Development of THz Devices With Electron Beam Lithography

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Center for Semiconductor and Optoelectronics (ZHO)

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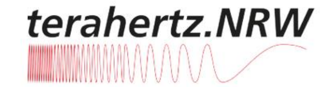
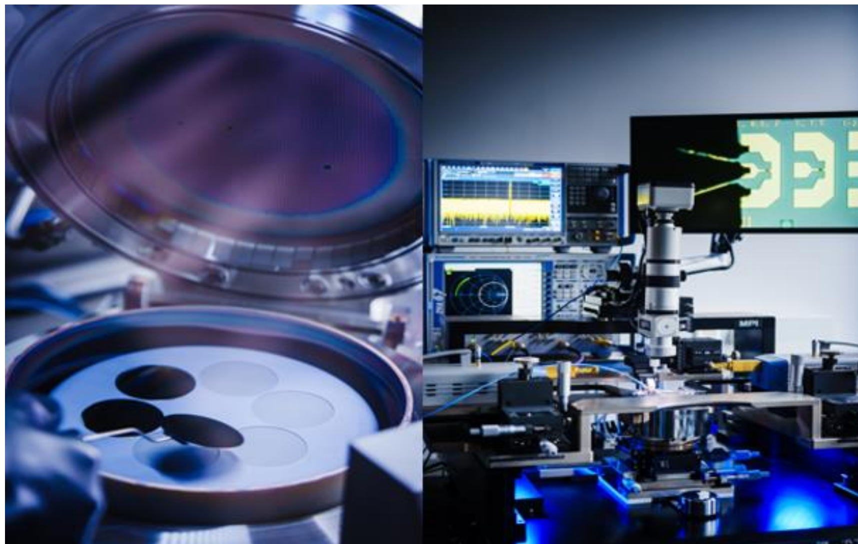
Introduction to ZHO

- Own clean room, work area~ 469 m^2, class 10
- Epitaxy: 2 MOCVDs, 1 MBE, InP/GaN based epilayer
- Lithography: JEOL 8100FS 100 kV system/ MJB6
- Metal Deposition: 2 electron beam deposition , 1 sputter
- Inspection: Zeiss LSM900 / JEOL IT800i
- CVD/ ALD/ RIE ICP/ Packaging
- High frequency measurement labor
- > 20 staffs





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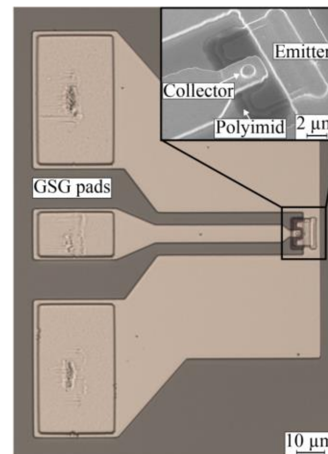
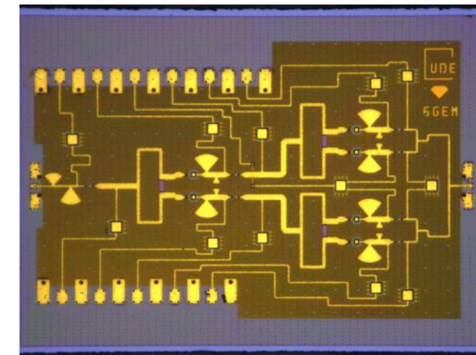
Research Focus: high frequency electronics

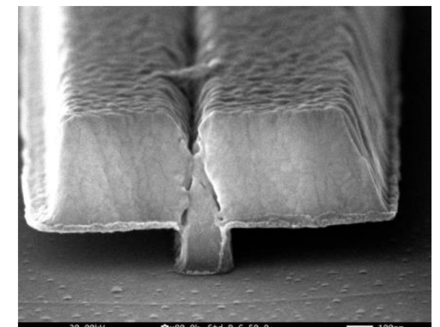
Tunneling Barrier Diode (RTD)



Double Hetrojunction Bipolar Transistor (DHBT)



High Electron Mobility Transistor (HEMT)



Scope of this work

Focus: InP based DHBT

Devices fabrication

Solving problem in lift-off and etching

Exposure parameters

Decision of resists

Buy a new machine

time

Introduction of Lithography in BHE

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JEOL 8100FS in BHE:

- The second machine in Germany
- Installed beginn 2023
- Acceleration voltage 100 kV system
- Beam current up to 200 nA
- Stage positioning resolution about 0.6 nm
- Resolution in sub 10 nm
- Load wafer up to 8 inch
- Successful exposure parameters and techniques for InP/Sapphier/Si-based devices

Photoresist used in BHE for nano fabrication

Resist	Dose [µC/cm2]	Tone	Resolution	Benefits	Contrast
PMMA series	640-800-1000	positiv	~5-10 nm	Less expensive	~ 2
maN 2410	140	negativ	~50-100	Easy removed with Aceton	< 1
CSAR series	200-300	positive	~5 nm	Good etch resistance	6-7
ZEP520A	100-200	positive	~5 nm	Much faster than PMMA	6-7
PMGI series	Not sensitiv to e^-	-	-	Very good for Bi-or Tri-layer	-

What is the base dose?

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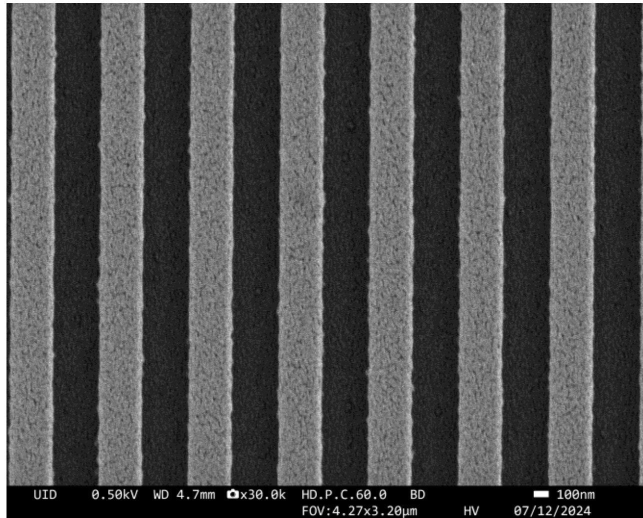
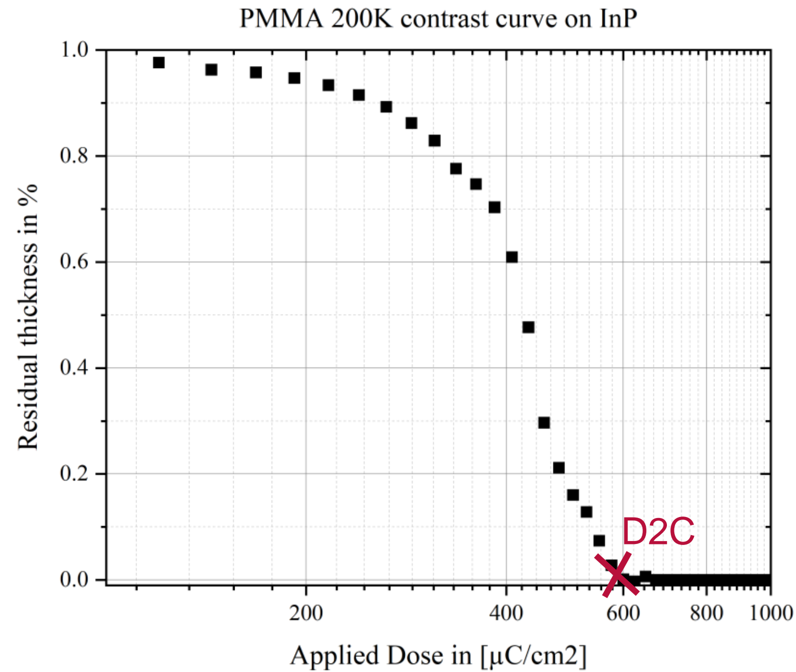
The dose in the machine, when combined with the dose factor and base dose, allows one to obtain the design pattern after processing.

The most used method is using line/space structure (50%/50%)



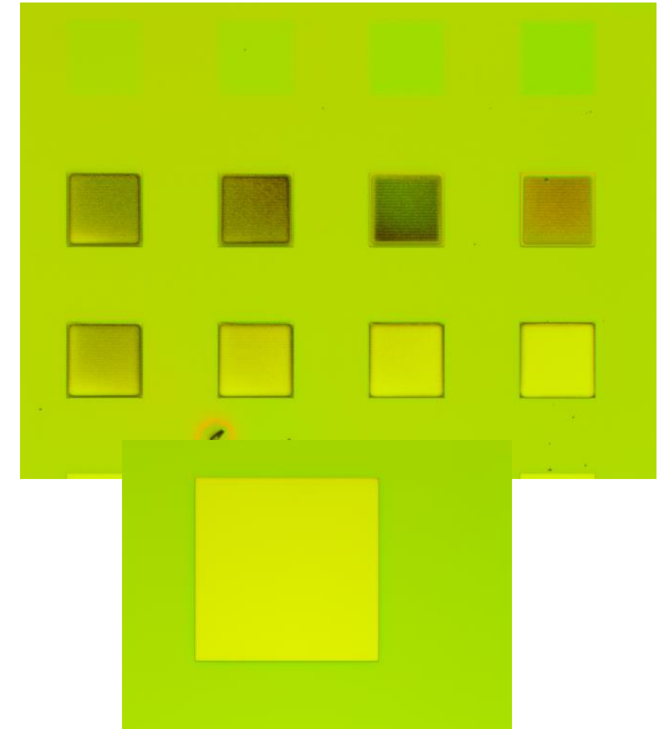
- The base dose is: $CD_{line} = CD_{space}$
- Valid only for thin and high contrast resist
- Process bias is not considered

Using contrast curve



- The base dose is 2x dose to clear
- Overexposure for large area pattern

Combination with OM photos



- no residual at the corner, usually the base dose is about 1.5x dose to clear.

Calibration of PMMA 950K on InP with 2 nA on InP

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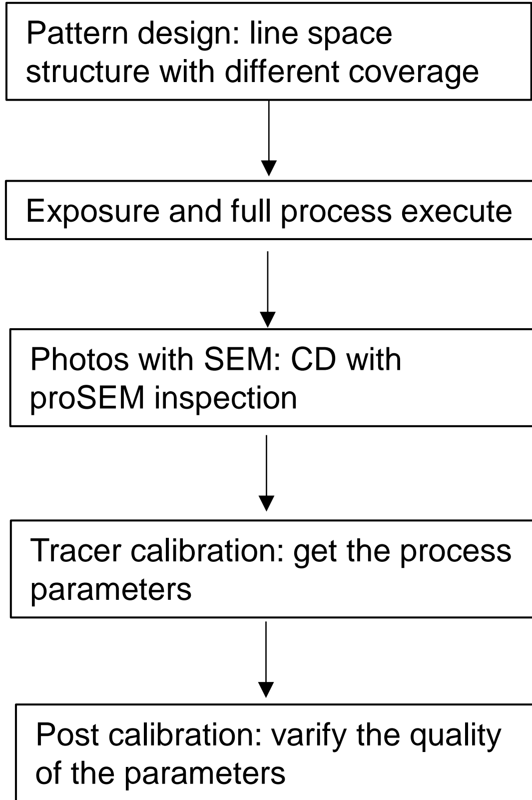
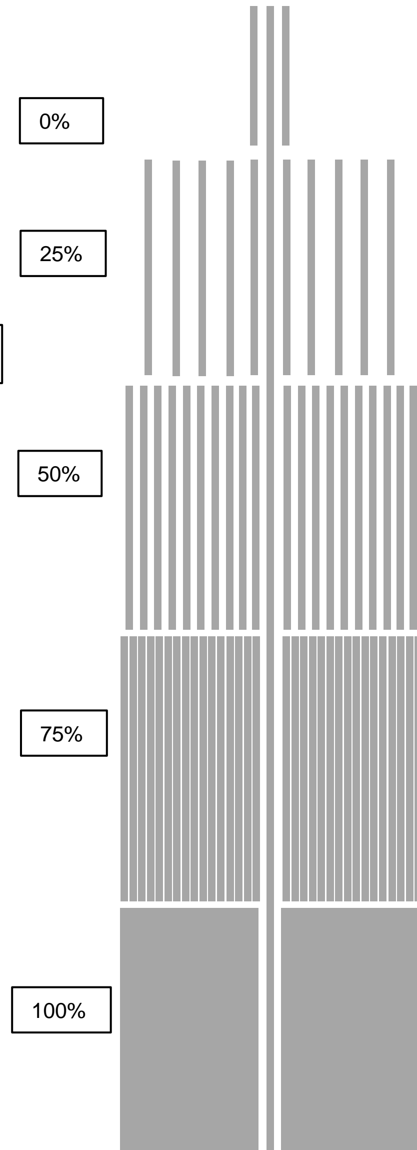
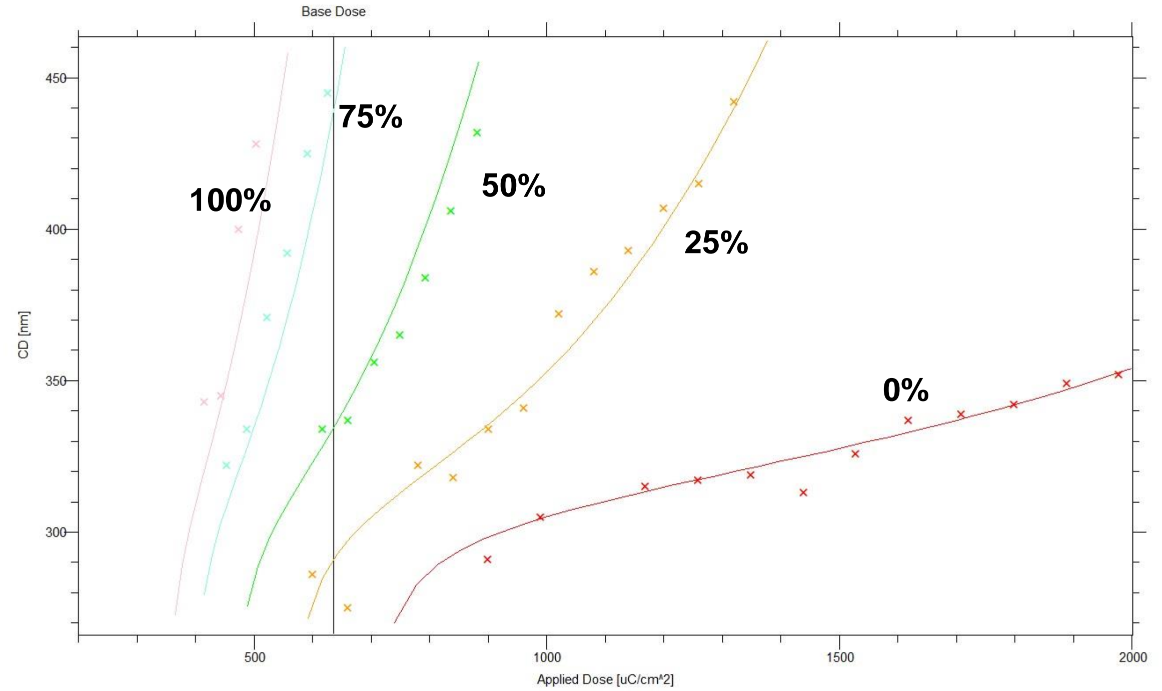
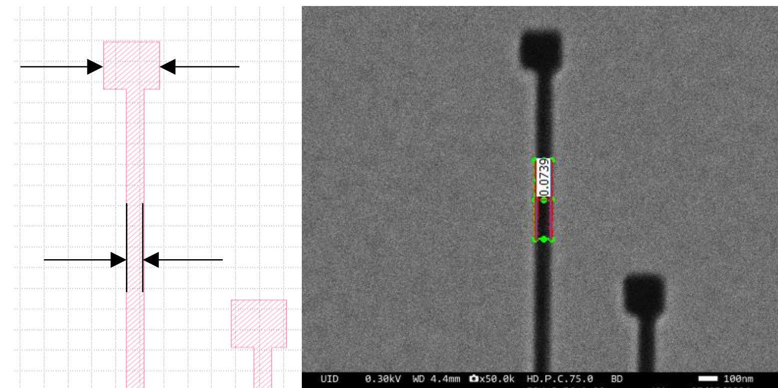




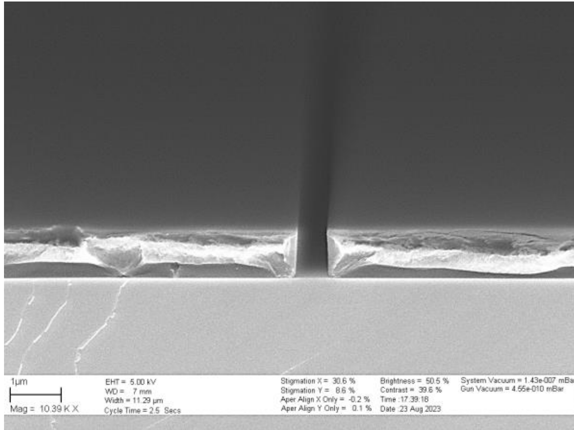




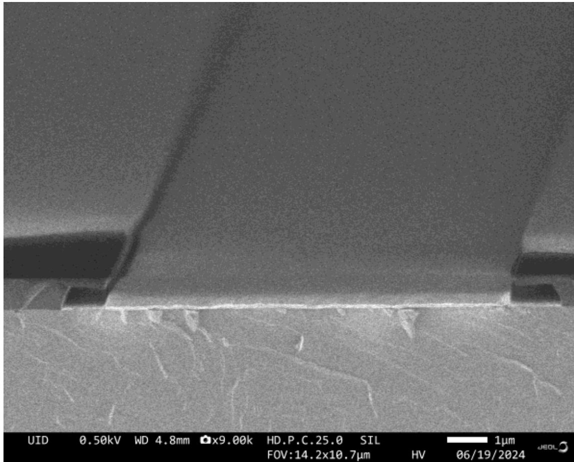
Design:
Line 75 nm, square 232 nm
Measurement:
Line 74 nm, square 236 nm

Photoresist for Lift-Off

Bi-Layer for Lift-Off

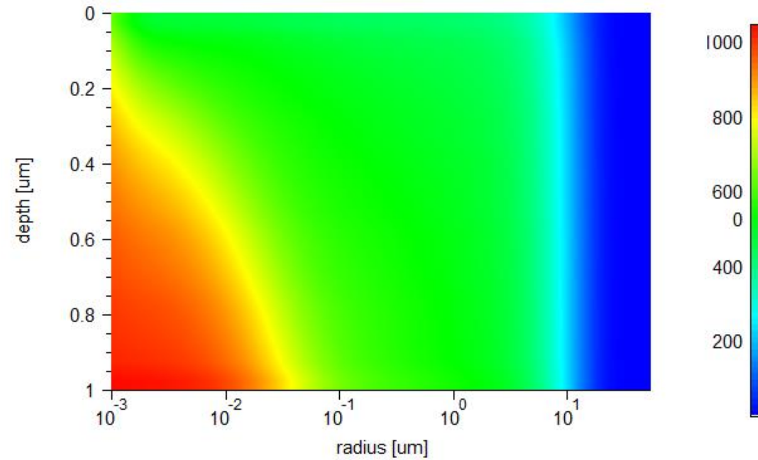


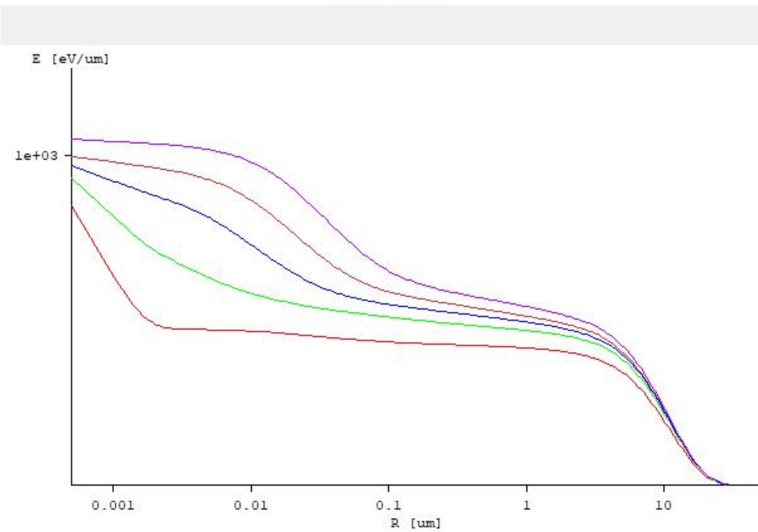
PMMA950K on PMMA600k, 500 nm CD design



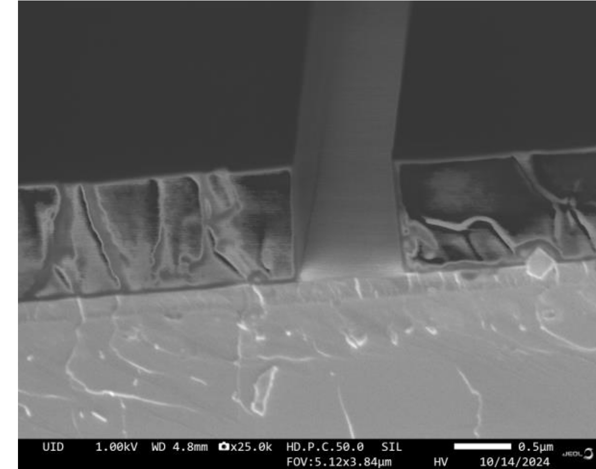
PMMA950K on PMGI with metal deposition, 10 µm CD design

Thick single layer for Lift-Off

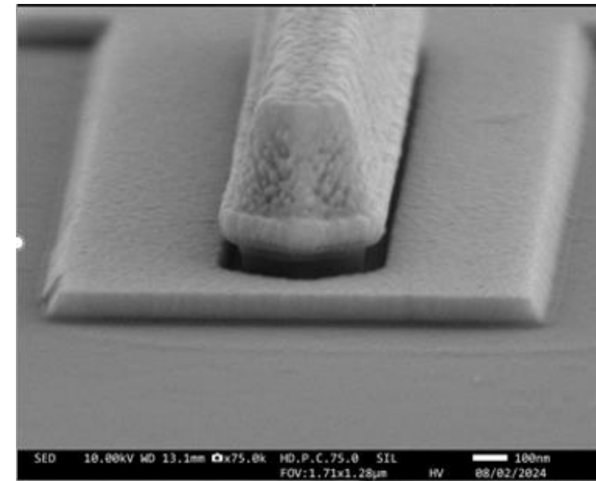




Z-dependent absorbed energy in CSAR18 on InP



AR-P 6200.18 (CSAR18) on InP, 500 nm CD design



Thin metal deposition with single layer CSAR18

Photoresist for InP/InGaAs Etching

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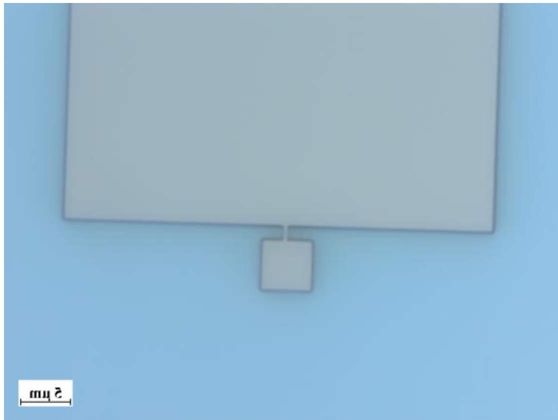
Issue 1: residuls at large pattern edge

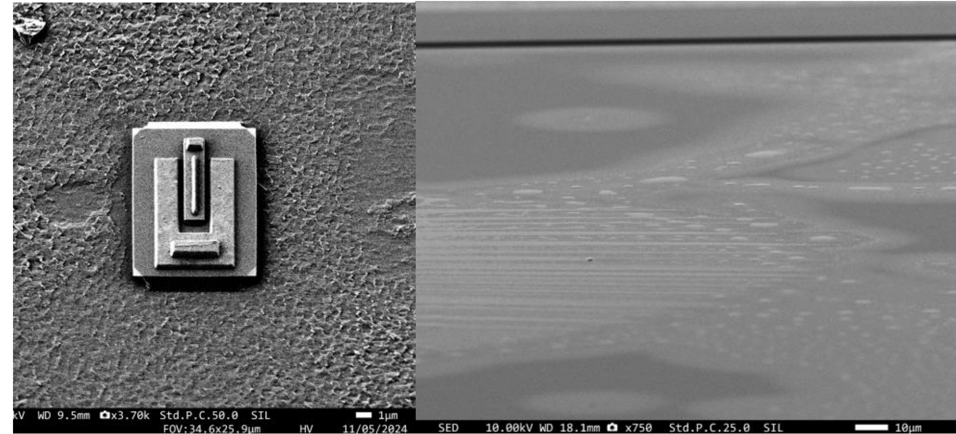
Dose: 180 µC/cm2 Development: maD525 for 275 sec.



Dose: 200 µC/cm2 Development: maD525 for 180 sec.

❖ Improvement: Lower dose, longer development

Issue 2: etching residual at surface

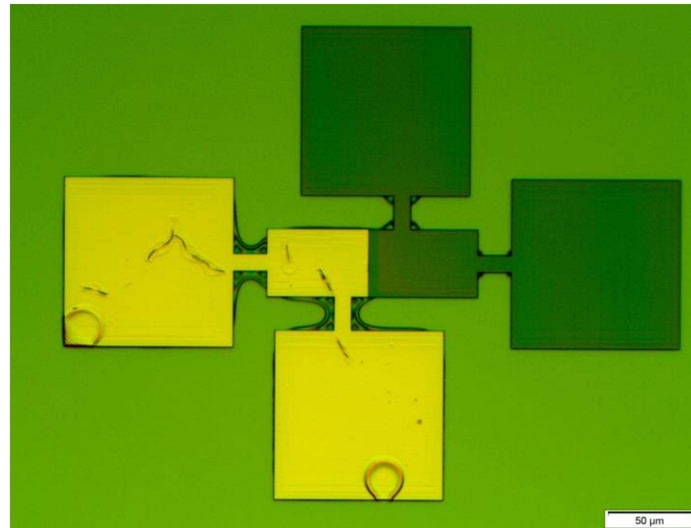


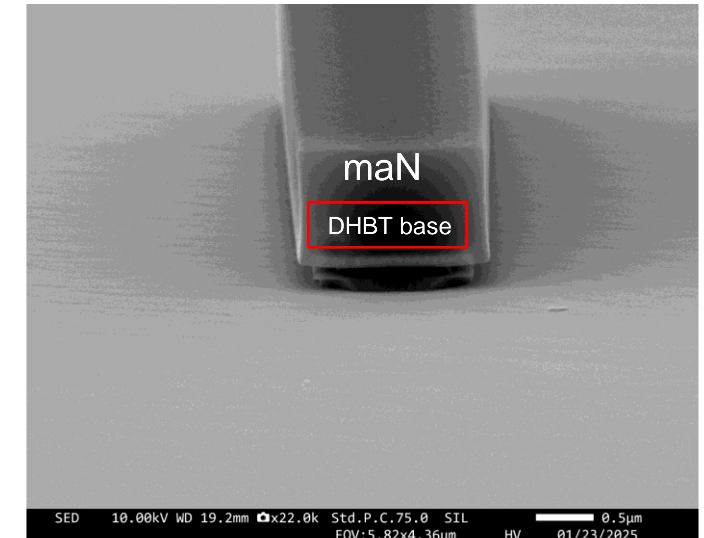
❖ Improvement: higher pre-bake temperature

For InGaAs/InP etching:

- maN about 5-10 nm thinner than without etching
- A very thin layer formed on the wafer surface
- Thin layer easy removed with acetone
- InP under thin layer are not cleared

Issue 3: application on metal





❖ Improvement: using 3D Topo PEC in Beamer

Issues with Metal Deposition: Carbon Contamination

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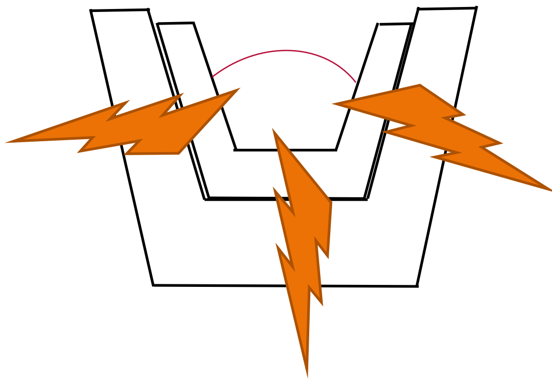
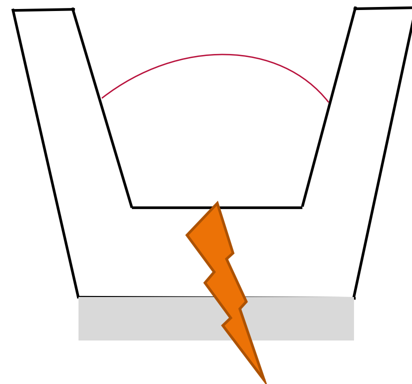
Contamination in metal using carbon based crucible

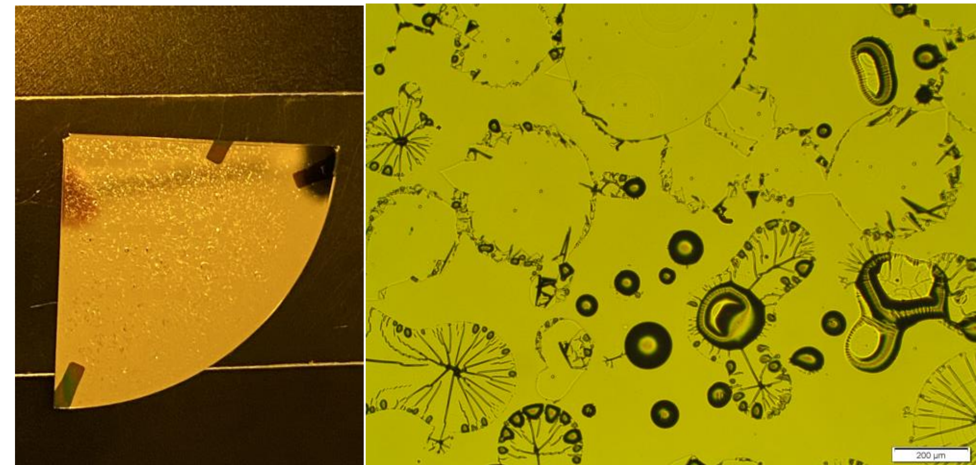
- Replacement of carbon based crucible with metal besed one, like Mo
- Crucible in crucible: 7-8 cc in 12 cc
- Thin spacer at the bottom

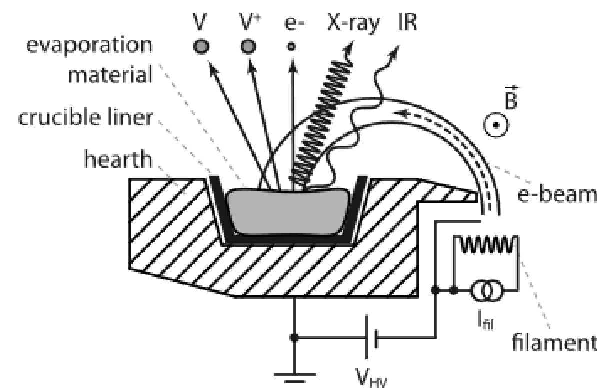


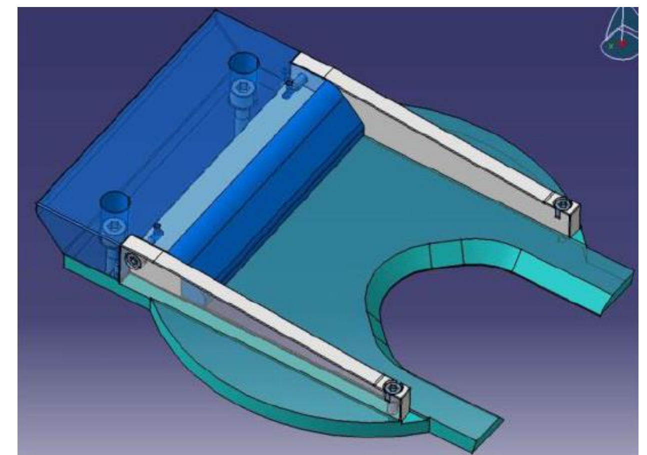


Bubules in PMMA after e-beam evaporation

- Strong CO2 signal (RGA) observed during Pt evaporation
- Could fixed with a maget kit
- Or PMGI underneath PMMA





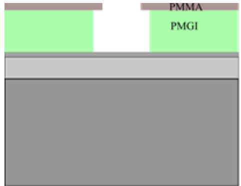


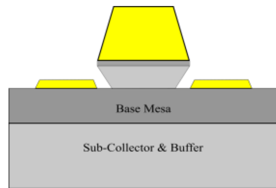
250 nm DHBT Fabrication-Application with 3D Topo PEC

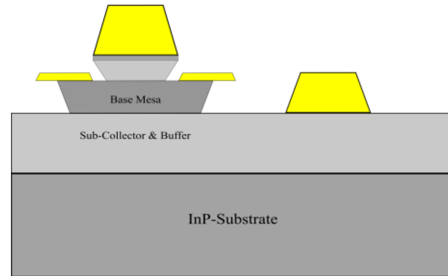
Collector

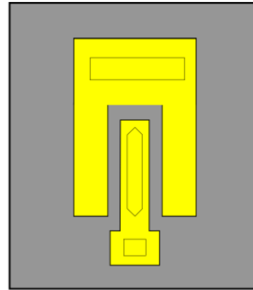
Emitter

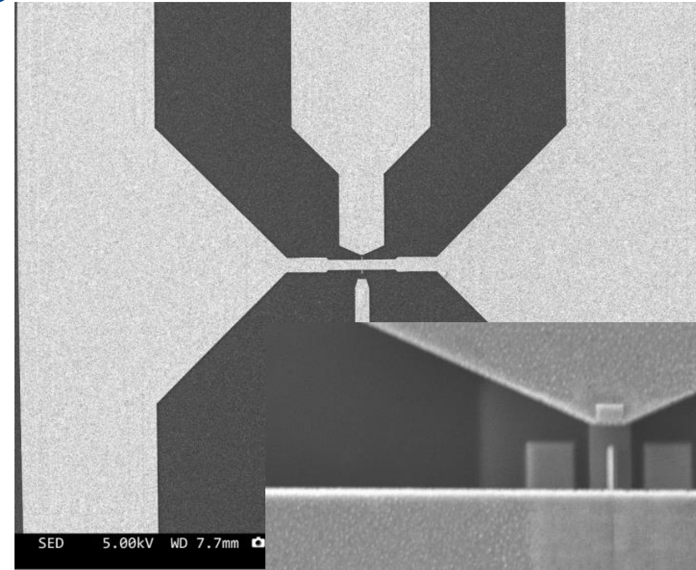
Base

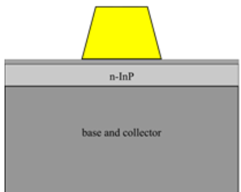


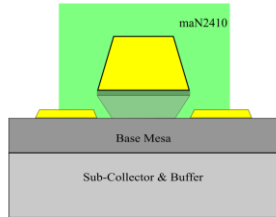


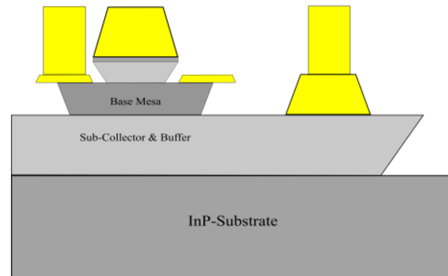




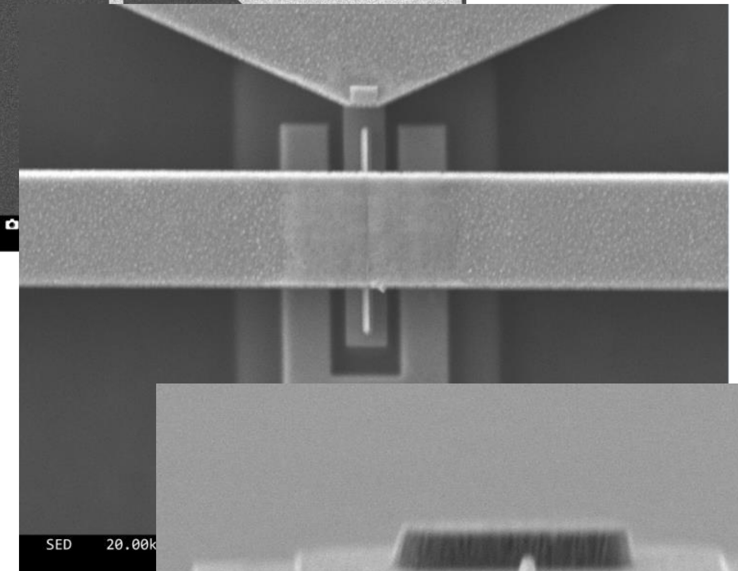


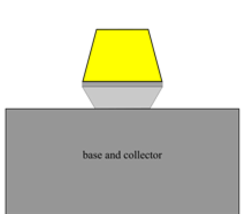


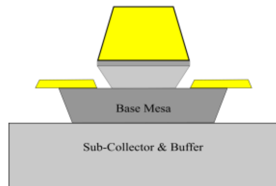


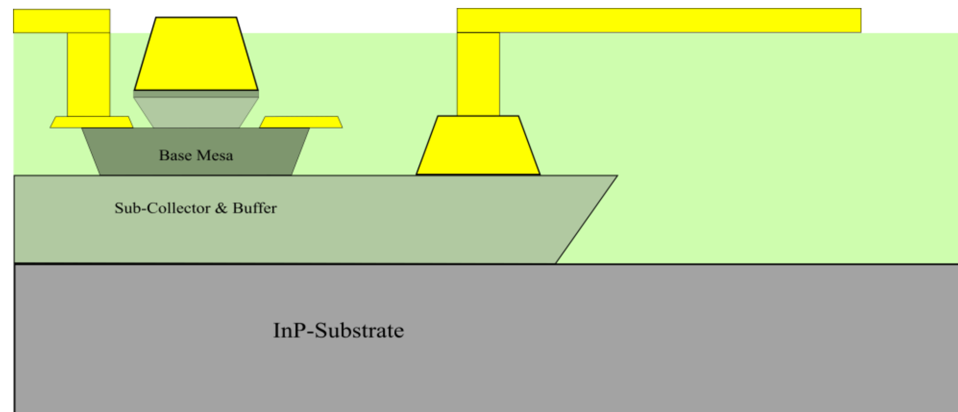


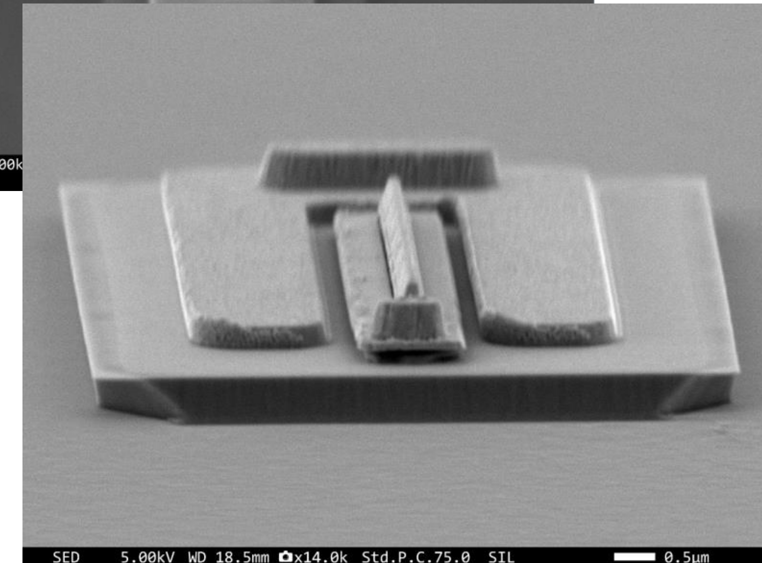
Planarization

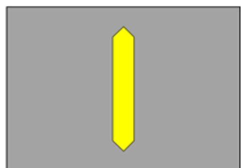


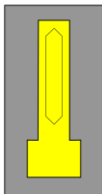












Conclusion

A story about how to build a THz device using 100 kV EBL

For department, we are looking for:

- Scientific collaboration for advanced nanofabrication (BMBF& SFB project)
- Industrial collaboration for THz device fabrication and application

For myselft, I am looking for:

- Scientific work as a post-doctoral researcher or
- Industrial work like engineer/manager

E-Mail: hao.zhang@uni-due.de

Thank you for your attention!

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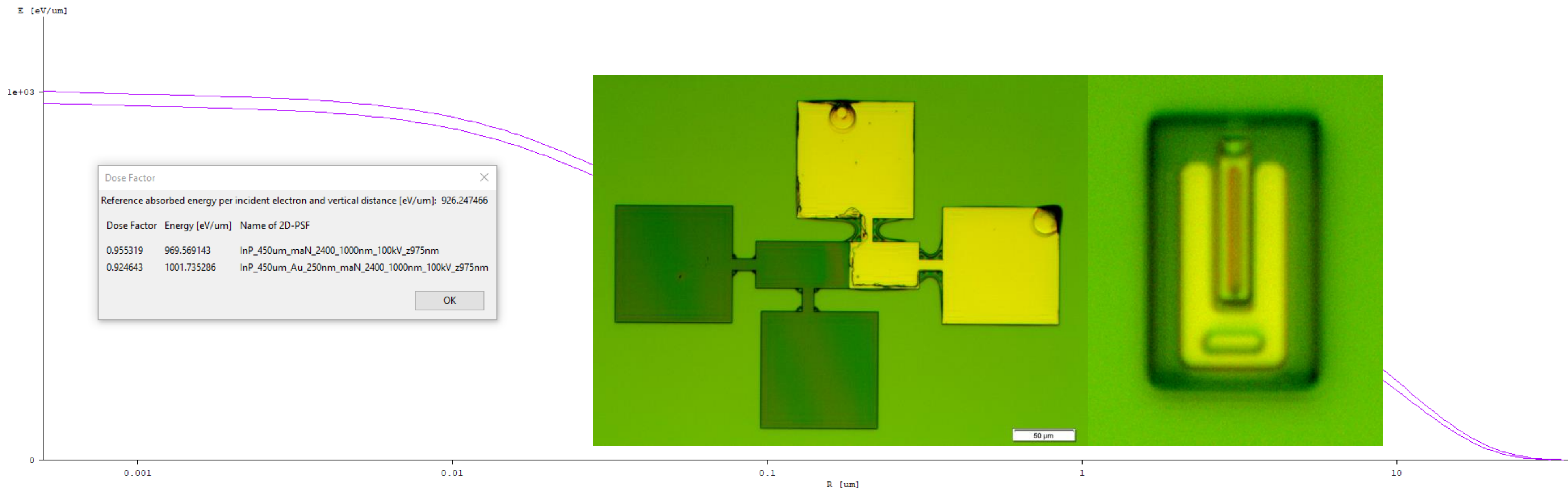
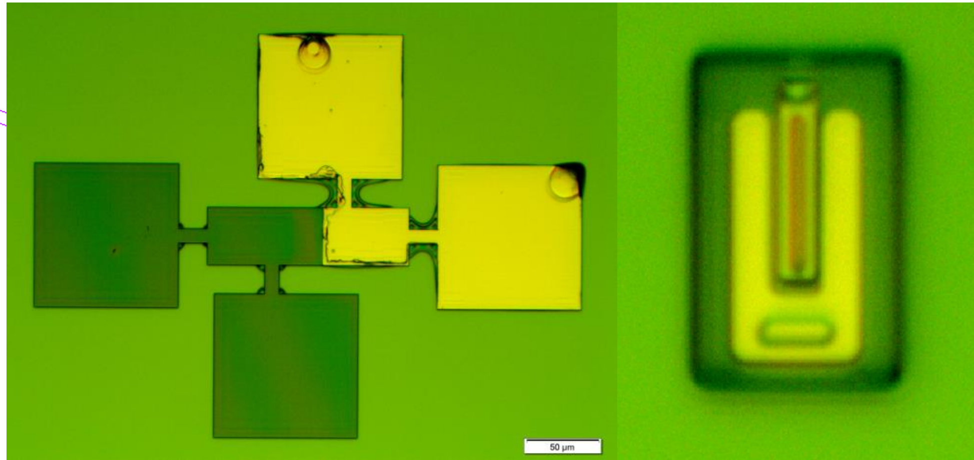
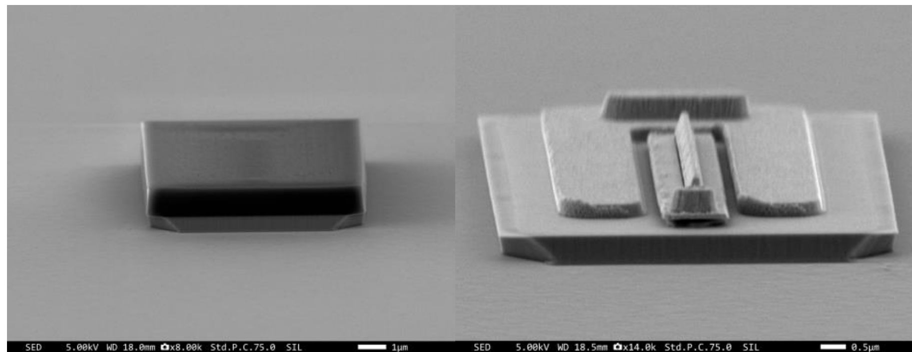
Fabrication Process for DHBT

3D PEC







Gray-Scale Application for InP based DHBT