Status of WU Nitride Photocathode Development

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Recent Measurements

- Improvements made to RHEED system
- Construction of tube sealing/transfer/QE system
- Low-temperature growth of amorphous GaN and InGaN cathodes.
  - Cathode was fabricated with increased In concentration (25%).
    Growth for about 3 hours, ~100 nm/hour.
- QE and electron diffraction as a function of annealing.
- Optical transmission measurements.
Photo of lab showing recent additions
Amorphous Cathodes

- Began experimenting with a-GaN cathode produced a number of years ago for NMR materials studies
- Restored surface, Cs-activated. Obtained QEs ~5%, encouraging further studies
- Grew ~0.3micron, InGaN cathode with 25% Indium, looked at RHEED data and QE as a function of annealing.
RHEED Measurements

Sapphire - 70deg

a-InGaN no anneal

Sapphire - 10deg

a-InGaN 300C

a-InGaN 390C
a-InGaN QE

Wavelength (nm)

QE (%)

No anneal, first activation
No anneal, second activation
300C anneal, first activation
300C anneal, second activation
Increased Indium concentration to 25% - increased quantum efficiency at all wavelengths, improved QE at long wavelengths
Optical Transmission

- Measured optical absorption using a Xe-lamp, double-grating monochromometer, UDT UV-enhanced reference photodiode and Keithley electrometer. Absorption is normalized to a measurement for an identical sapphire substrate with no coating.

- Compared with crystalline or amorphous GaN, broader band-edge, more absorption at long wavelengths showing band shifting.
Conclusions

• Increasing In concentration improves response at longer wavelengths (out to >400nm)

• Annealing improves QE up to about 300C, above which performance gain levels off.

• For amorphous cathodes, repeated exposure to Cs (with delay) increases QE even up to third activation.

• QE at UV increases to similar level as prior crystalline/epitaxial cathodes!

• Amorphous cathode growth allows use of new substrates - conductive coatings on glass for HV bias.
Future Work

Task List

- Optimize cathode structures

- Deposit a-InGaN on ITO-coated window, apply grid electrodes, apply voltage bias and measure gain-QE product versus voltages

- Experiment with “capping” cathodes with $In$, stripping methods for transfer.

- Transfer a-InGaN cathode grown on glass window to ANL (Spring 2011)

- Transfer glass MCP directly coated with nitride cathode material (Fall 2011)

- Finish development of new vacuum transfer stage for hot/cold indium sealing for transfer, transmission-mode QE measurements
Device Optimization

Growth Parameters

• Study a-InGaN cathodes on different substrates (sapphire windows, stainless steel, other glass windows with or without conductive coatings)

• Study effects of thermal annealing

• Study effects of variations in activation procedure: repeating Cs coatings, incorporation of oxygen during activation

• Increase In concentration

• Change doping levels

Characterization

• In-situ QE measurements versus wavelength (WU)

• RHEED measurements and analysis during growth (WU)

• Room-temperature optical transmission measurements (WU)

• Hall measurements of carrier densities, conductivity (ANL)
Tube Testing and Sealing

- Develop tube sealing/transfer/testing system
  - Transmission-mode QE measurements for comparison with reflection mold measurements
  - Hot (150 C) and Cold Indium seals
    - Ti evaporator for coating of window and housing in vacuum, compression of In wire in O-ring groove
    - Incorporate SAES getter into housing
Push-rod Detail

- Tube housing
- Adaptor
- Docking flange
- Indium O-ring groove
- Spring clip
- Small offset demate interface
- Ceramic spacer
- Wire adaptors to match tube pin-out
- Reducing flange with HV and signal feedthroughs
- Clip release screws
Resources Needed

- Salary support (0.75 FTE Dan Leopold, 0.5 Grad Student)
  - Request in to DOE as part of our 3-year operating proposal
- Theory support
  - Band engineering/reverse-engineering for heterostructures, doping profiles, amorphous materials
- Measurement support
  - Carrier densities, X-ray diffraction for crystalline cathodes, AFM of surfaces
- Supplies ($20k/year ?)
  - Indium wire (2m length, cost?)
  - Cs-Ion source ($1.4k)
  - Epitaxial sapphire substrates ($4k estimate for ~20)
  - Source materials ($1k)
  - SAES getters (5m strip, ST-707-CTS-NI-8D, $130)
  - ~150C heater (components ~$2k)
  - Power supply (HP 6552A power supply $3.5k)
  - Machine shop time for transfer system ($5k)
Backup Slides
Mechanical Design

LAPPD Godparent Review, Oct 5, 2010
• Eventually we might try more advanced band-engineering to achieve solid state PM