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

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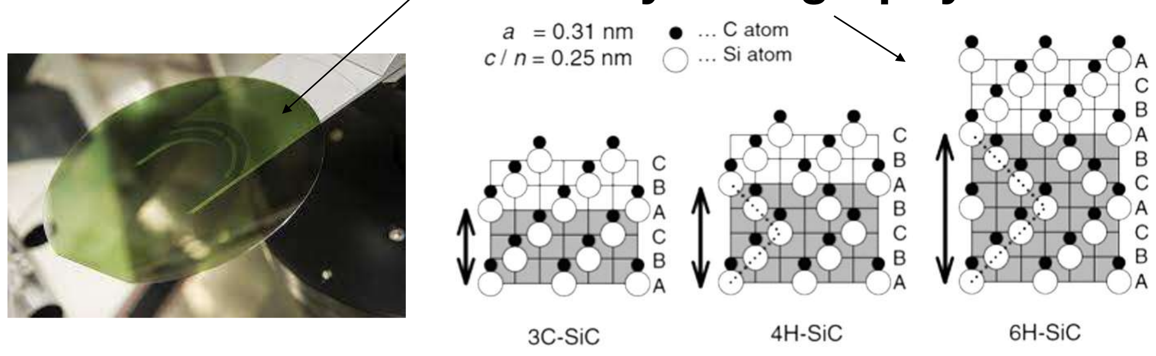
Context and objectives

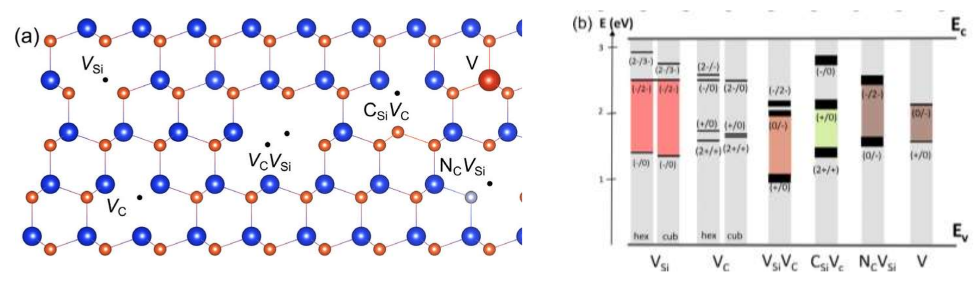
SiC wafer and crystallography



SiC is a wide bandgap semiconductor with :

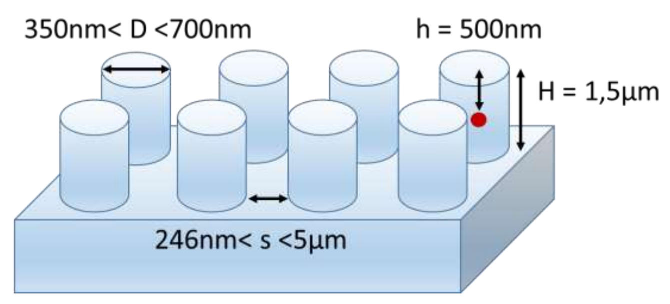
- Multiple polytypes, n and p-type doping possible [1]
- High thermal conductivity, chemical inertness, and high critical electrical field [2]
- High technology maturity → control of defects possible [3]

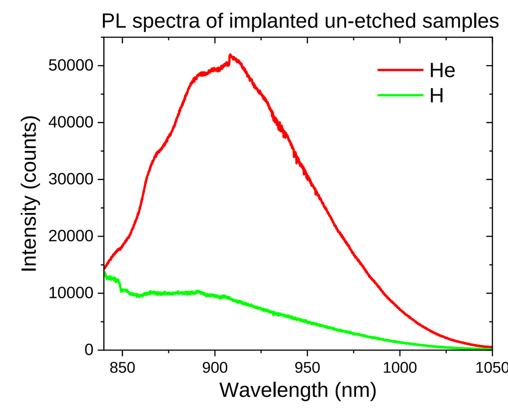
Color centers in SiC



- 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_CV_{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 < $1{,}10^{-5}$mbar
- **Lift-off**
  - 1st immersion few minutes in acetone
  - 2nd immersion for two days
  - Acetone spraying to remove last pieces of metal
  - 20s in IPA

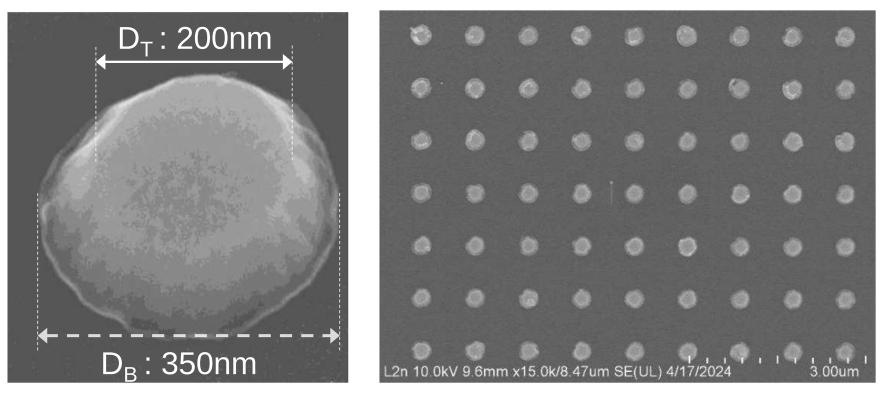
RIE/ICP plasma etching

- Deposition of a **100nm-thick Si layer**
- **Nano-pillars etching**
  - SF_6/O_2 : 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

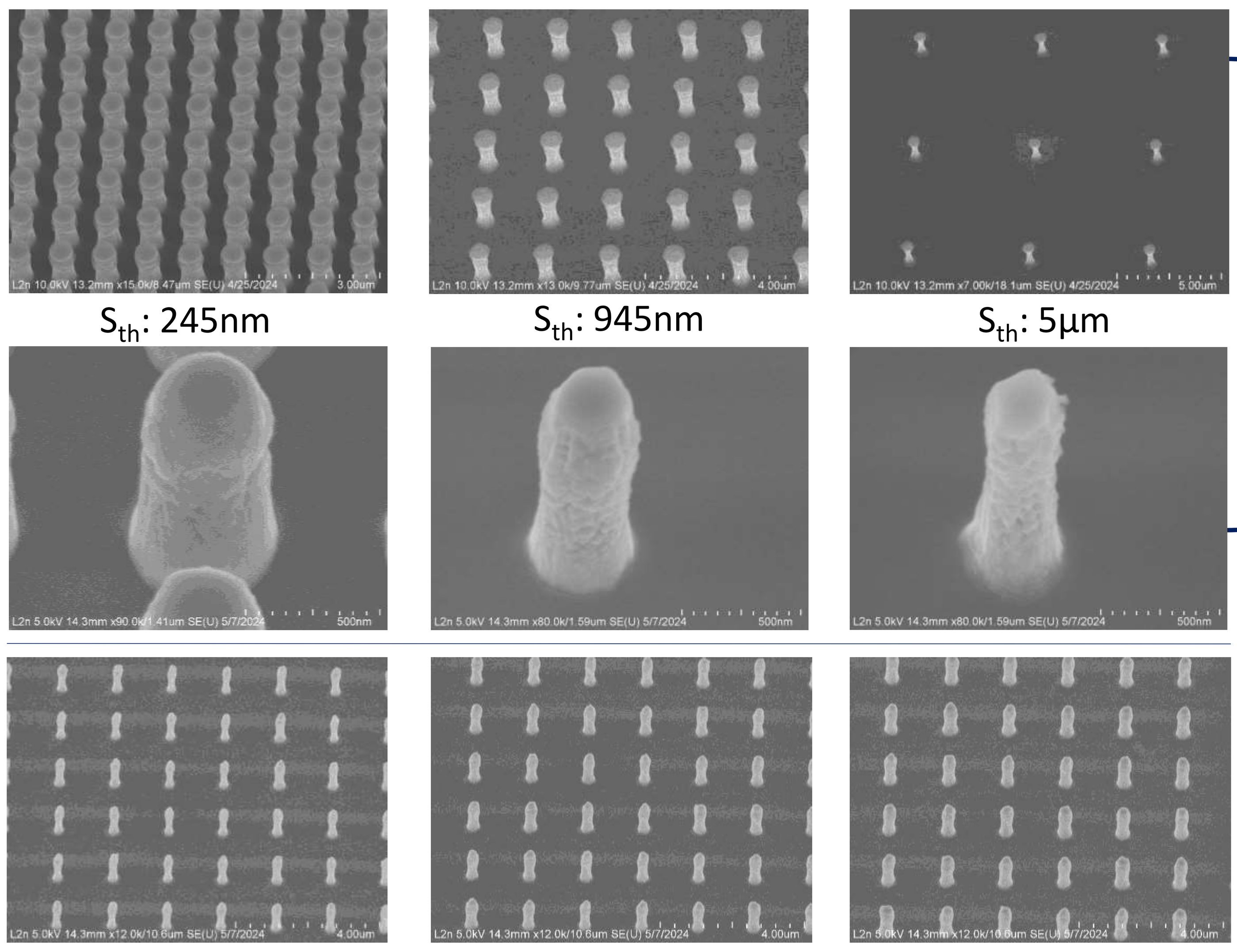


D_{th}: 350nm - S_{th}: 540nm

- **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

Nano-pillars



S_{th}: 245nm, S_{th}: 945nm, S_{th}: 5µm — **D_{th}: 700nm**

D_{th}: 245nm, D_{th}: 945nm, D_{th}: 5µm — **S_{th}: 940nm**

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 fell and non-linearity of lateral etching with D or S..

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

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