Status report of GaN photocathode
3rd collaboration BETH Meeting, online, 1st March 2021

Jana Schaber
Helmholtz Zentrum Dresden-Rossendorf
j.schaber@hzdr.de
www.hzdr.de
GaN Photocathode Research

Agenda

- Short overview of GaN chamber (Set-up)
- Thermal heat treatment
- Main caesium activation
- Highlights 2020
- Latest activations on GaN on sapphire
- GaN on copper (Siegen)
- Summary and Outlook
GaN Photocathode Research

GaN chamber
GaN Photocathode Research

Sample is usual chemical cleaned with EtOH, Piranha solution (H₂O₂, H₂SO₄), HCL, EtOH

→ Removal of adsorbed gases such as N₂, O₂, H₂O, CO, CO₂, ...

Reached T on sample: 650°C → on sensor 466°C, 250°C → 145°C on sensor

Heating time: various, min. 20 min but max. 60 min

Vacuum in good 10⁻⁸mbar
Applying stepwise current to the halogen lamp → observe vacuum
Wait till vacuum stabilizes/ lamp released adsorbed gases
When 145°C on sensor is reached → means 250°C on sample in real
Hold 250°C on sample for 20 min then turn off
Wait till vacuum and cathode temperature is back in normal range
GaN Photocathode Research

main Cs activation

Activation cycle:

1. Thermal cleaning
2. Cs-activation
3. QE tracking

---

**1.** due to vacuum

**2.** adjusting LED spot

**3.** shutter open
1212 nA (maximum)
GaN on sapphire

- GaN on sapphire is heated at 650°C for 25 min
- 4a and 4b showing enormous increase
- 4b activation was stopped after 55 min
- Activations 4c and 4d behaved normally (curve runs in maximum)
- 4a activation leads to 4.7% QE
- Degradation still going on fast (after 2 days only 0.5% QE)

GaN on silicon

- GaN on silicon is heated at 250°C (20-60 min)
- All 5 cycles show same QE (about 2.6% QE)
- Thermal treatment time seems to have no effect on QE
- Degradation for all curves similar, sample survive now about 6 days and still have 0.5% QE left
GaN Photocathode Research
activations on GaN/sapphire #2021.01

GaN activation curves
- 3.3 A on caesium source
- 150 V on anode and UV LED (310 nm)
- Vacuum was kept in $10^{-10}$ mbar range
- Resulting in saturation plateau

@ end → Detect QE over time → next cycle

Total activation times:
7a: 52 min
7b & 7d: 25 min
7c: 30 min

• Thermal heat treatment: 250°C for various times
GaN Photocathode Research

- Maximum total photocurrent $\sim 3700 \text{ nA}$
- Freshly prepared: hit GaN:Cs with green light (5 mW, 535 nm) $\rightarrow$ only $\sim 20-40 \text{ nA}$
- QE drops very fast in the first $\sim 50 \text{ h}$
- After 50 h: QE slowly decreases
- Lifetime: longer than before (after 600 h still 1.4% QE)

$\rightarrow$ all activations between 10 - 11.5% QE
- Thermal heating: \(~250^\circ\text{C}\) for 20 min
25.02.21 Cs-activation on AOI3 GaN on Cu (Siegen)
310 nm UV-LED w. 125 µW
3.4 A on Cs dispenser and 150 V on anode

- Pressure [mbar]
- Photocurrent [nA]

- Pressure
- Photocurrent

- hitting the sample with green light
  (535 nm, 5mW): 0.02 nA

- Cs deposition stopped
- Open LED shutter completely

- 300 V on anode
GaN Photocathode Research

Summary

- Thermal heat treatment is important for QE and lifetime
- Vacuum conditions & LED shutter improve lifetime
- Highest QE so far: 11.5%
- QE from Siegen: works but maybe the surface is still dirty
Charaterization and comparison of commercial available GaN wafer
\(\rightarrow\) GaN on sapphire, Si, SiC (different substrates)
\(\rightarrow\) AFM, XPS, EDX, SEM, RBS

Connection from activation chamber to XPS chamber
\(\rightarrow\) planned in 1st quarter 2021 \(\rightarrow\) delayed

Activation of GaN wafer with Cs and characterization of activated GaN
\(\rightarrow\) further activations and improvement

Nagoya activation: Cs and O alternatively

Comparision to GaAs & selfmade GaN (Uni Siegen)

Improvements on Chamber:
\(\rightarrow\) install heating option for anode
\(\rightarrow\) better temperature measurement (new IR sensor)