On the formation of Black Silicon in SF_6-O_2 plasma: The CORE sequence and BSi on Demand

Nguyen, Vy Thi Hoang

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On the formation of Black Silicon in SF_6-O_2 plasma: The CORE sequence and BSi on Demand

By

Vy Thi Hoang Nguyen

Supervision

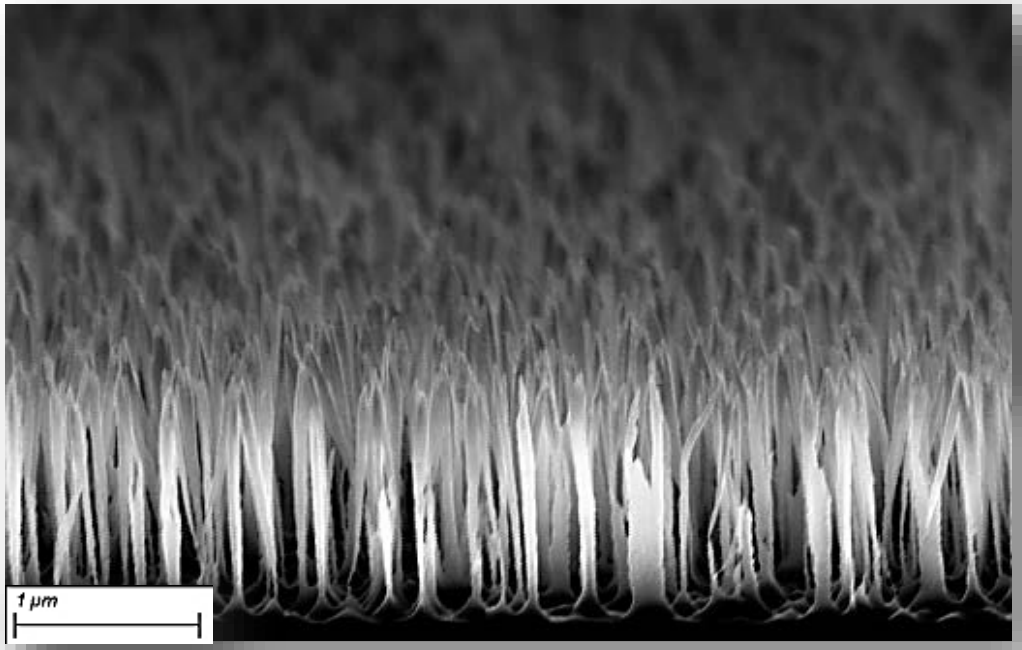
Henri Jansen *Flemming Jensen* *Jörg Hübner*

Outline

- Motivation and aim
- Background on BSi and Bosch
- Approach: the CORE sequence
- Result: BSi on demand
- Conclusion

Motivation and aim

- BSi (or micrograss or microroughness) is a dense field of Si nanostructures which reduces the reflection of light
- Properties: Enhanced light absorption and surface area, Super-hydrophobicity
- Applications: Photovoltaic, Chemical and catalytic device, Anti-bacterial, Anti-fogging and self-cleaning surfaces, etc.
- However, the formation of this roughness is considered to be ‘very annoying’ in most MEMS-related applications

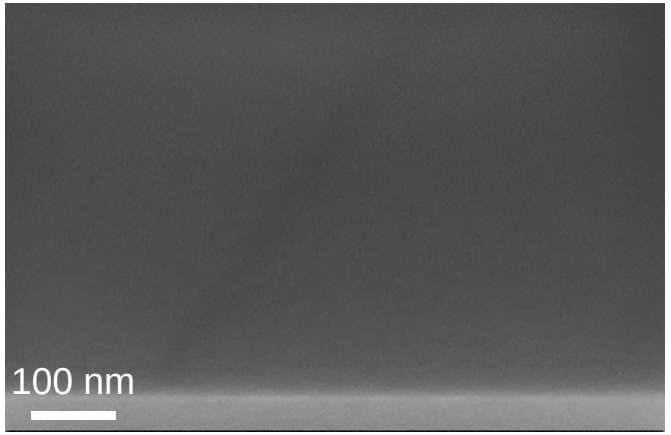


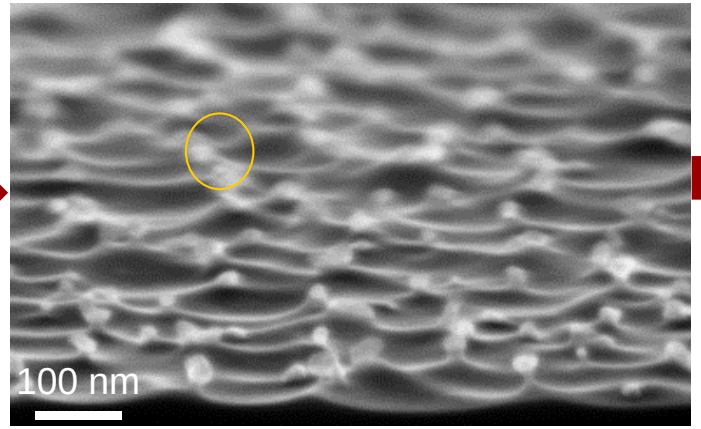
Our aim:

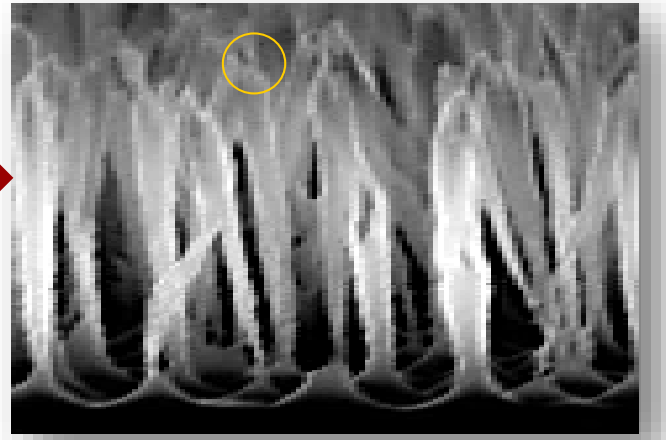
- to find the root cause of BSi
- to control the evolution of BSi to either start, enhance or reduce its appearance

Background and current understanding of BSi formation

- BSi is considered to be mainly due to micromasking
- The evolution into long pointy nanostructures is due to a highly directional ionic flux with the correct balance between passivation and etching







Where is the micromask coming from?

FC - related

1. Fluorocarbon deposits from the reactor walls that loose adhesion and form particles
2. Plasma fluorocarbon deposition and insufficient ion etching

O - related

3. Oxide participants/clusters/defects/impurities inside e.g. Czochralski Si
4. Non-volatile SiO_xF_y particles arriving from the plasma (plasma dust)
5. Redeposit from sputtered SiO_x that forms at horizontal Si surfaces
6. (Inhomogeneous) removal of (inhomogeneous) native oxide
7. Plasma oxidation of the Si surface and randomly insufficient ion etching (puncturing)

Others

8. Mask sputtering and subsequent redepositing
9. Non-volatile sulfur compounds (SO_xF_y) formed in the plasma bulk
10. AlF_3 particles sputtered from the reactor walls or wafer clamp
11. ‘Dirty’ wafers due previous process steps (e.g. resist residues or scum)
12. Natural roughness of the silicon surface (causing self-shadowing)
13. Temperature-dependent amplification of particle diffusion along the surface

Where is the micromask coming from?

FC - related

1. Fluorocarbon deposits from the reactor walls that loose adhesion and form particles
2. Plasma fluorocarbon deposition and insufficient ion etching

Conventional Bosch process

O - related

3. Oxide participants/clusters/defects/impurities inside e.g. Czochralski Si
4. Non-volatile SiO_xF_y particles arriving from the plasma (plasma dust)
5. Redeposit from sputtered SiO_x that forms at horizontal Si surfaces
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7. Plasma oxidation of the Si surface and randomly insufficient ion etching (puncturing)

Novel CORE process

Others

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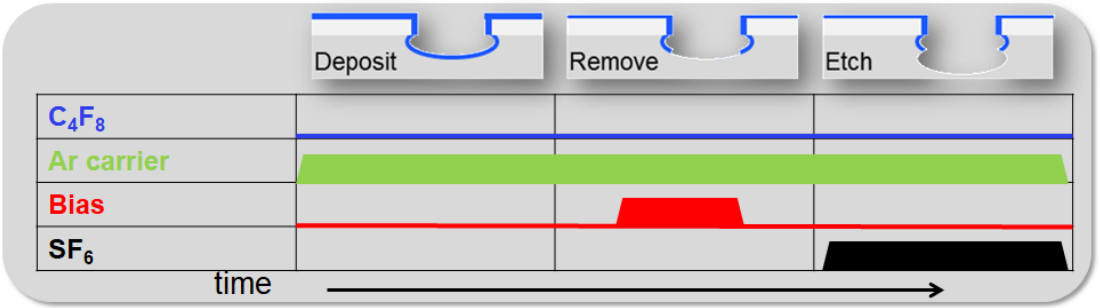
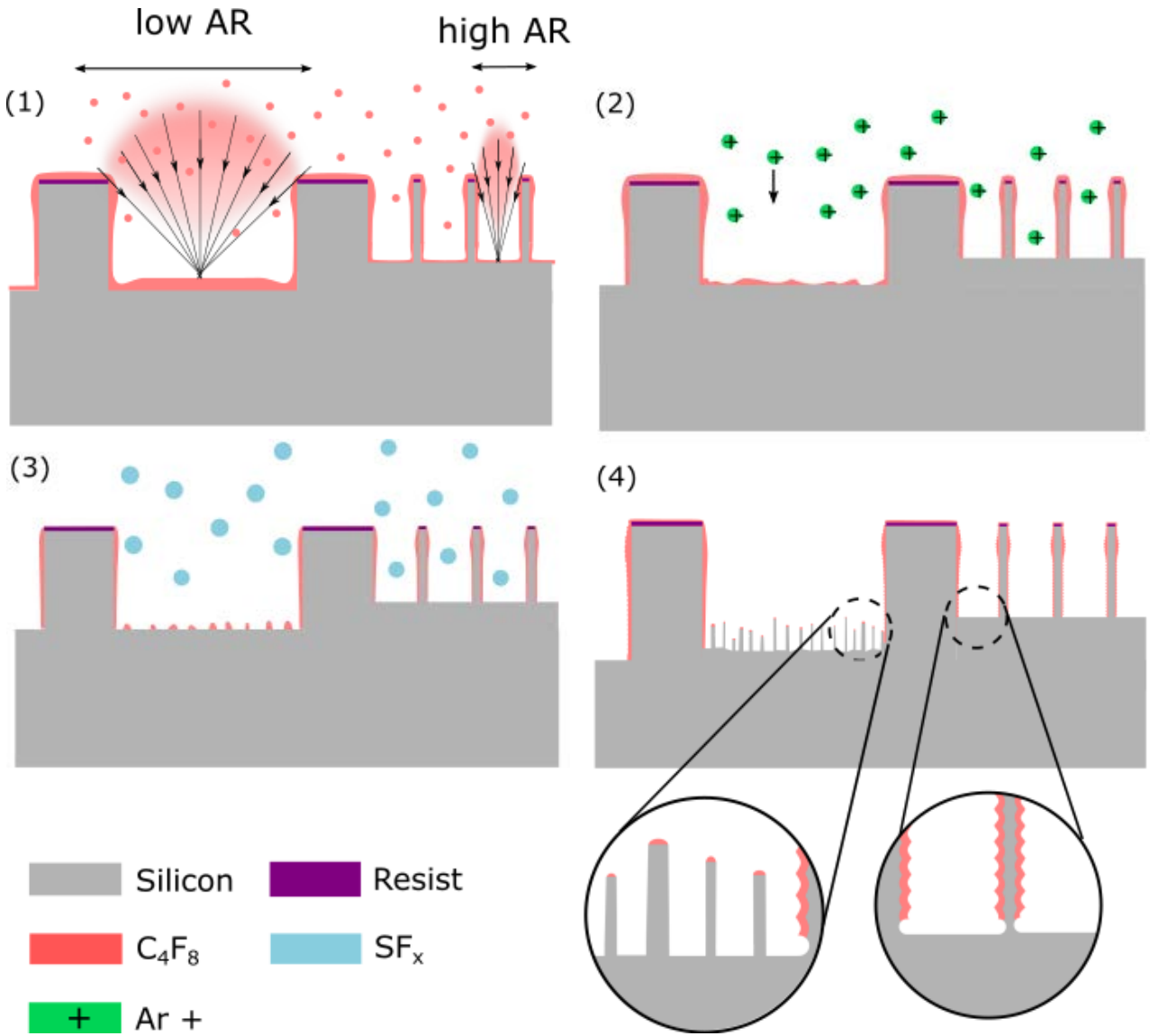
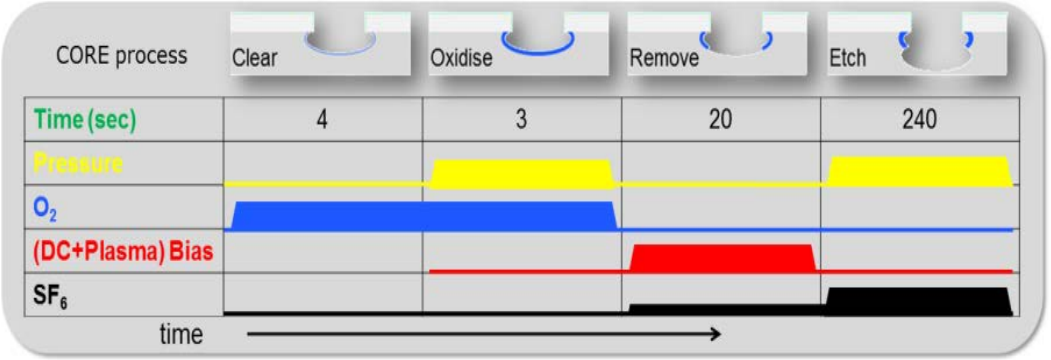
The Bosch process and BSi formation



- **The Deposition step** → 'Deposition lag'
- **The Removal step** → No 'removal lag'.
- **The Etching step** → the well known RIE lag
- In general, high aspect ratio structures are having less grass inside

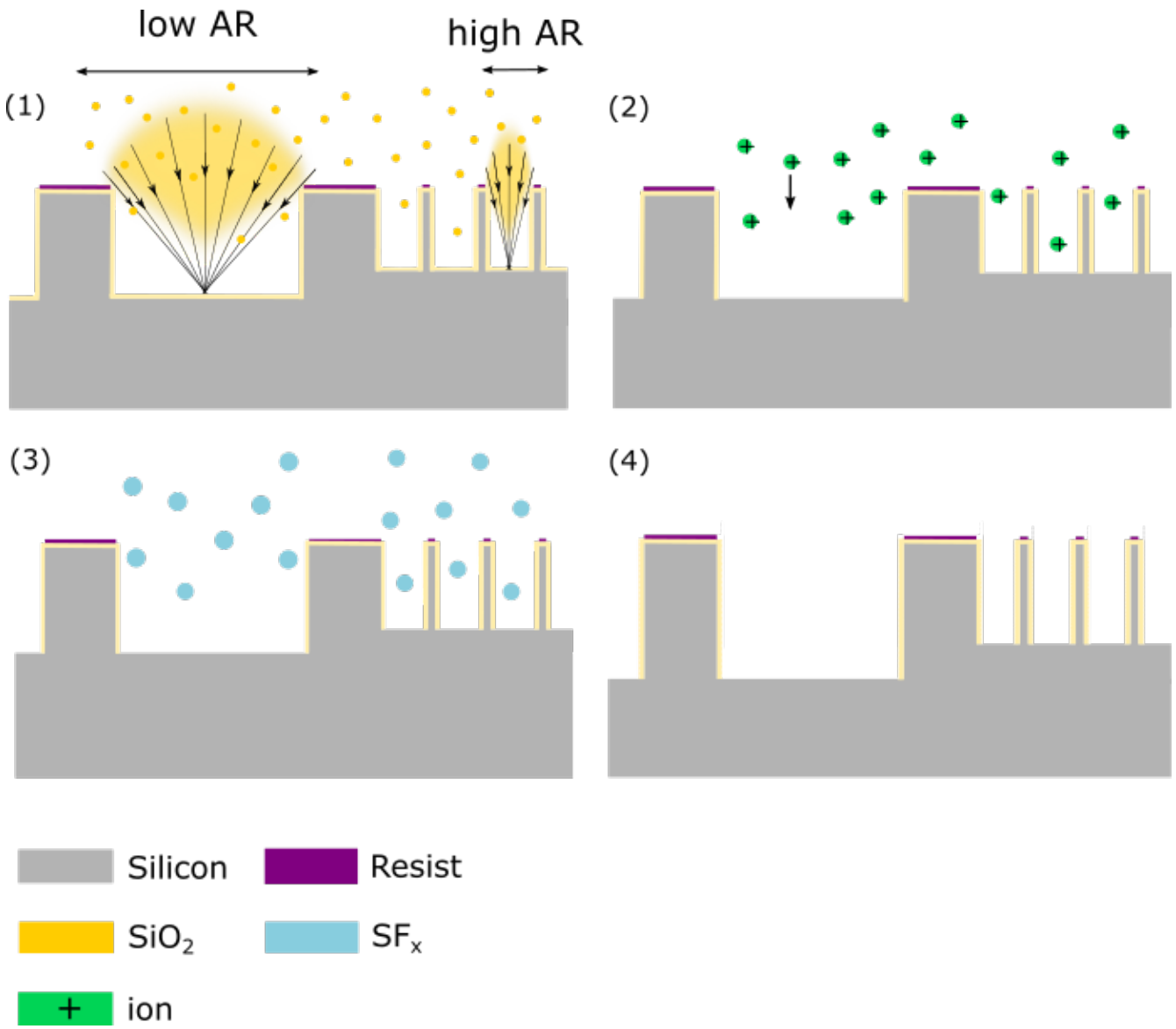


The CORE process and BSi formation



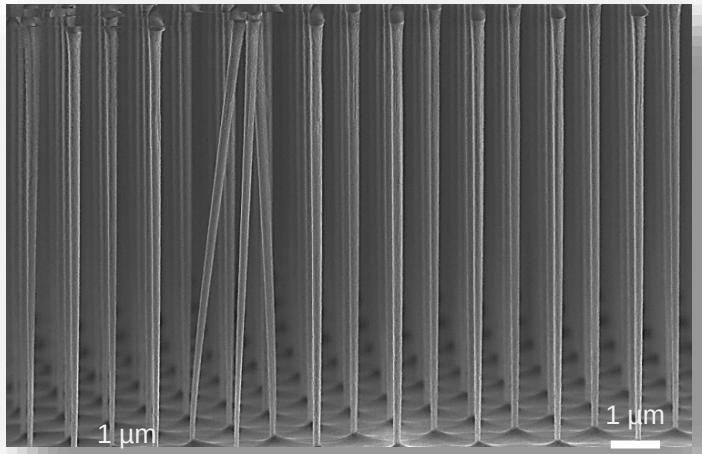
- BSi is everywhere or nowhere

→ BSi on demand

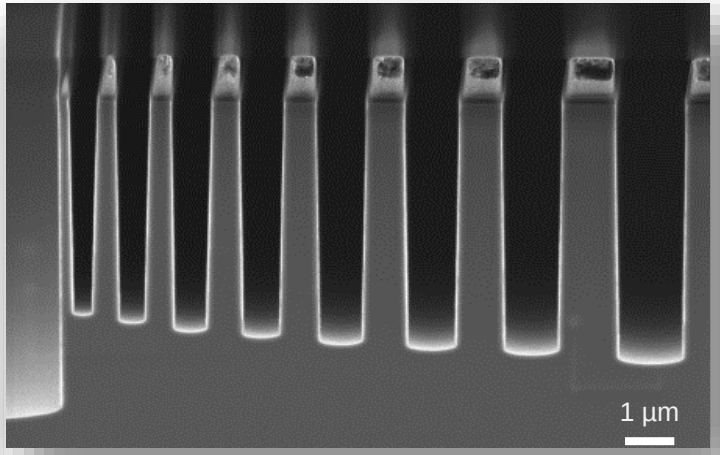


The CORE process: examples

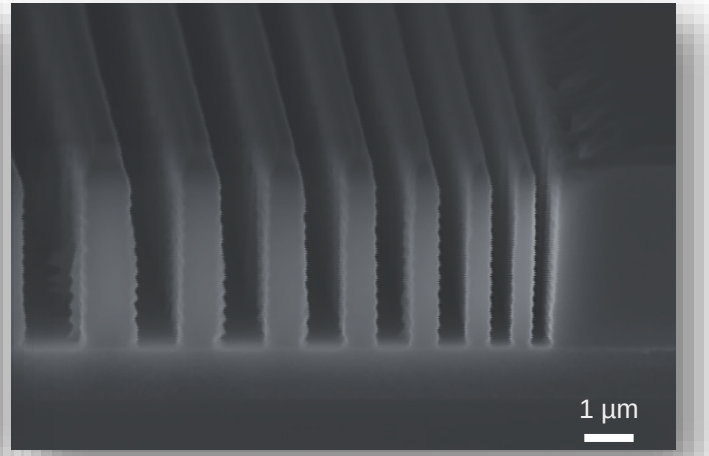
- The etching profiles is pattern independent
- Apply for both micro and nano structure without tuning



Sub-micron pillars



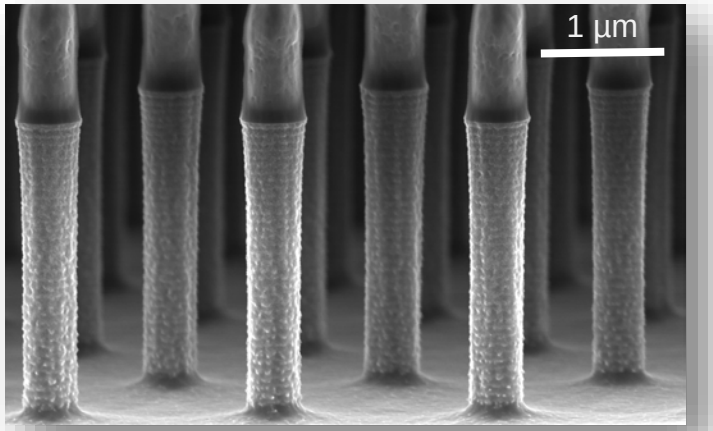
Sub-micron trenches

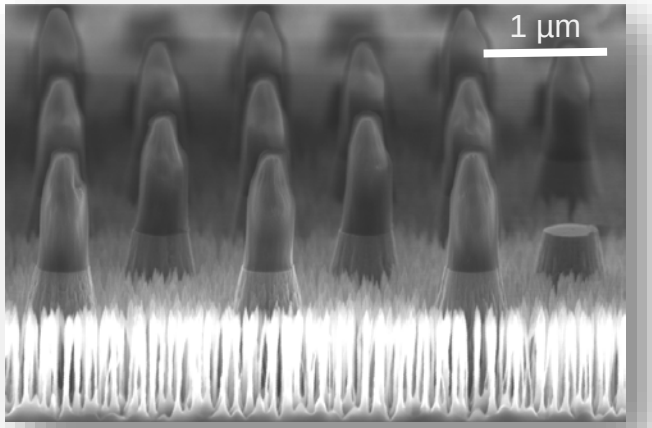


Nano - trenches

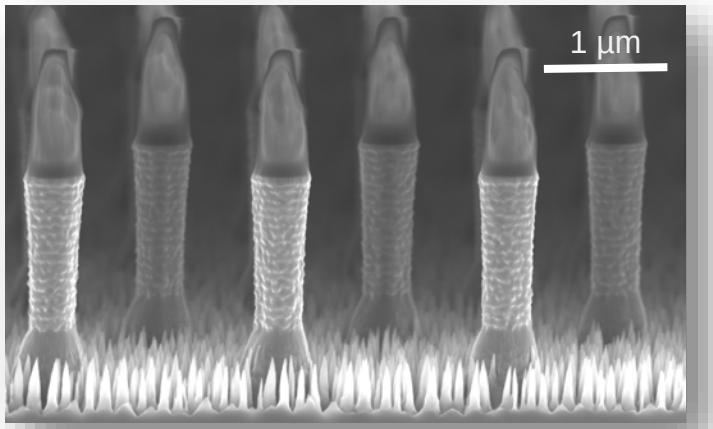
The CORE process: BSi on demand

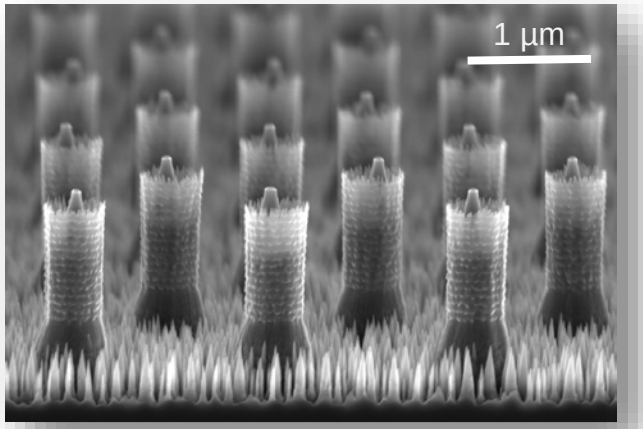
Silicon pillars etched with a smooth and a black silicon recipe





Silicon pillars etched with smooth recipe followed by a black silicon recipe.





Conclusion

- BSi is considered to be mainly due to micromasking and directional transferring
- It is difficult to predict the evolution of BSi as the deposition lag of fluorocarbon is unavoidable → Bosch sequence can not prevent the BSi
- The CORE sequence uses the self-limiting growth of oxide to prevent the deposition lag
- The evolution of BSi can be controlled and manipulating at demand

Thanks for listening !