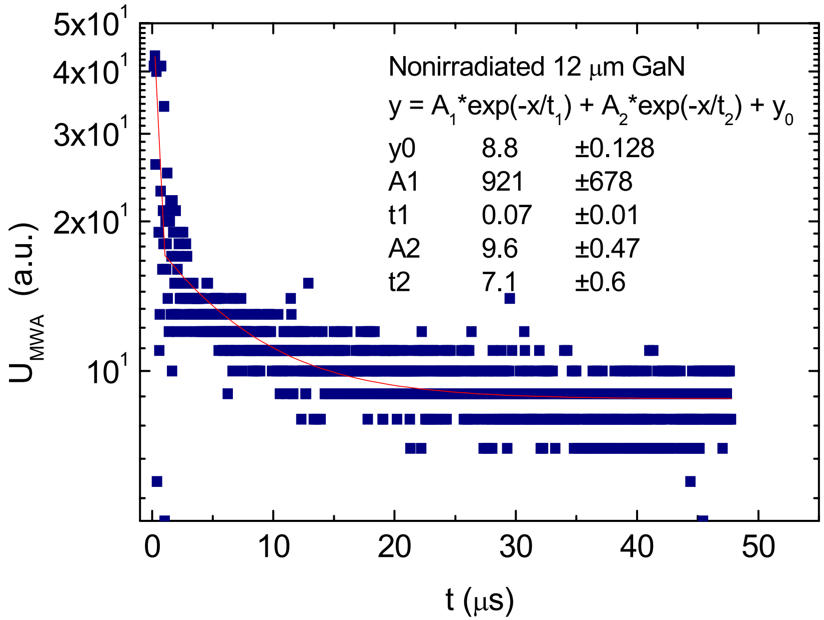
The different conditions in the sample illustrate the current time dependence.

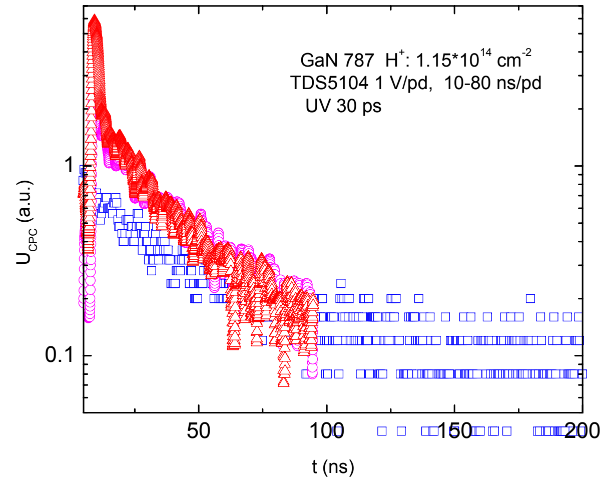






Photoresponse

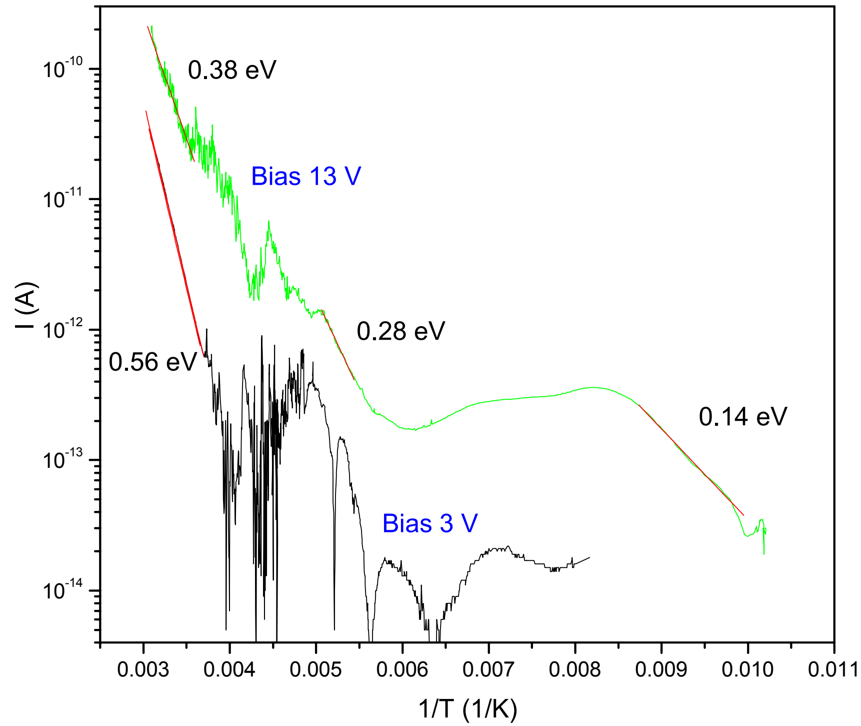




Non-irradiated GaN,		
Initial time constant		
	70 ns,	
asymptotic decay		
A_2	11	1
t_2	**7.08 μs**	1.07
A_3	3.8	0.3
t_3	**170 μs**	29
y_0	2.2	0.2

Sample	24 GeV/c H^+ (cm^{-2})	τ_{in} (ns)	τ_{as} (ns)
783	$1.05*10^{16}$	5.2	
784	$5.63*10^{15}$	4.4	13.8
786	$1.80*10^{15}$	5.0	25.9
787	$1.15*10^{14}$	2.7	50.0

TSC in the sample irradiated up to fluence 1.05 10^{16} cm^2



The characteristics measured at different bias additionally demonstrate the existance of instabilities related to the percolation through the inhomegenities in the sample. These inhomogeneities are similar as was observed in the thin samples and are related with the structural defects (influenced by irradiation).

Further analyze of defects structure and stability is planned!

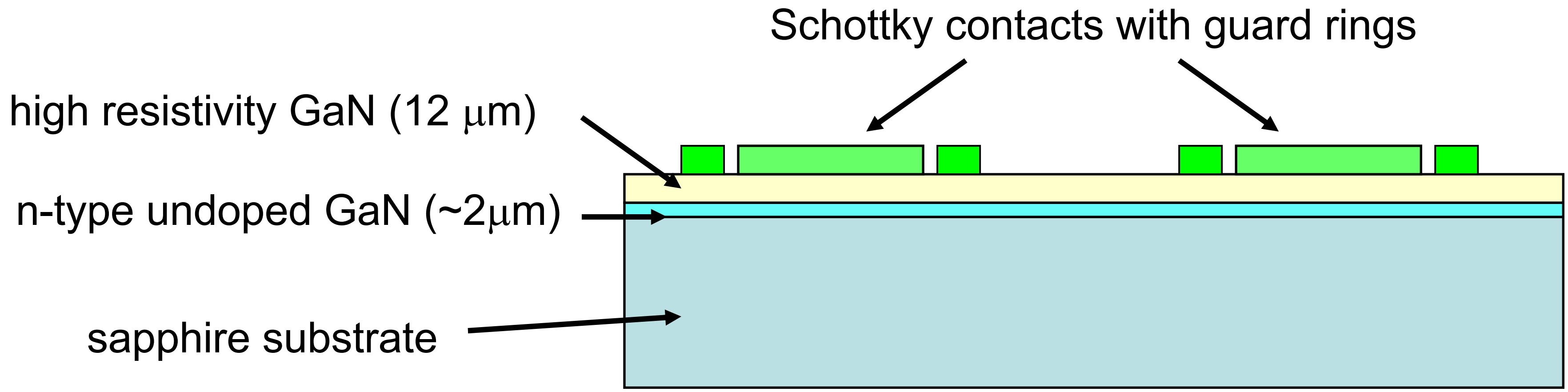
Conclusions

- Material improved, but it still is much to do (it is necessary to remove a defects related to the misfit of substrate and GaN lattice by a growth of SI-GaN on n*GaN).
- How this material works: next talk
- Characterization is in progress (Glasgow, Surrey, Vilnius)

Thank You for your attention!

Acknowledgement: This work was partly supported by Lithuanian Science and Study Foundation Program

Samples


Schottky contacts with guard rings
high resistivity GaN (12 μm)
n-type undoped GaN (~2μm)
sapphire substrate