Institute of Radiation Physics

Radiation Source ELBE

The attempt of using GaN as a photocathode in SRF Gun II

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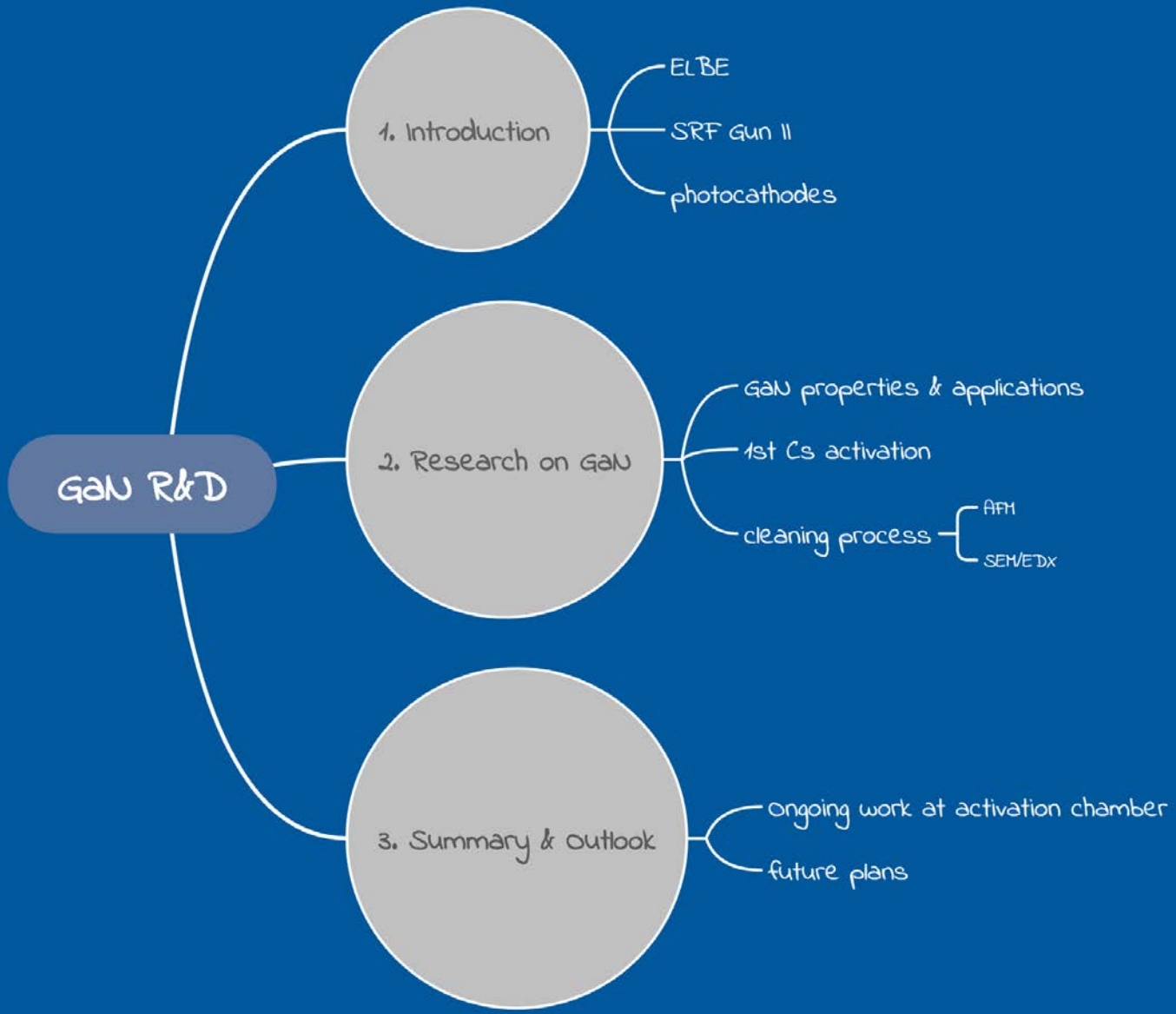

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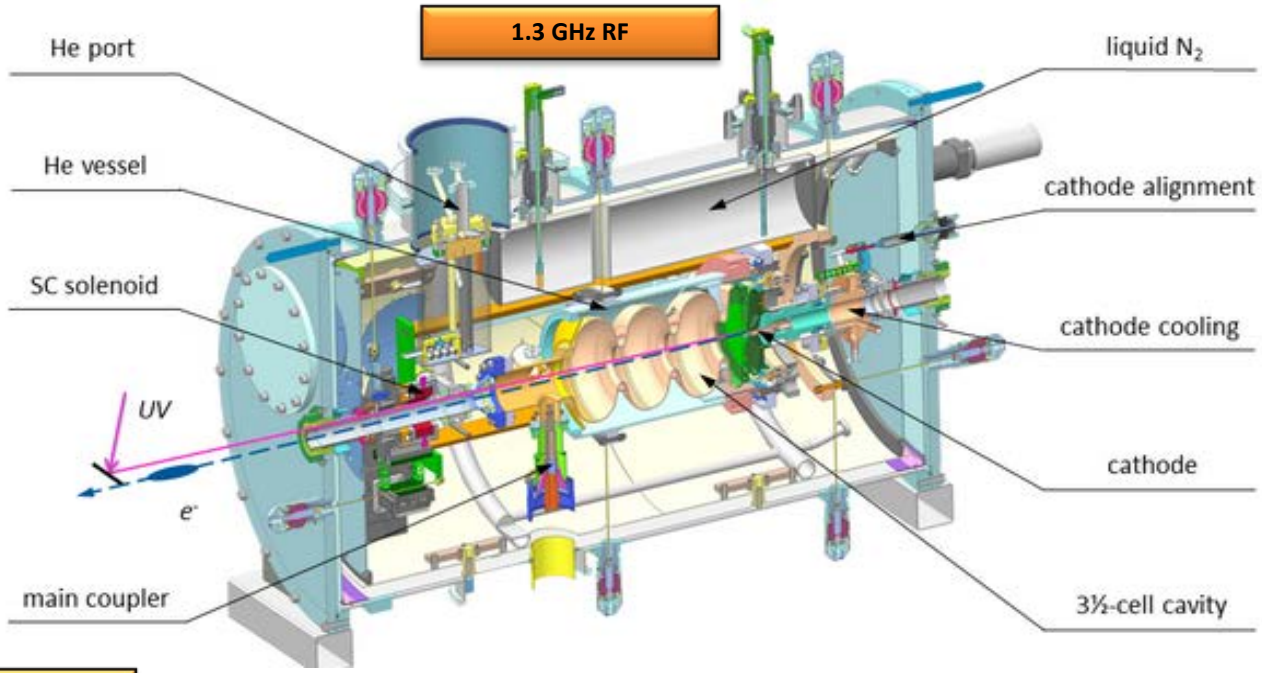
Introduction

Setup SRF Gun II



Core: 3.5 cell Nb cavity	cooled down at 2 K with liquid helium, low electrical losses & cw mode
SC solenoid	cooled down at 2 K, reduces the emittance
UV laser	illuminates the photocathode

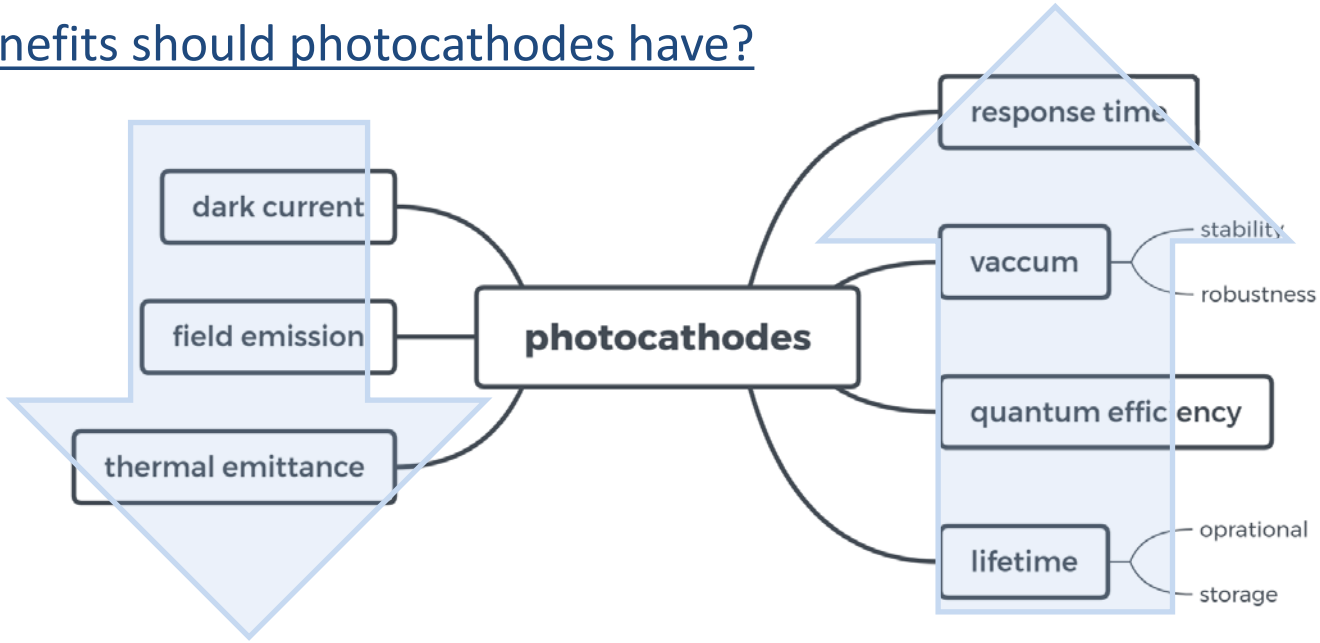
Development of photocathode plays an important role:

- copper: used for demonstration of the working cavity and the first commissioning (QE of 10^{-5} with a bunch charge of several pC)
- magnesium: mostly used for medium bunch charges of hundreds of pC (QE of 10^{-3} after cleaning)
- Cs_2Te: preparation and vacuum requirements are more complicated and higher (QE of 10^{-2})

Member of the Helmholtz Association

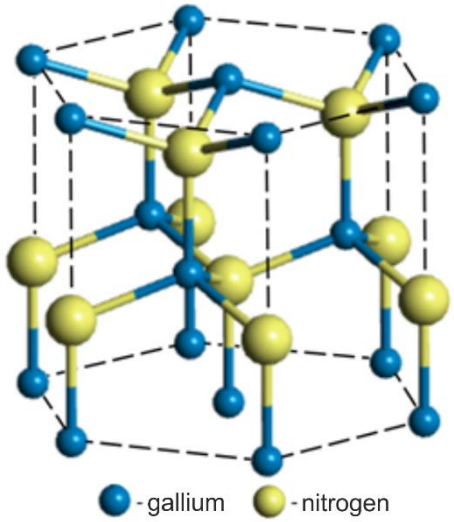
Research on (new) material

What benefits should photocathodes have?



❖ Properties of GaN

- direct semiconductor
- band gap of 3.37 eV @ 300 K
- Wurtztite structure:
  →alternating bilayers of Ga and N in c-direction (**ABAB**)
- mostly on sapphire substrate or others

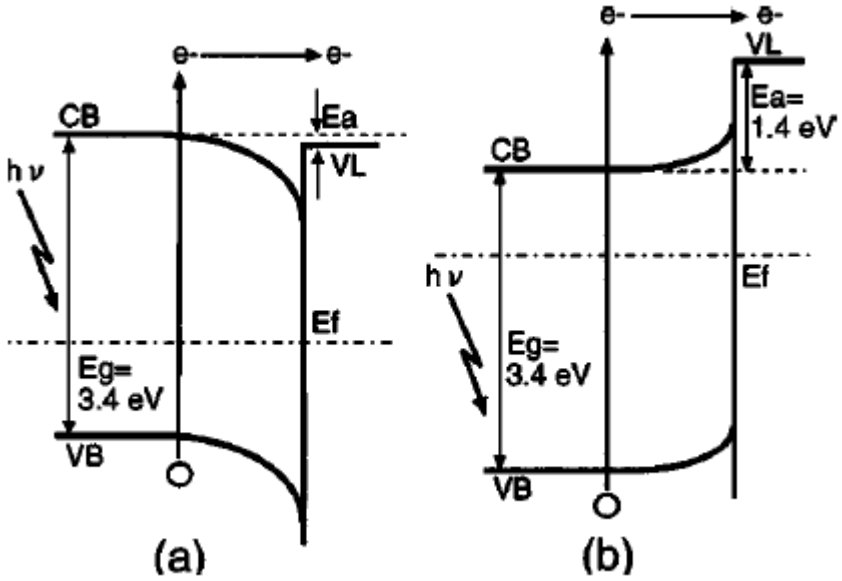


❖ Applications of GaN

- Light emitting diodes (LEDs)
- Laser diodes (LDs)
- UV detectors
- Data storage (Blu-Rays)

Focus on Research on GaN

GaN band structure



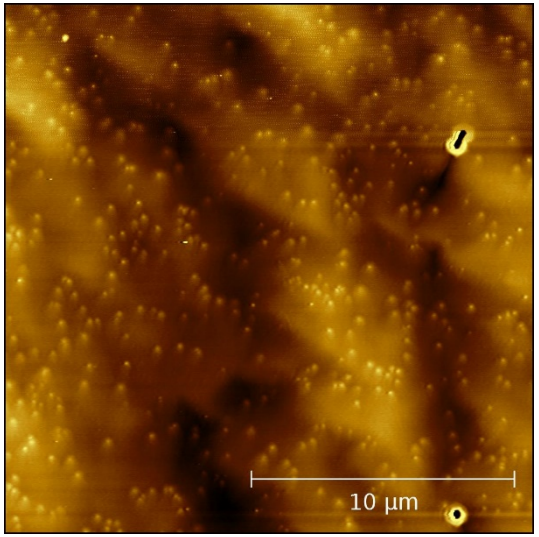
- Band gap of 3.4 eV → Laser wavelength of 365 nm needed
- (a) Mg GaN (Cs): Mg doping rate of $10^{16}cm^{-3}$ (minimum) to $10^{19}cm^{-3}$ (maximum)
  shift of vacuum level to lower energy than CB
  NEA: electron excite over the band gap and easily enter into vacuum
- (b) undoped GaN: high potential barrier, electrons cannot leave the surface

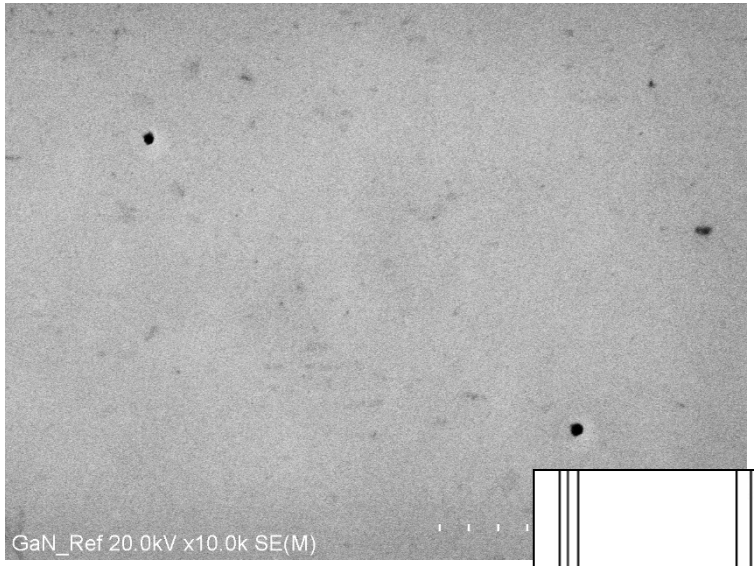
Problem of high doping: many trap sites and recombination centers

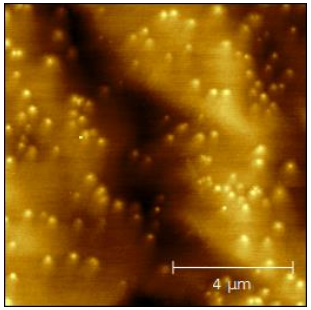
Uchiyama, Shoichi et al. 2011. "GaN-Based Photocathodes with Extremely High Quantum Efficiency GaN-Based Photocathodes with Extremely High Quantum Efficiency." 103511(2005):1–4.

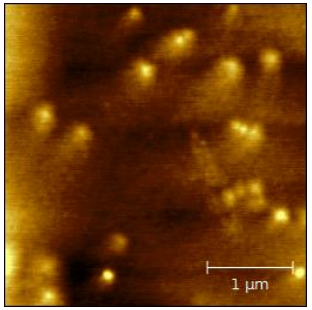
Cleaning of GaN

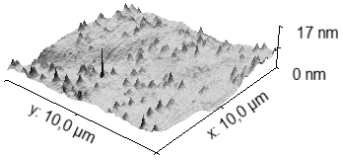
Untreated GaN

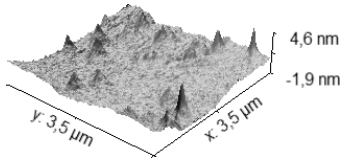


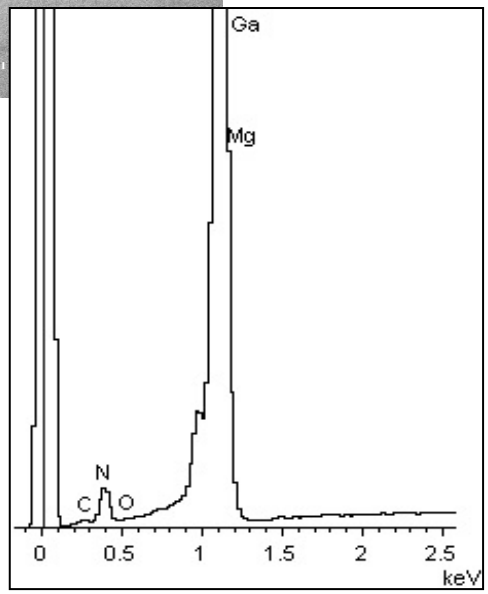












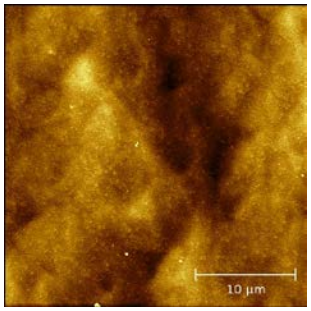
→ Roughness between 1.4 to 1.7 nm

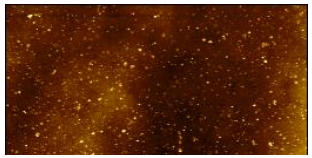
→ not sensitive enough

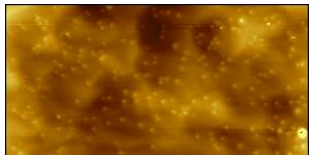
Cleaning of GaN

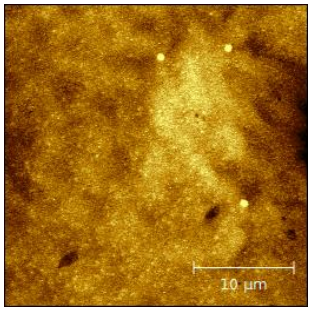
in ultrasonic bath for 15 min

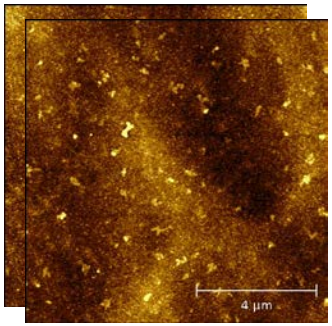
- MeOH
- Aceton
- Ethanol
- Propan-2-ol

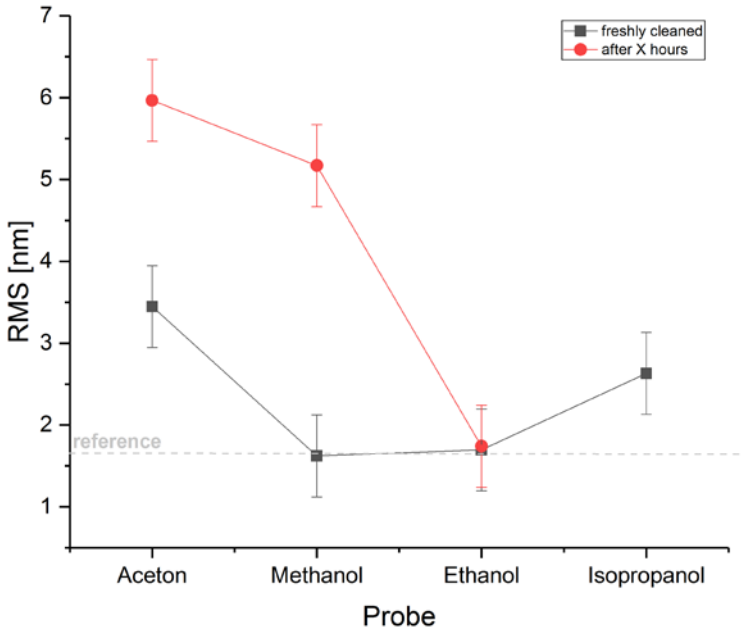


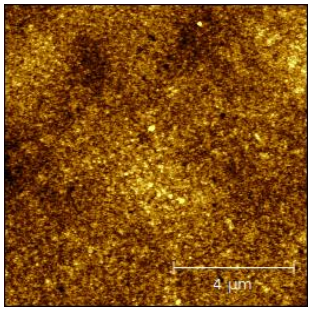




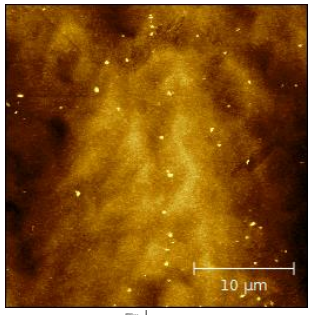


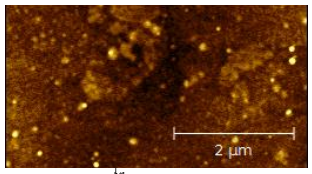


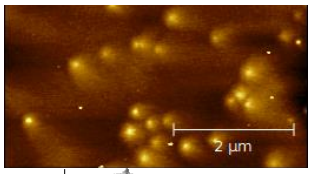


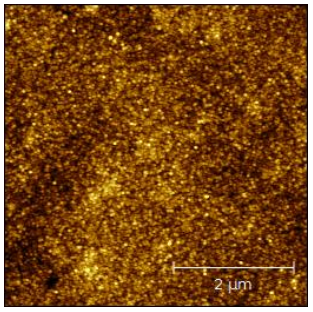


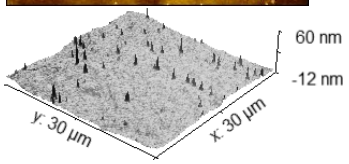
after 4-6 hours on air

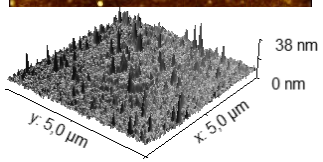


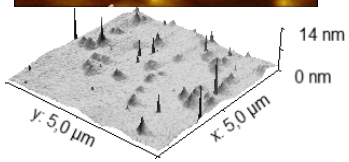


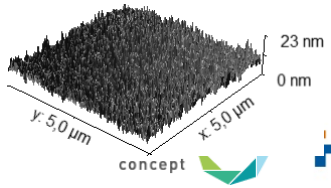








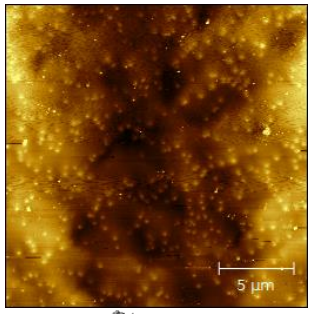


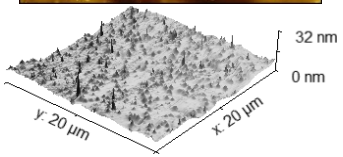


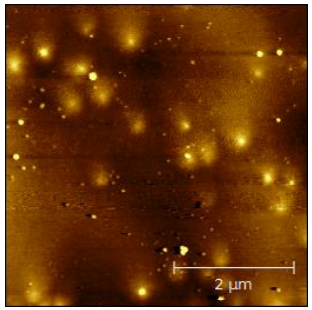
Cleaning of GaN wafer pieces

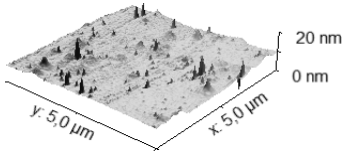
Piranha solution:
H_2SO_4:H_2O_2 (1:1)

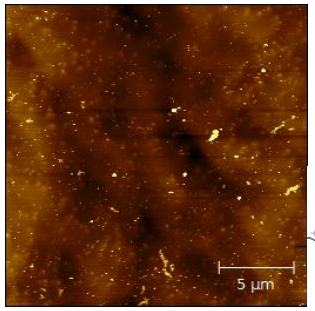
GaN: Piranha/aceton



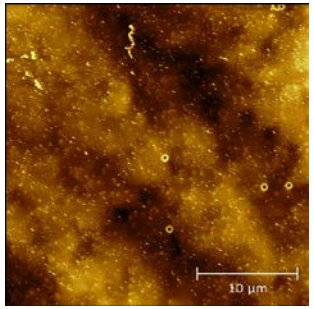


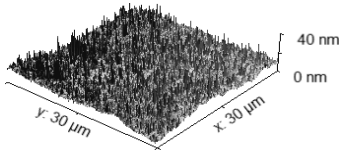


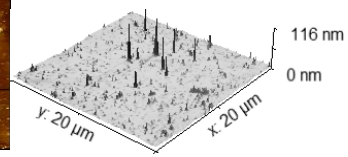




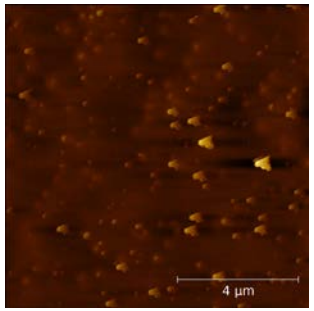
after 4 h

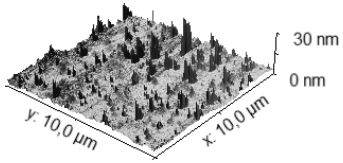


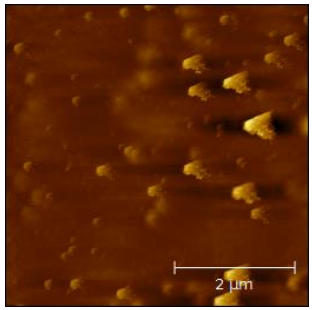


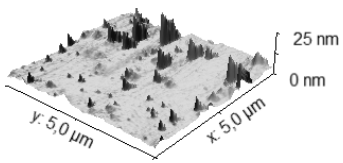


GaN: Piranha/water

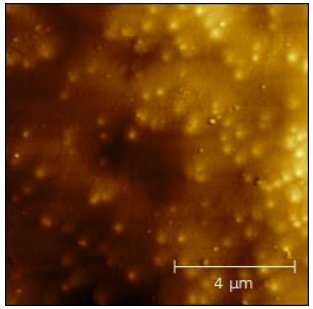


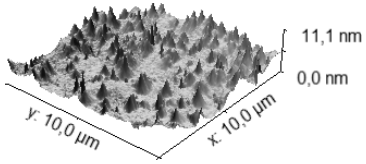


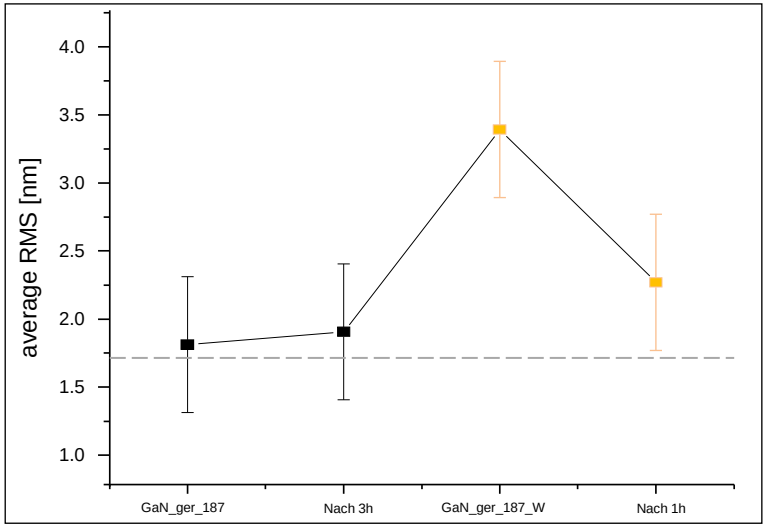




after 3h



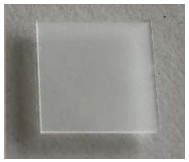




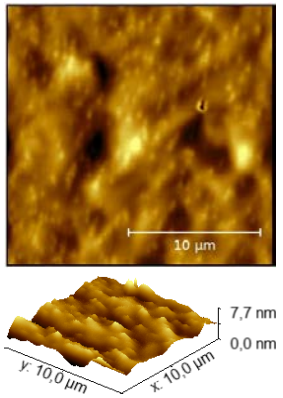
Cleaning of GaN

AFM Imaging

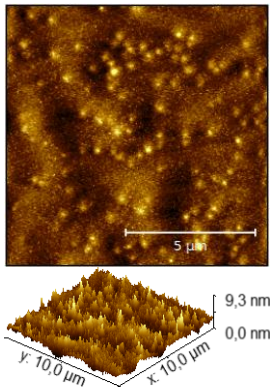
	sample No.	1	2	3	4
basic treatment	H_2SO_4:H_2O_2 (1:1), T ~140°C (15 min)	✓	✓	✓	✓
	rinsed 2 x H_2O	✓	✓	✓	✓
	40% HF (30 s)	-	✓	✓	-
	0.5% HF (2 min)	-	-	✓	✓
	H_2O rinsing tank (10 min)	-	-	✓	✓
post-treatment	EtOH & benzene:Isopropanol (3:1) (1 min)	✓	-	✓	✓



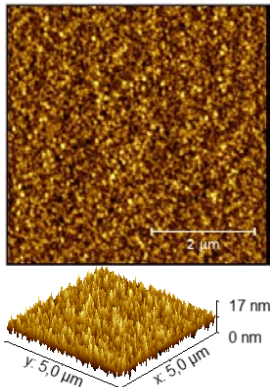
5 µm GaN on sapphire



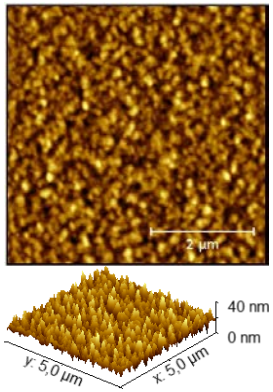
reference: uncleaned GaN



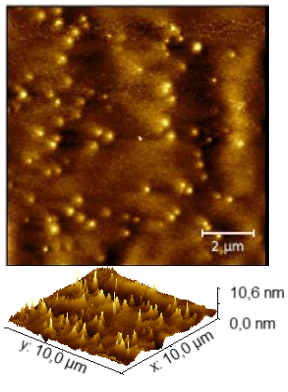
sample 1: basic treatment



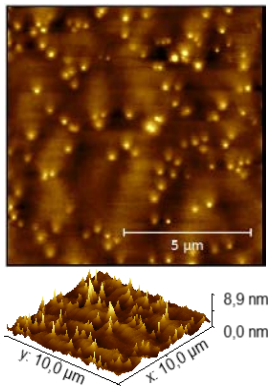
sample 2: conc. HF



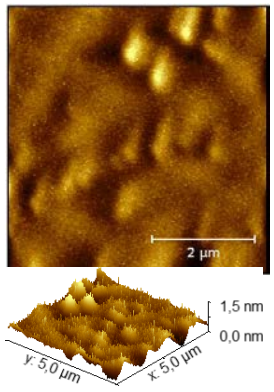
sample 3: conc. HF & 0.5% HF



sample 4: 0.5 % HF



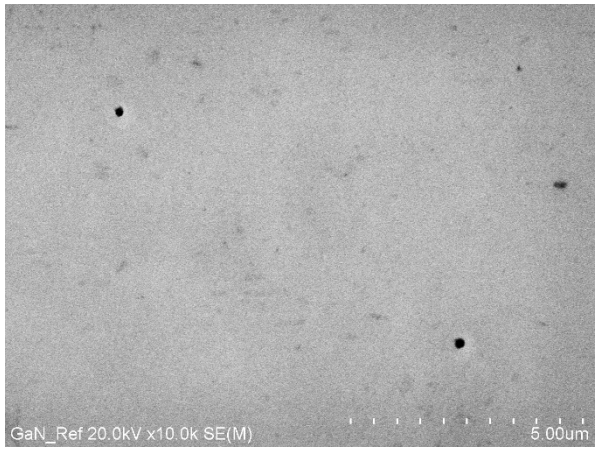
sample 4: 0.5 % HF (6 h)



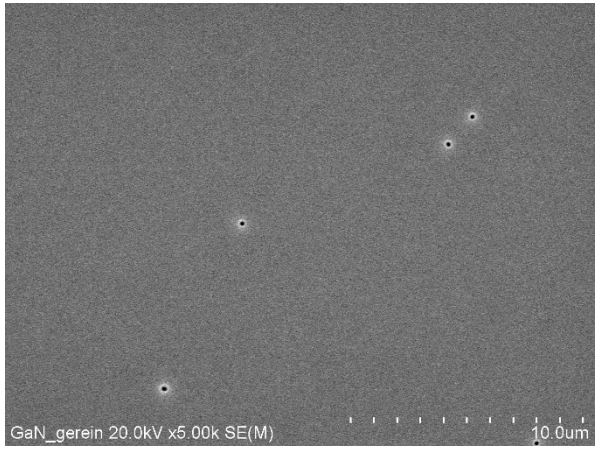
sample 4: 0.5 % HF (120 h)

Cleaning of GaN wafer pieces

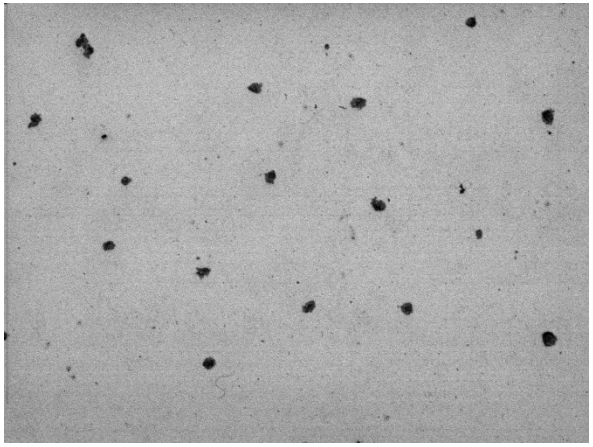
GaN: reference



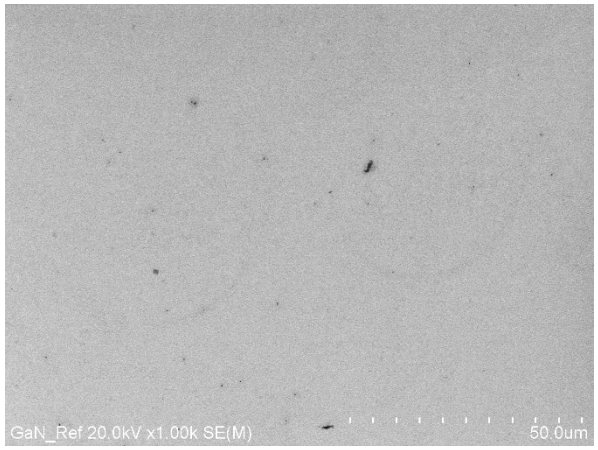
GaN_mit 0.5 HF gereinigt

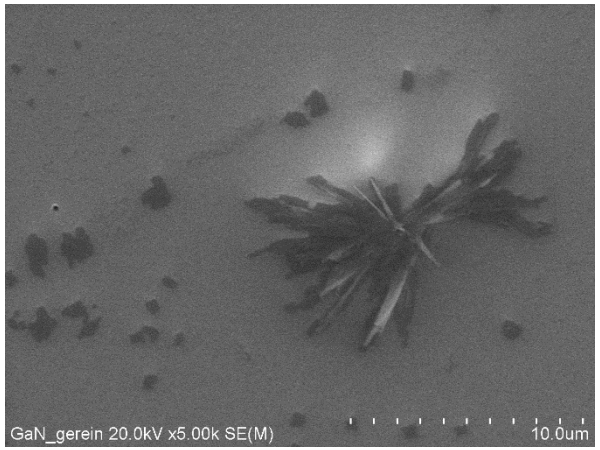


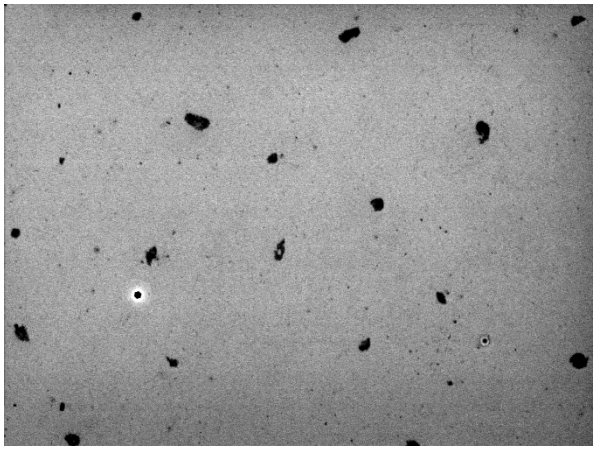
GaN: Piranha/ water, after 4h on air



after several hours





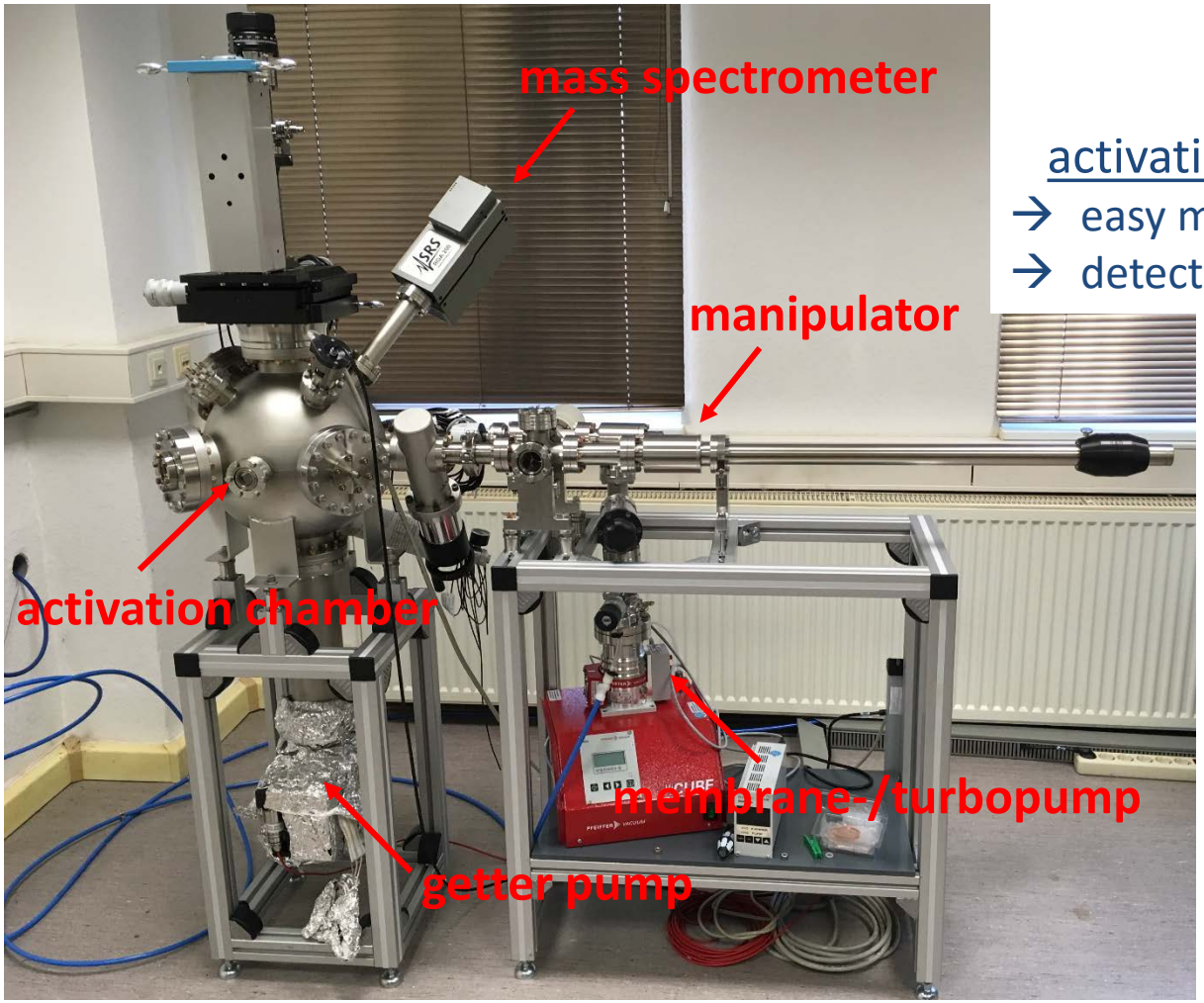


Crystal growth after cleaning ?!?!

→ Avoid air exposure+ use Glovebox & sealed bags

Focus on Research on GaN

OnGoing work- GaN(Cs)

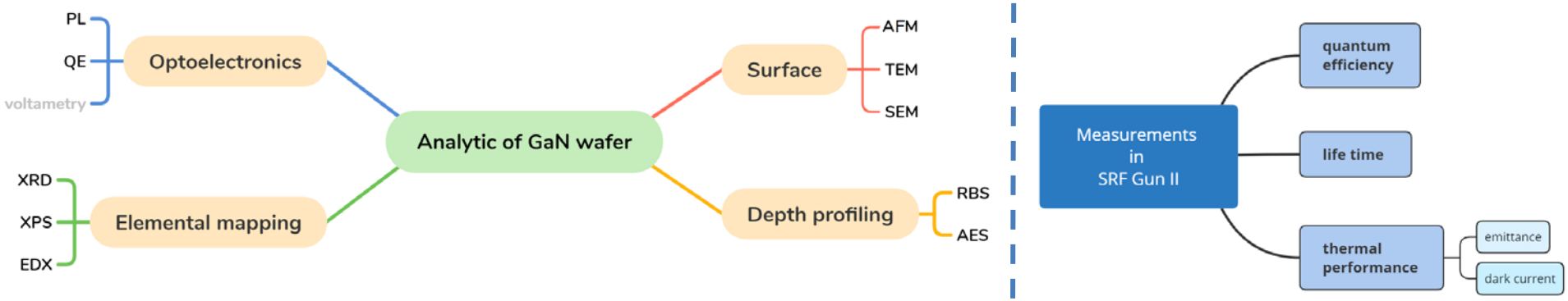


Planed:
combination of
activation chamber with SEM/EDX

→ easy measurement of activated GaN
→ detect contaminations

Summary and Outlook

- Charaterization and comparison of commercial available GaN wafer (surface parameters, depth profile, elemental mapping, cleaning process, QE)
- Activation of GaN wafer with Cs and characterization of activated GaN
- Comparision to GaAs & selfmade GaN (Uni Siegen)
- If sucessfully: test in SRF Gun II as a photocathode for high brightness beam



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