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GaN UV detectors for synchrotron-based protein structure studies

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Outline

Biological Applications for UV detectors

- Proteomics
- Circular Dichroism (CD)
- Diode requirements for Synchrotron based CD experiment

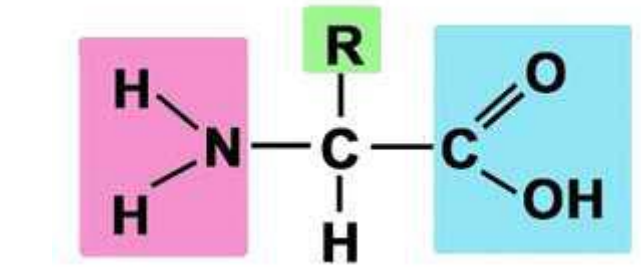
Gallium Nitride

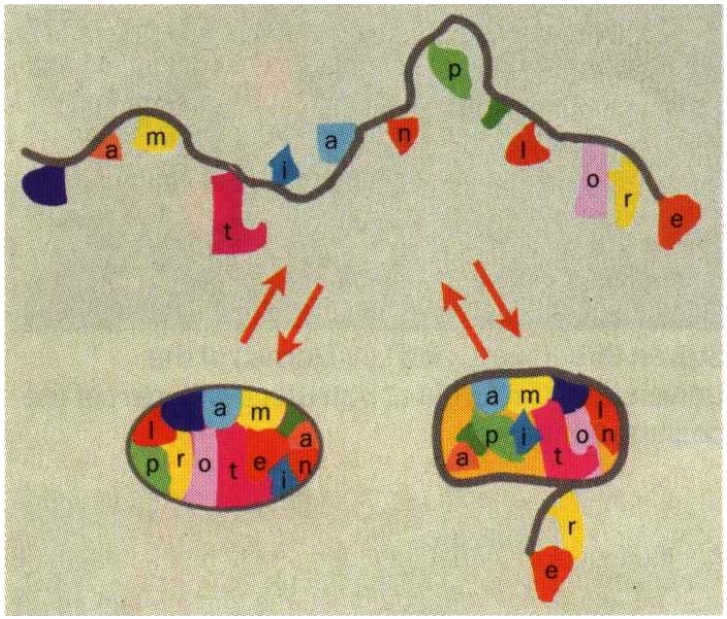
- Properties of GaN
- Design & Fabrication of GaN UV Diodes
- Material Characterisation & Optimisation
- Diode designs for Synchrotron

Conclusions

Proteomics

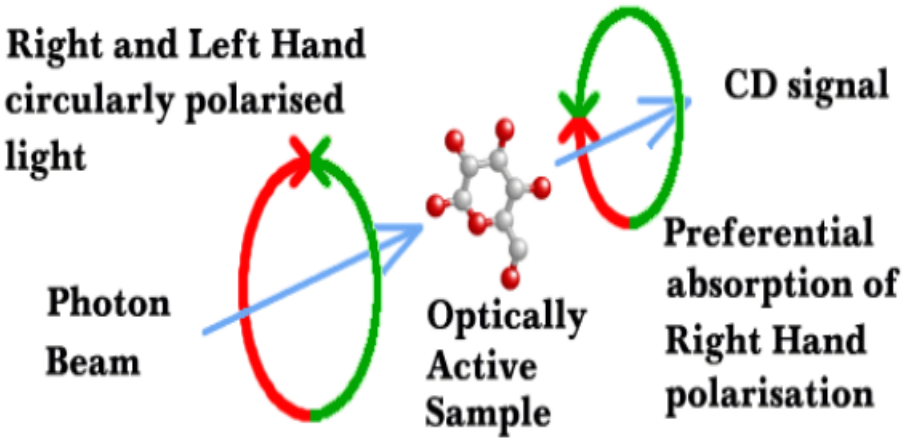
Proteomics – the study of the full expression of proteins by cells in their lifetime



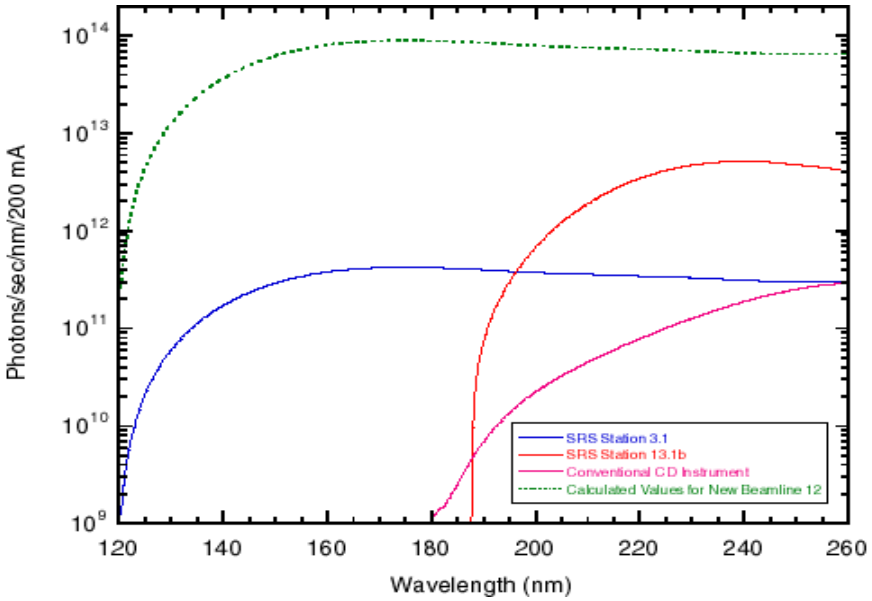


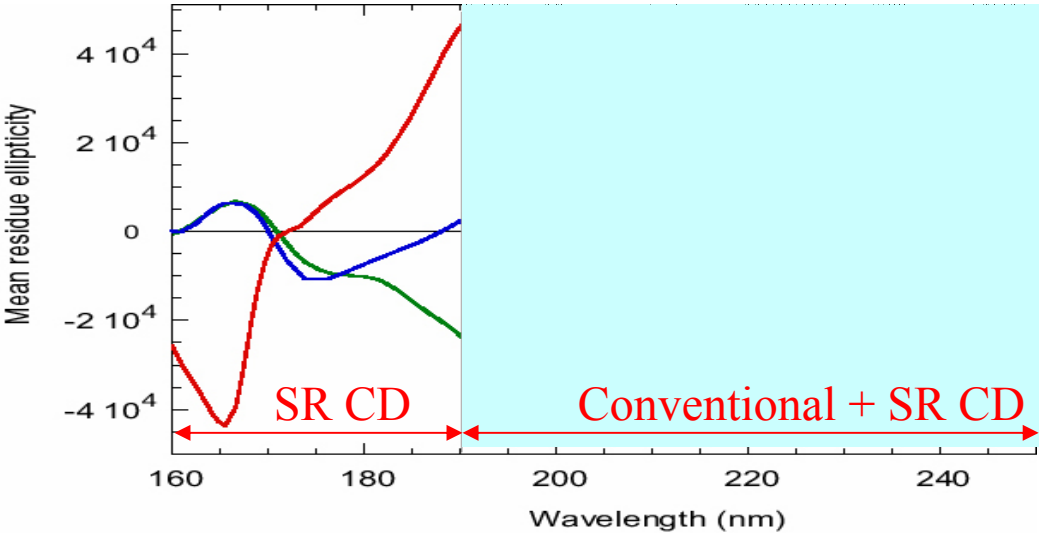
- Proteins are chains of amino acids
- For amino acids to form a protein the extended chain of amino acids must "fold" into a compact globular object with exactly the right shape
- We would like to know more about the “dynamic” and folded structures
- Offers insight to diseases such as Alzheimer's disease and Cystic fibrosis, caused by “mis-folding” of proteins

Circular Dichroism



CD is the measurement of the difference in absorption between left and right circularly polarised light as it passes through a medium





Wallace, B.A. and Janes, R.W. (2001) SRCD Spectroscopy of Proteins: Secondary Structure, Fold Recognition and Structural Genomics. Curr. Opin. in Chemical Biology

Synchrotron based CD experiment

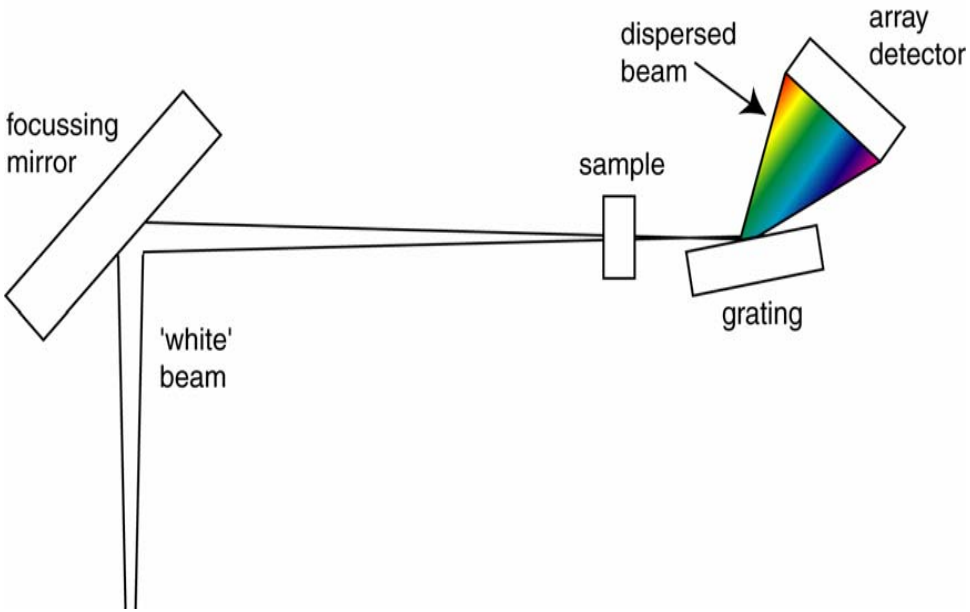
Current Method

- Measure CD at a λ
- Repeat for each λ

  => Slow (can take 2 days/run)
- Uses large amounts of protein

New Method

- Use Array to measure all λ simultaneously
- Require design for diode with 46 channels



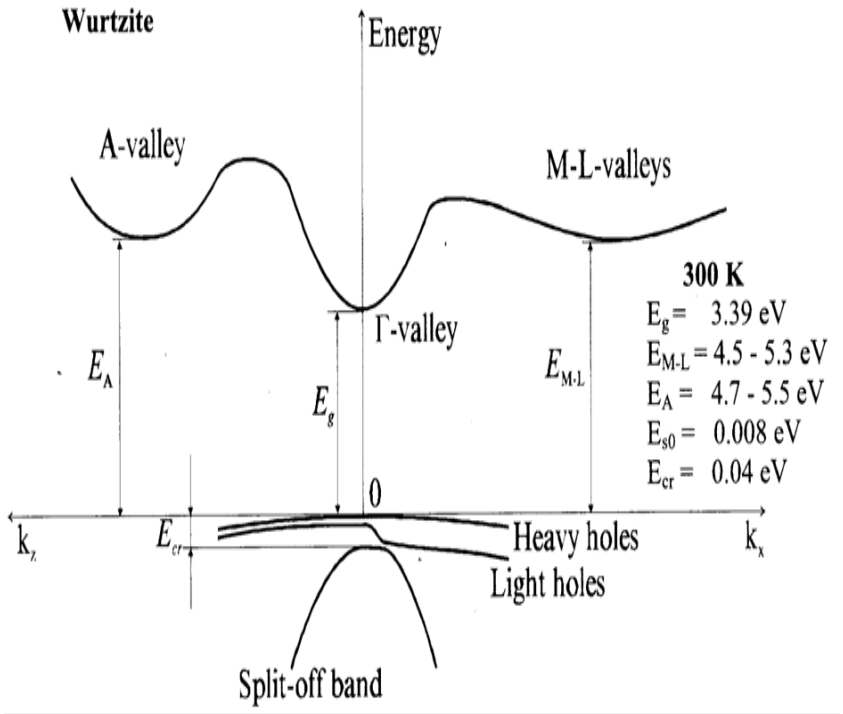
Properties of GaN

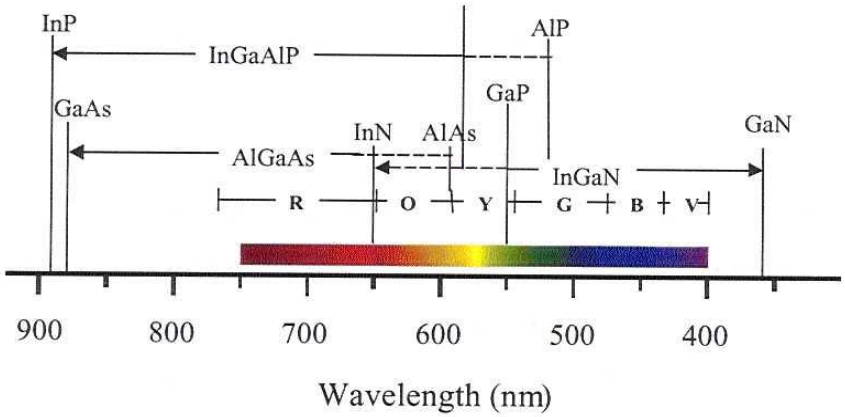
GaN (Gallium Nitride)

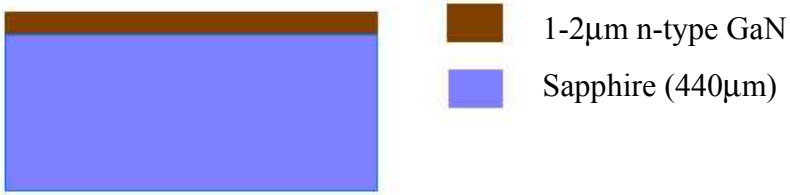
- Compound Semiconductor
- Direct Wide Bandgap (~3.4eV)
- Solar Blind Material (λ_{cut}~360nm)

=> Higher SNR for UV than for eg Si.

=> Ideal Material for UV detectors



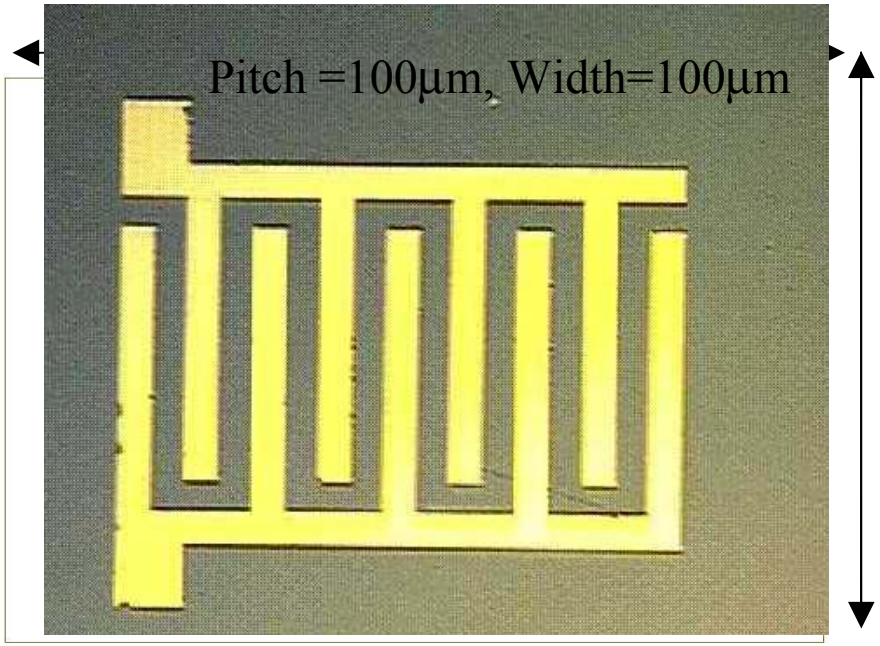


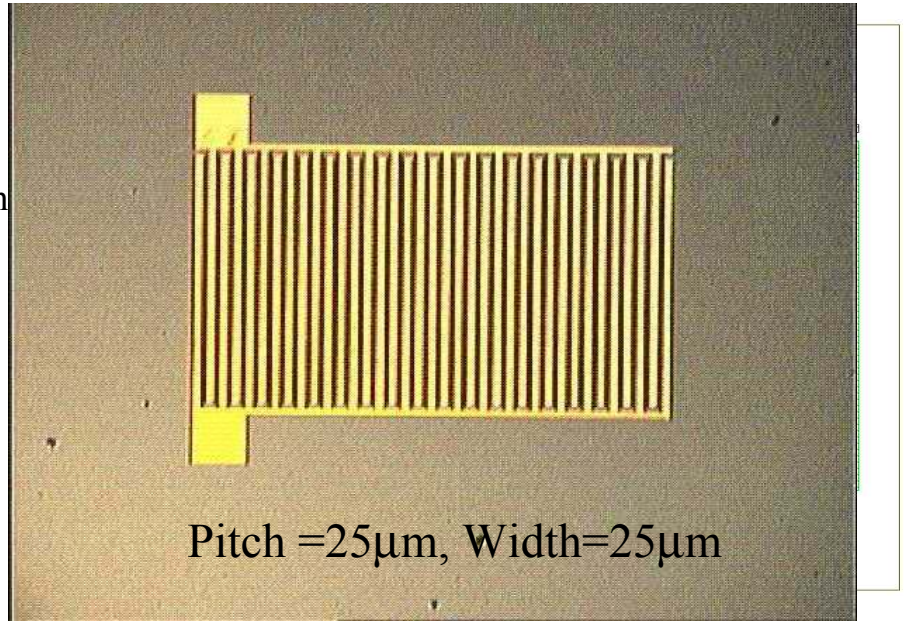


Design & Fabrication of GaN Diodes

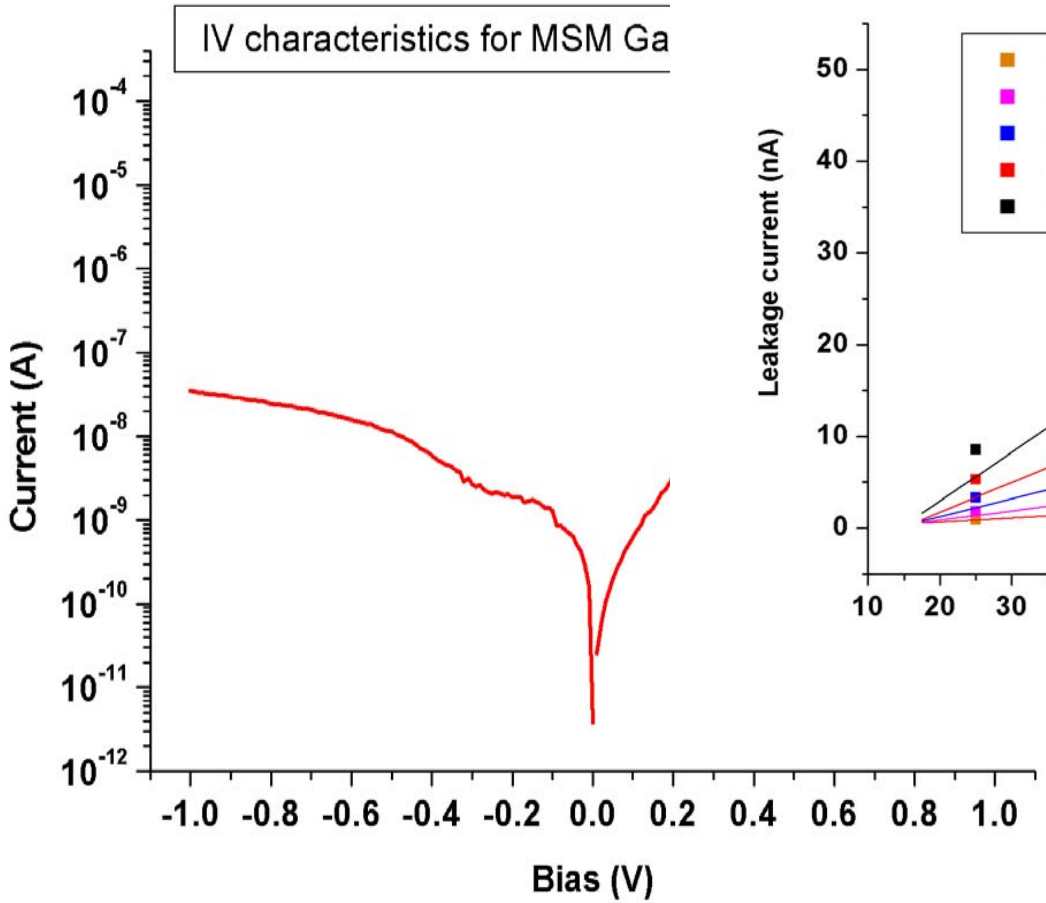
MSM (Metal-Semiconductor-Metal) Diodes

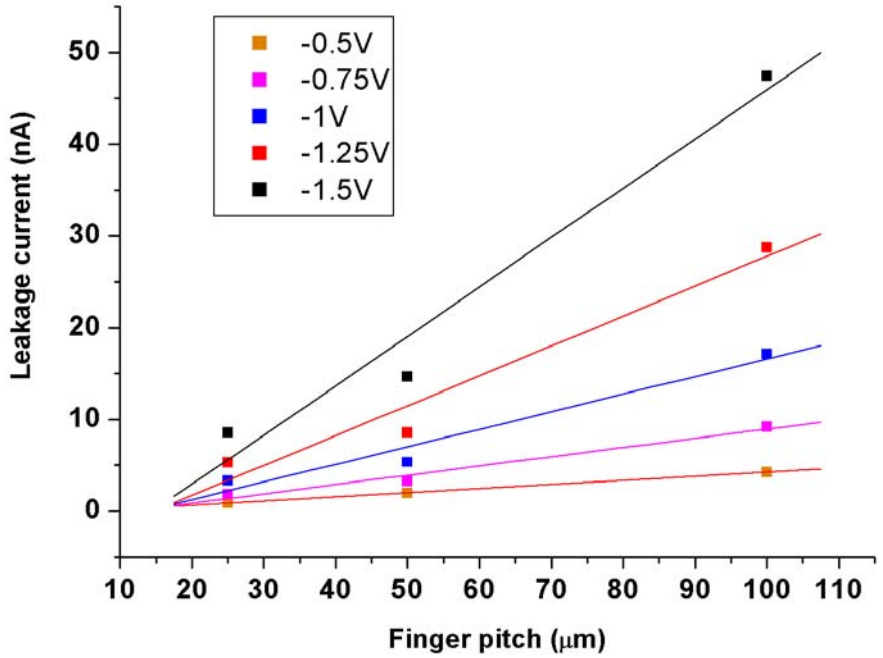
- Schottky (Rectifying) Contacts
- Interleaving Finger Design
  - minimised response time
  - Increased active area



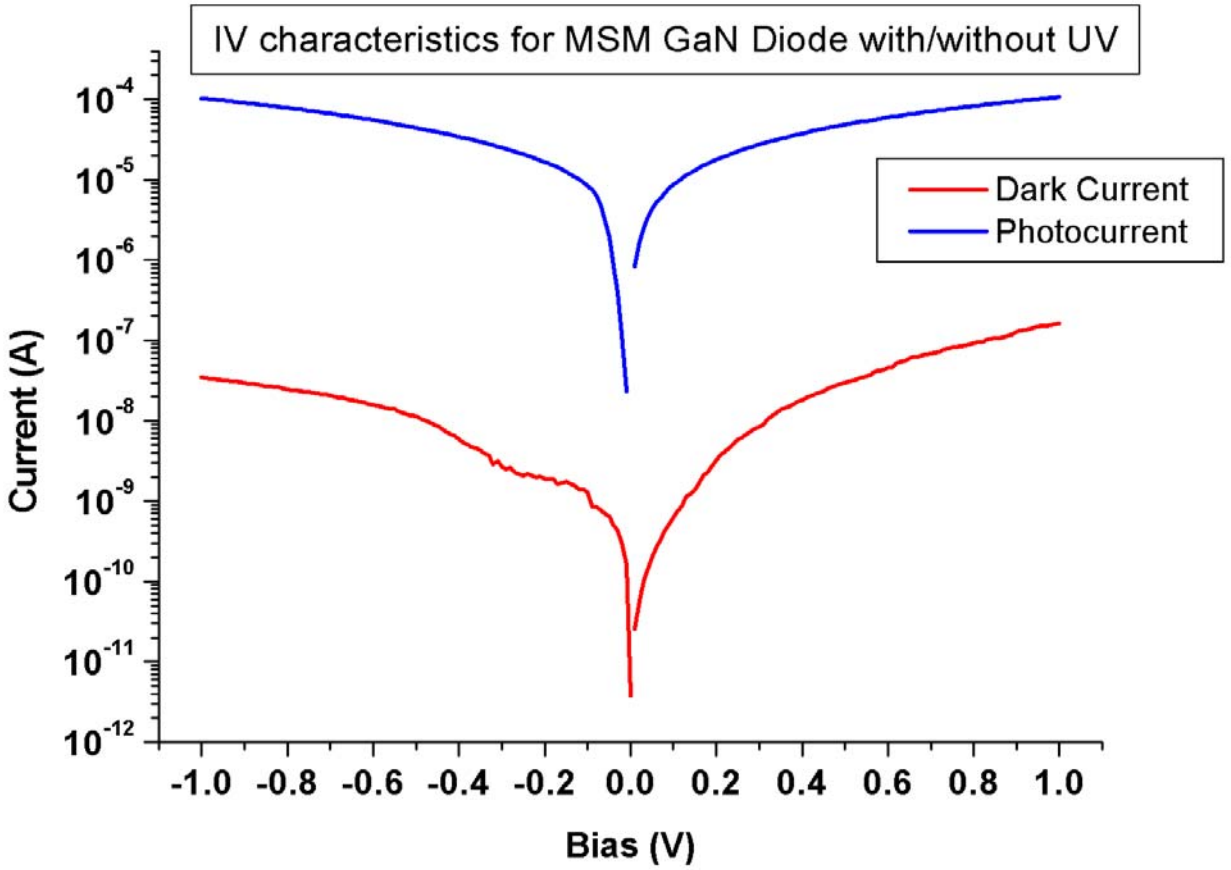


I-V Characteristics

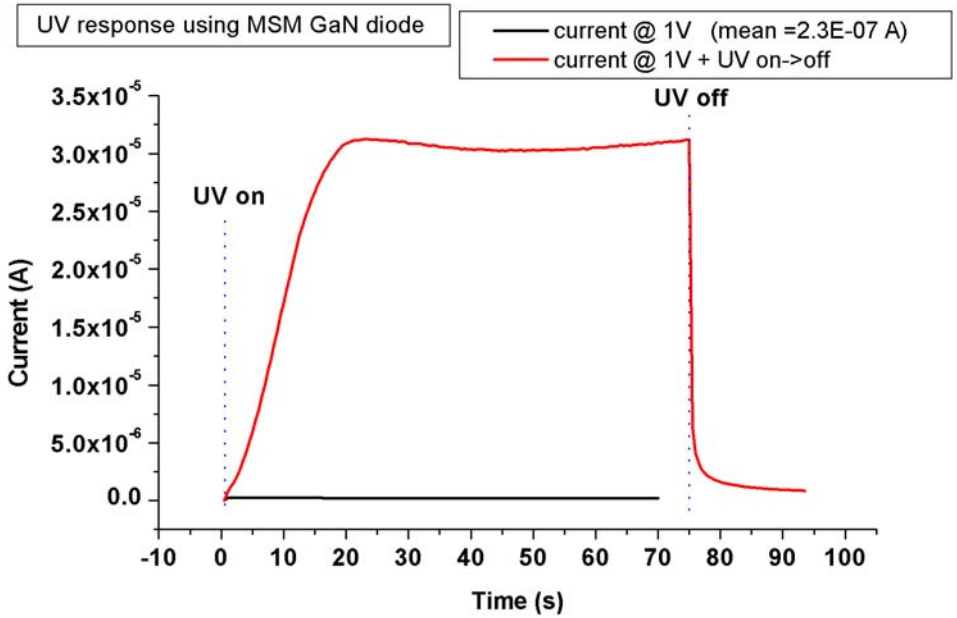




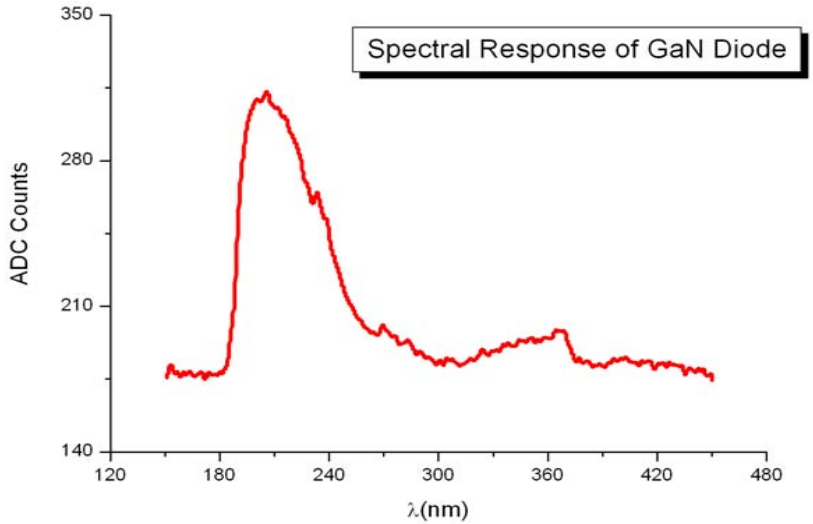
UV Response


IV characteristics for MSM GaN Diode with/without UV
Dark Current
Photocurrent
Current (A)
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
-1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0
Bias (V)

UV Response

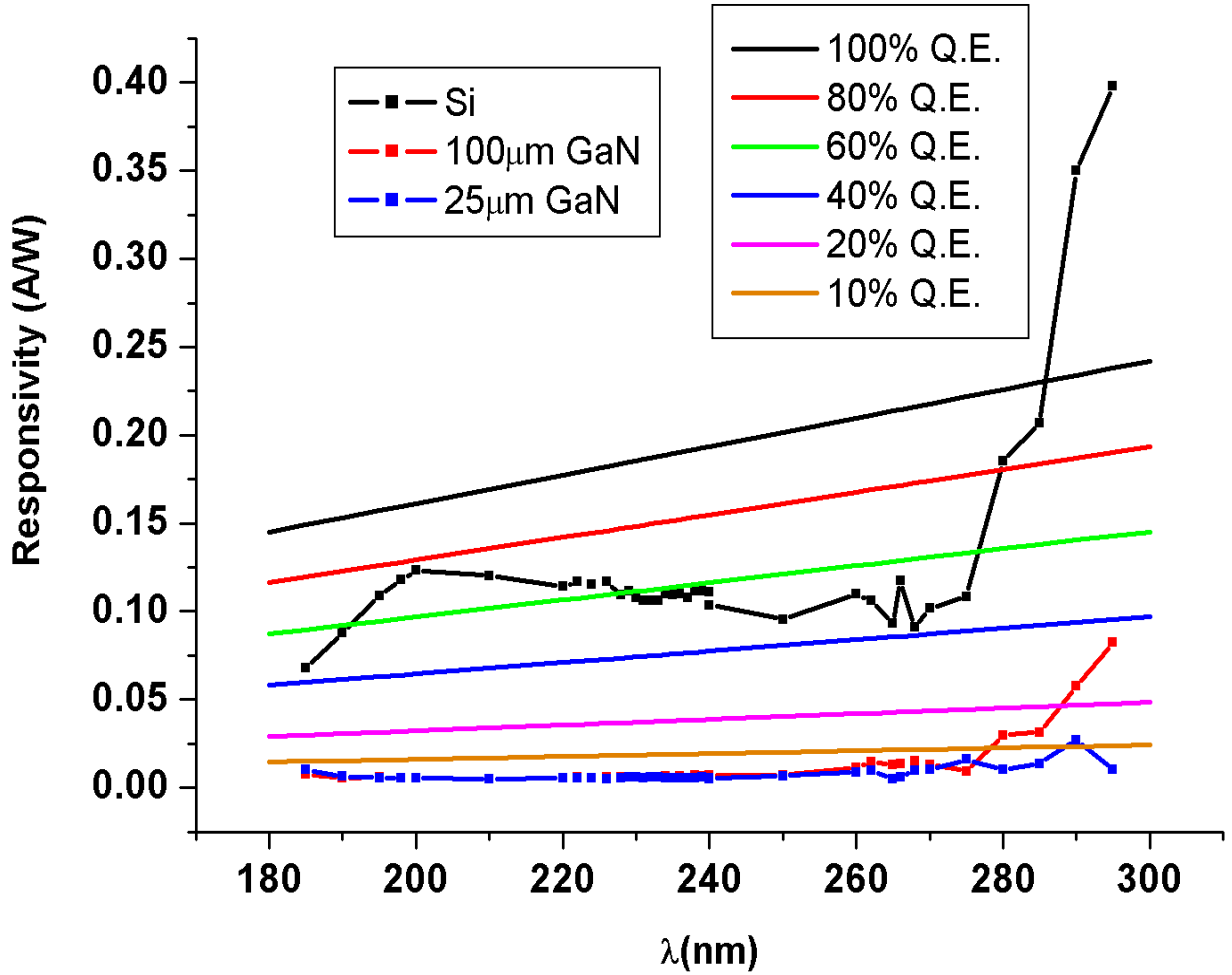


- Material response to UV @ 0V

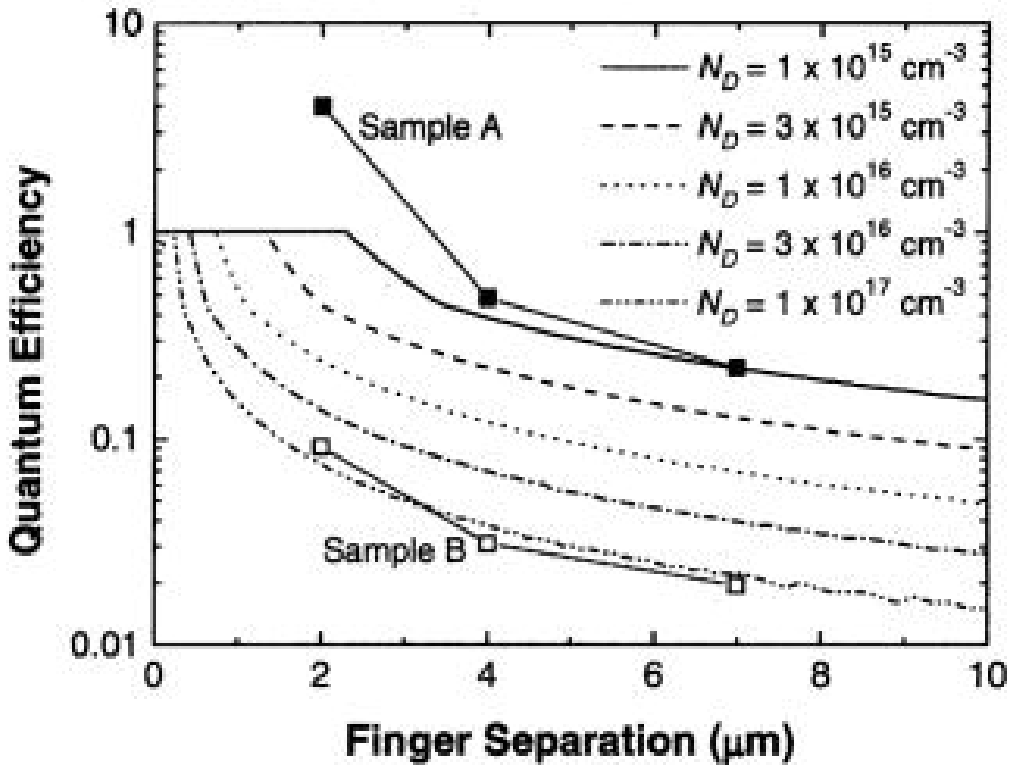


- Spectral response to Deuterium Source

Responsivity



Finger Separation



Monroy et al, Vol 77 (22) Applied Physics Letters (2002)

- Fabricated samples have too large a finger separation

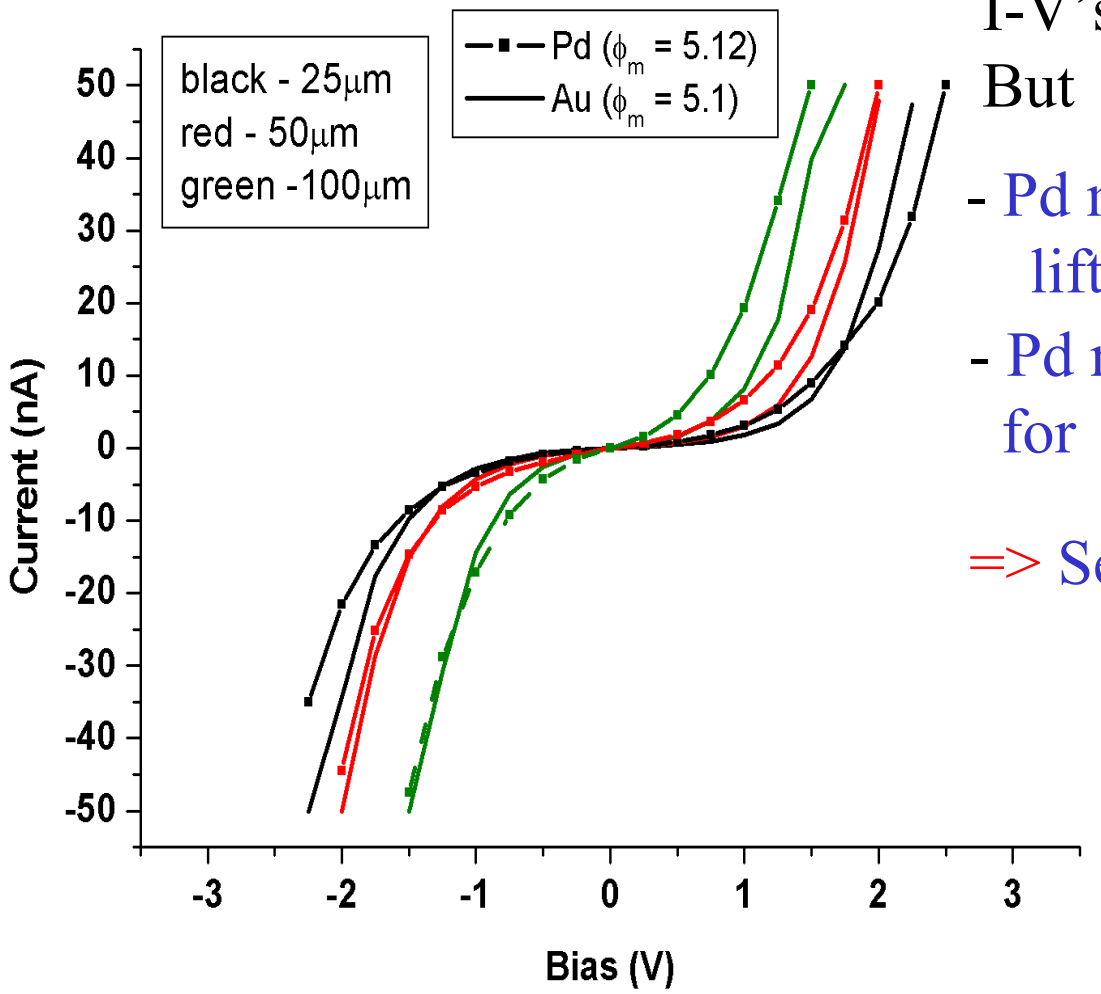
$$\tau_C = R_L C$$

$$C = \frac{A\varepsilon_0(\varepsilon_{GaN}+1)}{L+W}\frac{\pi}{4\ln(\frac{\pi}{8}+\frac{L}{W})}$$

- Larger finger separation (100μm) τ_c ~2s

- Need to decrease finger separation <10μm

Schottky Contacts



I-V's similar

But

- Pd more successful than Au at lift-off
- Pd more transparent than Au for UV (Pd~70%, Au~55%)

=> Semi-transparent Contacts

Semi-Insulating Material

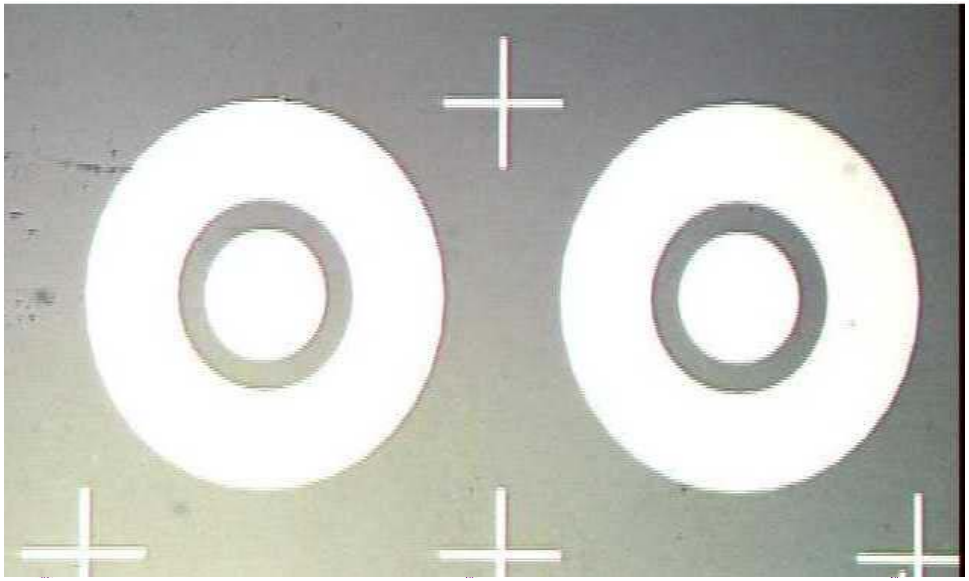
Grown by

Compound Semiconductor Technologies

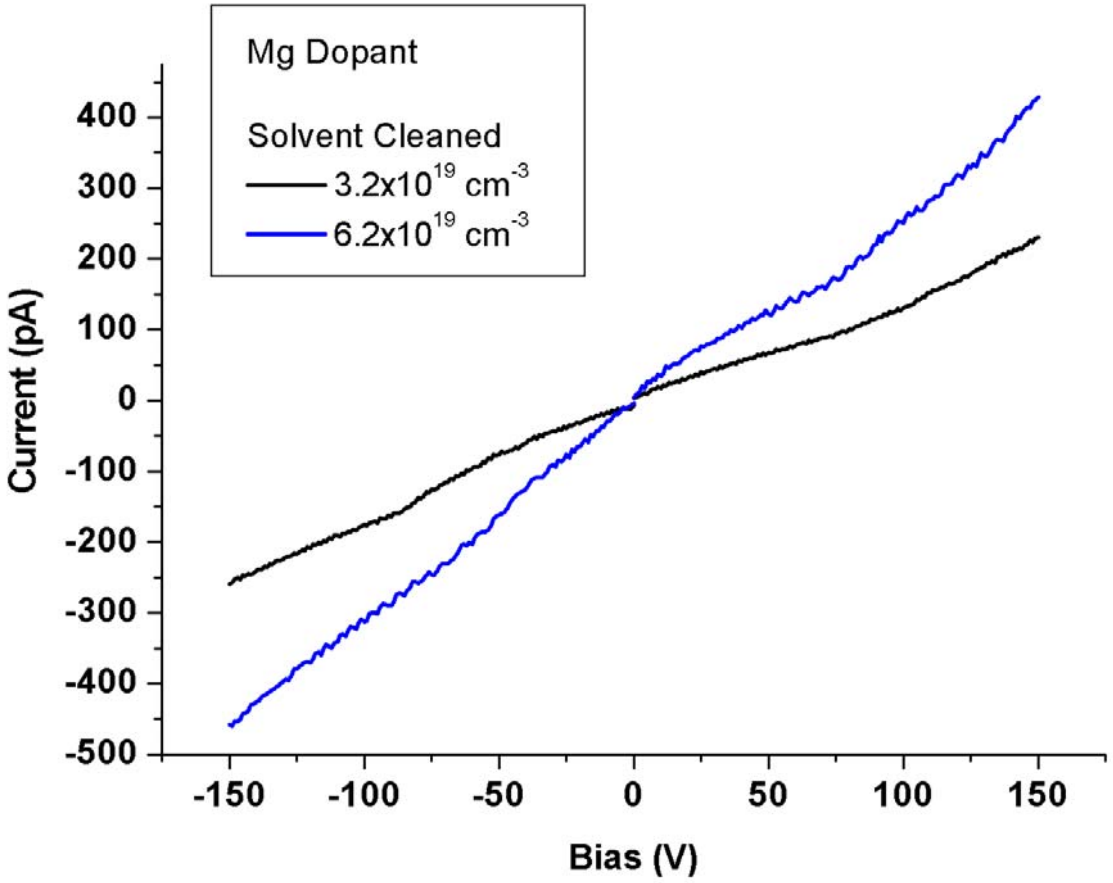
1µm Mg Doped GaN 3.2/6.2x$10^{19}$$cm^{-3}$

1µm Undoped GaN

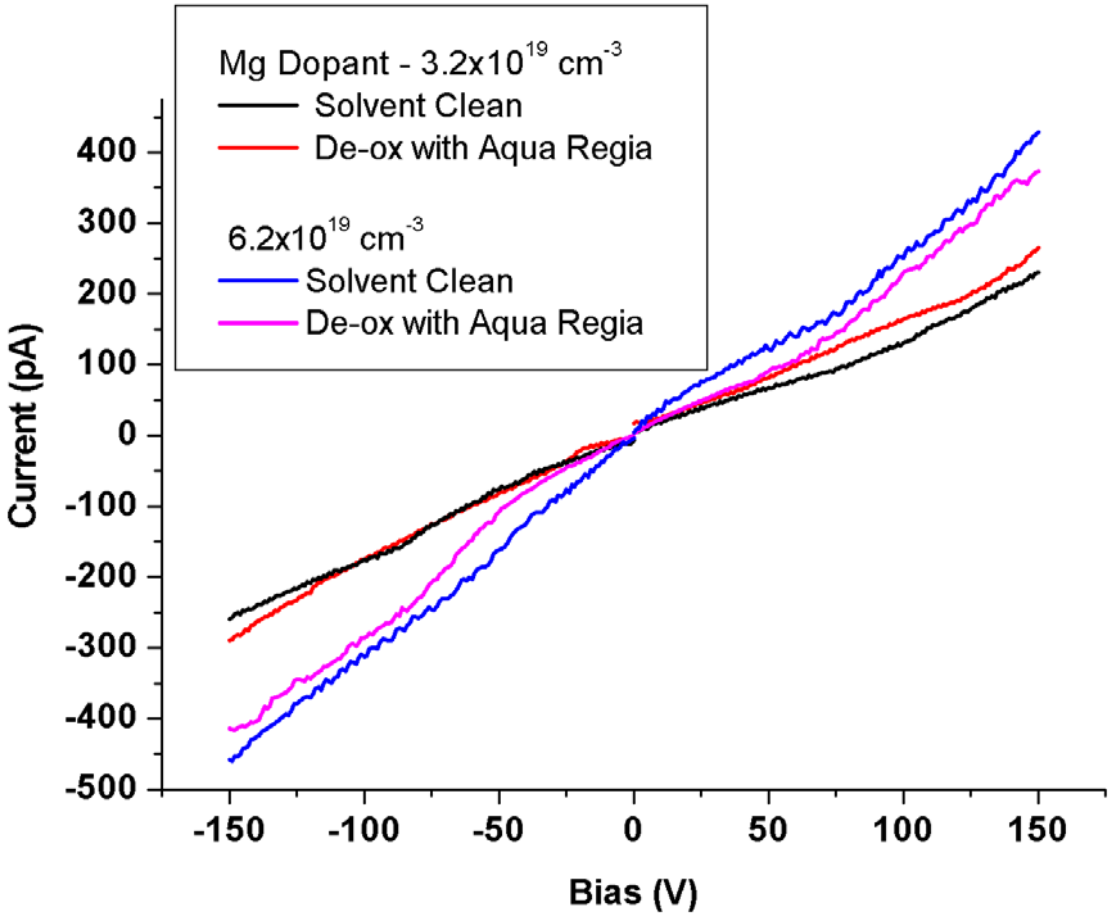
Sapphire



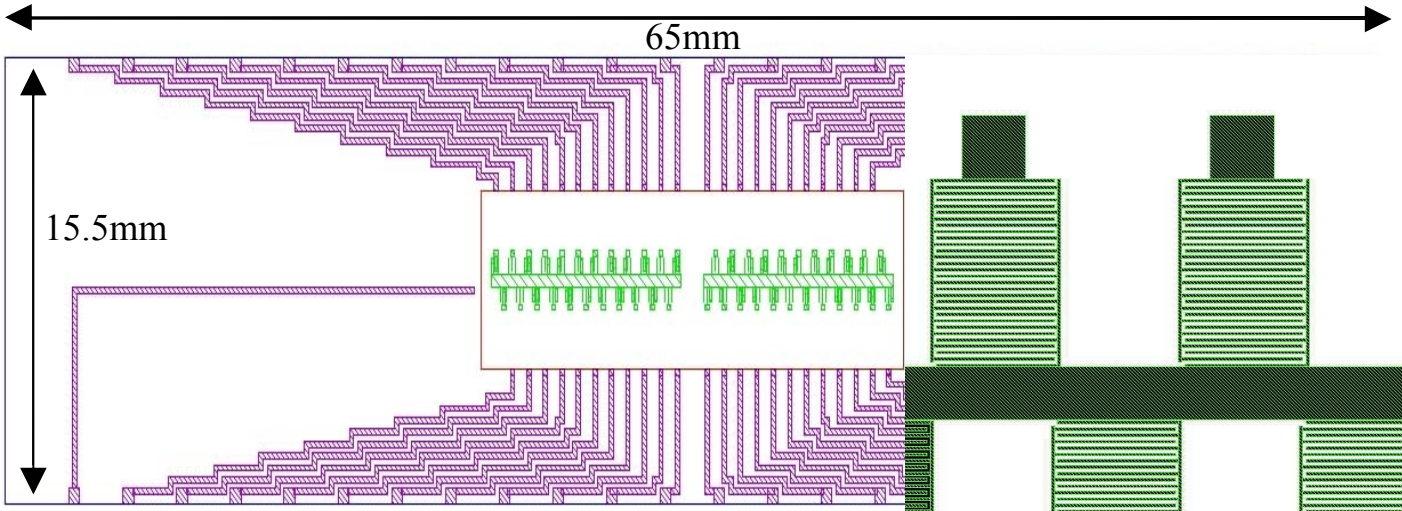
Semi-Insulating Material

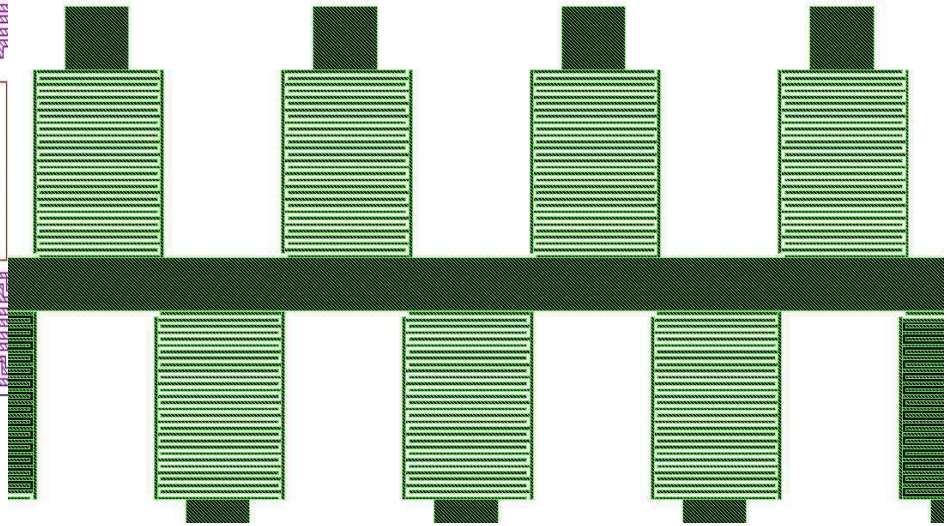


Surface Preperation



Design for Synchrotron Diodes





Green - GaN fingers (10μm width, 10μm pitch)
10nm Pd contacts
Purple - PCB design for integration to DIP socket

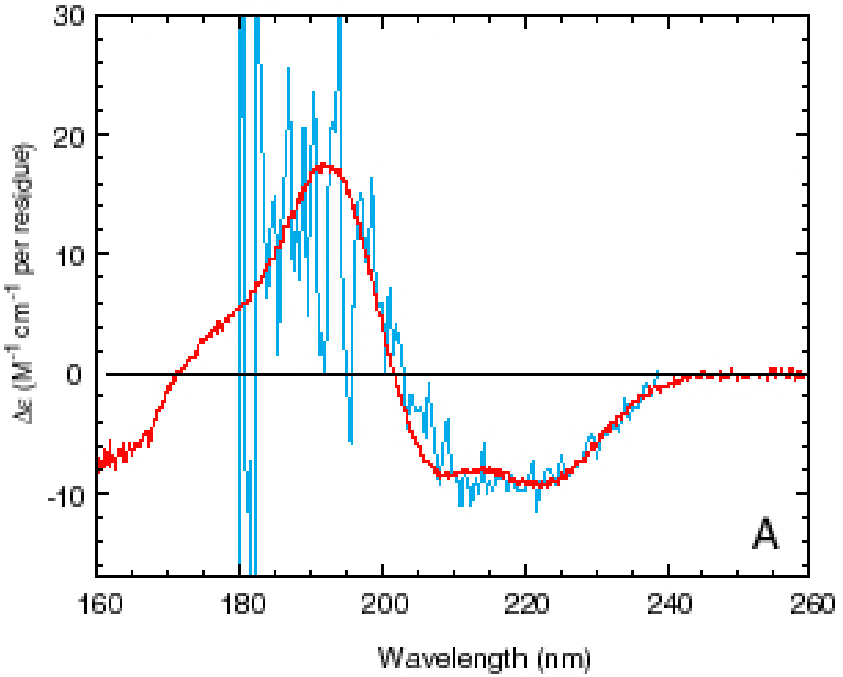
- Entire GaN diode = 6x20mm^2
- Solar Blind – No need for setup to be "light tight"
- Diode can be operated unbiased – 0V

Conclusions

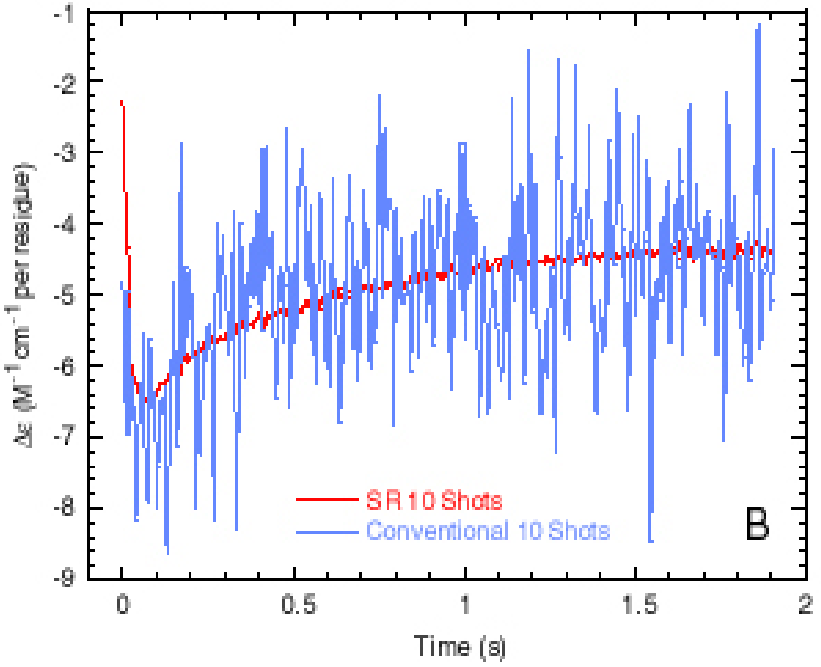
Conclusions

- UV detectors successfully fabricated on GaN
- Progress made in optimising of
  - Device Geometry
  - Schottky Metals
  - De-oxidation
- Unactivated Mg Doped GaN looks promising
- Finished Design for GaN Diodes for CD measurements at Synchrotron

Thanks for your attention!



A) shows short collection time CD spectra of myoglobin. The signal-to-noise ratio is approximately 100 times better with SR at short wavelengths, and 10 times better above 200 nm.



B) shows SRCD and conventional stopped-flow CD data on the folding of lysozyme (at 225 nm). The signal-to noise ratio is approximately 20 times better with SR than with the state-of-the art conventional instrument used.