I-V & CCE results of Neutron Irradiated GaN Detectors

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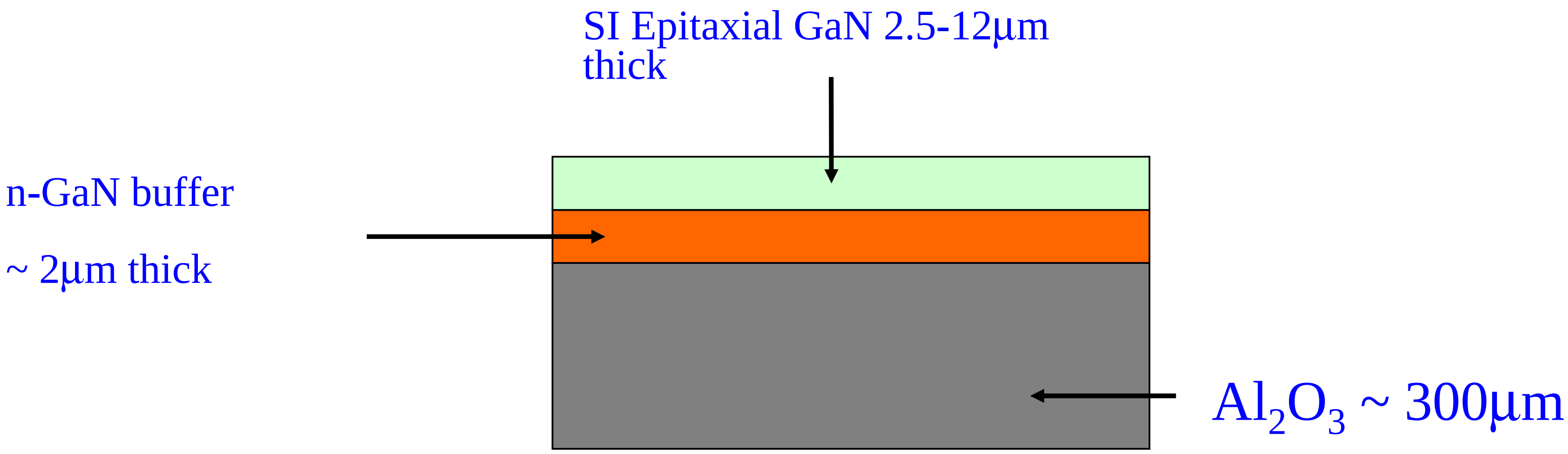
Outline

- Material studied
- Detector fabrication
- Detector characterisation
  - I-V & CCE measurements
- CCE experimental set-up
- Irradiations performed
- I-V & CCE results
- Inductively Coupled Plasma (ICP) etching of GaN
  - I-V, C-V and CCE results
- Conclusions & work in progress

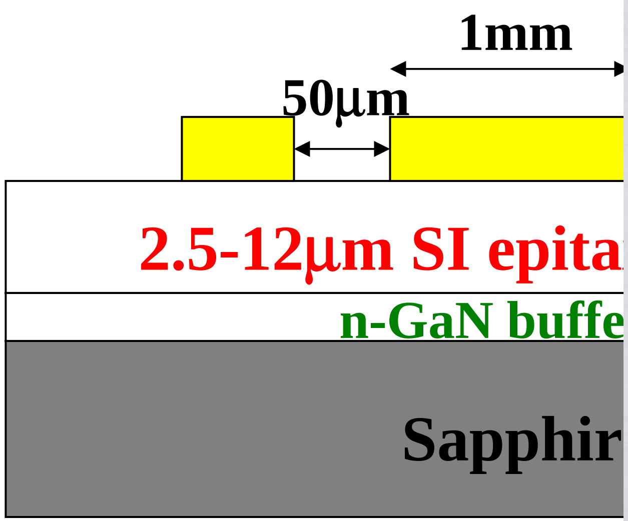
GaN Material Studied

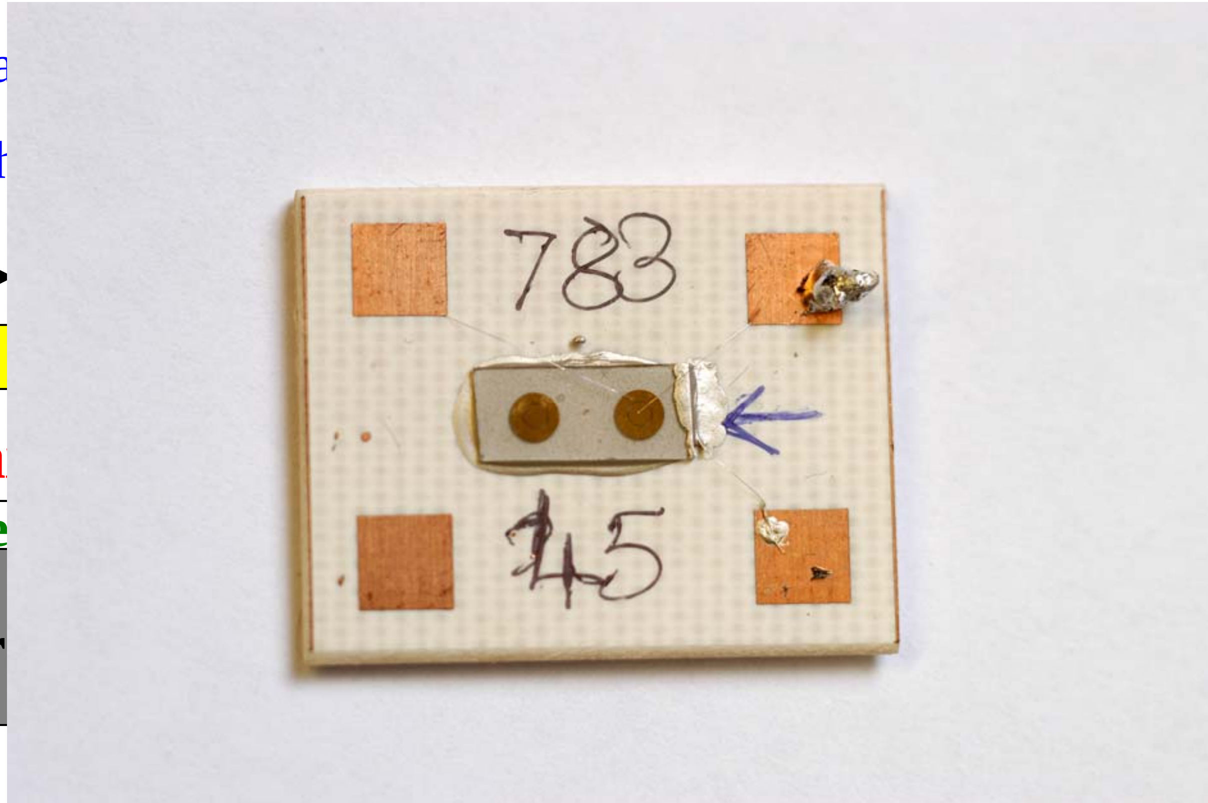
- 3 GaN materials investigated (all grown by MOCVD)
  - 2 GaN wafers obtained from Tokushima University, Japan.
  (2.5µm semi-insulating epi GaN, known as "36 GaN" & "45 GaN")
  - 1 GaN wafer obtained from LUMILOG, France
  (12µm semi-insulating epi GaN, known as "12 GaN")



Detector Fabrication

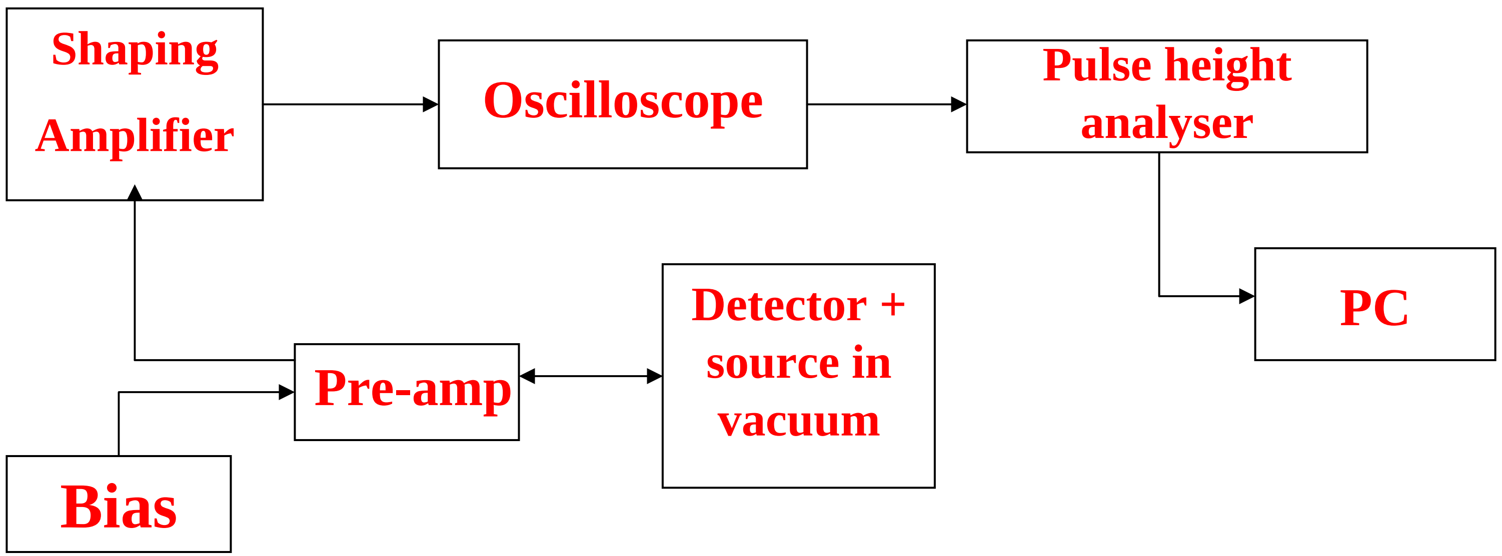
- Fabricated pad/guard ring structures using photolithographic techniques
- Samples 10 mm by 5 mm. Two Pad/guard ring structures per sample.
- Pad 1mm diameter. 50µm spacing between pad and guard ring. Guard ring 500µm wide
- Deposited 200 nm Pd to make Schottky contact. 200 nm Au on top of this to facilitate wire bonding
- Somehow needed to make a
- Coated side of material with





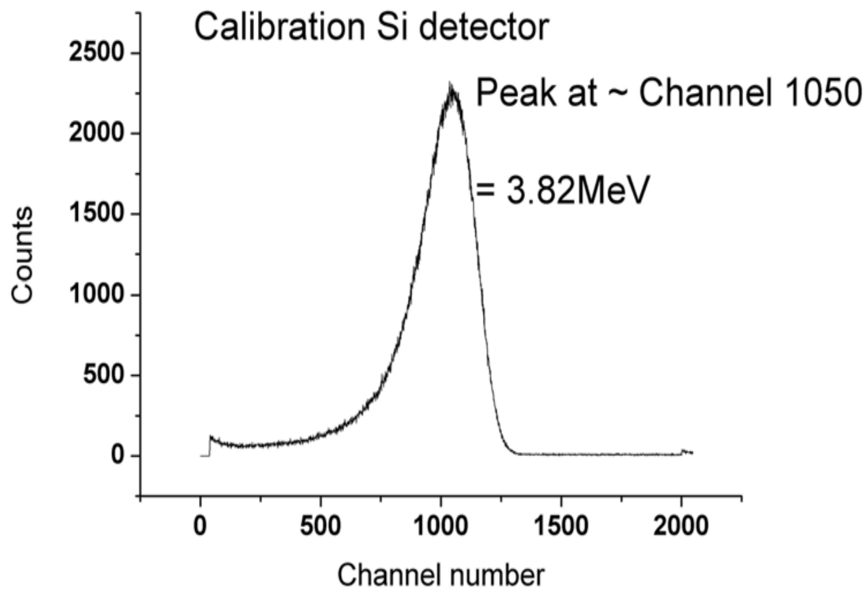
Detector Characterisation

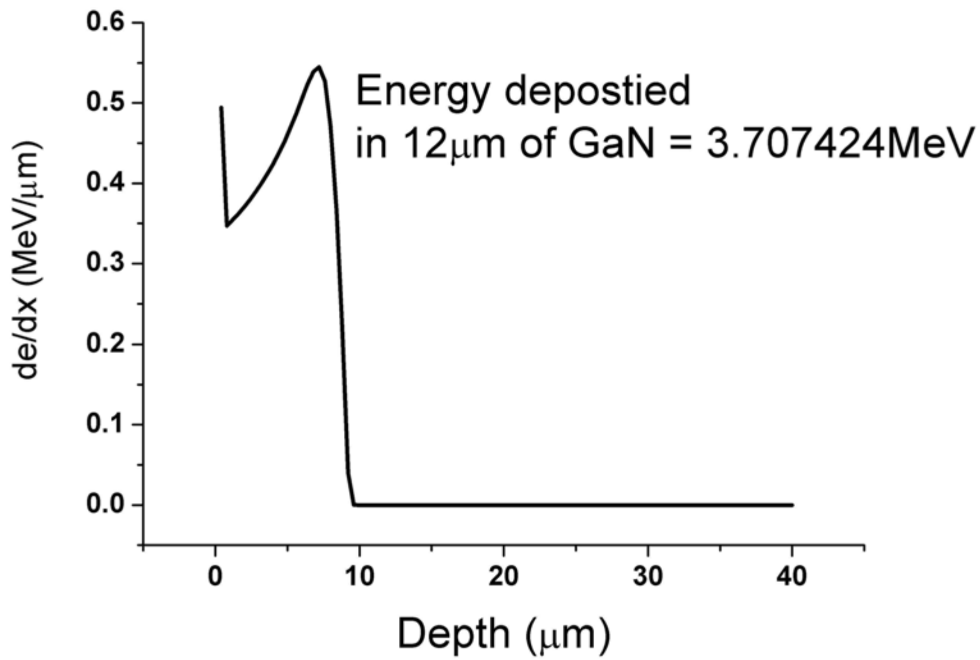
- Detectors characterised pre- and post- irradiation by performing
  - I-V measurements using a Keithley 237 measurement unit
  - CCE measurements using 5.48 MeV α particles from an ^{241}Am source
- All measurements performed at room temperature (~ 23°C)
- Detectors left in dark for ~ 2 hours before performing I-V's.



CCE Measurement

- We use a source with a large attenuation of the α particles
- Need to establish energy of the emitted alpha particles
- From observed spectrum (below left) the energy of the α particles emitted from our americium source is taken to be 3.82 MeV
- Then use SRIM simulation (below right) to calculate the amount of energy that should be deposited by an α particle with incident energy of 3.82 MeV in 2.5 μm /12 μm of GaN.
- Found to be 3.707MeV
- Also used 5.48 MeV α particles from a second source to check results

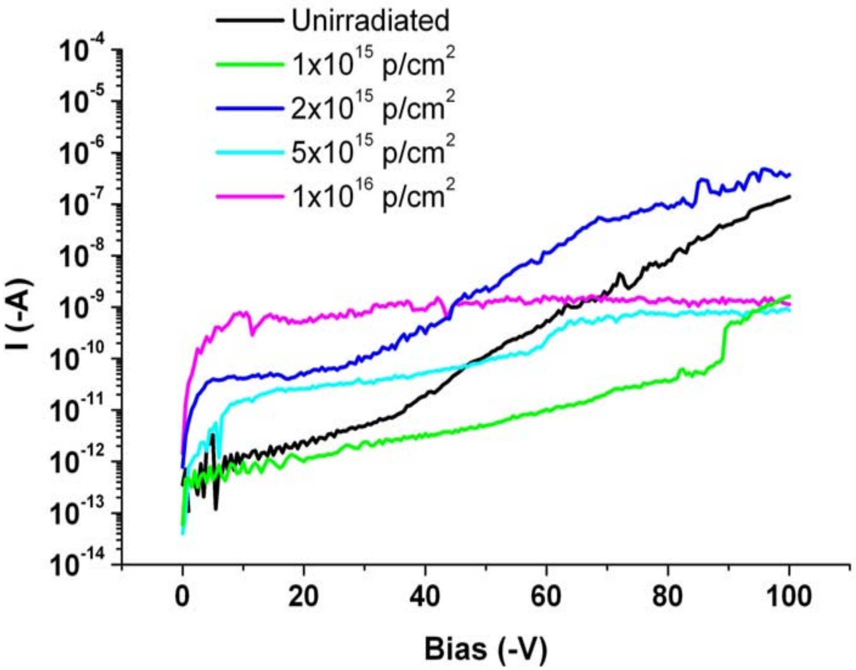


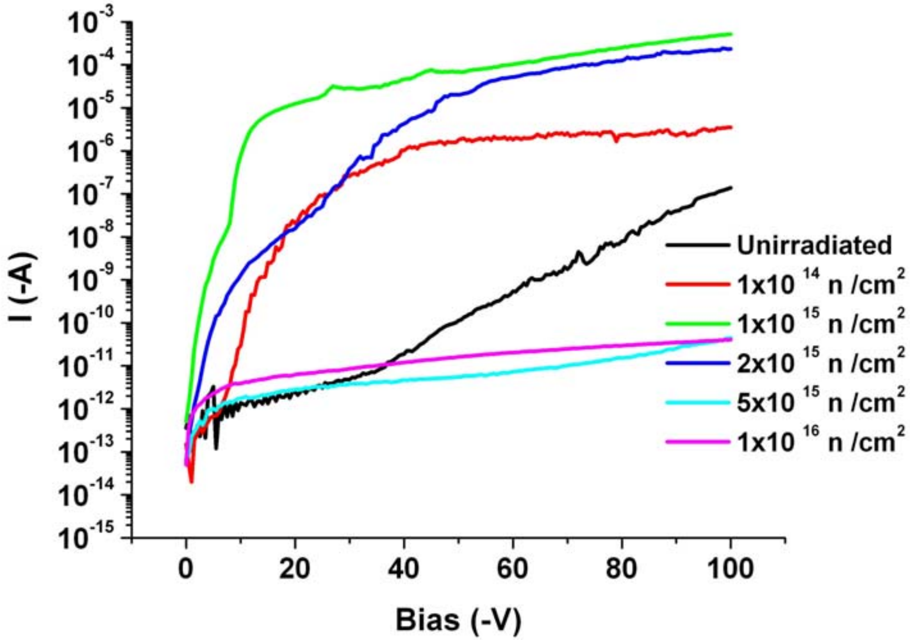


Irradiations Performed

- Detectors irradiated with 24GeV/c protons at CERN (1-3x10^{13} p/cm^2/hour) & neutrons at the TRIGA reactor in Ljubljana (5x10^{12} n/cm^2/s)
- 5 samples from each wafer = 30 samples irradiated.
- Detectors irradiated to fluences:
  - 1 x10^{14}/cm^2 (both proton and neutrons)
  - 1 x10^{15}/cm^2
  - 2 x10^{15}/cm^2
  - 5 x10^{15}/cm^2
  - 1 x10^{16}/cm^2
- Detectors stored at –20^{o}C after irradiation

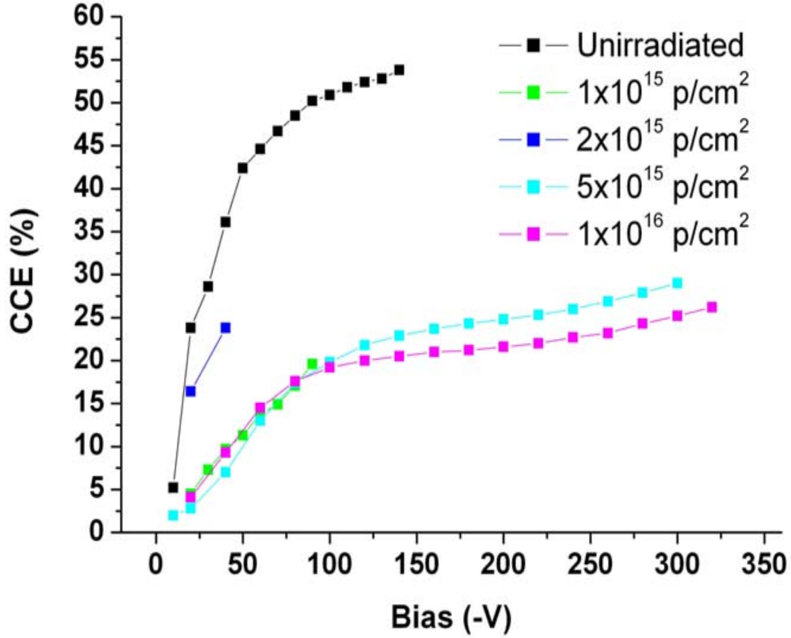
I-Vs of Irradiated 12μm GaN

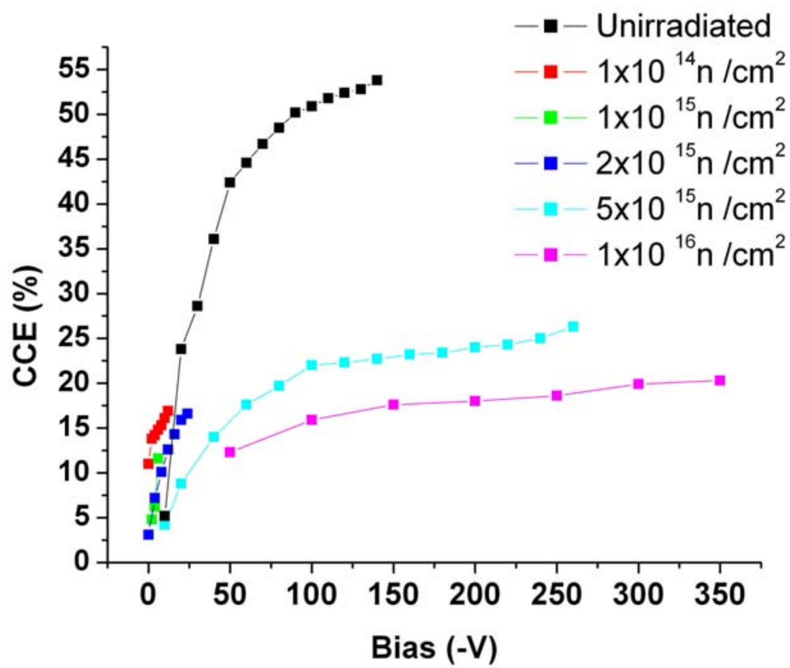




- Proton irradiations on left, neutron irradiations on right
- Detectors irradiated to fluences > $5x10^{15}/cm^2$ show very low leakage current at a bias of -100V

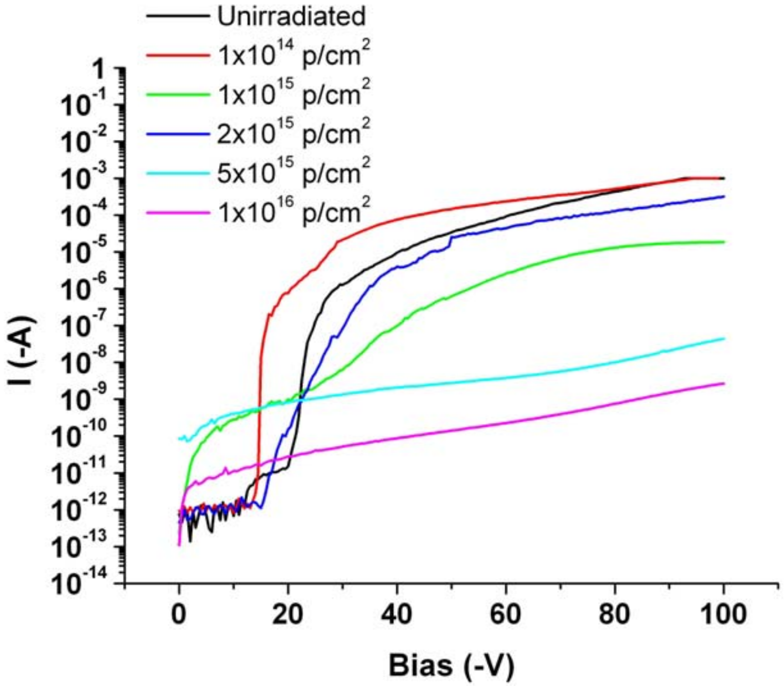
CCEs of Irradiated 12µm GaN

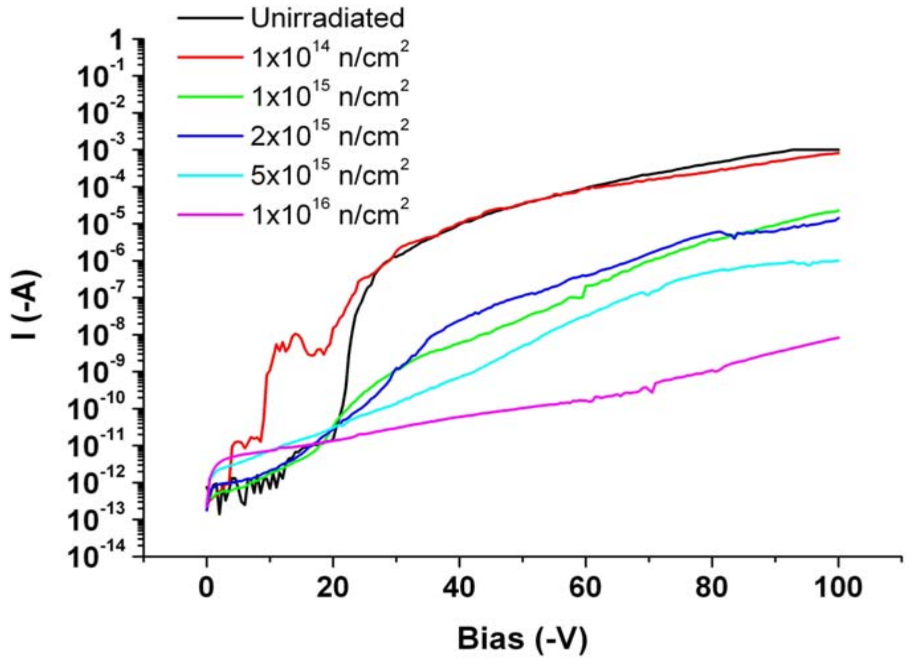




- Unirradiated CCE_{max} = 53%
- Large leakage current of some irradiated detectors results in CCE values only being available at small bias voltages e.g. 10^{14}, 10^{15} & $2x10^{15}$ /cm^2
- CCE_{max} drops to ~ 23% after irradiation to 10^{16} p/cm^2 & to 17% after irradiation to 10^{16} n/cm^2

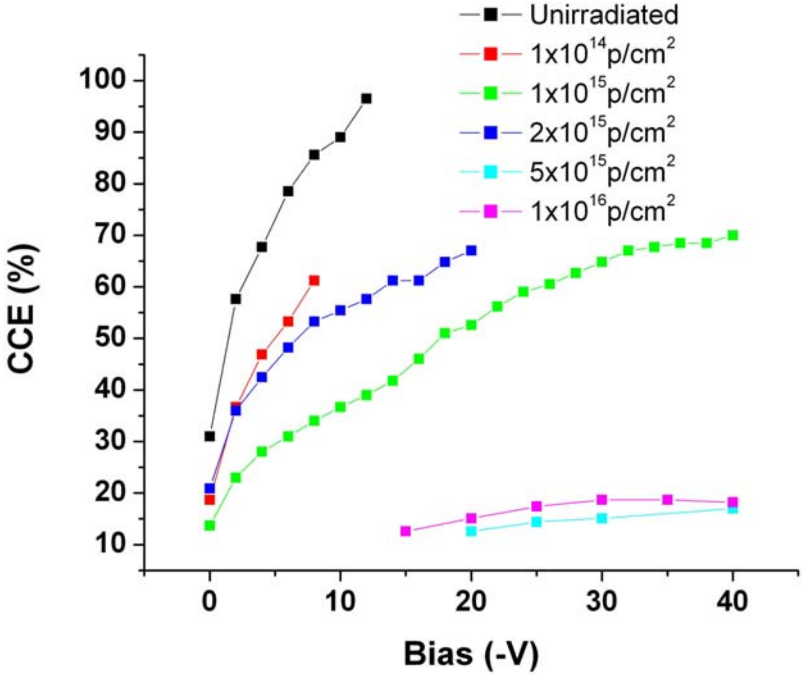
I-Vs of Irradiated 45 GaN

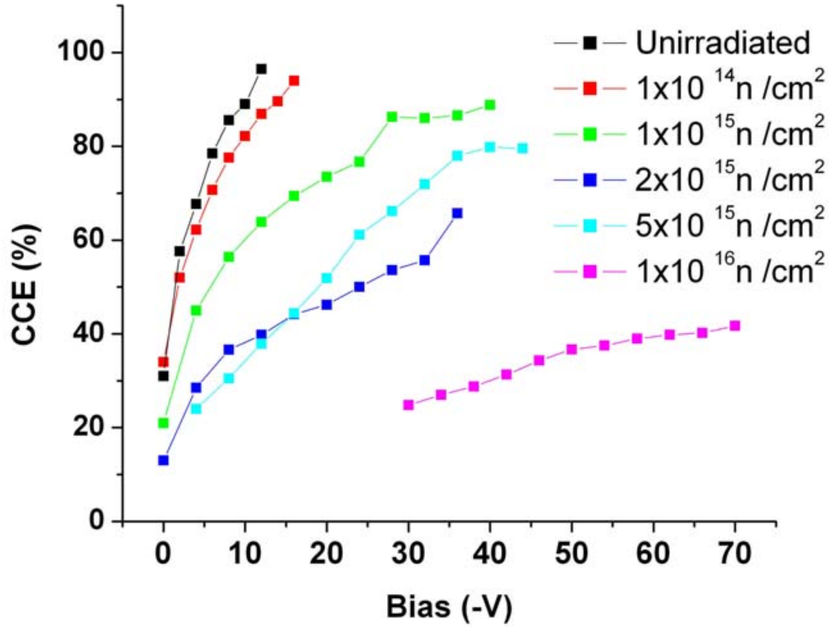




- In general, at reverse biases greater than 30V irradiated detectors show lower leakage current than unirradiated detector
- Detectors irradiated to fluences > $5x10^{15}/cm^2$ again show very low leakage current at a bias of -100V

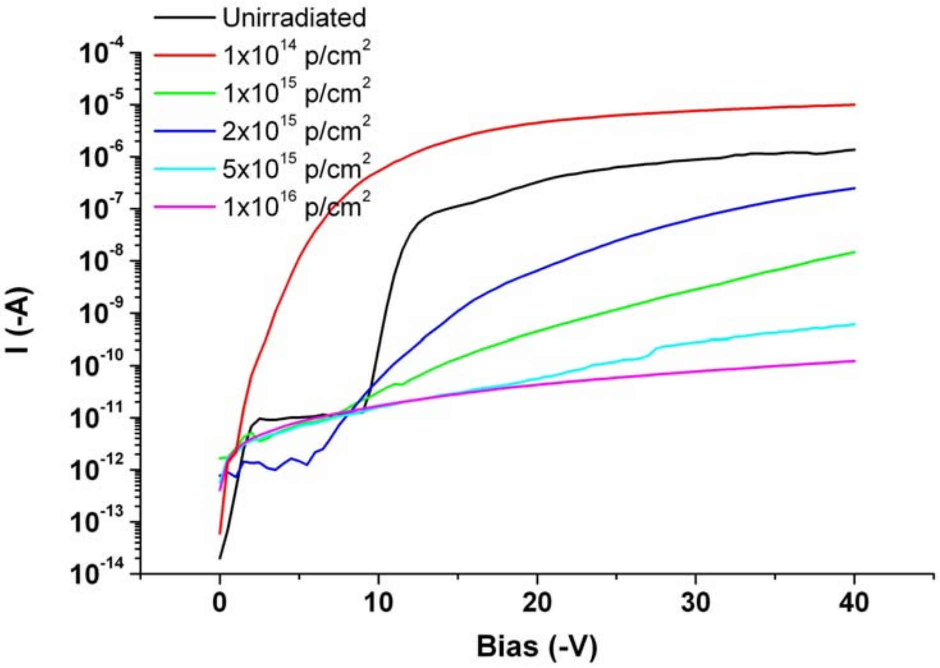
CCEs of Irradiated 45 GaN

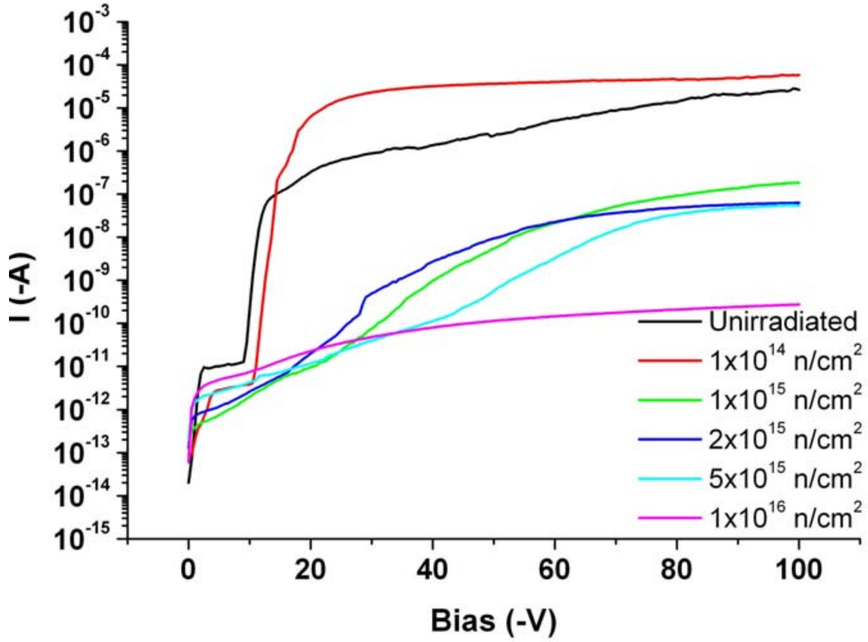




- Unirradiated CCE_{max} = 97%
- CCE_{max} drops to ~ 20% after irradiation to 10^{16} p/cm^2 & to 40% after irradiation to 10^{16} n/cm^2

I-Vs of Irradiated 36 GaN

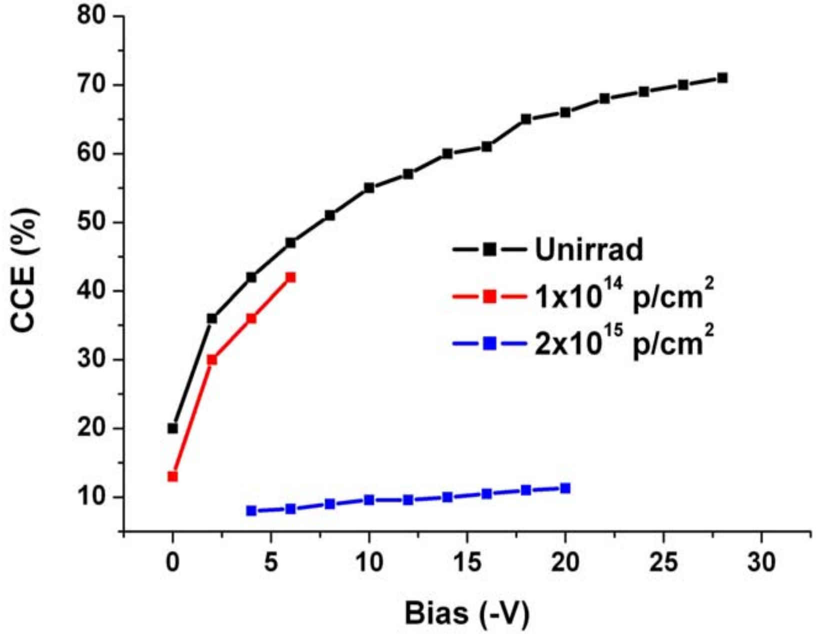


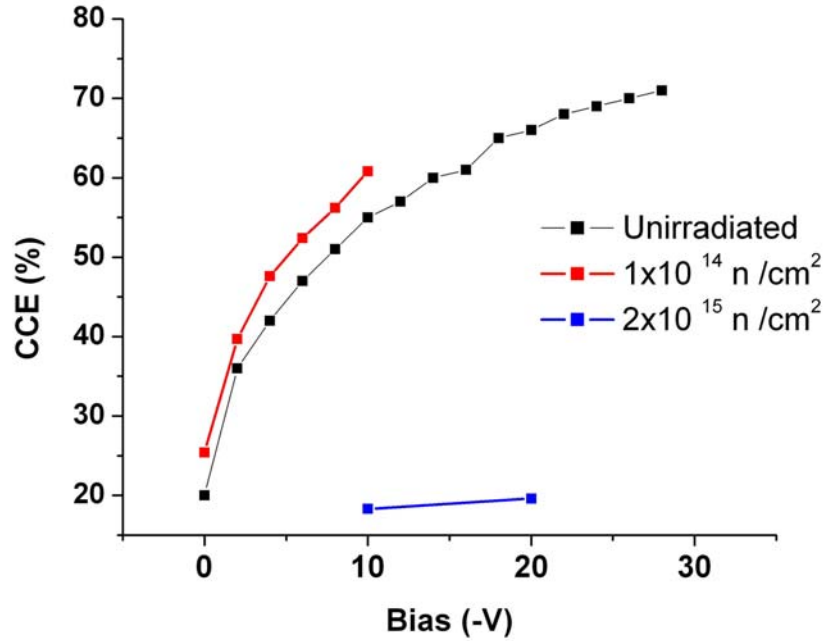


- Again we see that the irradiations result in detectors exhibiting lower leakage current than the unirradiated detector (except $10^{14}/cm^2$ irradiated detectors)

- Detectors irradiated to fluences > $5x10^{15}/cm^2$ show very low leakage current

CCEs of Irradiated 36 GaN



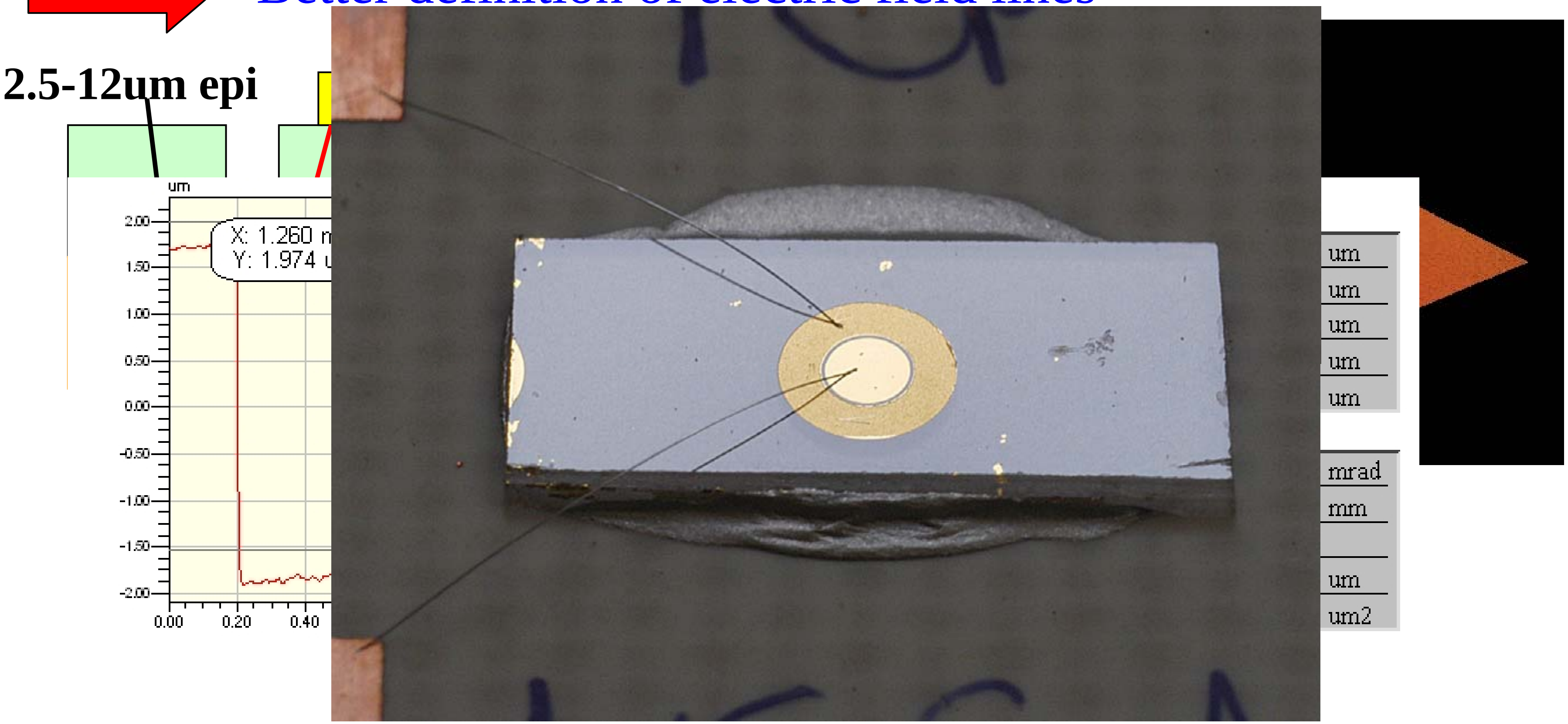


- No CCE measurements for $1x10^{15}/cm^2$, $5x10^{15}/cm^2$ & $1x10^{16}/cm^2$
- Unirradiated CCE_{max} = 70%
- CCE_{max} drops to ~ 10% after irradiation to $2x10^{15}$ p/cm^2 & to 20% after irradiation to $2x10^{15}$ n/cm^2

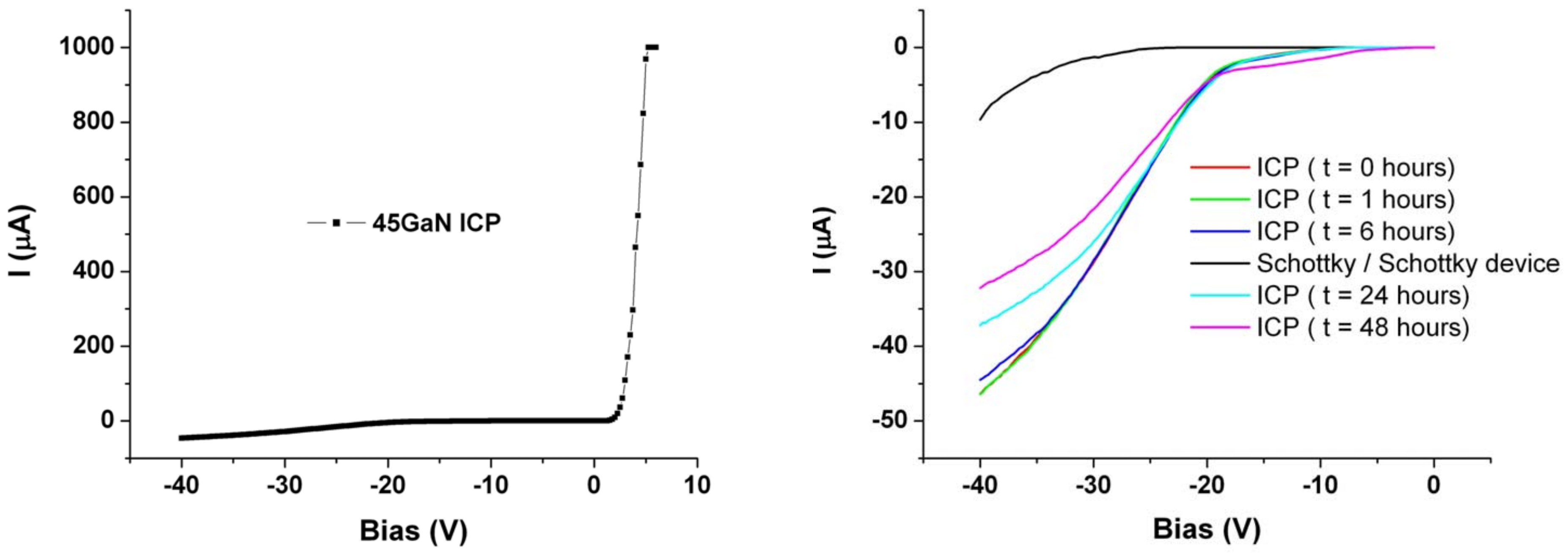
ICP etching of GaN

- Schottky/ Schottky diode electric field lines are not well defined
- Would like to make contact to the n-GaN buffer layer

→ Better definition of electric field lines

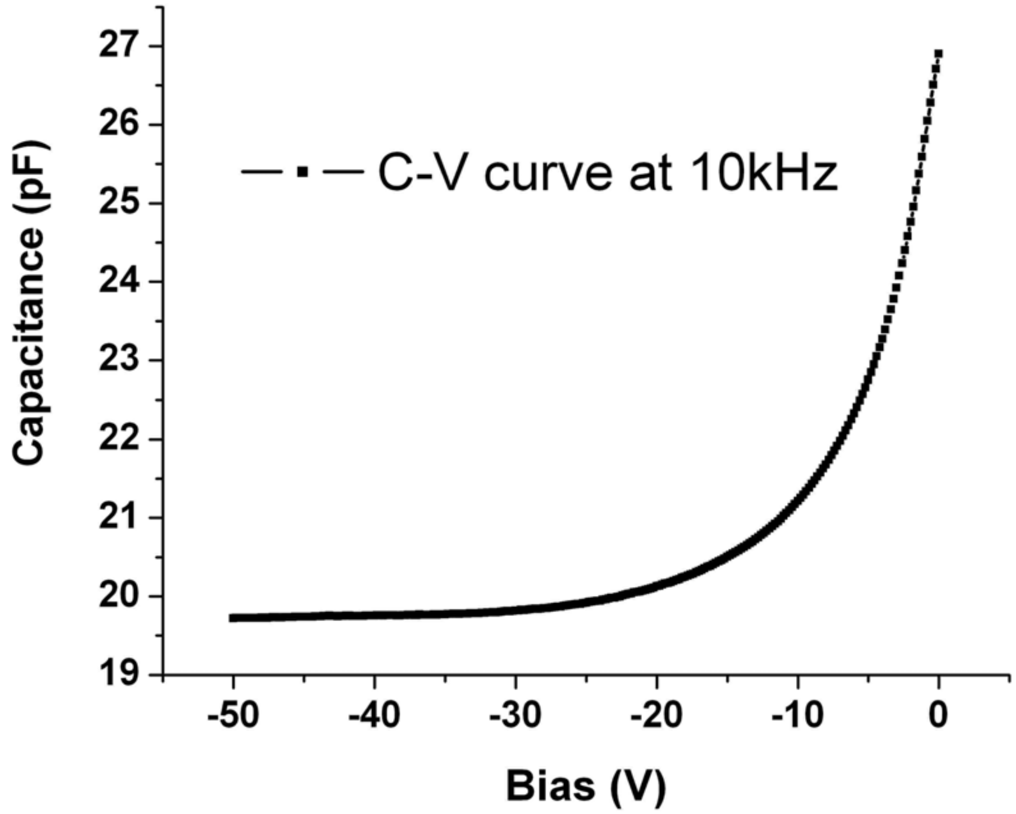


ICP 45 GaN sample I-V Results



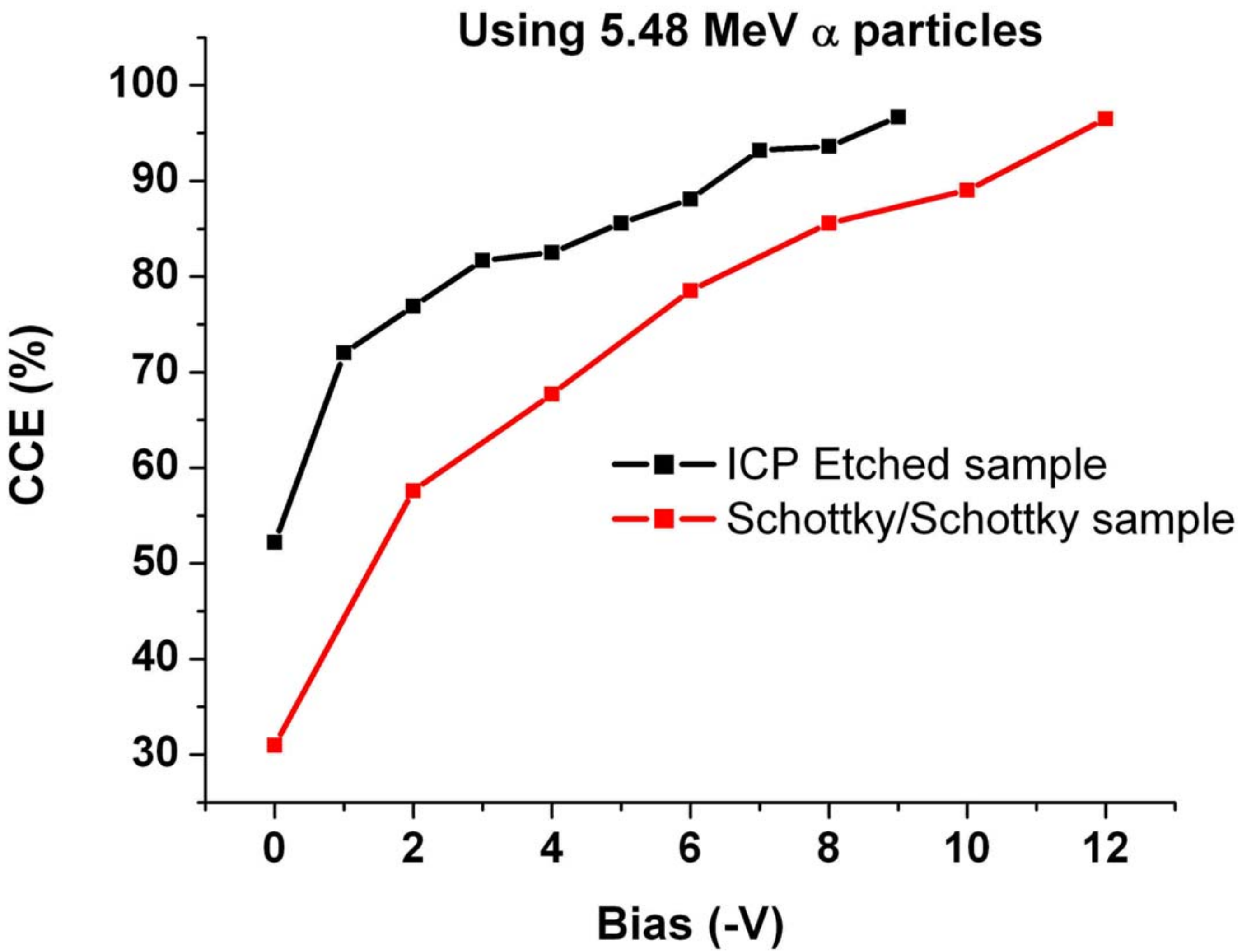
- GaN 45 sample etched October 2005
- Etch depth measured to be 3.5 um using interferometry
- Etching has increased leakage current

ICP 45 GaN sample C-V Results



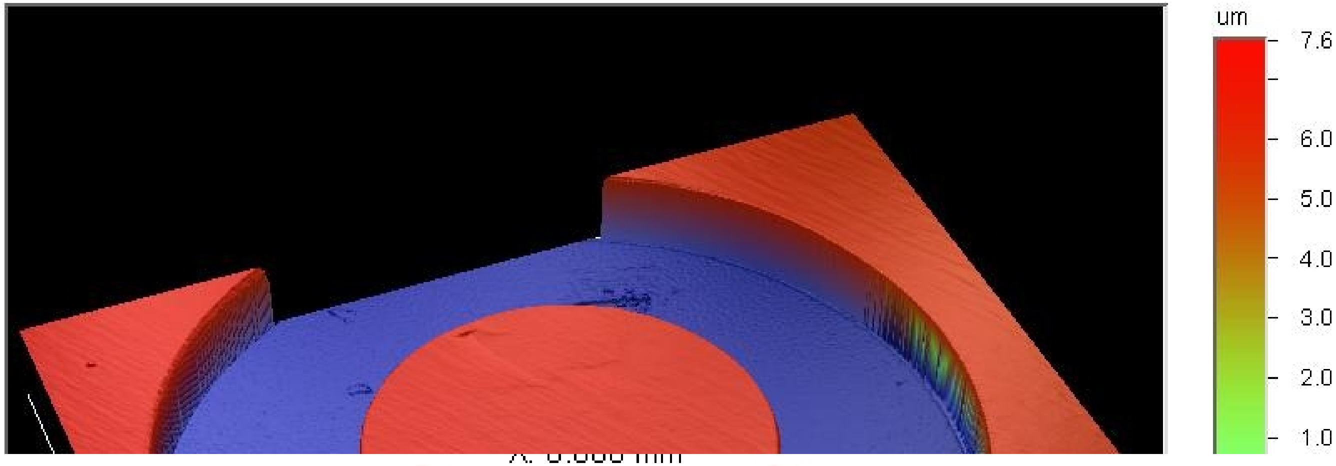
- First reliable C-V measurement I have made on GaN!

ICP 45 GaN sample CCE



Work in Progress

- We l



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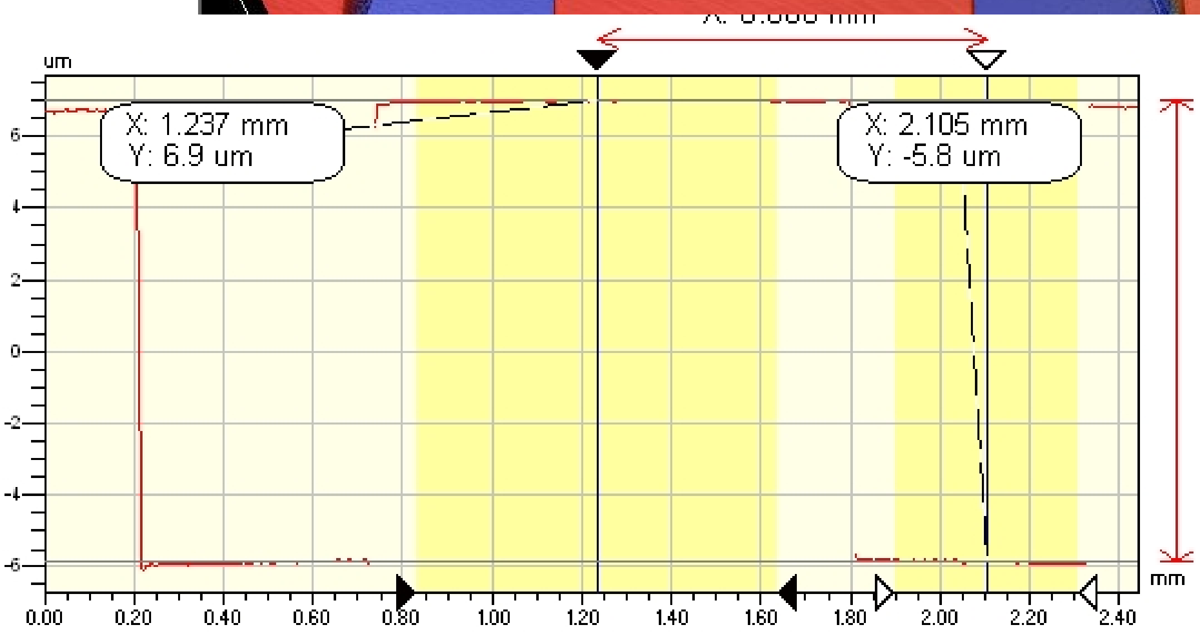


Rq	6.06 um
Ra	5.75 um
Rt	12.88 um
Rp	6.99 um
Rv	-5.88 um

Angle	-14.76 mrad
Curve	-13.83 mm
Terms	None
Avg Ht	2.58 um
Area	2239.75 um2

Y Profile

m

Conclusion

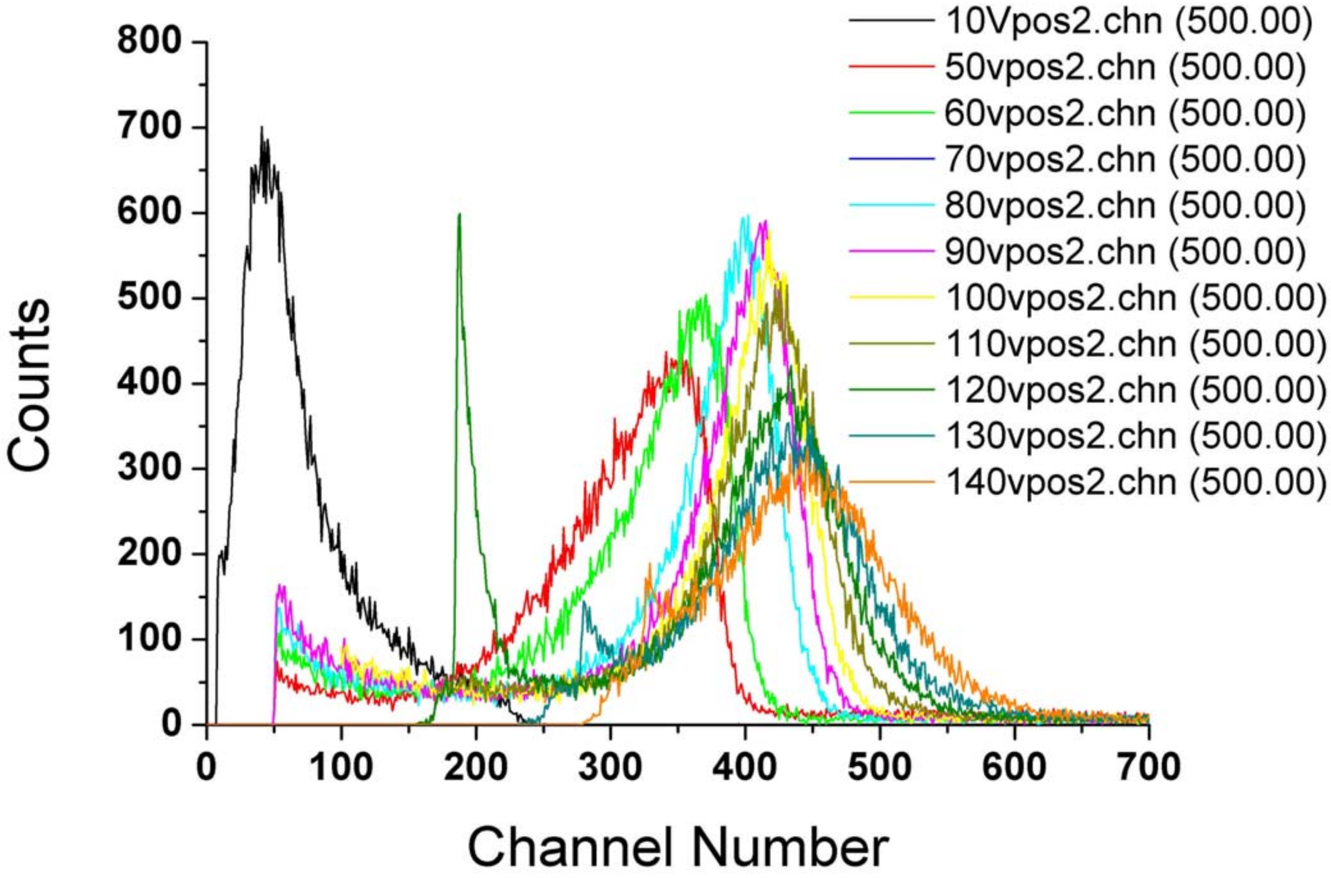
- Comprehensive study of GaN as a radiation hard material
- We have irradiated 3 different GaN materials (2 x 2.5um epi and 1x 12um epi) with protons and neutrons to various fluences
- Glasgow & Vilnius have characterised irradiated detectors by I-V, C-V, CCE, photoluminescence, microwave absorption, contact photoconductivity & thermally stimulated current techniques (see J. Vaitkus talk next)
- We have shown that thicker epi GaN has a CCE_{max} of ~ 23% after 10^{16} p/cm^2 & 17% after 10^{16} n/cm^2

Many thanks to Maurice Glaser and Federico Ravotti for performing proton irradiations

& to Gregor Kramberger for performing neutron irradiations

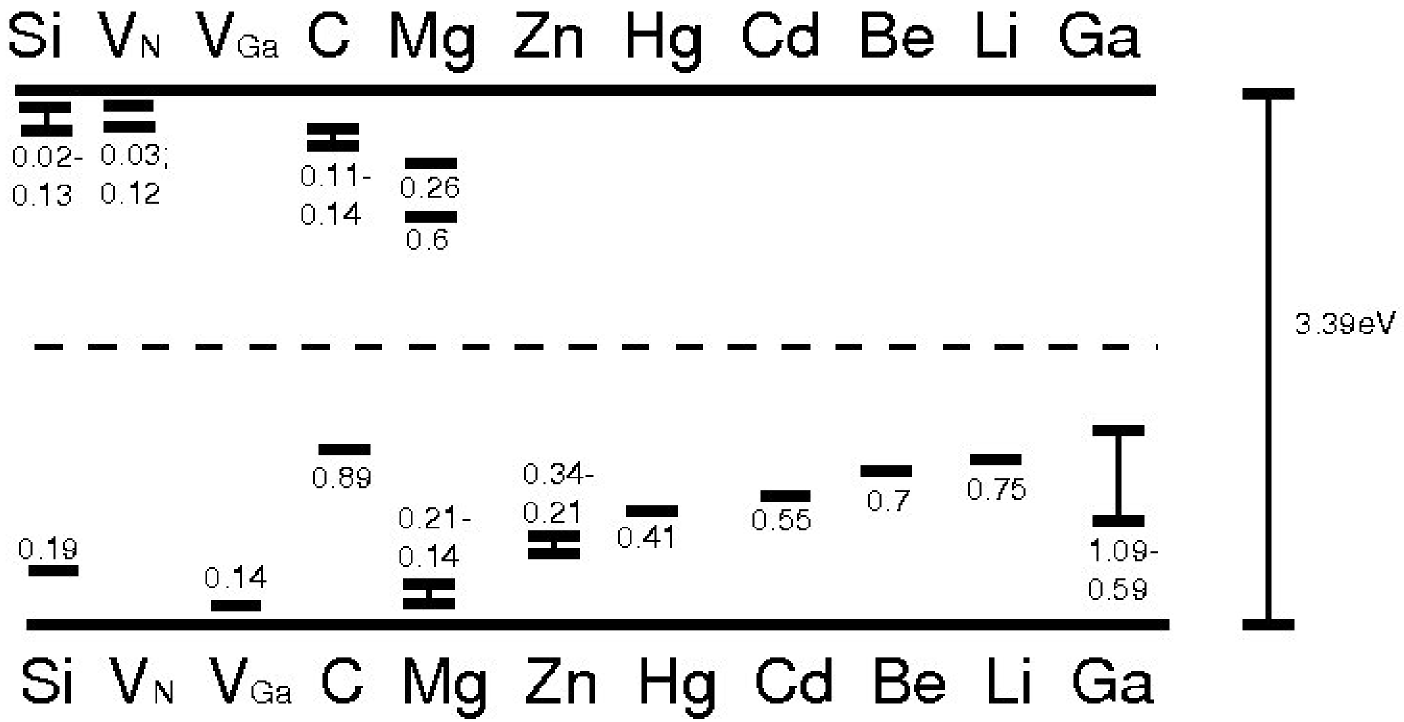
Back up Slides

CCE Spectra



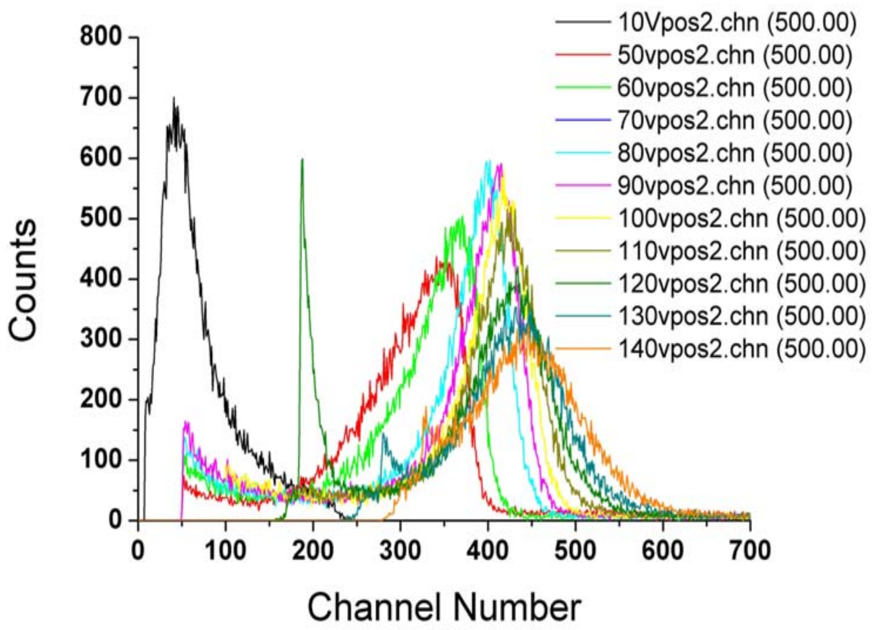
Counts
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
Channel Number
10Vpos2.chn (500.00)
50vpos2.chn (500.00)
60vpos2.chn (500.00)
70vpos2.chn (500.00)
80vpos2.chn (500.00)
90vpos2.chn (500.00)
100vpos2.chn (500.00)
110vpos2.chn (500.00)
120vpos2.chn (500.00)
130vpos2.chn (500.00)
140vpos2.chn (500.00)

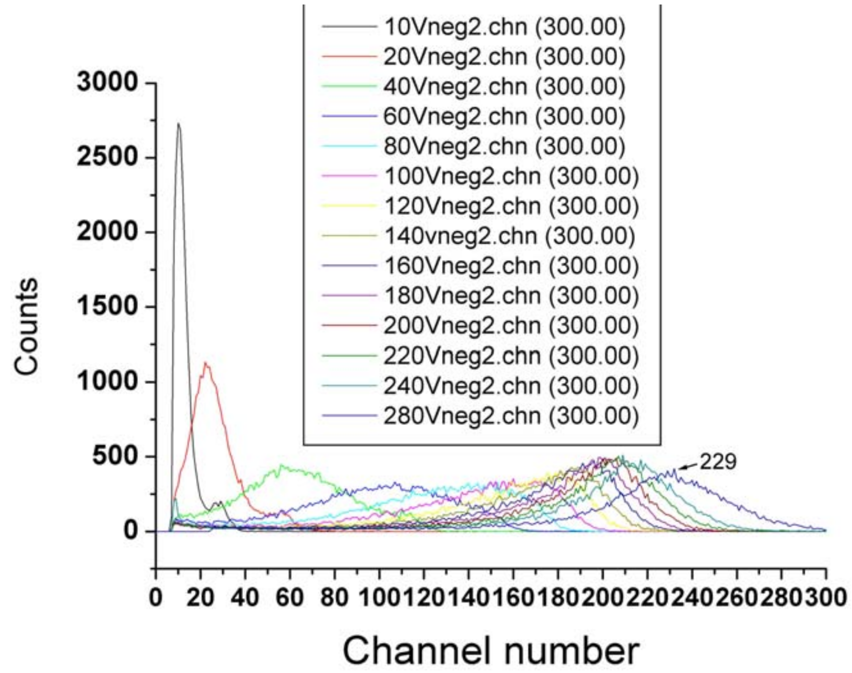
Known Defects in GaN



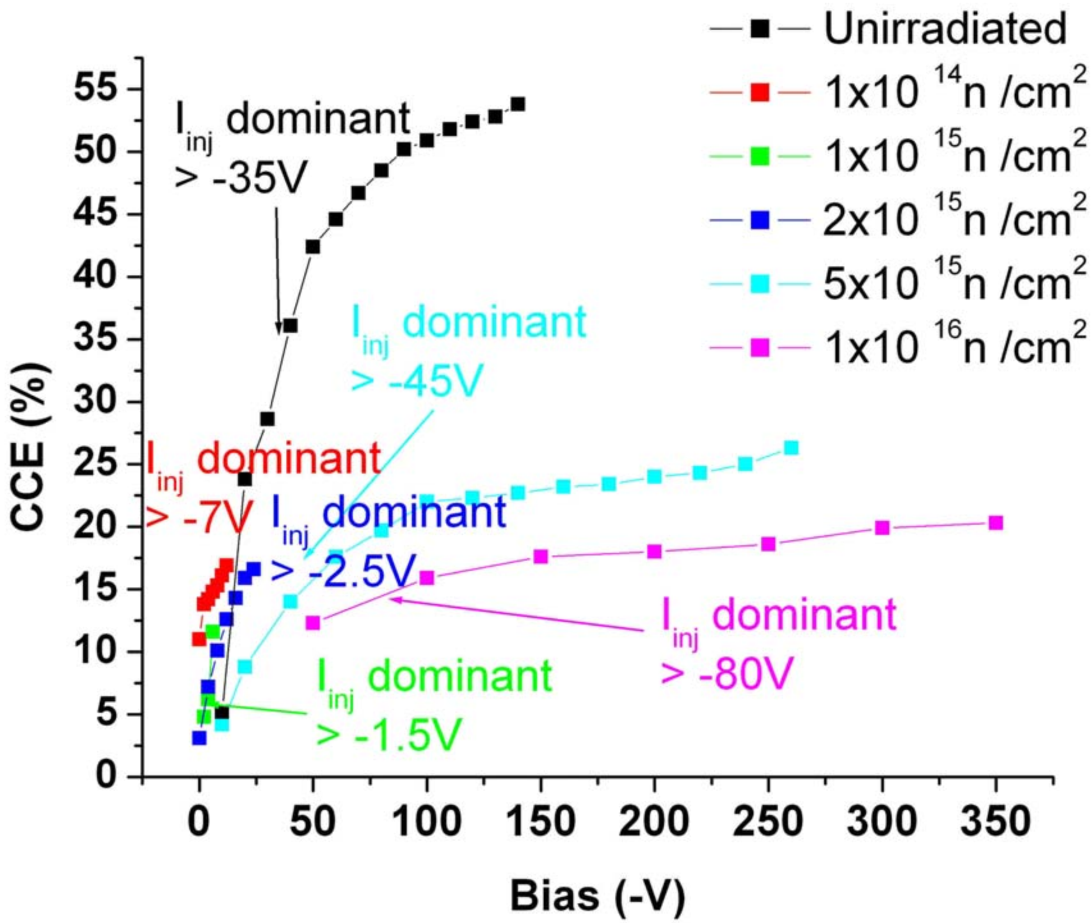
CCE Spectra

- Spectra from an unirradiated detector shown on the left and from the detector irradiated to $5e^{15}p/cm^2$ on the right



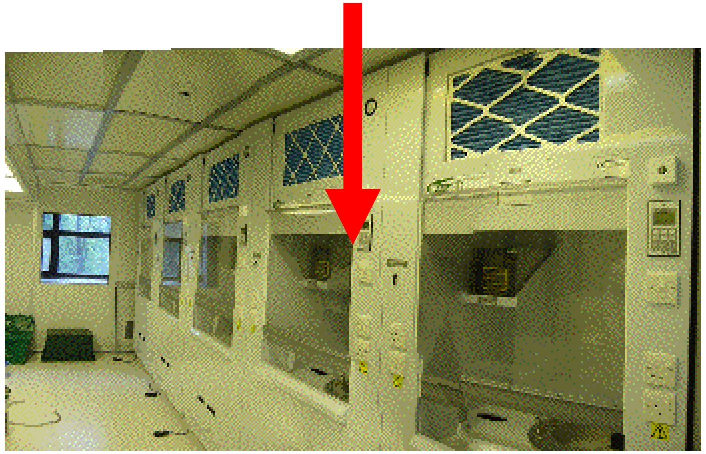


Injection Current

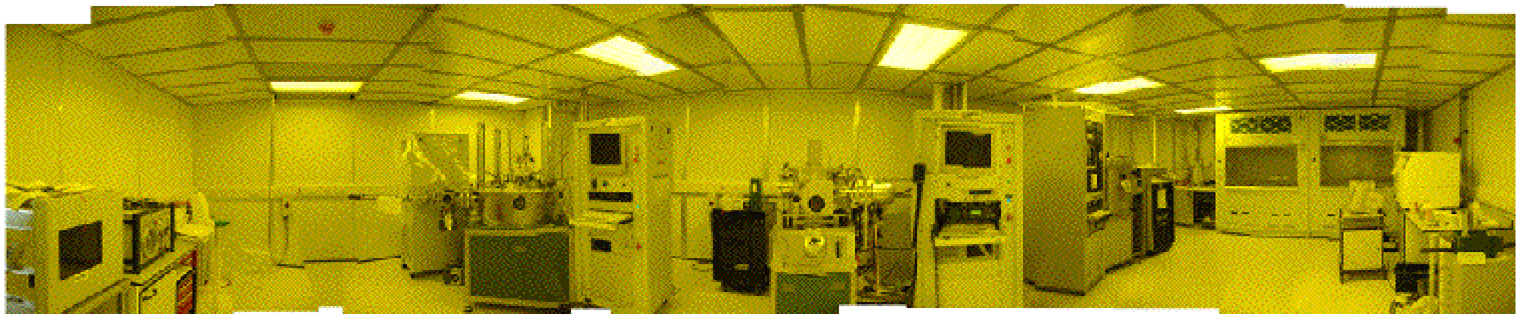


Detector Fabrication

- Detectors fabricated using tools in the new £6 million cleanroom facility. Cabinets class 100, electron beam lithography room class 10

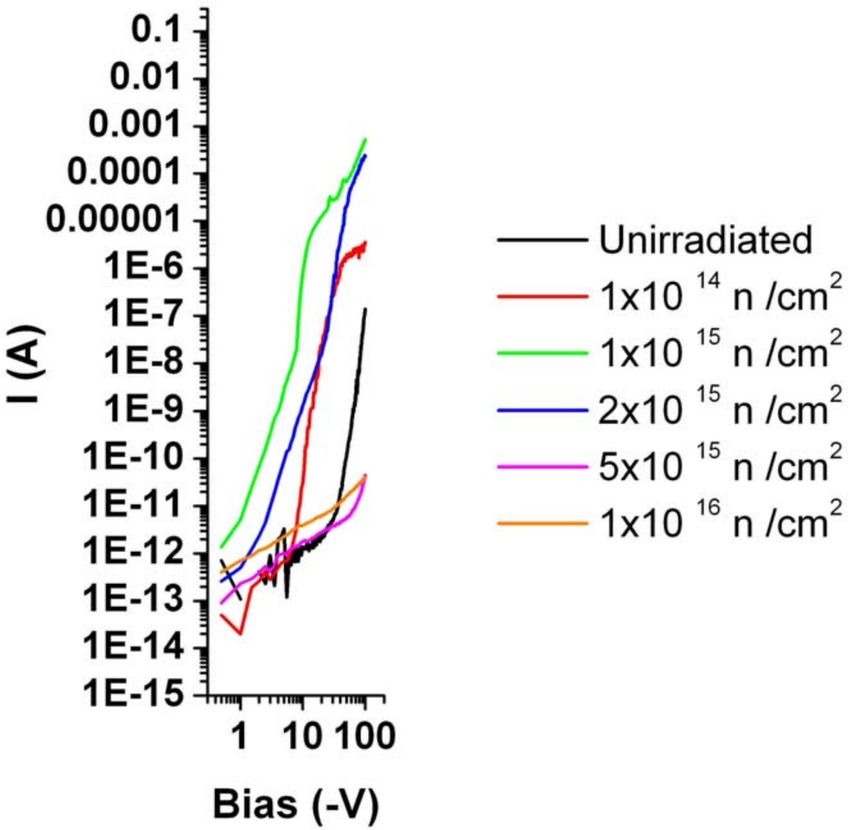


E-beam lithography 3nm spot



JWNC
The James Watt Nanofabrication Centre

Injection Current 2



ICP etching : CH4/H2 gas