

Institute of Radiation Physics

Radiation Source ELBE

Status report of GaN photocathode

3rd collaboration BETH Meeting, online, 1st March 2021

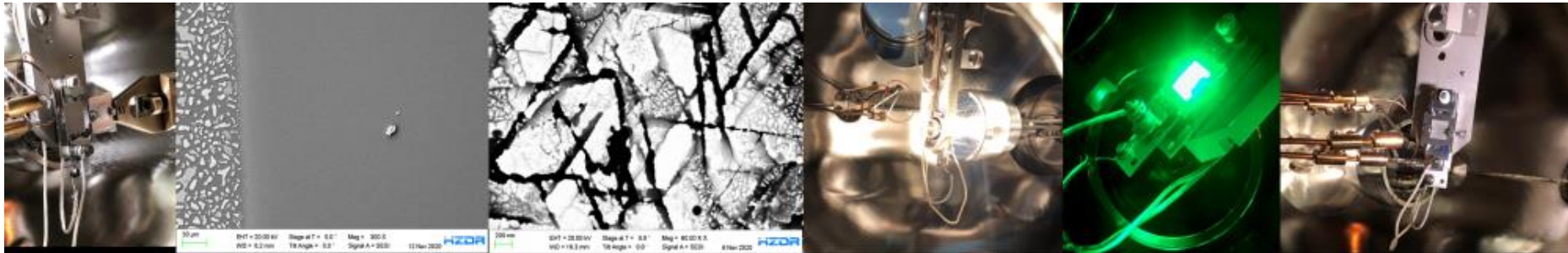
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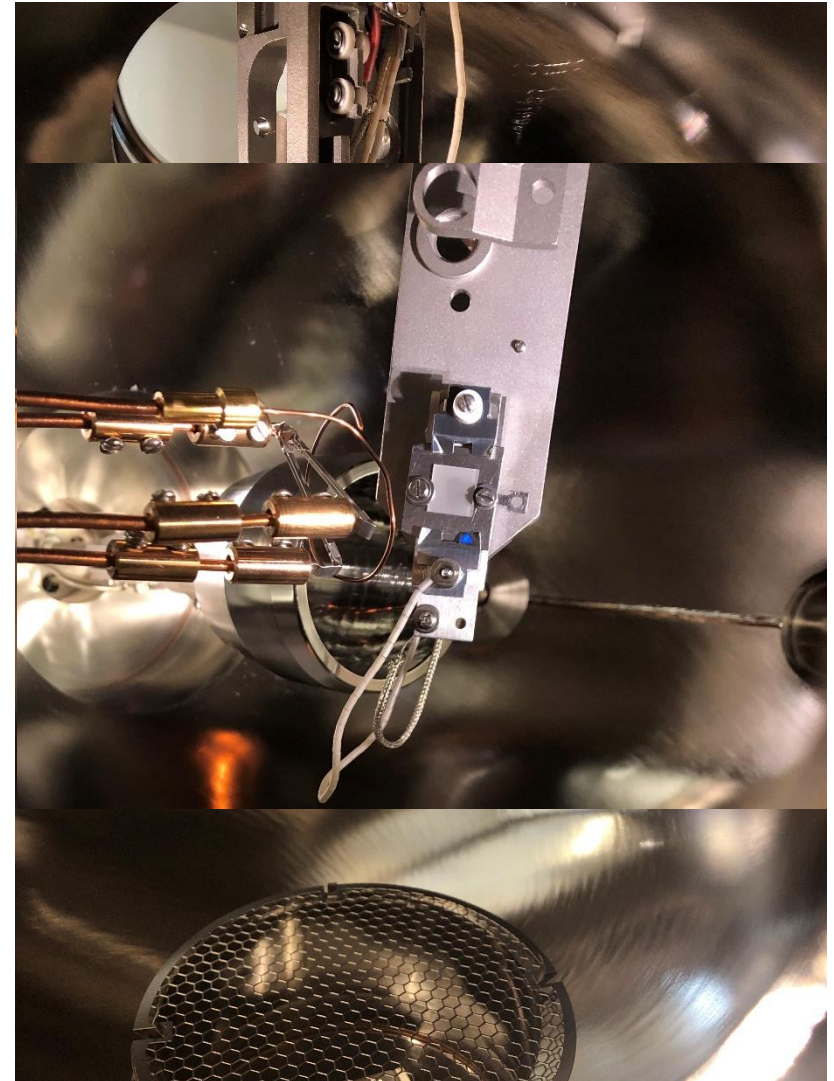
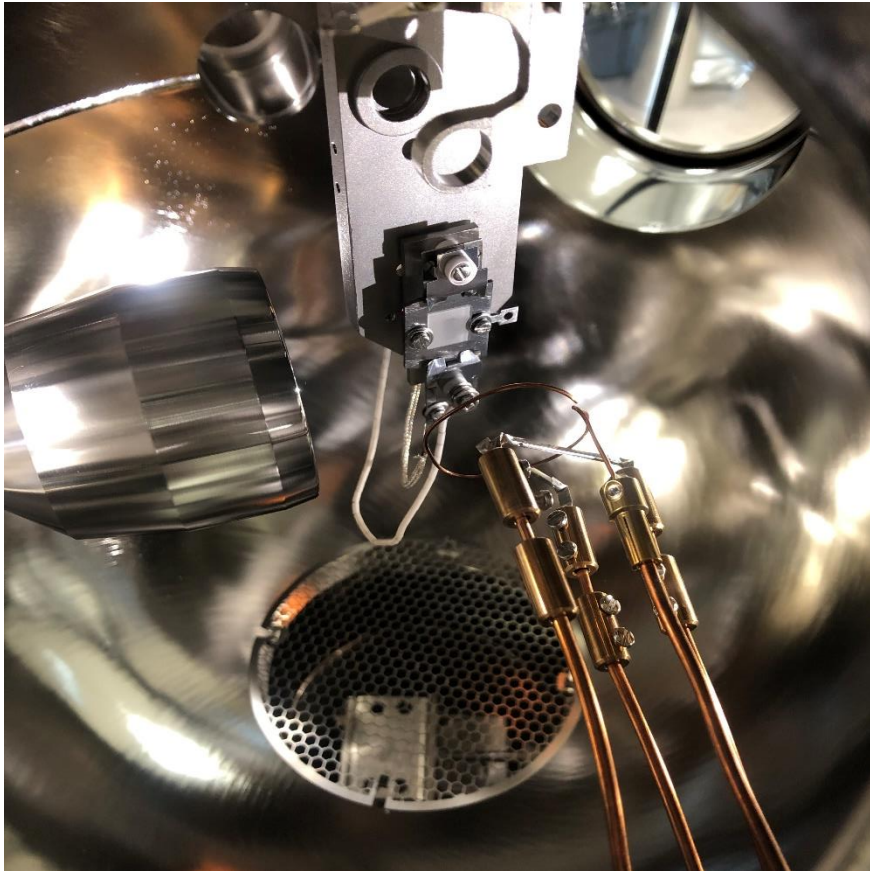
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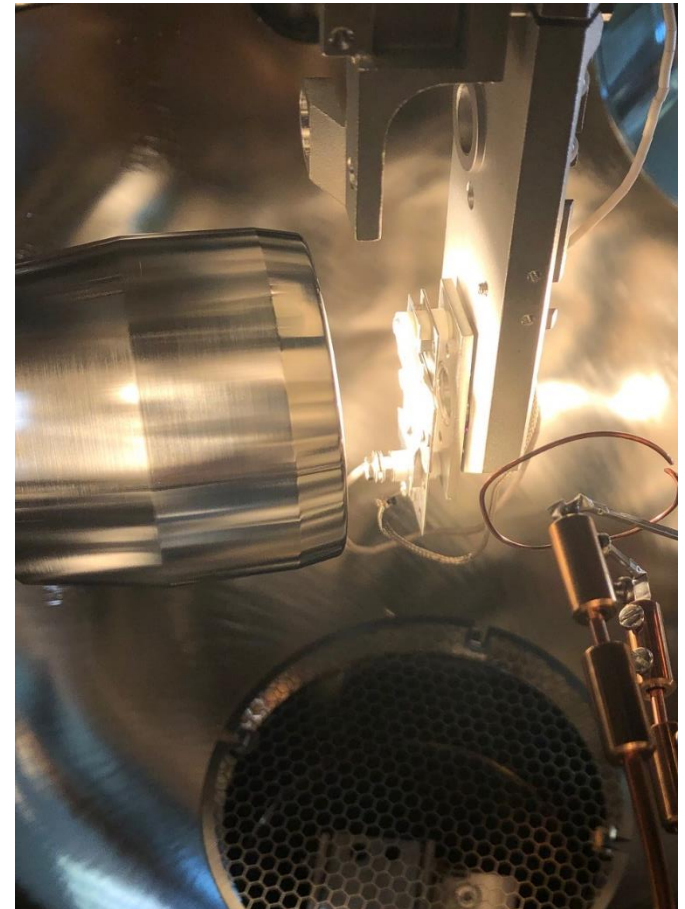
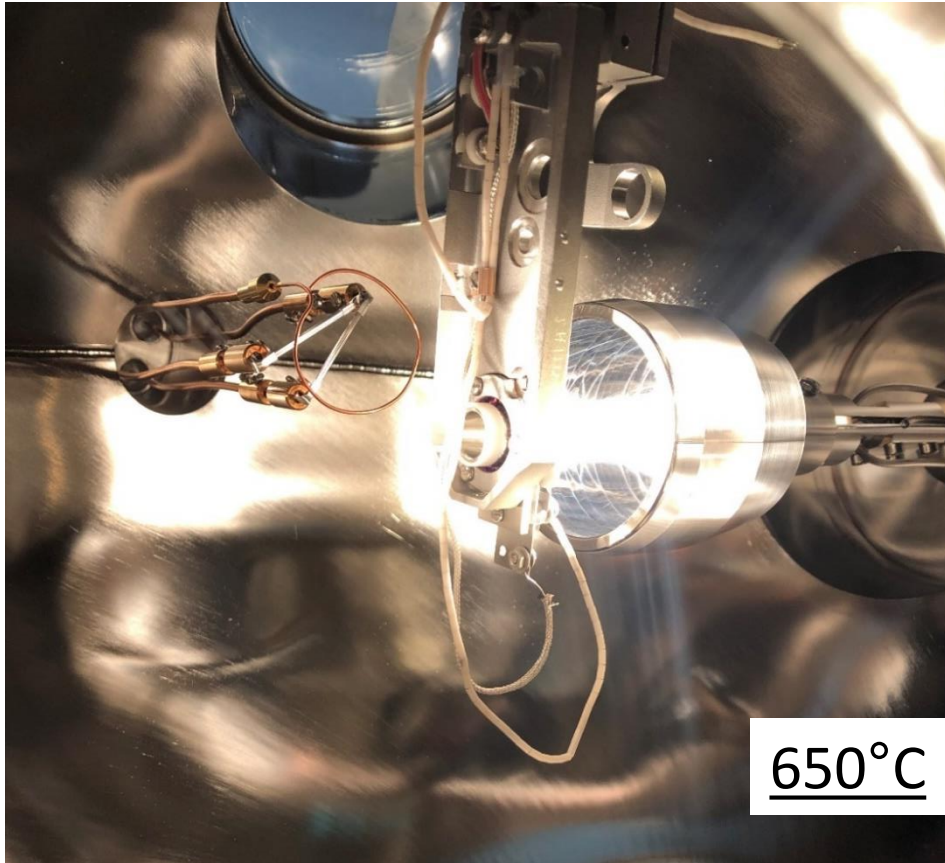
- Short overview of GaN chamber (Set-up)
- Thermal heat treatment
- Main caesium activation
- Highlights 2020
- Latest activations on GaN on sapphire
- GaN on copper (Siegen)
- Summary and Outlook



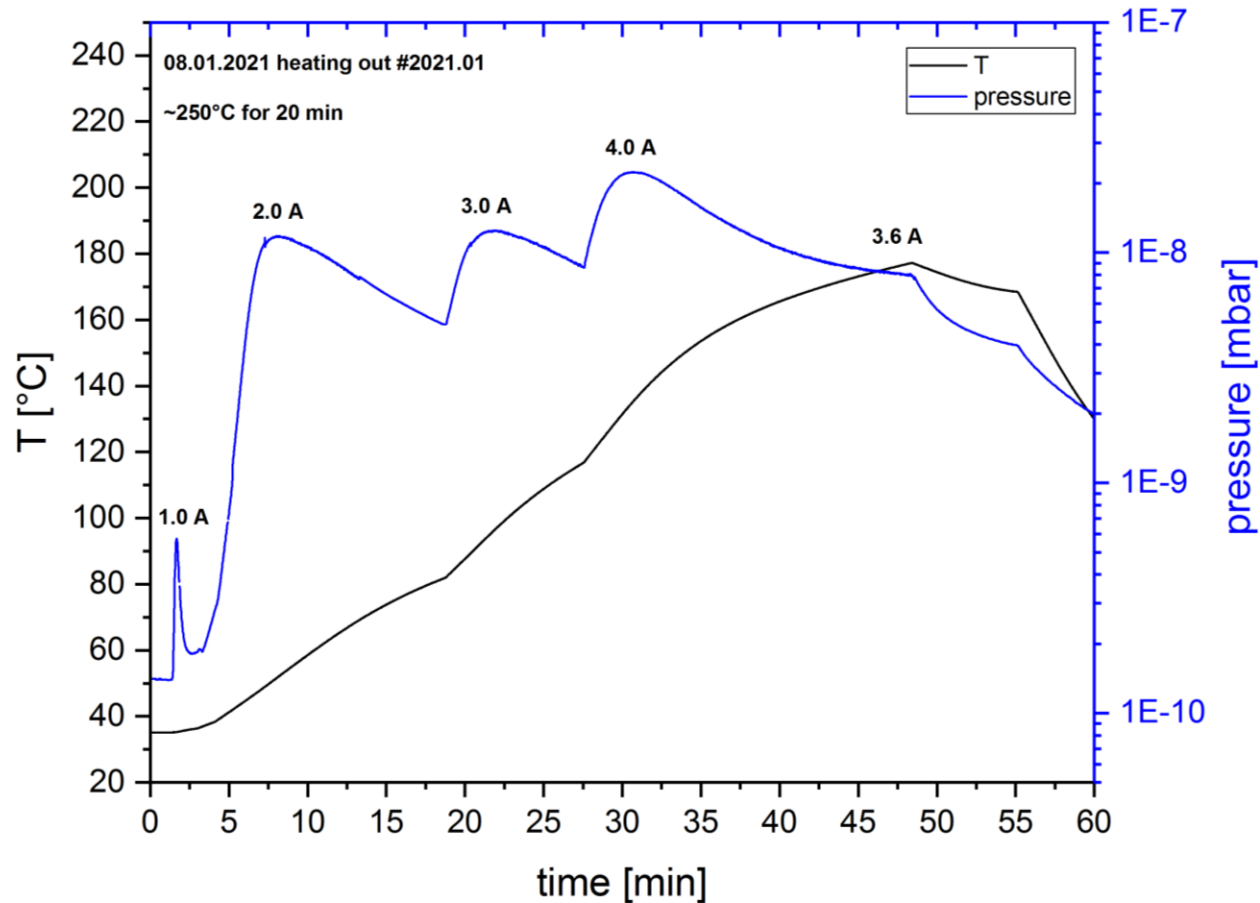
GaN Photocathode Research

thermal heat treatment

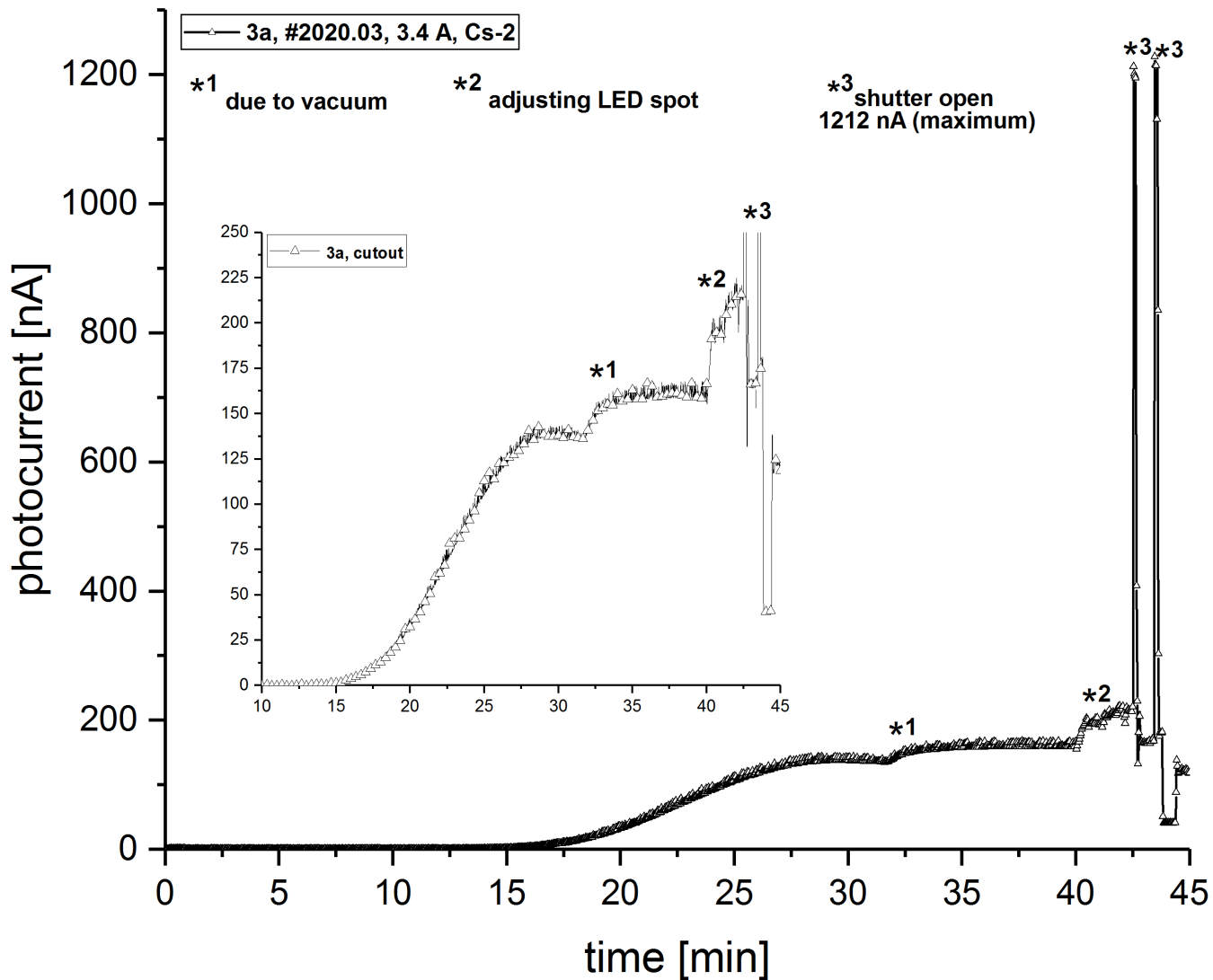
Sample is usual chemical cleaned with EtOH, Piranha solution (H_2O_2 , H_2SO_4), HCL, EtOH
→ Removal of adsorbed gases such as N_2 , O_2 , H_2O , CO , CO_2 , ...



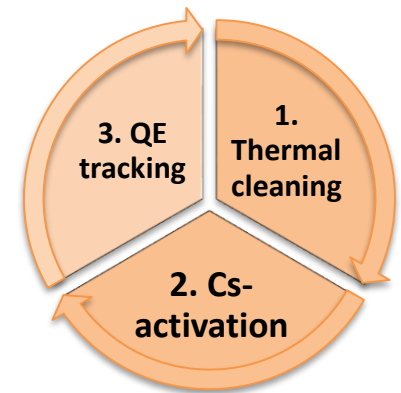
- Reached T on sample: 650°C → on sensor 466°C, 250°C → 145°C on sensor
- Heating time: various, min. 20 min but max. 60 min
- Vacuum in good 10^{-8} mbar



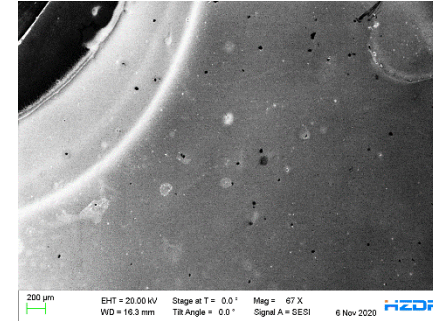
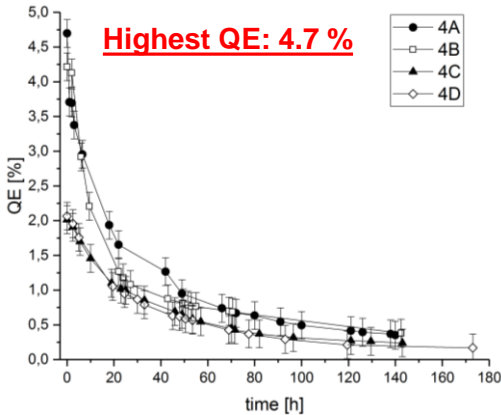
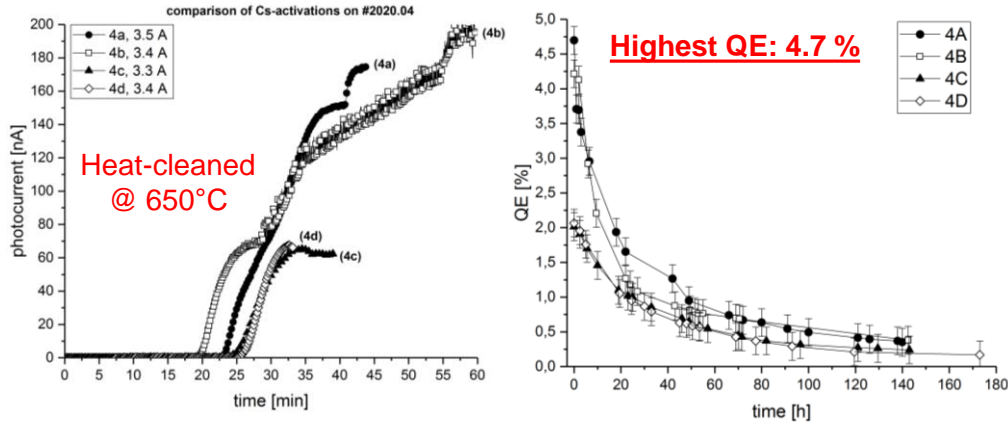
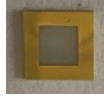
- Applying stepwise current to the halogen lamp → observe vacuum
- Wait till vacuum stabilizes/ lamp released adsorbed gases
- When 145°C on sensor is reached → means 250°C on sample in real
- Hold 250°C on sample for 20 min then turn off
- Wait till vacuum and cathode temperatur is back in normal range



Activation cycle:



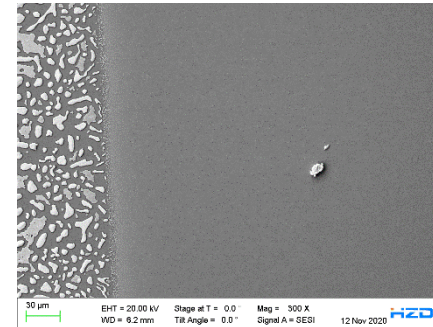
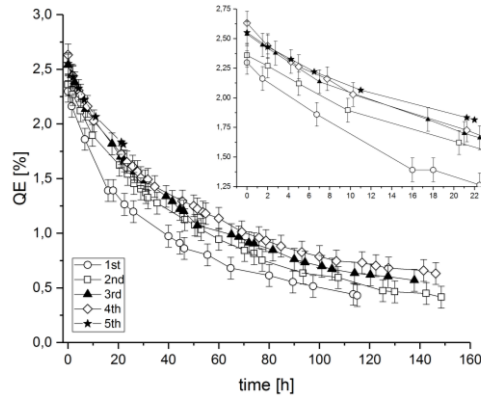
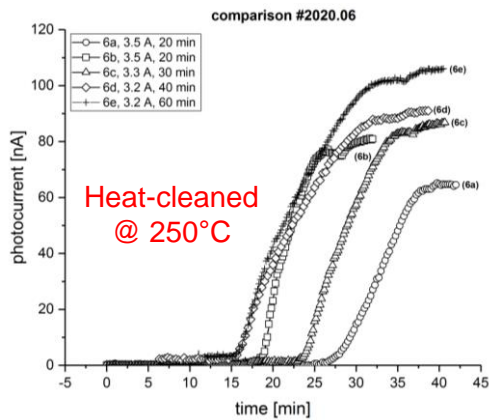
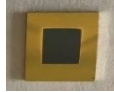
GaN on sapphire



- 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)

Fig. 3: SEM image of used GaN on sapphire sample

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

Fig. 6: SEM image of used GaN on silicon

Fig. 4: photocurrent activation curves for GaN on silicon

Fig. 5: QE tracking from GaN on silicon

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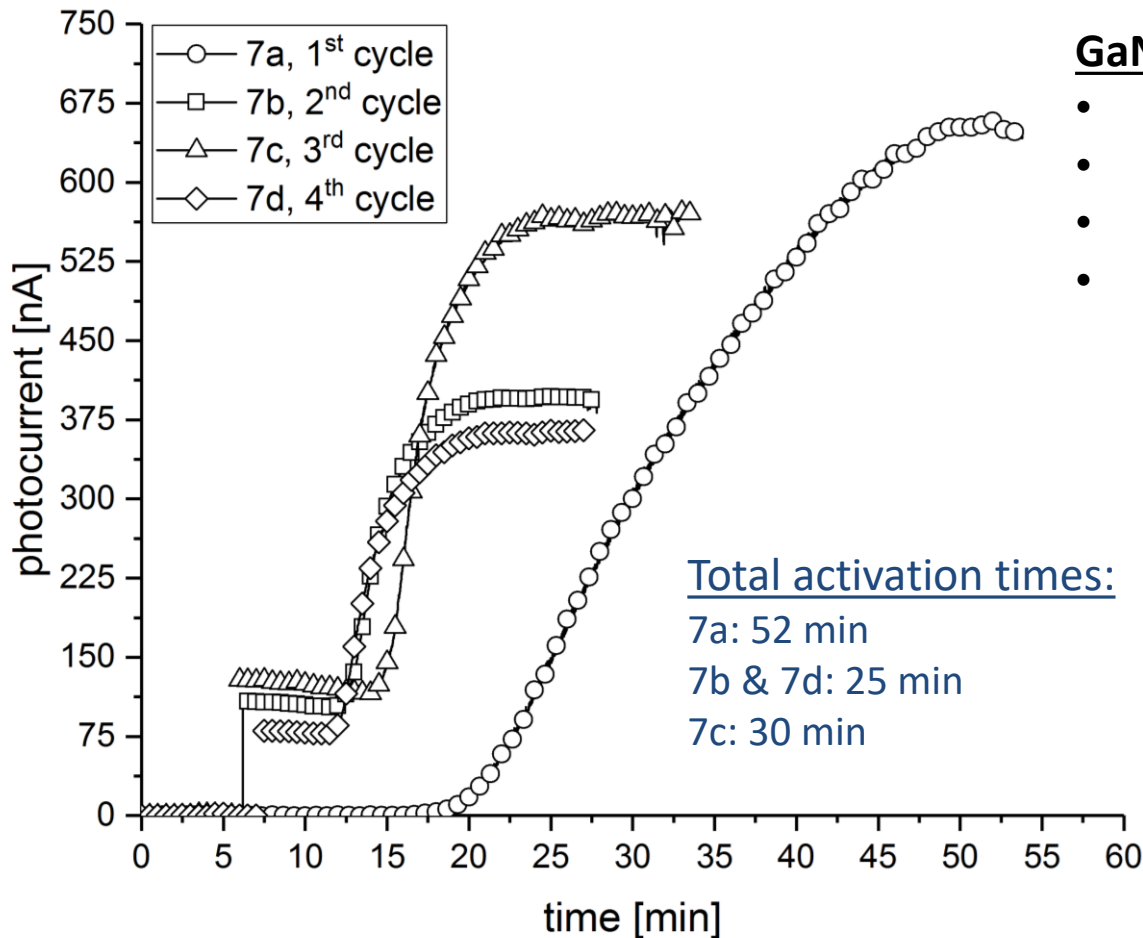
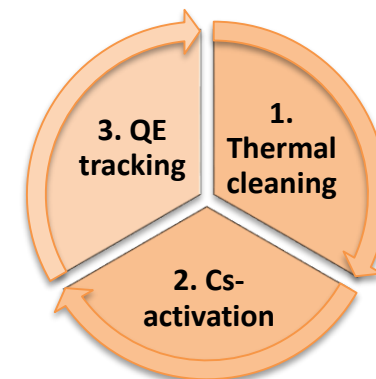
activations on GaN/sapphire #2021.01

latest activation(s)

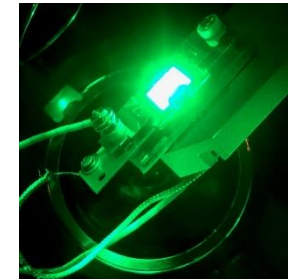
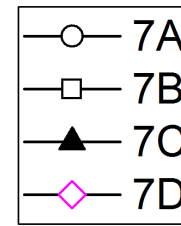
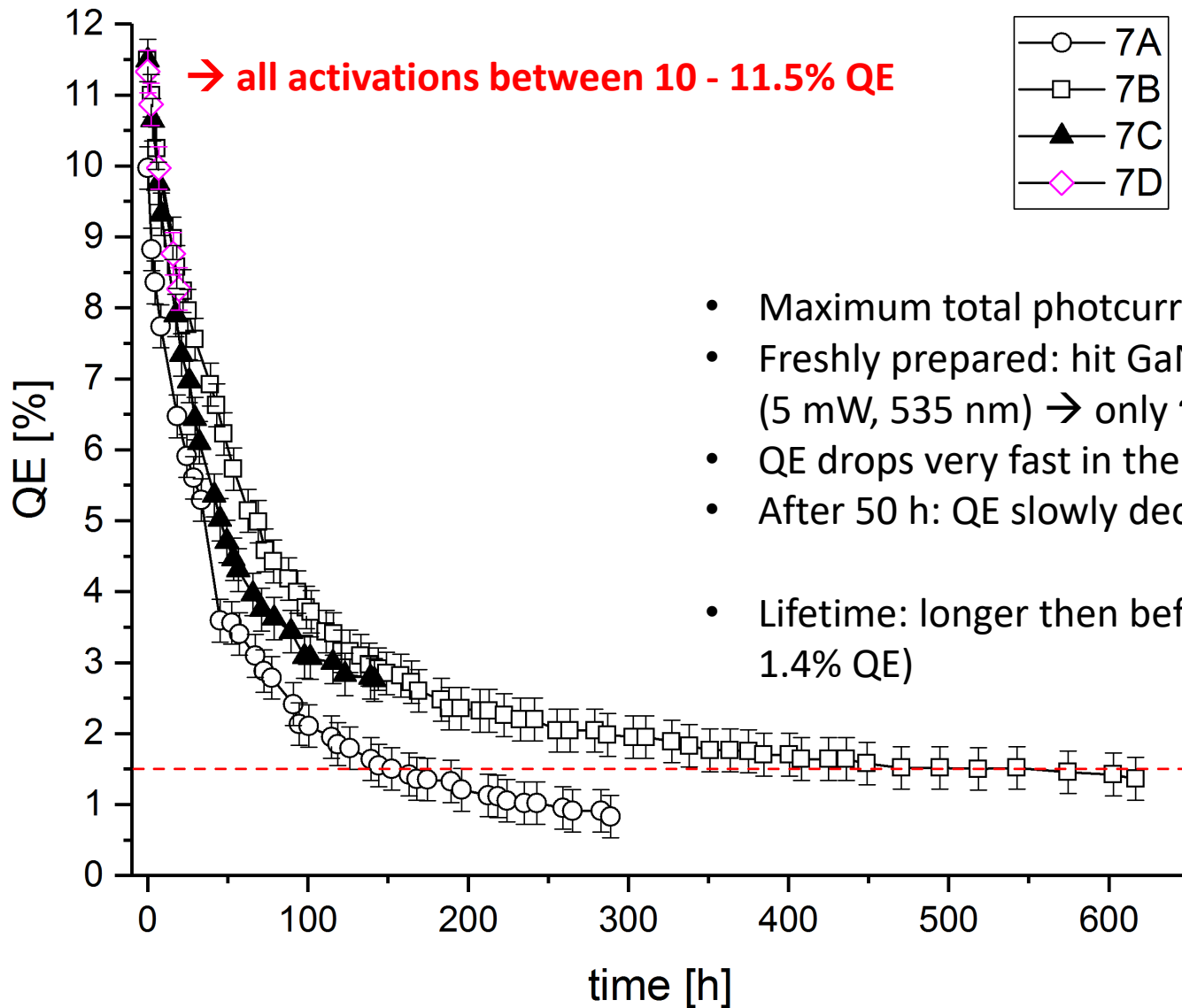
GaN activation curves

- 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

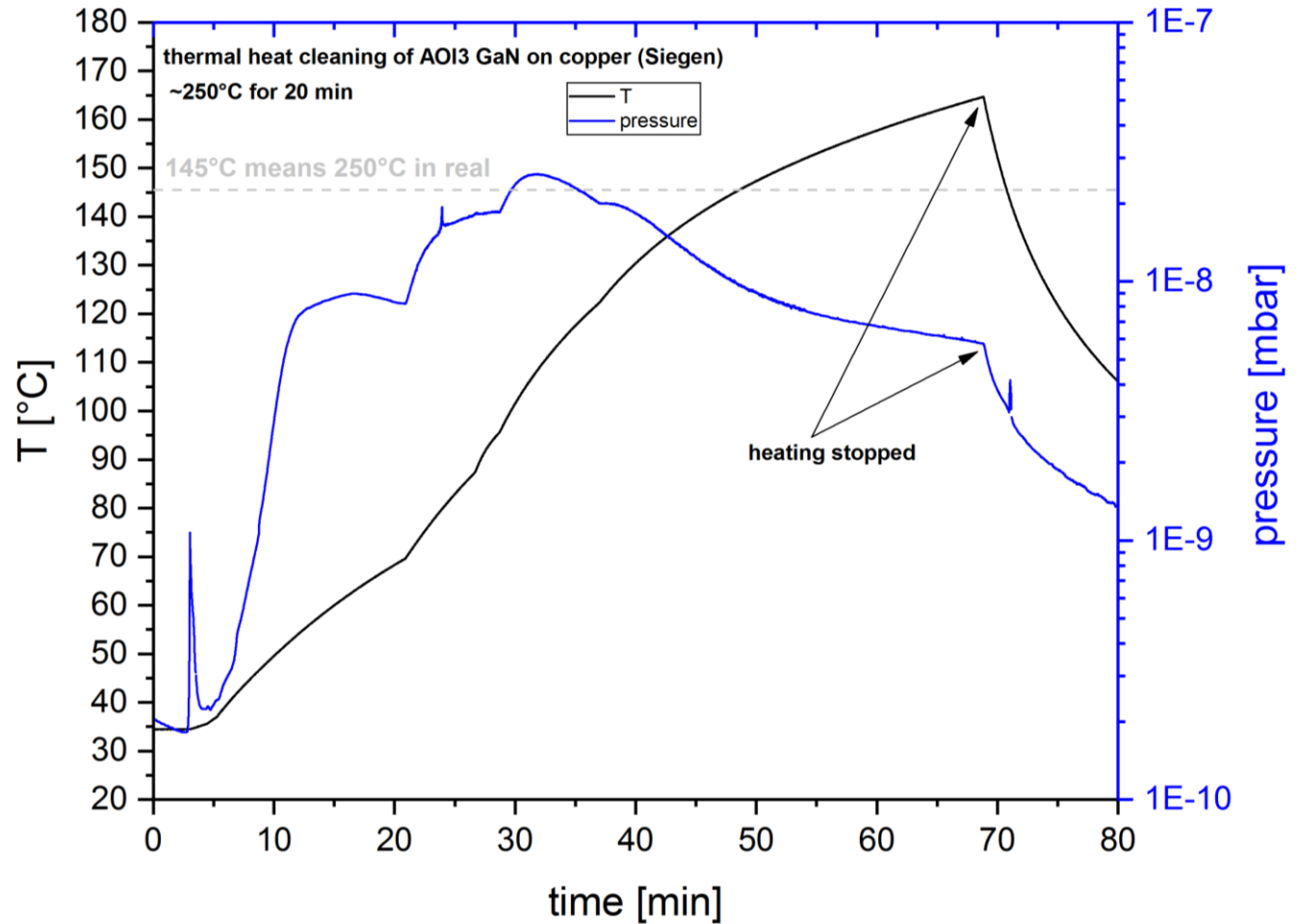
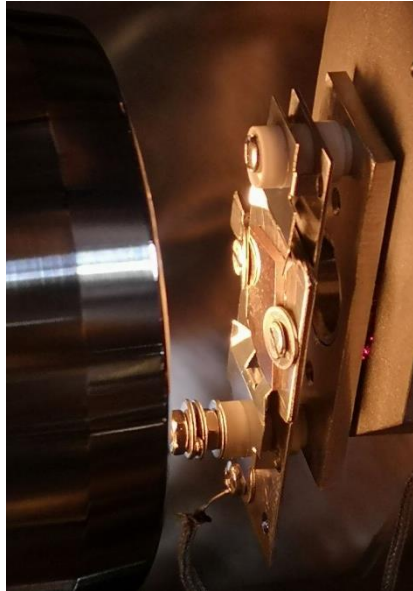


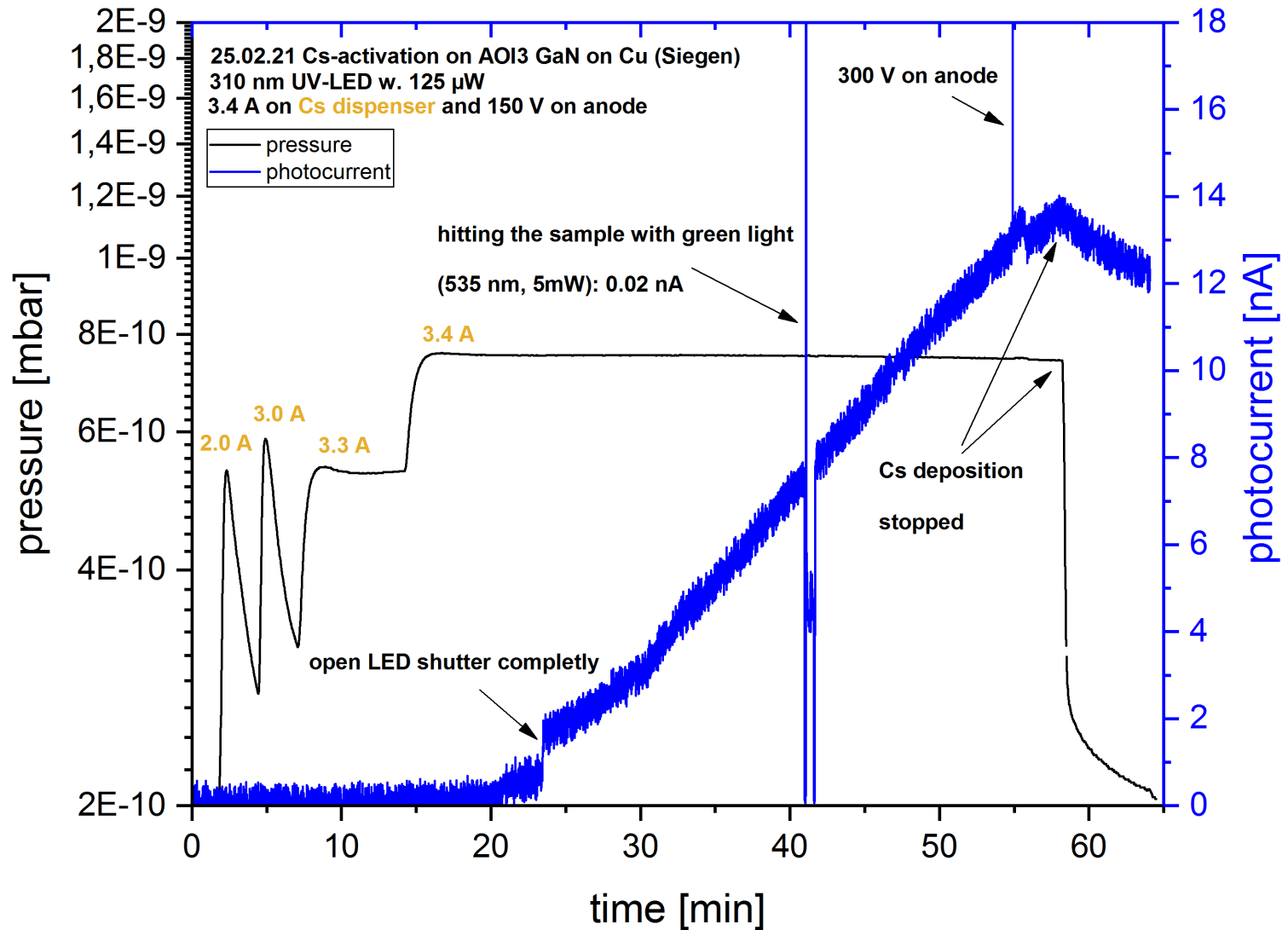
- Thermal heat treatment: **250°C** for various times

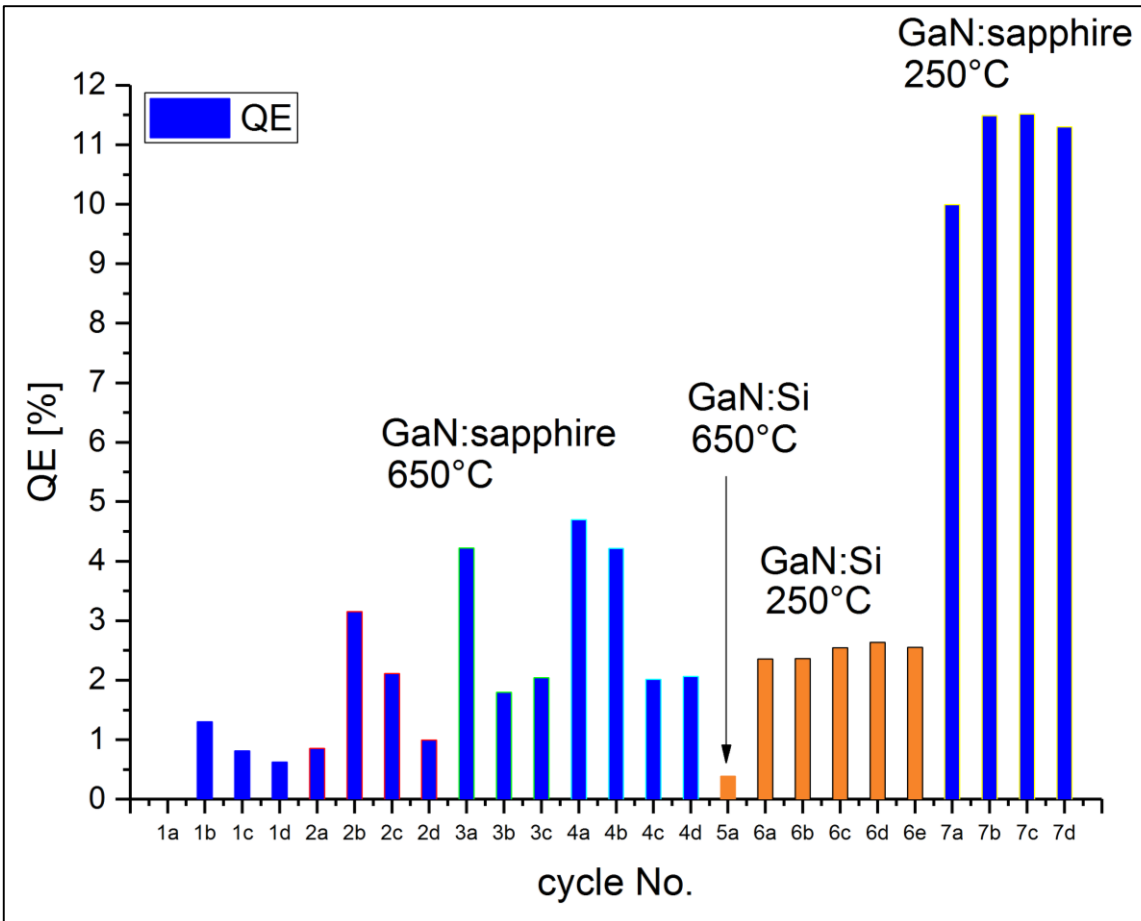


- Maximum total photocurrent ~3700 nA
- Freshly prepared: hit GaN:Cs with green light (5 mW, 535 nm) → only ~ 20-40 nA
- QE drops very fast in the first ~50 h
- After 50 h: QE slowly decreases
- Lifetime: longer then before (after 600 h still 1.4% QE)

- Thermal heating: $\sim 250^{\circ}\text{C}$ for 20 min





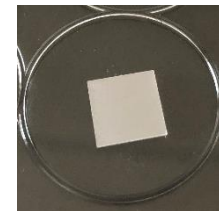


- Thermal heat treatment is important for QE and lifetime
- Vacuum conditions & LED shutter improve lifetime
- Highest QE so far : 11.5%
- QE from Siegen: works but maybe the surface is still dirty

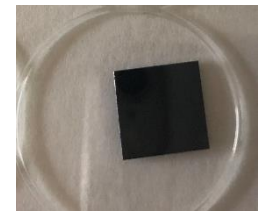
- Characterization and comparison of commercial available GaN wafer
 - GaN on sapphire, Si, SiC (different substrates)
 - AFM, XPS, EDX, SEM, RBS
- Connection from activation chamber to XPS chamber
 - planned in 1st quarter 2021 → delayed
- Activation of GaN wafer with Cs and characterization of activated GaN
 - further activations and improvement
- Nagoya activation: Cs and O alternatively
- Comparison to GaAs & selfmade GaN (Uni Siegen)
- Improvements on Chamber:
 - install heating option for anode
 - better temperature measurement (new IR sensor)



XPS facility in front of GaN chamber



GaN on sapphire



GaN on Si



GaN on sapphire and Si sputtered with gold