Enhanced Ultraviolet and Suppressed Blue and Yellow Photoluminescence from Neutron Irradiated GaN Crystals as Scintillator for Radiation Detection

Ke-Xun Sun[1] Nicholas Chang[1], Shaul Aloni[2], and Ron N elson[3]

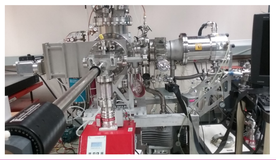
[1]University of Nevada, Las Vegas (UNLV), Molecular Foundry, Lawrence Berkeley National Laboratory (LBNL)

[3]Los Alamos Neutron Science Center (LANSCE)

Ke-Xun.Sun@unlv.edu

NNSS-UNLV Laboratory for Security Science and Engineering

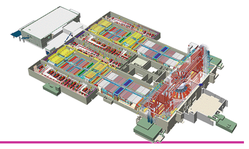
- Sponsored by Nevada National Security Site
- Faculty: Ke-Xun Sun
- Capability & Projects
  - Neutron experiment (LANSCE, NIF)
  - Radiation hardness mechanism study (LBL)
  - Quantum structured GaN for radiation detection (LBL)
  - RadHard GaN Detectors & Imagers
  - GaN Scintillation Detectors
  - GaN Photocathode Detectors
  - GaN Semiconductor Devices
  - Lasers and Optics
  - Fiber Optics Sensors
  - Photonic Doppler Velocimetry
  - RF & Microwave Electronics and Photonics
  - High Performance Computing

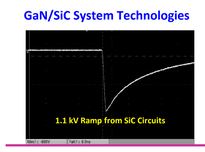


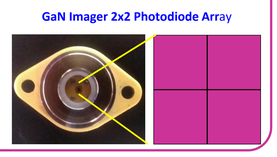
Abstract

Gallium Nitride (GaN) and their compounds InGaN and AlGaN are highly luminescent and transparent wide-bandgap semiconductor materials. GaN materials and devices have revolutionized illumination industry, and provided standard, high efficiency light sources to daily life. Similarly, GaN can be potentially a highly efficient photoluminescence and radioluminescence source for optical and radiation detection.

Enhanced photoluminescence from electron beam irradiated InGaN was the key discovery by Akasaki and Amano that led to design and fabrication of high-efficiency InGaN LEDs. Here we report photoluminescence (PL) measurements taken on various neutron irradiated GaN samples. We observed enhanced ultraviolet photoluminescence (UVPL) and suppressed blue and yellow photoluminescence (BPL & YPL) from neutron irradiated HVPE-grown GaN substrates. The enhanced UVPL is particularly suitable for scintillation detection of ionizing radiation. For potential imaging sensor applications, we also characterized the PL uniformities at various neutron irradiation fluences. We present more detailed experimental results and data analysis conducted recently.

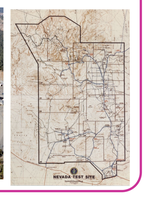






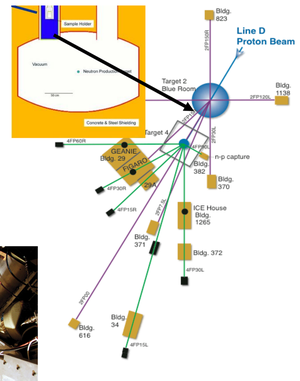
A Multi Institution Collaboration

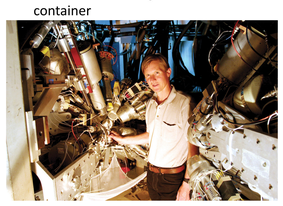
- Molecular Foundry, Lawrence Berkeley National Lab (LBL): Photoluminescence (PL) spectroscopic analysis, Cathodoluminescence, and Time Resolved Absorption measurements
- Los Alamos Neutron Science Center (LANSCE): High fluence neutron irradiation, with neutron energy distribution from 1 MeV to 800 MeV
- Nevada National Security Site (NNSS) / Mission Support and Test Services (MSTS): Application motivation and sponsorship of UNLV projects
- University of Nevada Las Vegas (UNLV): Experiments and data analysis at UNLV, LANSCE, LBL, and project coordination
- Industry: HVPE-Grown GaN Samples

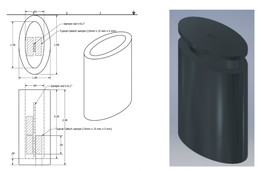


High Fluence Neutron irradiation 1E16 n/cm2 At LANSCE East Port 2015-2016 Run Cycle

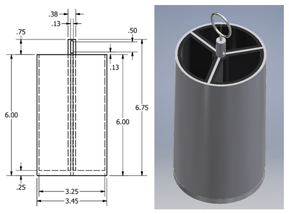
- HVPE-grown GaN samples to study radiation effects
  - Holder: 4" diameter
  - Conductive base
  - Allow different fluence levels
    - Three compartments so samples can be removed at different times
    - Three lead containers to provide proton shielding
- Additional 1/8" of flexible Borated shielding in each container



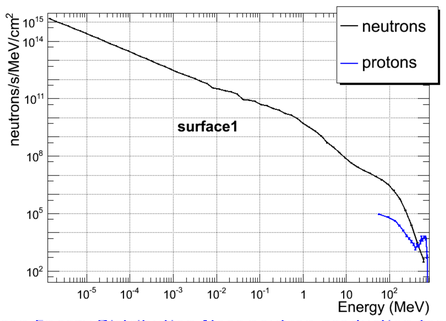




Drawing and rendering of lead cup.



Drawing and rendering of sample holder.

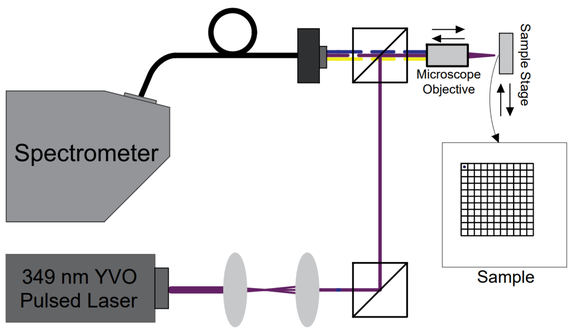


Neutron Energy Distribution Near neutron production target.

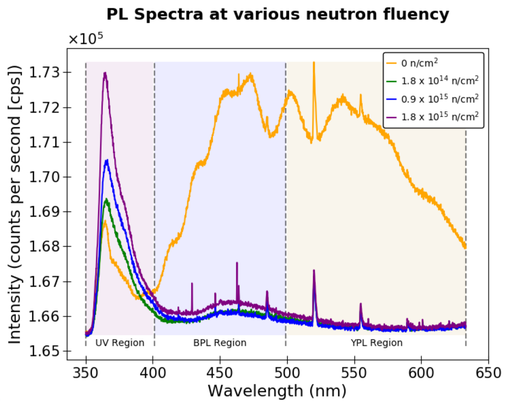
Neutron fluence ~1x10^{16} n/cm^2 1-100 MeV & 100-800 MeV

Experimental Observations Using Molecular Foundry Instruments

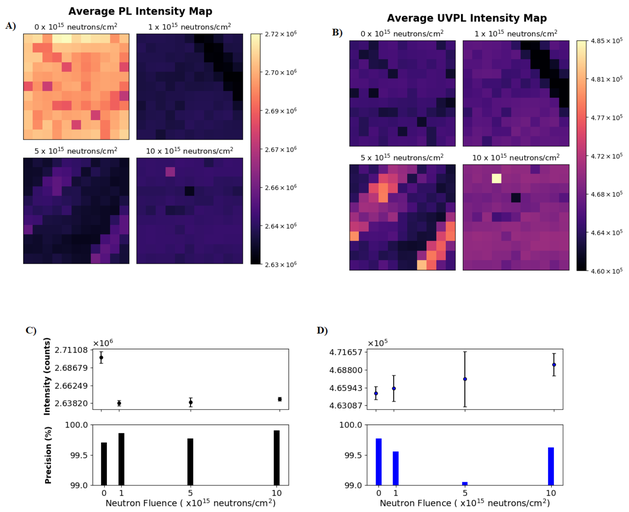
PL Measurement



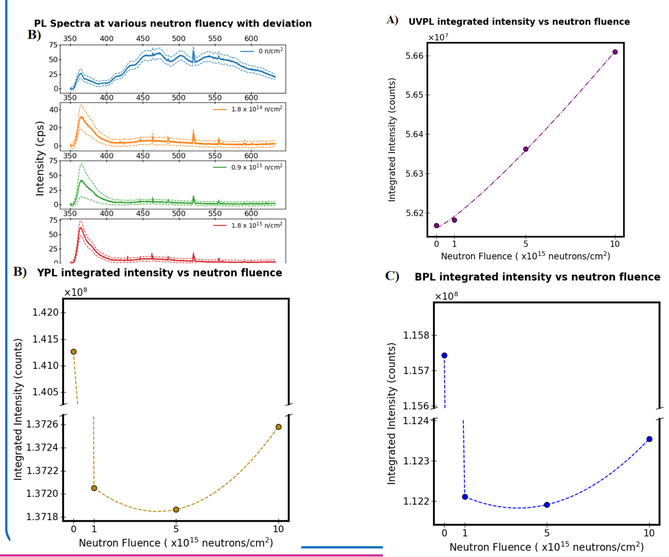
UV PL Enhanced and Yellow PL Suppressed



PL Uniformity

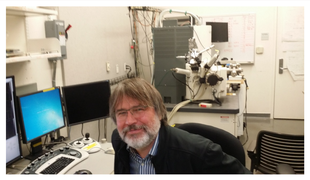


PL Internsity vs neutron fluence



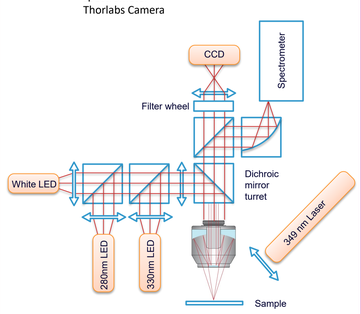
LBL Molecular Foundry Experiment Setup

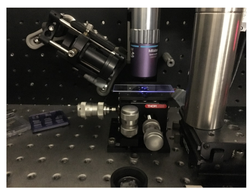
LBL UV Inspection Microscope

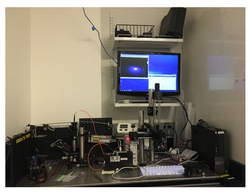


349 nm laser tripled
YVO laser
NUV 50x Mitutoyo objective
Ocean optics spectrometer
Thorlabs Camera

Optional:
Reflective optics
190-20000nm
UV sensitized
CMOS camera







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Conclusions

- High fluence, fast neutron irradiated GaN samples are analyzed at the Molecular Foundry as a result of user proposal "Radiation Hardness Assessment and Mechanisms for GaN Materials and Devices"
- UV Photoluminescence is relatively enhanced by x1.5~x3 times
- Yellow photoluminescence suppressed significantly
- Raman scattering E_1 to A_1 ratio increased with neutron radiation
- The observed neutron effects are beneficial for developing ultrafast optical and radiation detectors

Collaboratiive work by UNLV. Mulecular Foundry at Lawrence Berkeley National Lab, and Los Alamos Neutron Science Center at Los Alamos National Lab supported by Department Of Energy.