



HAL
open science

Technology development for nano-pillars fabrication in silicon carbide to enhance light collection from color centers

Enora Vuillermet, Serguei Kochtcheev, Elise Usureau, Nicolas Bercu, Mihai Lazar

► To cite this version:

Enora Vuillermet, Serguei Kochtcheev, Elise Usureau, Nicolas Bercu, Mihai Lazar. Technology development for nano-pillars fabrication in silicon carbide to enhance light collection from color centers. Journées Renatech Litho/Gravure 2024, Jun 2024, Valbonne, France. hal-04618701

HAL Id: hal-04618701

<https://hal.science/hal-04618701>

Submitted on 20 Jun 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

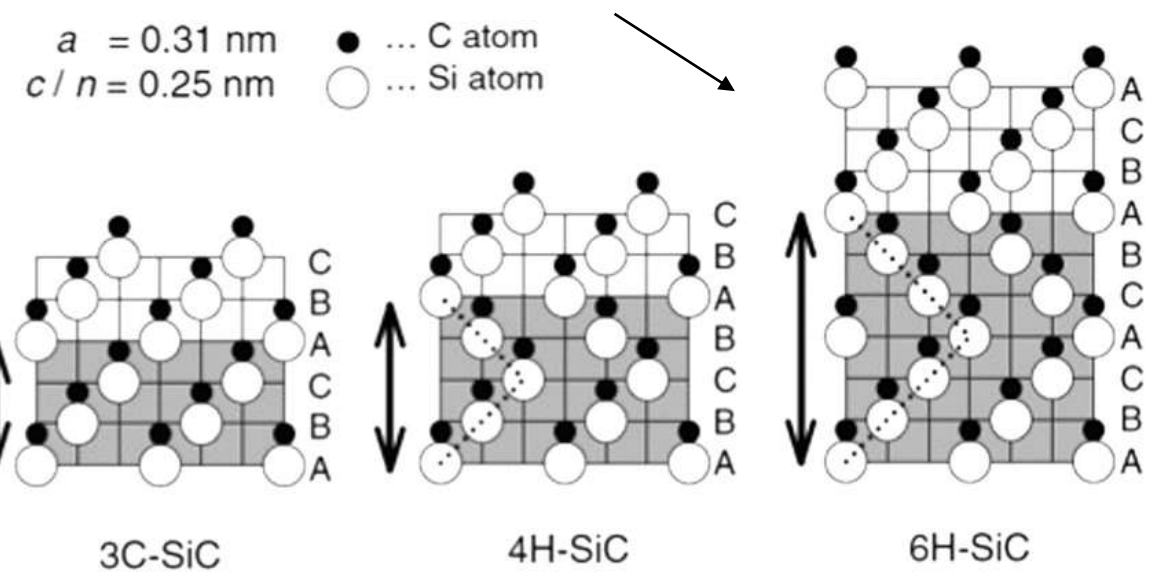
L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Technology development for nano-pillars fabrication in silicon carbide to enhance light collection from color centers

E. Vuillermet, S. Kochtchev, E. Usureau, N. Bercu, M. Lazar
L2n, CNRS UMR 7076, University of Technology of Troyes, University of Reims Champagne Ardenne,
12 rue Marie Curie, 10000 Troyes, France

Context and objectives

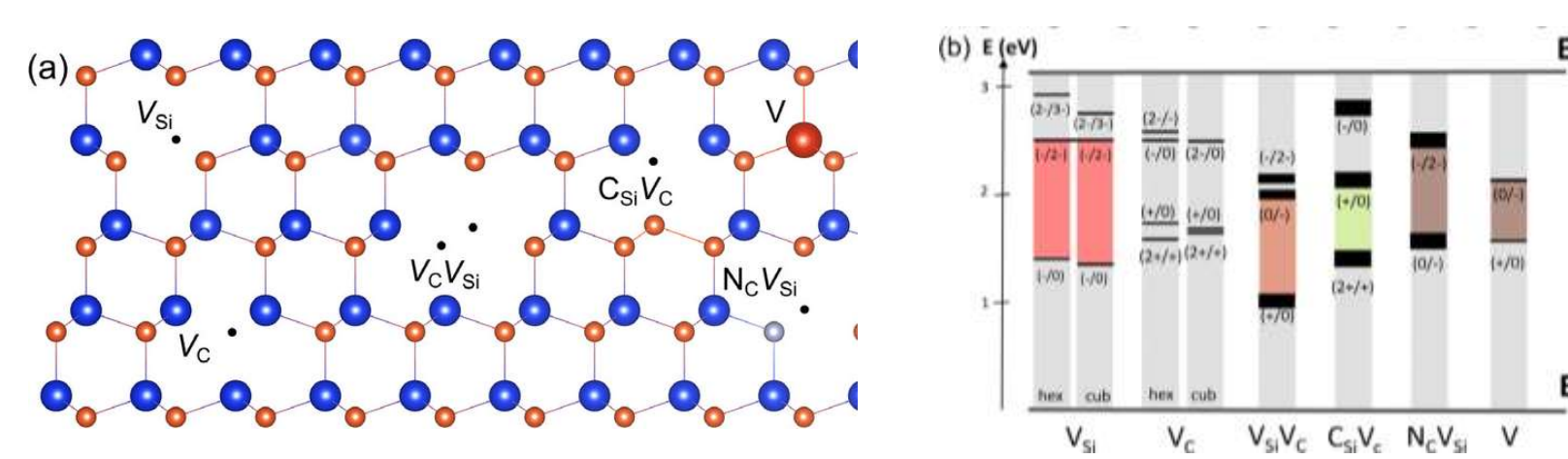
SiC wafer and crystallography



SiC is a wide bandgap semiconductor with :

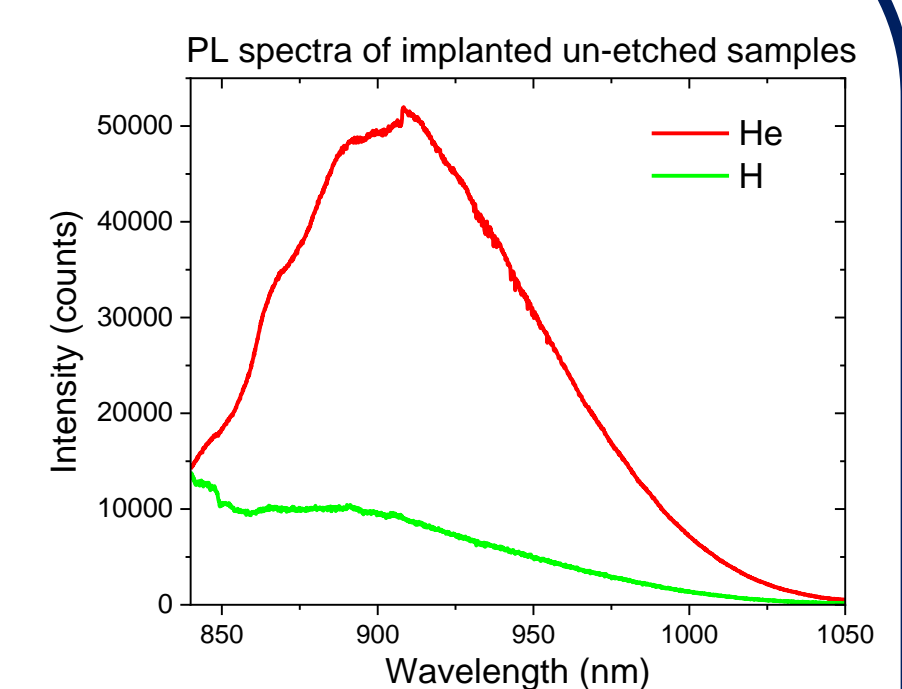
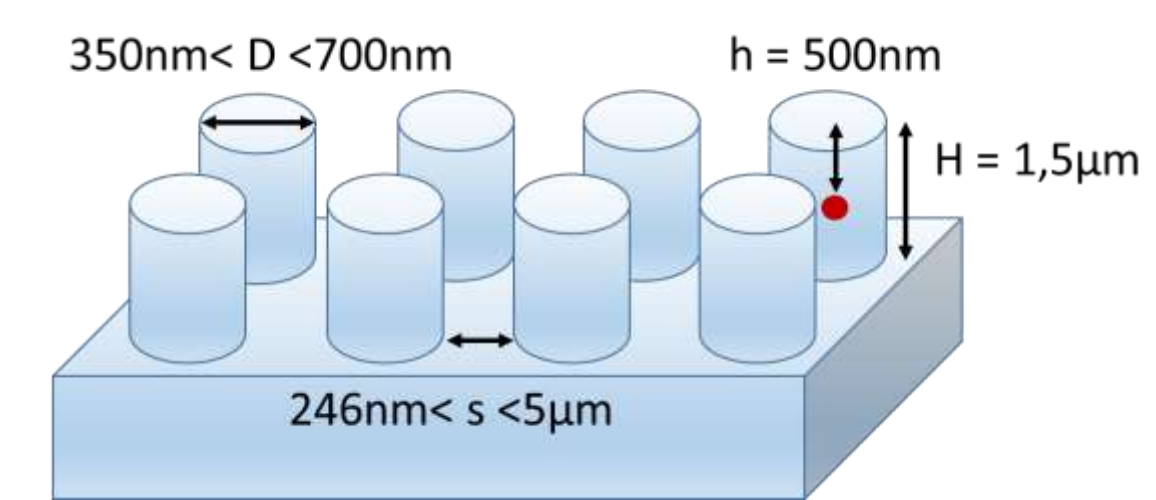
- Multiple polytypes, n and p-type doping possible [1]
- High thermal conductivity, chemical inertness, and high critical electrical field [2]
- High technology maturity → control of defects possible [3]

Color centers in SiC



- Point defects within the lattice [4]
- Created by **large scale ion implantation**
- Single photon **room temperature** sources : qubits
- Emission of **NIR light** in SiC [5]
(visible light in diamond)

Objective of this work



- **Fabrication of nano-pillar arrays to enhance light collection** of the silicon vacancy (V_{Si}) and the divacancy carbon-silicon ($V_C V_{Si}$).
- H and He ion implantations in n-doped 4H-SiC samples generate the point defects. PL measurements of the un-etched samples confirm the presence of the V_{Si} .

Methods

E-beam lithography

- Surface cleaning with HF
- Pre-bake of the samples at 170°C for 20min
- **PMMA resist 4,5g/L**
40s, 2500rpm, 1000rpm/s
- Baking of the resist at 170°C for 30min
Resist thickness : 450nm
- **E-beam lithography**
- Gun 20kV
- Aperture diameter 30μm
- Dose 1,45
- Current 345pA



E-beam Physical Vapor Deposition

- **Development**
- 1min20s in MIBK/IPA
- 15s in IPA
- **Cr-mask deposition**
- 75nm 0,1nm/s, 30mA (x2)
- Vacuum < 1,10⁻⁵mbar
- **Lift-off**
- 1st immersion few minutes in acetone
- 2nd immersion for two days
- Acetone spraying to remove last pieces of metal
- 20s in IPA



RIE/ICP plasma etching

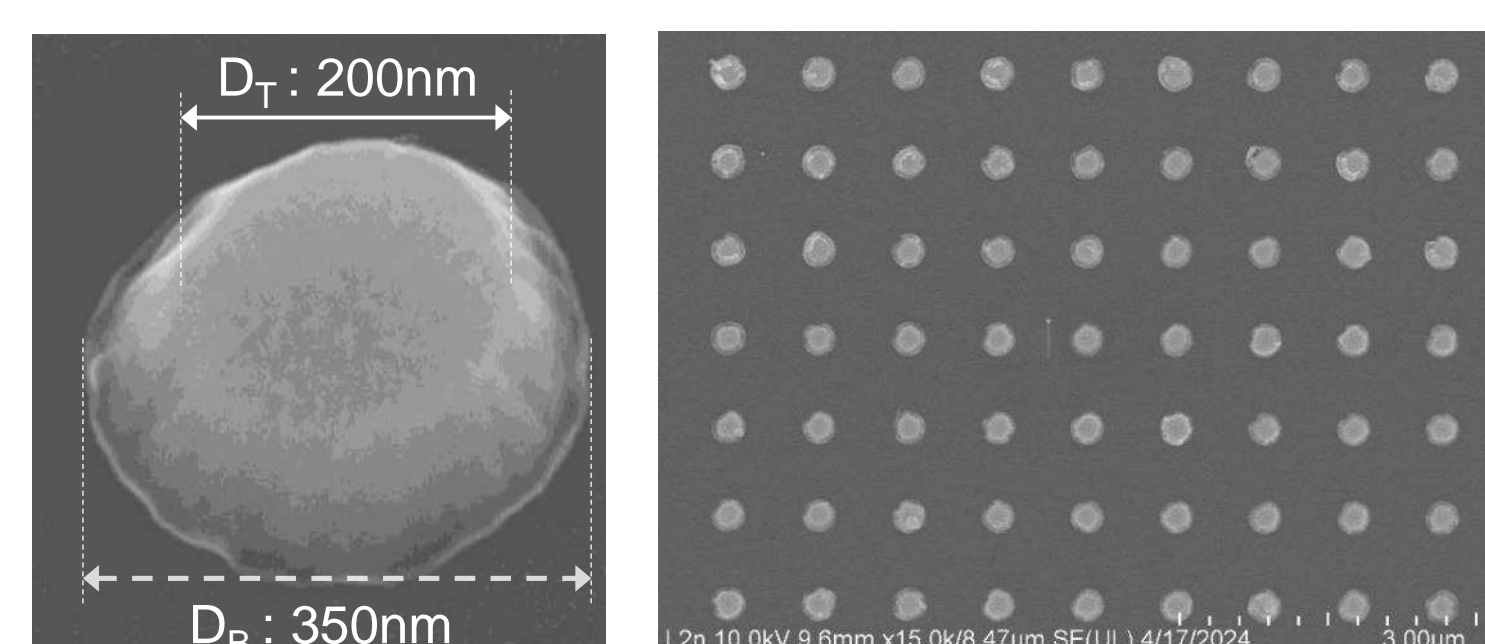
- Deposition of a **100nm-thick Si layer**
- **Nano-pillars etching**
- SF₆/O₂ : 10/2sccm, 8mbar pressure
- RIE/ICP power : 100/1000W for 5min
- Bias : -260V
- **Cr-mask removing** : 2 days in a Cr-etchant



→ Arrays of SiC pillars obtained with different diameters (D) and spacings (s)

Results and Discussion

Cr-masks



- **Conic geometry** of the mask
 - Bottom of the mask has the diameter wanted ($D_B = D_{th}$)
 - Top of the mask is about 150nm less large than the bottom
- Lead to etched nano-pillars at least **150nm thinner** than wanted

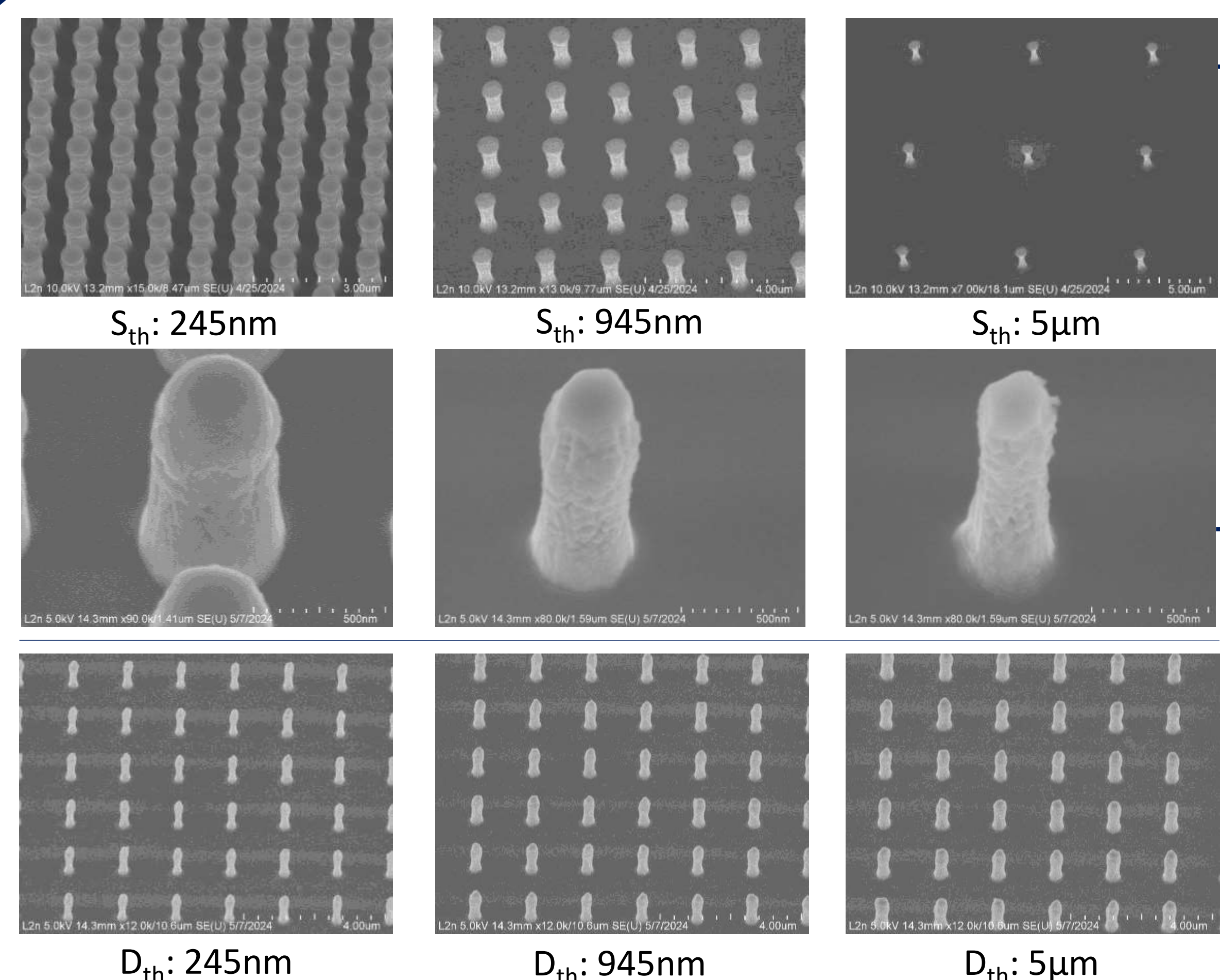
Conclusion

- **Nano-pillars arrays** with different diameters and spacings were fabricated. Pillars have a height of 1,4μm with **no trenching**.
- **Conic aspect of the Cr-mask** : heating and deformation of the PMMA resist during deposition ? D_{th} should be increased of about 150nm to compensate.
- **Lateral etching** of the pillars : different etching parameters will be used to reduce this phenomenon. We can also increase D_{th} if lateral etching is repeatable.
- Next experiments will be done in **implanted samples** and PL spectra will be measured.

References

- [1] K. Ashida et al. *JVSTB*. **2015**, 33, 04E104
- [2] She, X et al. *IEEE Trans. Ind. Electron.* **2017**, 64, 8193–8205
- [3] Maximilians, J. **PhD thesis**, Universität Würzburg, Germany, **2015**
- [4] M.E. Bathen and L. Vines, *Advanced Quantum Tech.* **2021**, 3, 2100003
- [5] Castelletto, S et al. *J. Phys. Photonics* **2020**, 2, 022001

Nano-pillars



Diameters (nm)							
D_{th}	D_B	D_T	S_{245}	S_{335}	S_{540}	S_{945}	S_{5000}
700	700	550	550	530	500	470	410
650	650	500			490	410	
600	600	450			450	350	
550	550	400			390	260	

- **Lateral etching** of the nano-pillars : ↗ when the spacing ↗. When D_{th} ↗, lateral etching ↘ slightly.
- No trenching is observed. Pillars height is 1,4μm.
- **Nano-pillars of smaller dimensions fall and non-linearity of lateral etching with D or S.**