E1: Generic build-up of etch process: 3D-sculpturing by Si plasma etching (ADVANCED)

Technology Development of 3D Silicon Plasma Etching Processes for Novel Devices and Applications

Bingdong Chang
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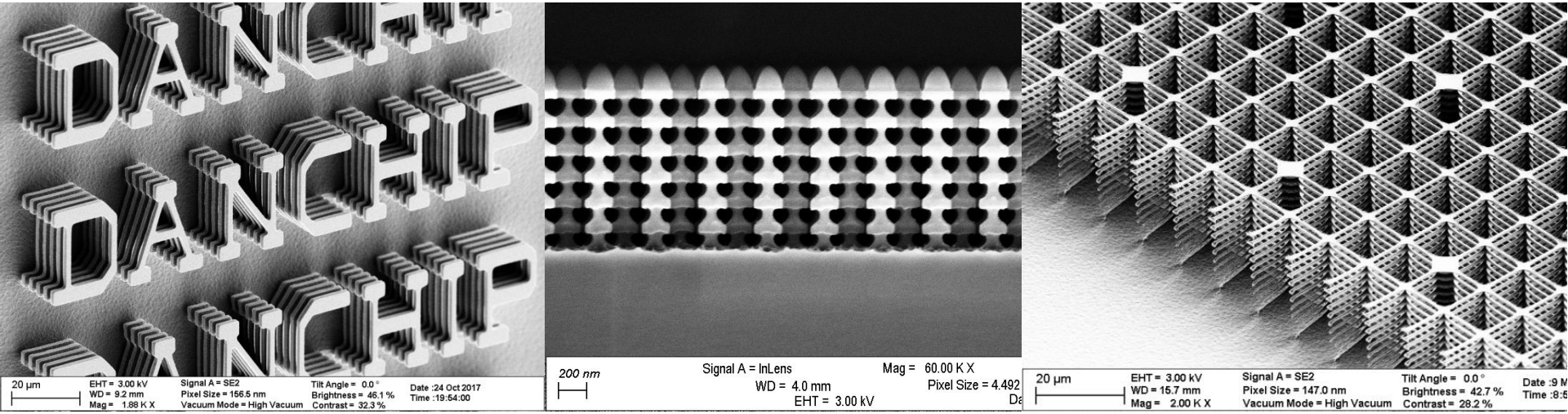
7 May 2019



MICRONOVA Centre for Micro and Nanotechnology
myfab
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NNN Nordic Nanolab Network

1. Introduction of the etching tool

   • Etching machine: DRIE-Pegasus (SPTS);
   • Real time monitoring system: OEI/OES, Claritas EPD, Oscilloscope, etc.

2. Introduction of the etching strategy

   • DREM process;
   • 3D DREM process.

3. Applications of fabricated 3D silicon micro- and nanostructures

   • 3D photonic crystal membranes;
   • ZnO nanowires/3D silicon micromesh for photocurrent and photocatalysis

4. Conclusions and perspectives

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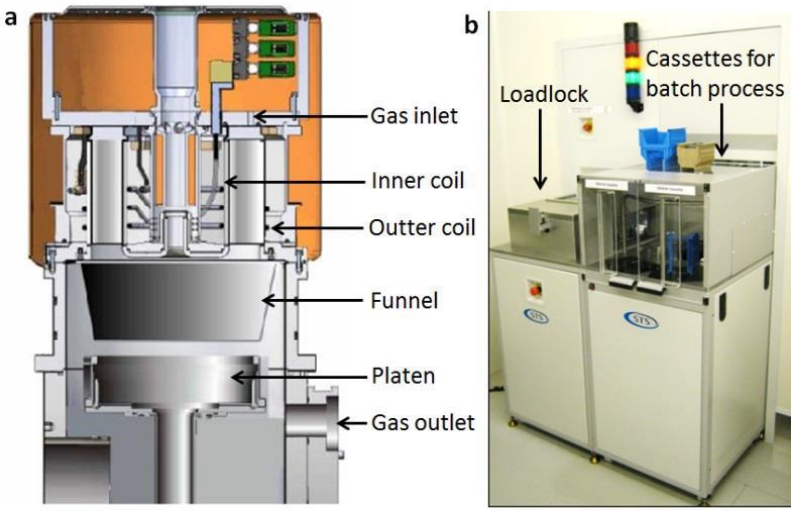
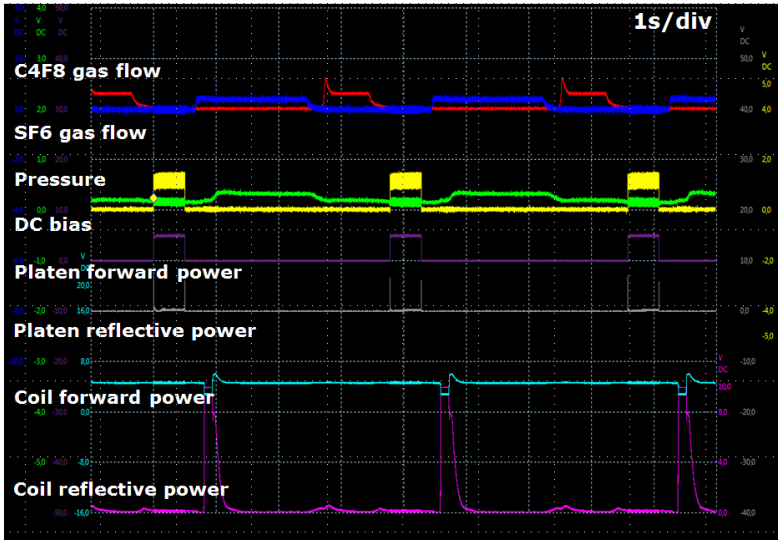
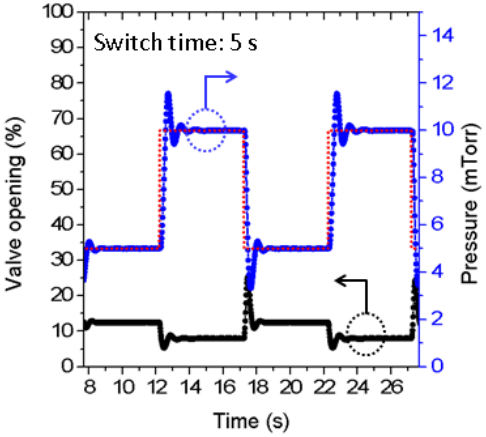
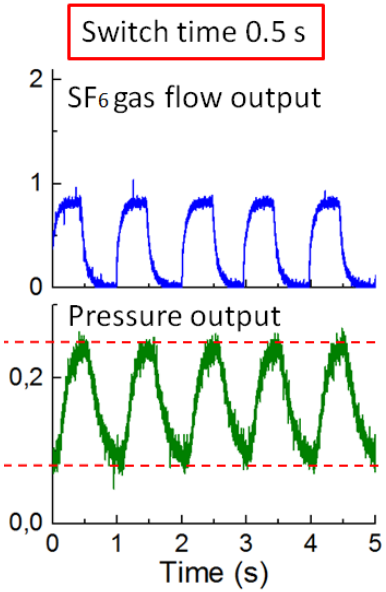


- DRIE-Pegasus (SPTS);
- Installed real time monitoring systems for precise process control;
- Oscilloscope;
- Optical emission spectroscopy (OES);
- Optical emission interferometry (OEI);
- Claritas end-point detection system.

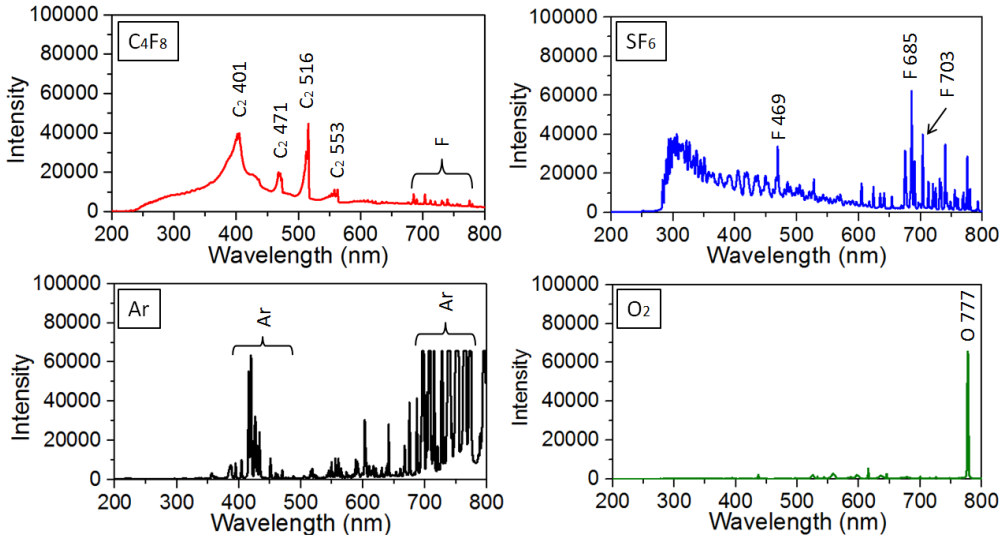


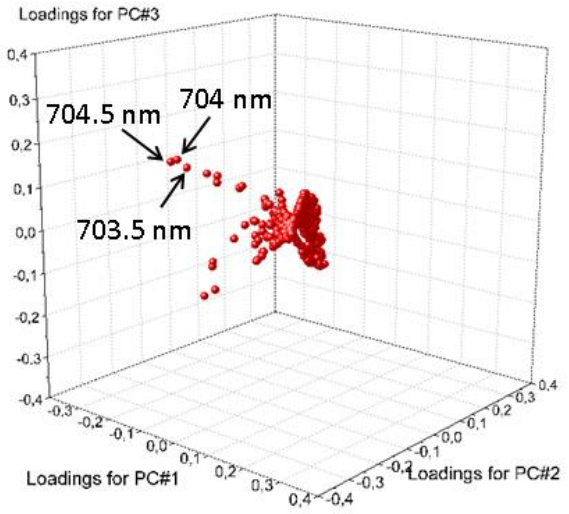


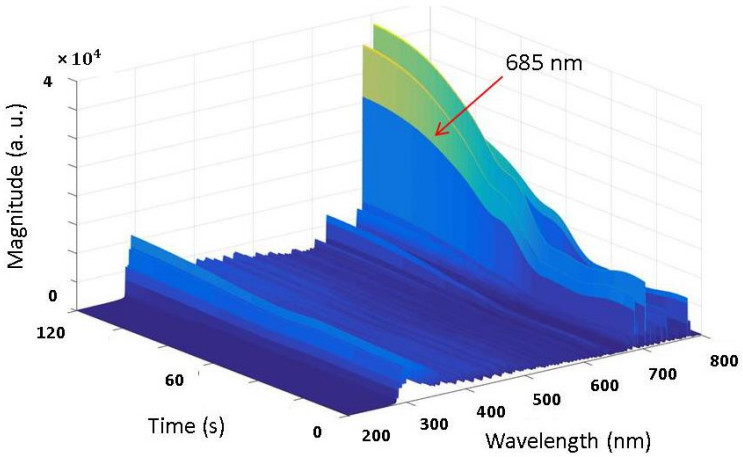


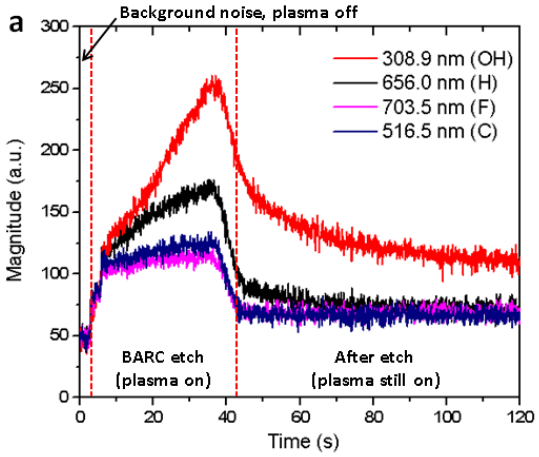
Optical emission spectroscopy (OES)

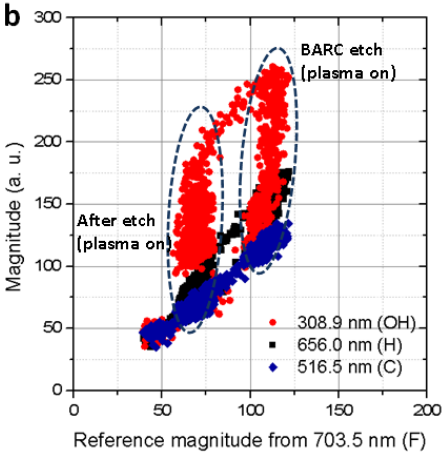
- Tracing the ”fingerprints” of different species;
- Principal component analysis (PCA) to choose best wavelength for analysis;
- End-point detection of silicon etch and BARC etch.





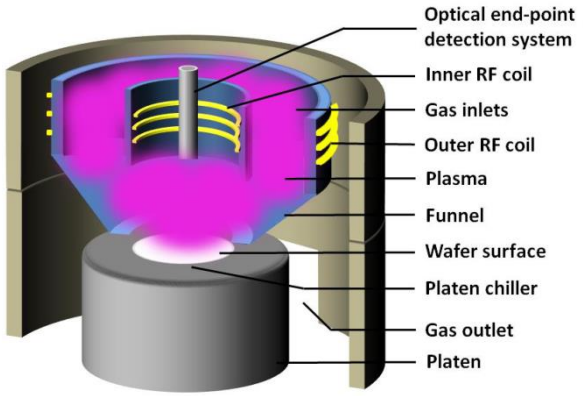


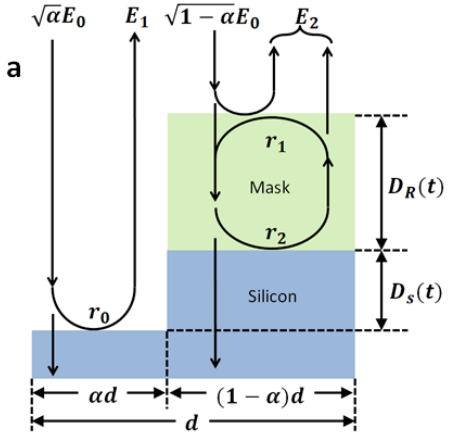


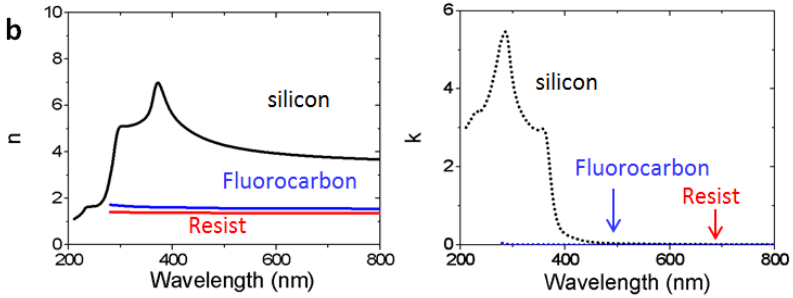


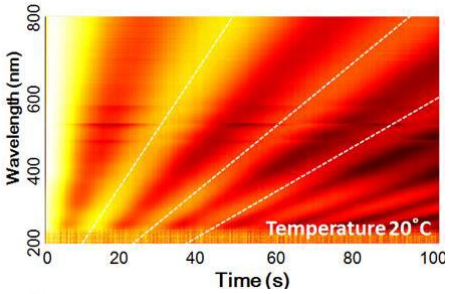
Optical emission interferometry (OEI)

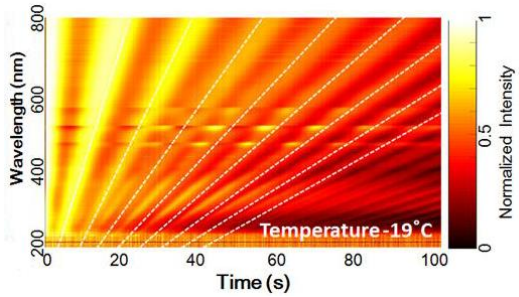
- Studying etch mechanism (e.g. fluorocarbon deposition process);

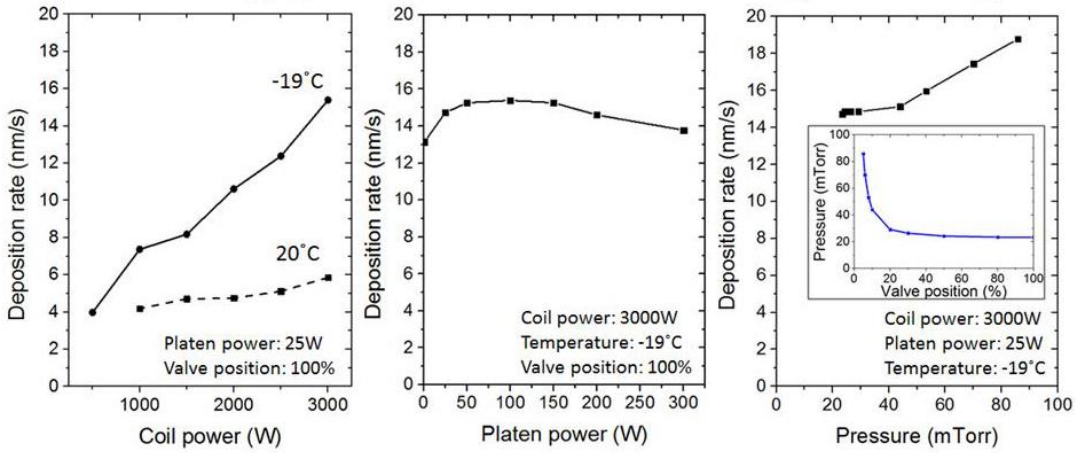






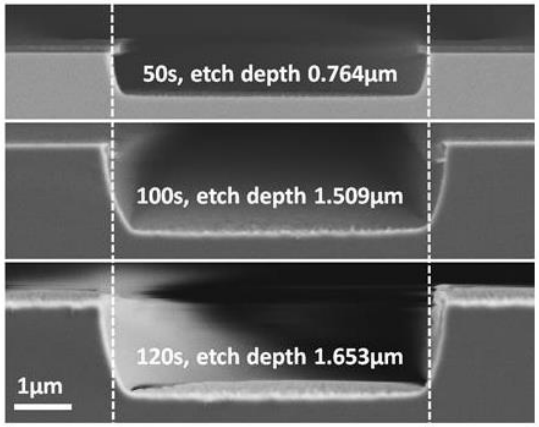


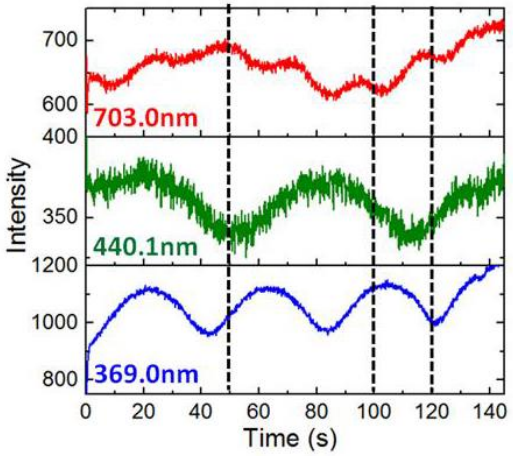


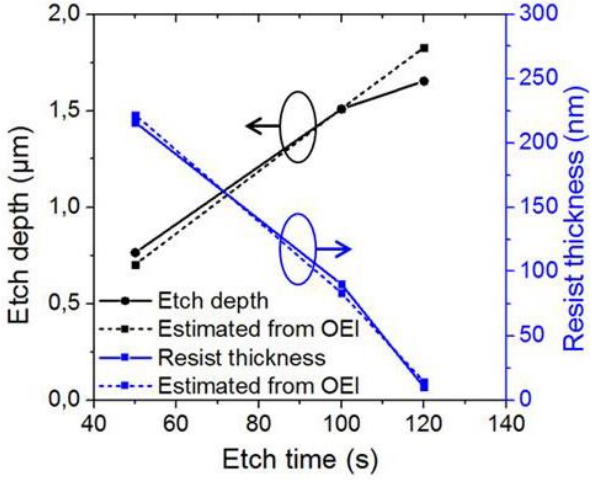


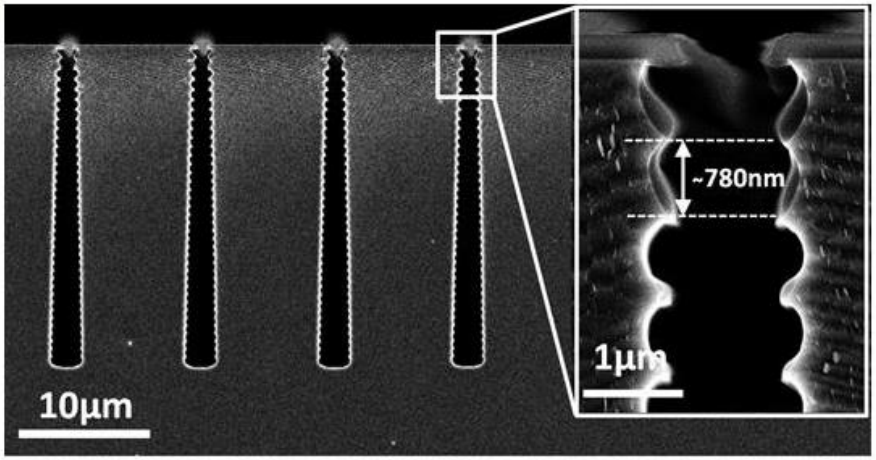
Optical emission interferometry (OEI)

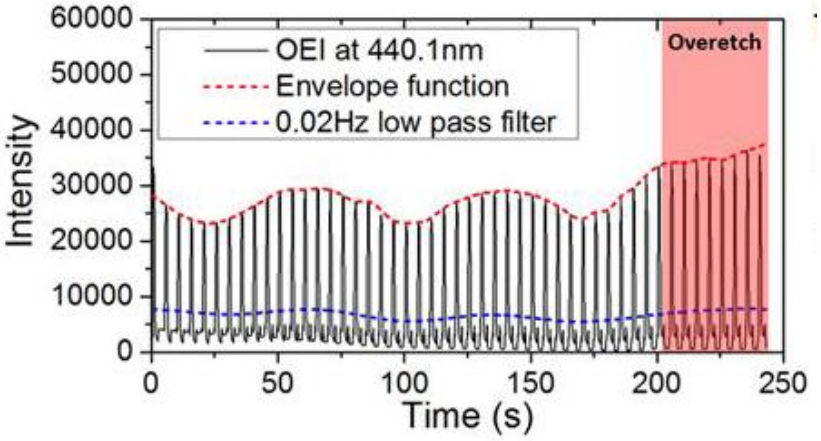
- Real time monitoring of mask etch rate;
- Real time monitoring of silicon microstructures etch rate.





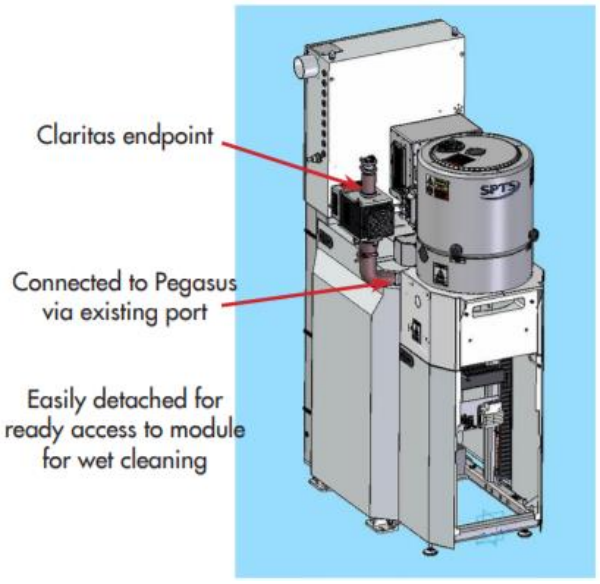


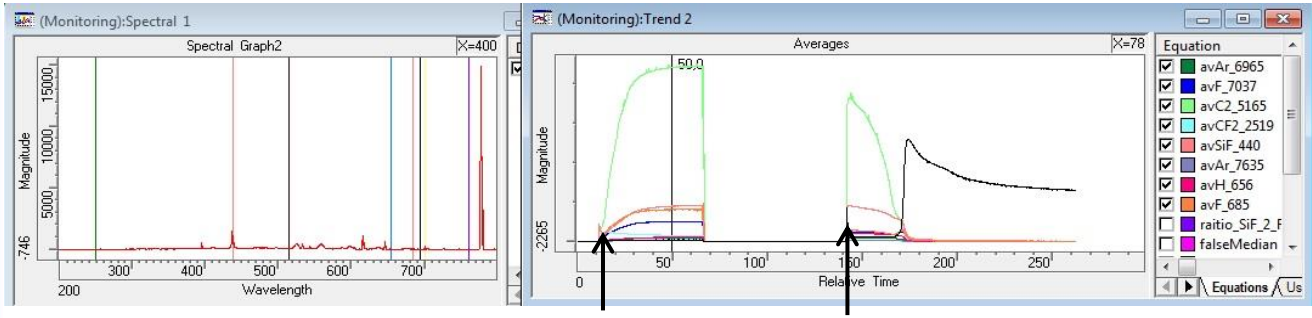


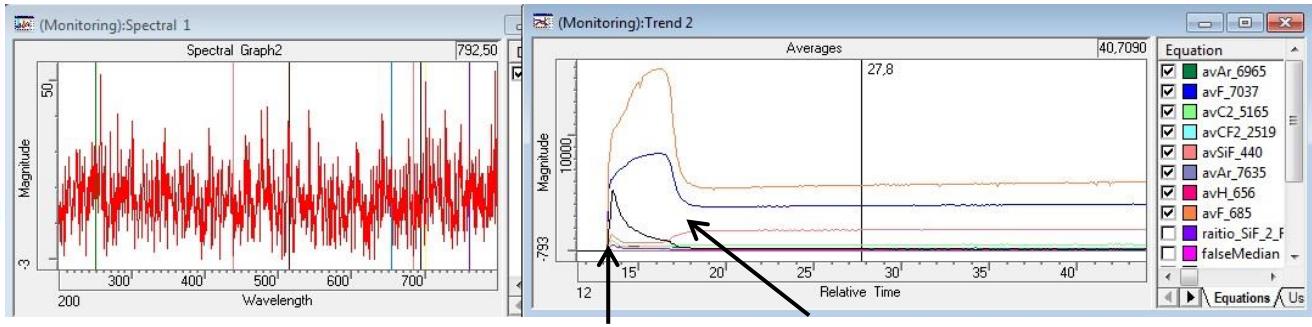


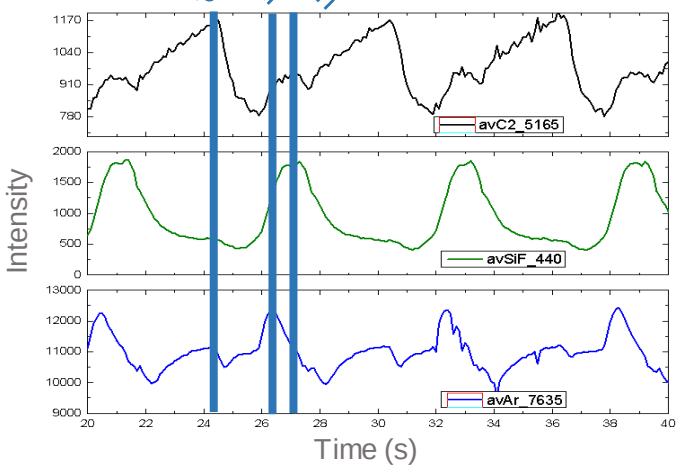
CLARITAS endpoint detection system

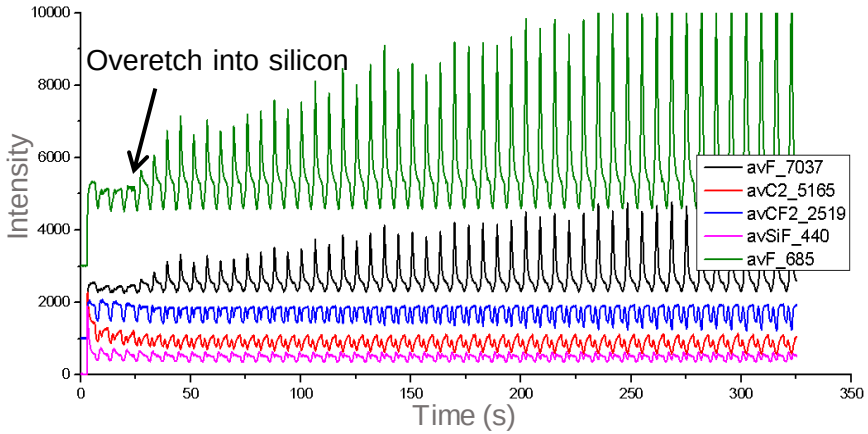
- Endpoint detection based on OES inside a sub-chamber;
- Good signal for low loading area < 2%











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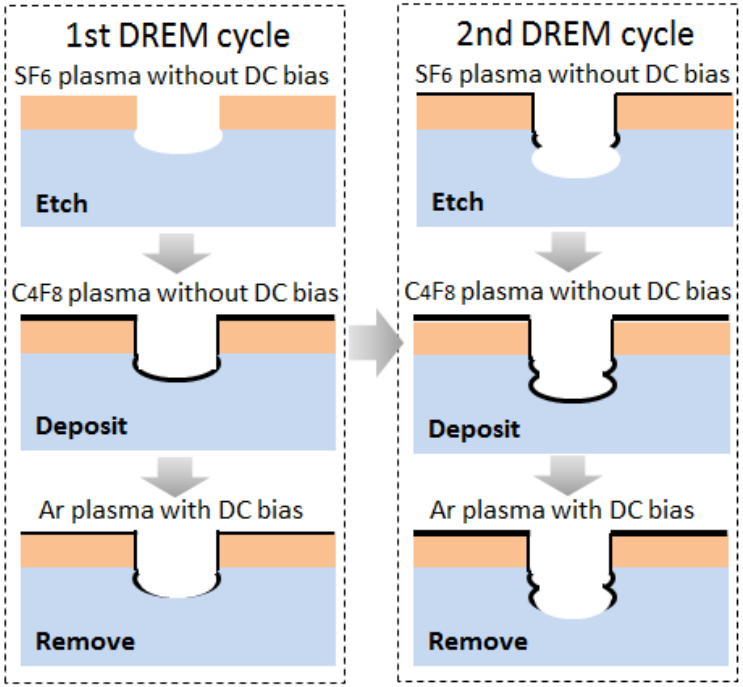
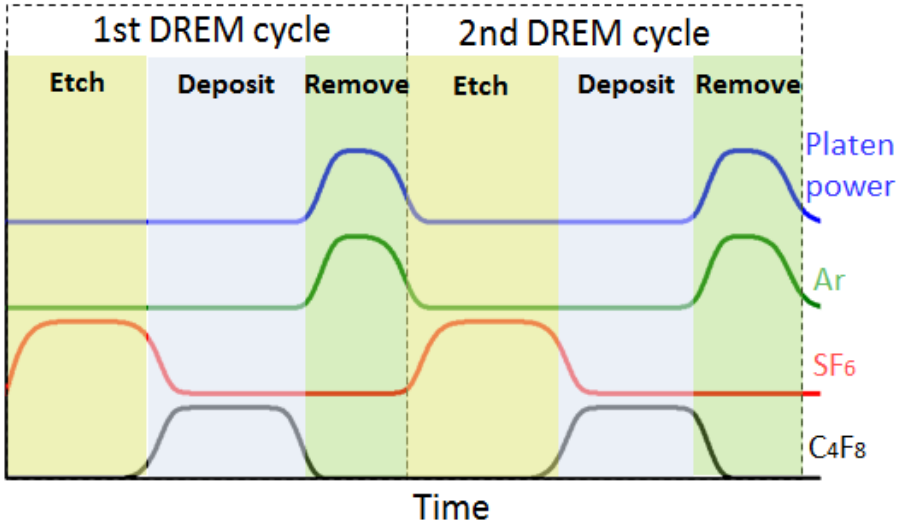
DREM process (a modified Bosch process):

- 3 step process: **D**eposit, **R**emove, **E**tch **M**ethod;
  Deposit: low platen power to reduce sputtering;
  Remove: low pressure argon to create anisotropic profile;
  Etch: low platen power to reduce scallops.

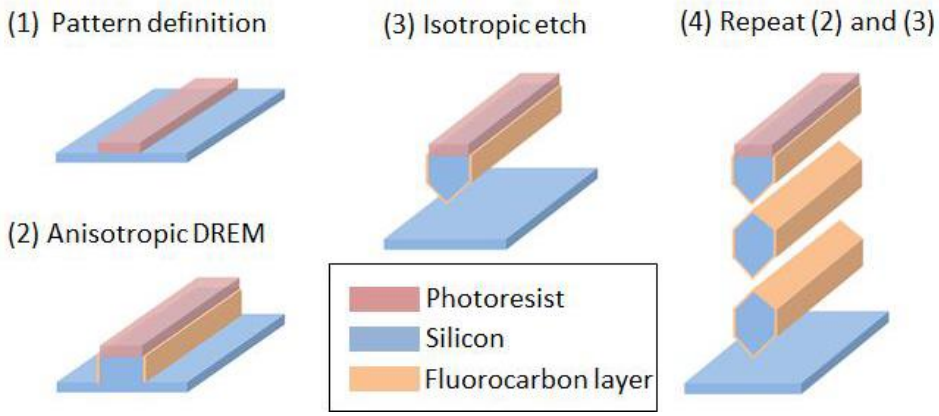
- Parameter ramping for uniform scallop size distributions.

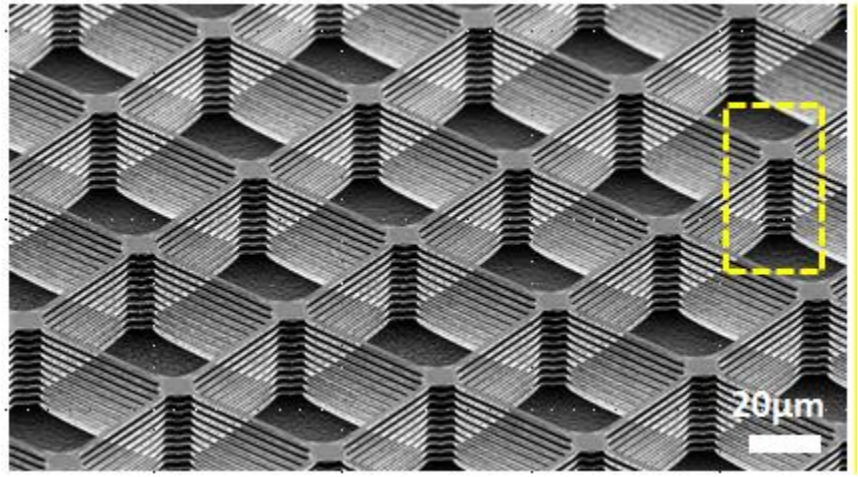


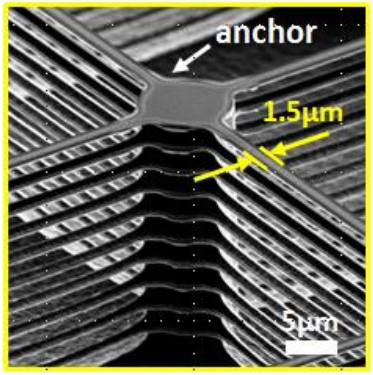


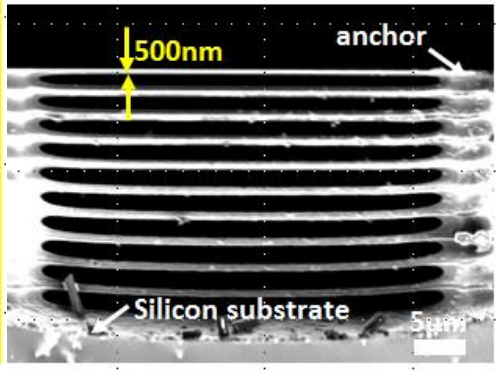
3D silicon structures fabrication with DREM process

- Combining DREM process with isotropic etch process;
- Control the sizes of suspended structures.









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DREM2: a facile fabrication strategy for freestanding three dimensional silicon micro- and nanostructures by a modified Bosch etch process

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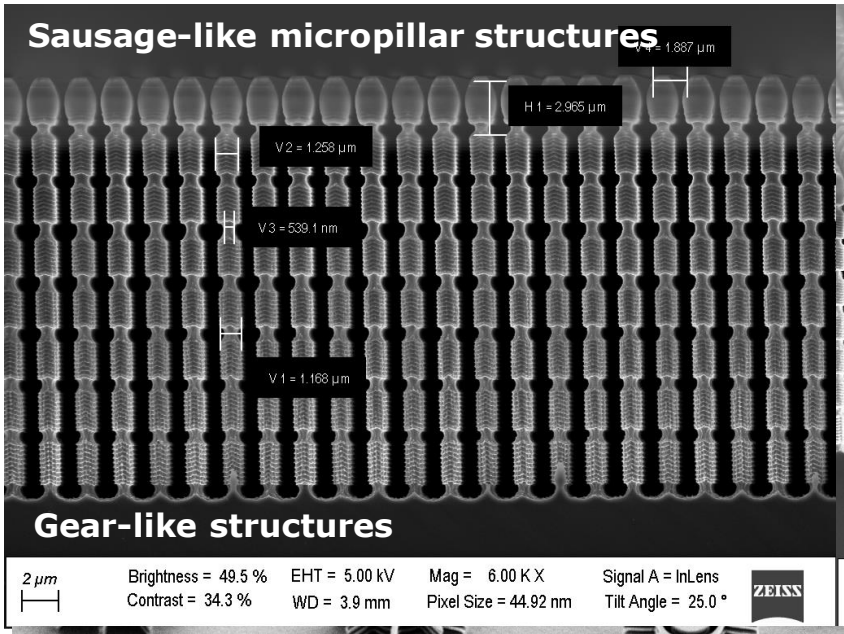
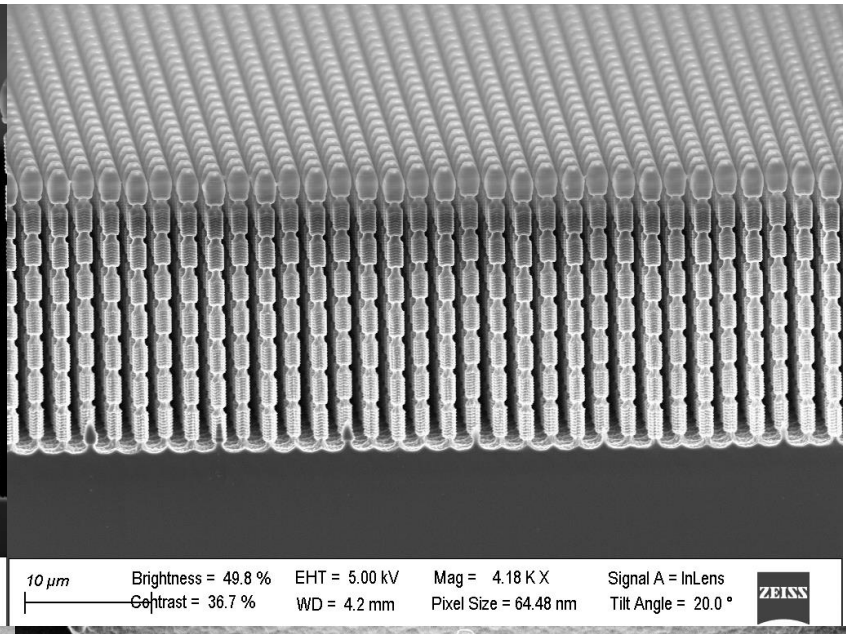
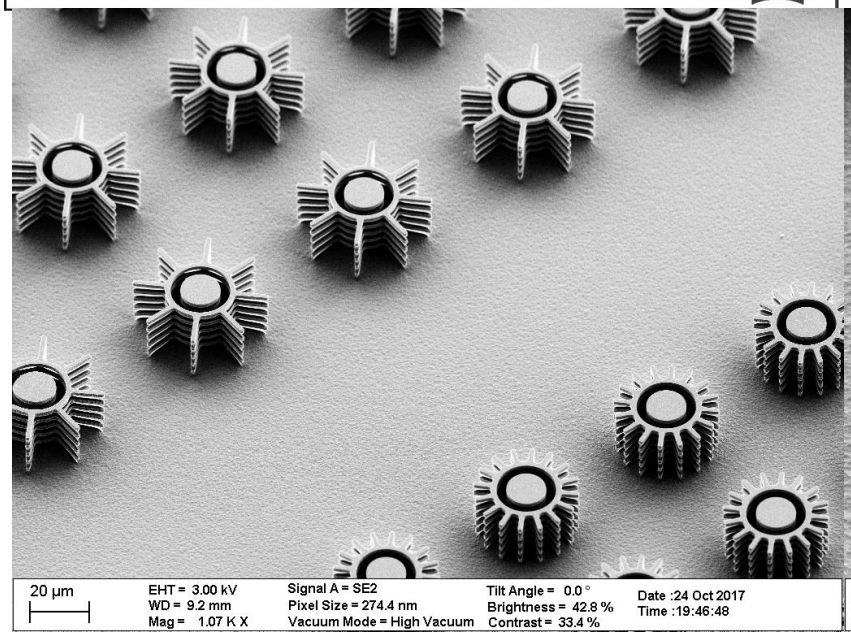
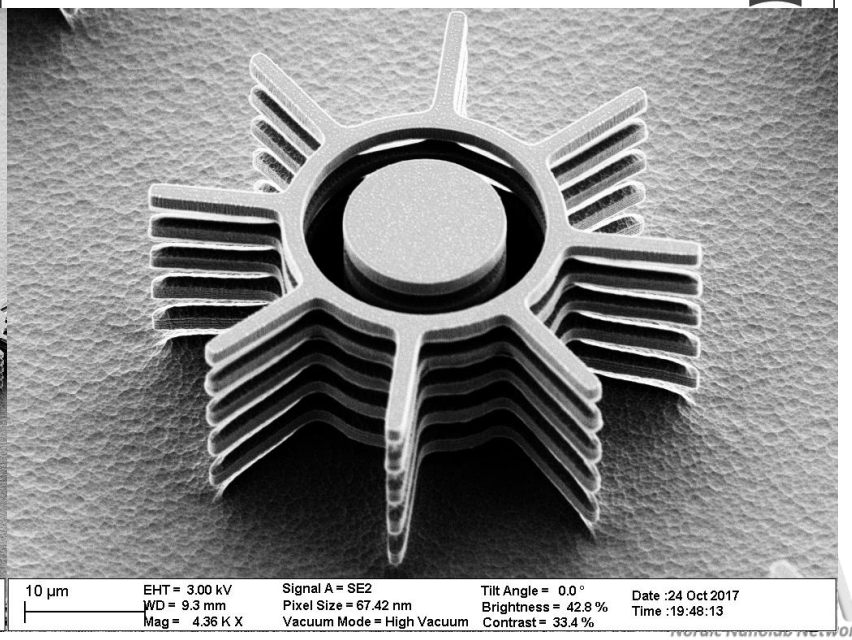
3D microstructures created with modified DREM process

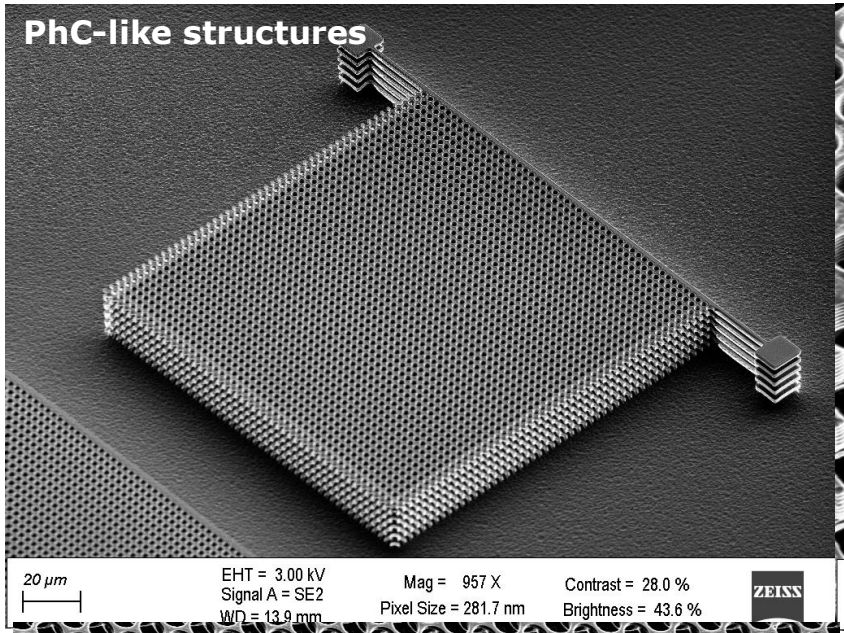


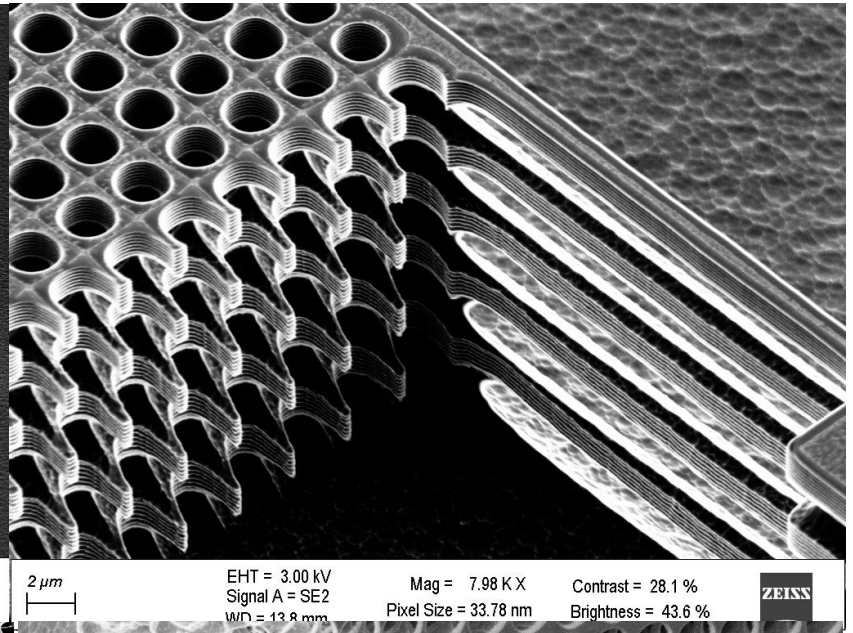


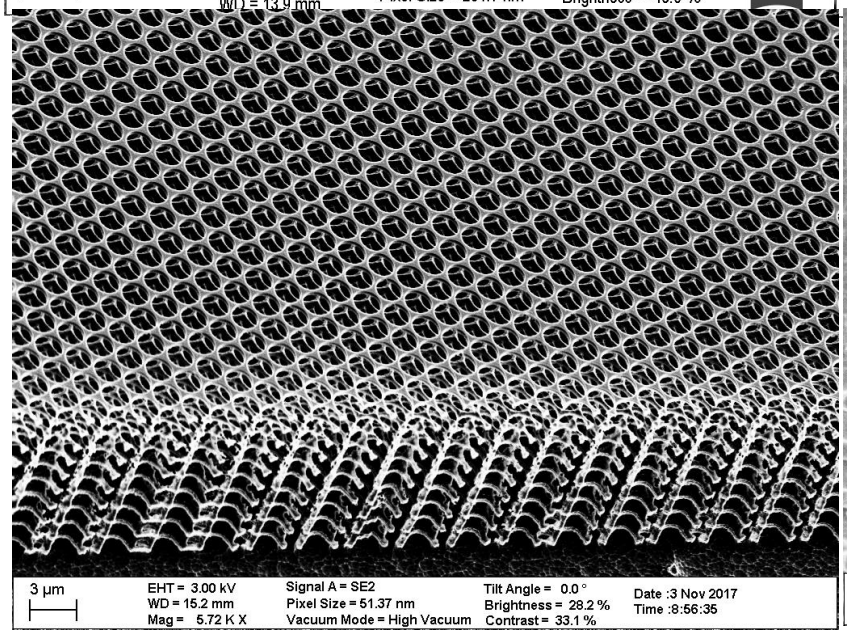


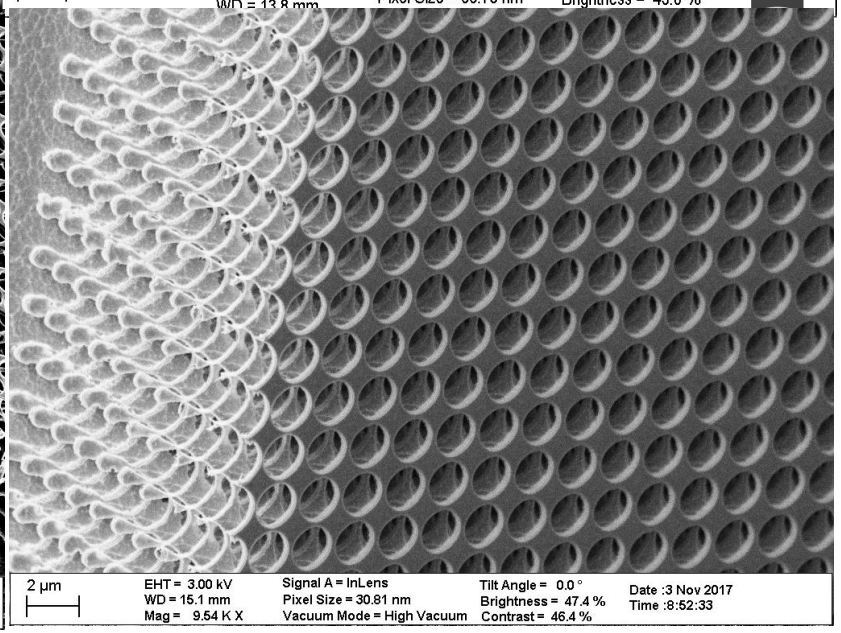


PhC-like structures

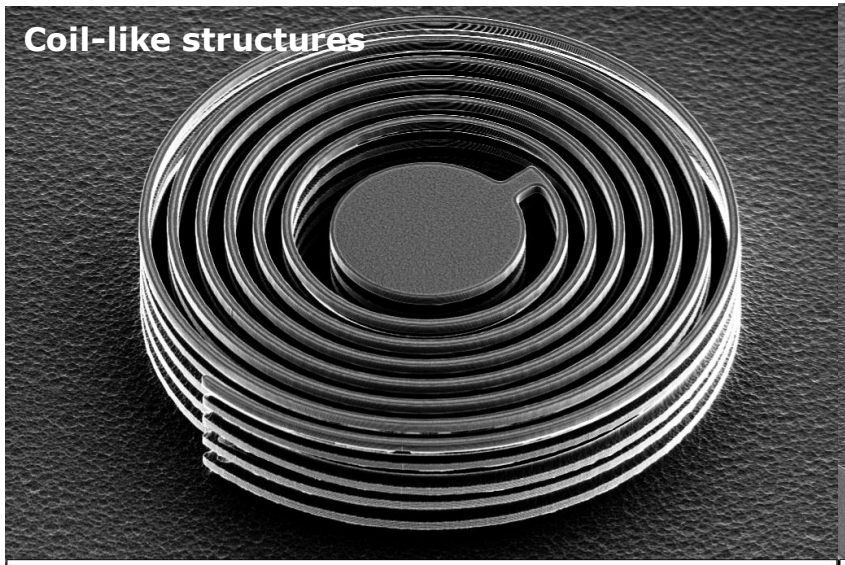


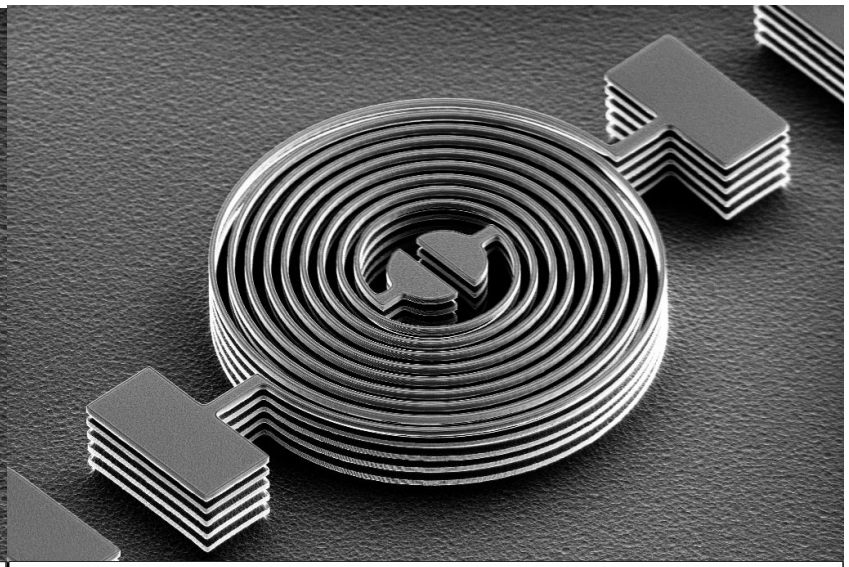




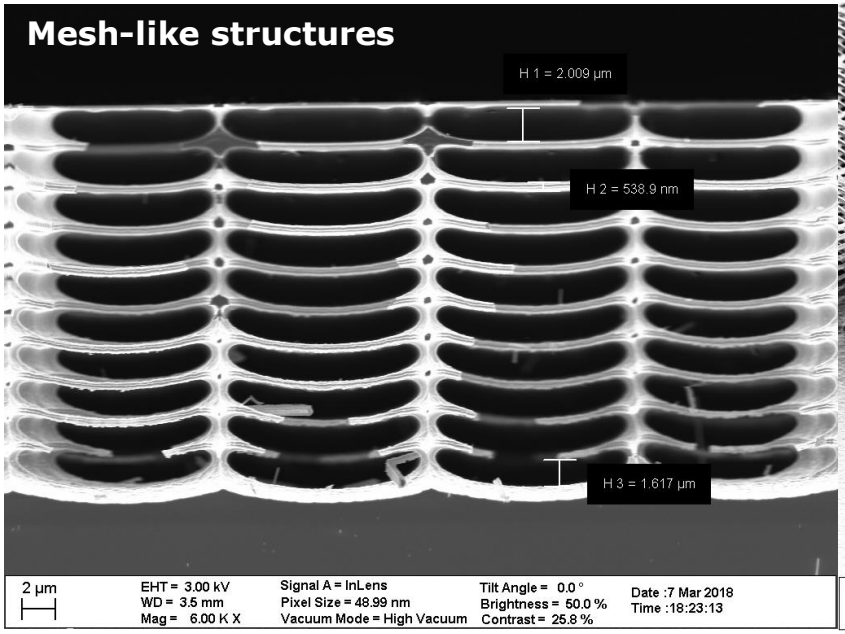


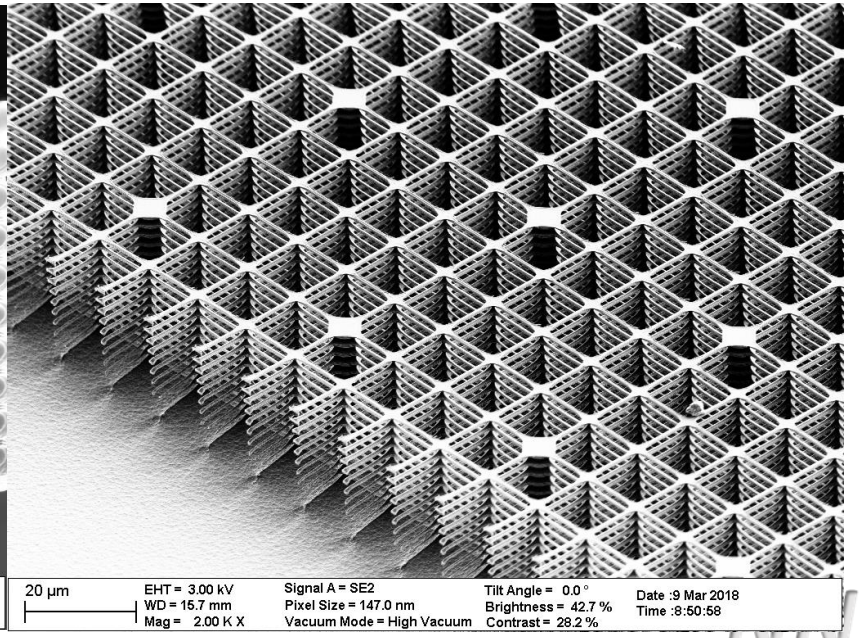
Coil-like structures





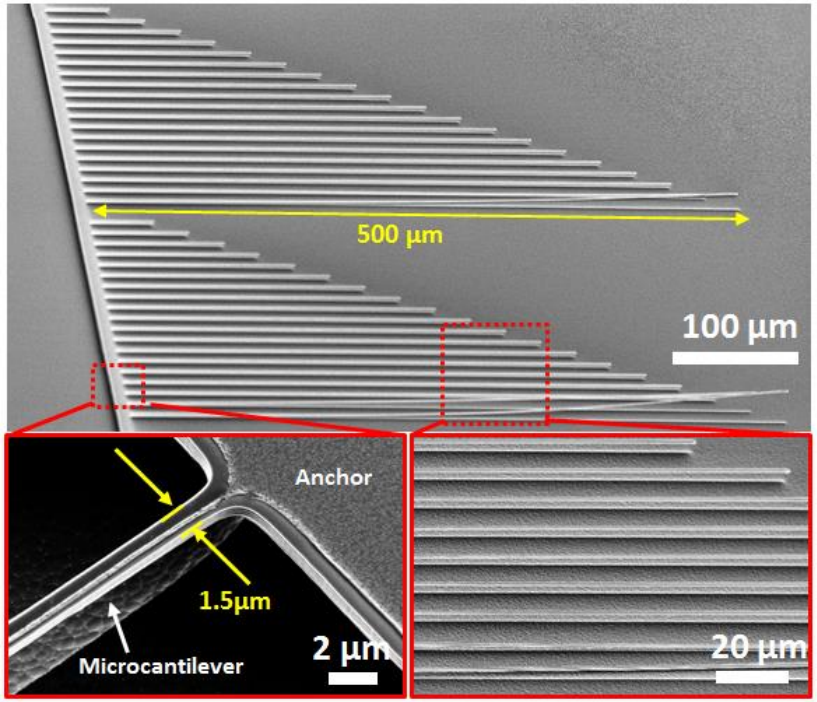
Mesh-like structures



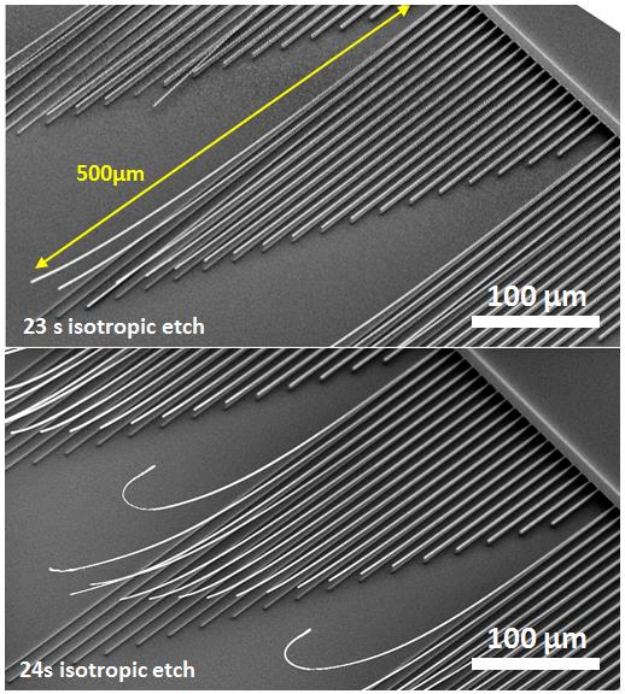


Suspended silicon structures created with modified DREM process

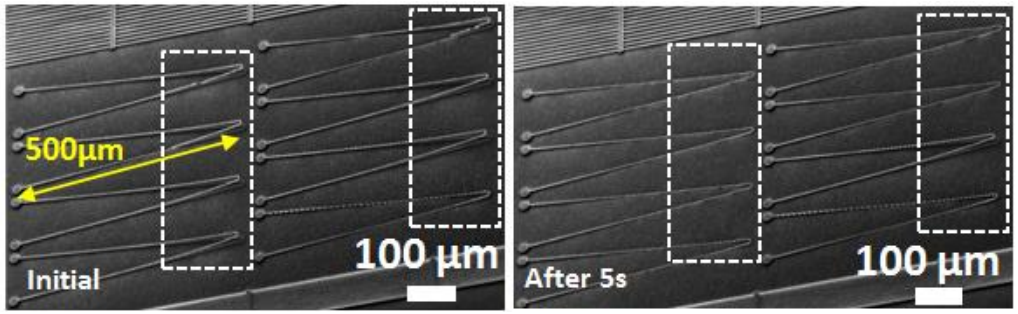
Ultralong cantilevers by dry releasing



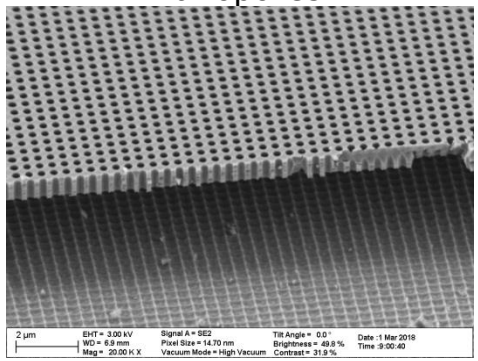
Folding of ultralong cantilevers



Clamping driven by electrostatic force

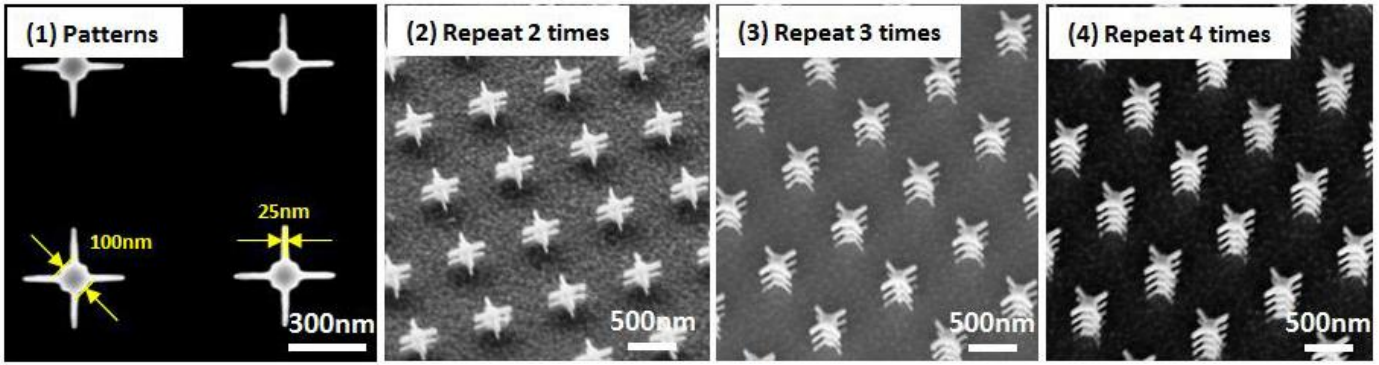


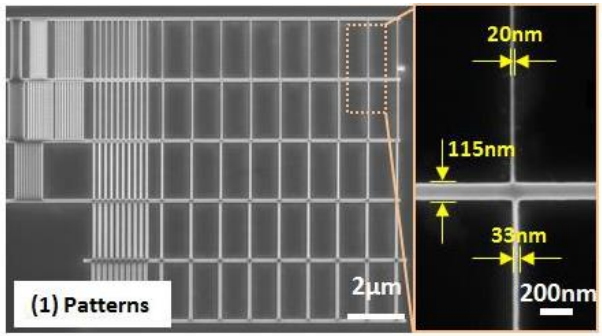
Suspended membranes with nanopores

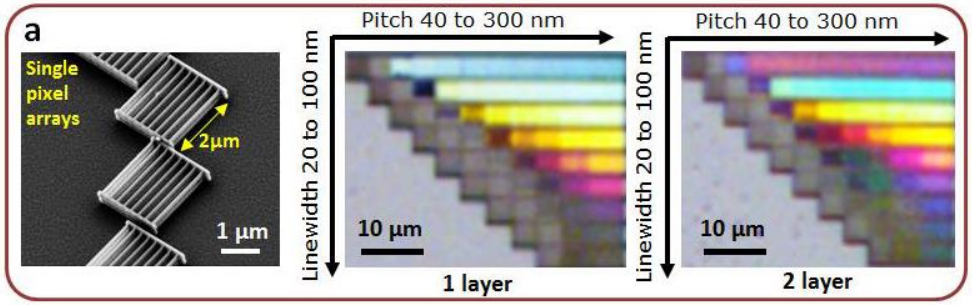


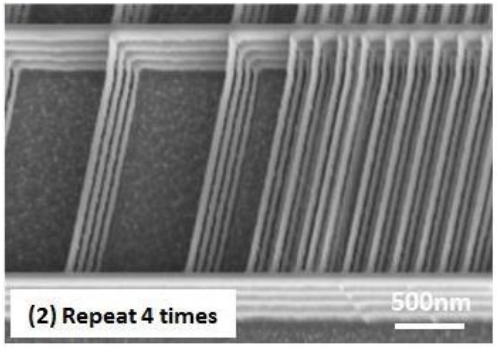
3D nanostructures created with modified DREM process

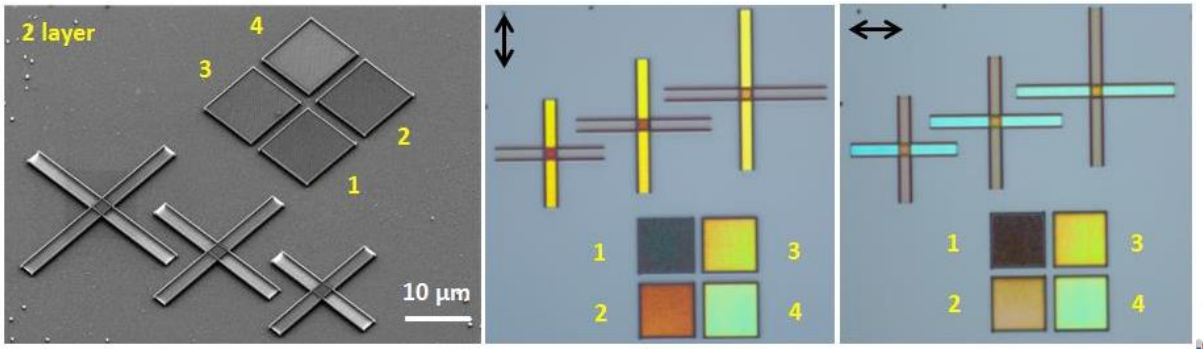
- Patterned with e-beam lithography, polarization dependent structural color generation











Nordic Nanolab Network

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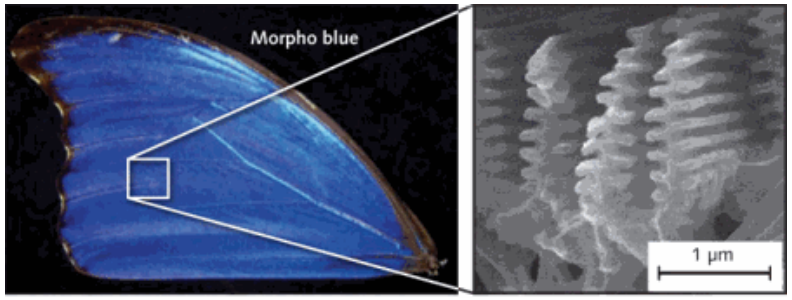
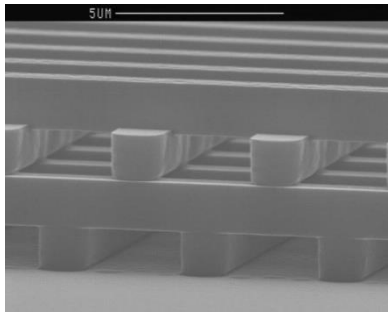
4. Conclusions and perspectives

Large area 3D photonic crystal membranes with embedded planar cavities

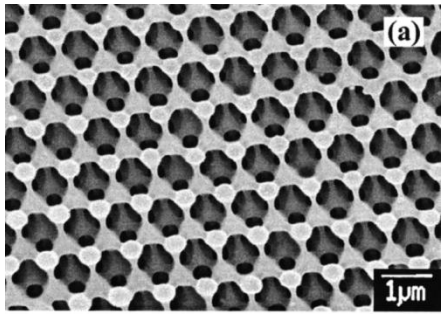


Saito, A., Osaka University

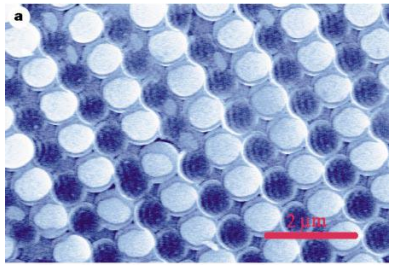
- Complicated process flow using traditional method (woodpile, inverse opal, etc);
- Time comsuming fabrication process (2 photon polymerization, etc);
- Non-conventional fabrication method (multi-angle lithography or etching);
- Difficult for integration;



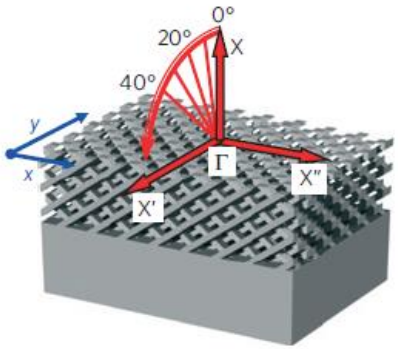
Lin, S.Y., et al. 1998.



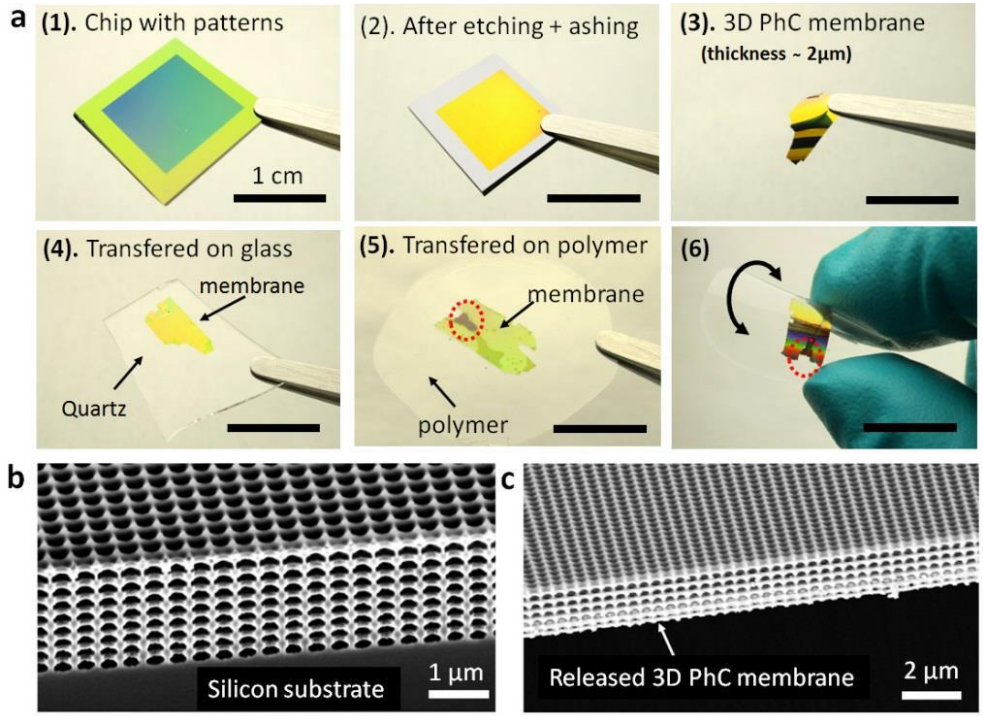
Wang. X., et al. 2000.



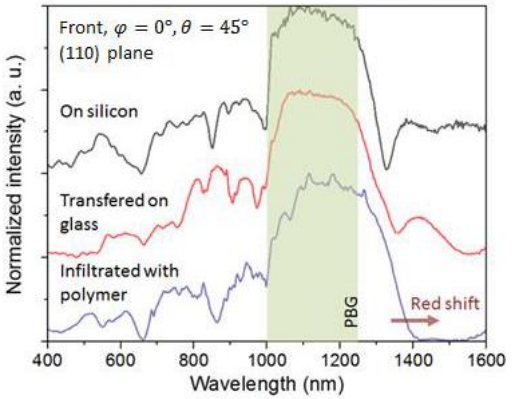
Blanco, A, et al. 2000.

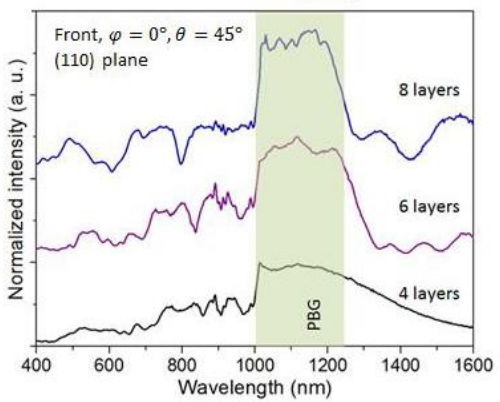


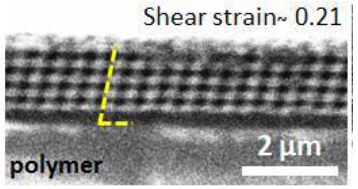
Takahashi, S., et al. 2000.

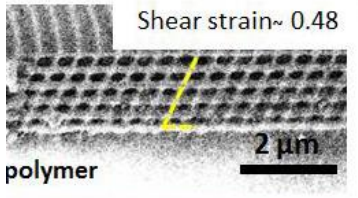


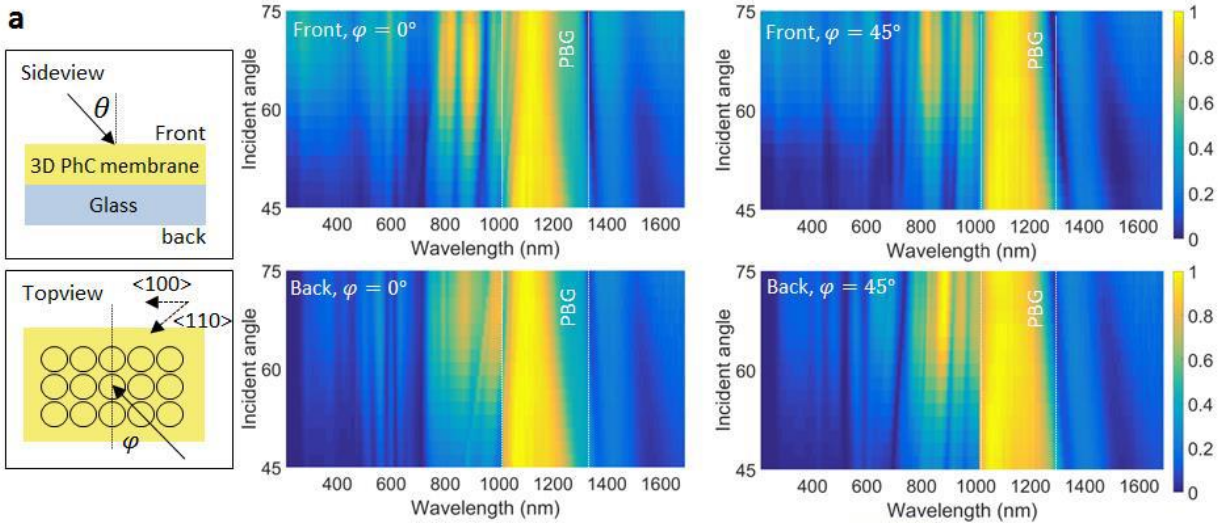
- Complete bandgap;
- Capability to be transferred onto other substrates;
- Feasibility for introducing planar cavities.



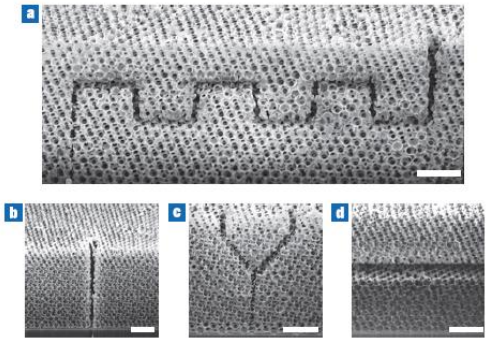




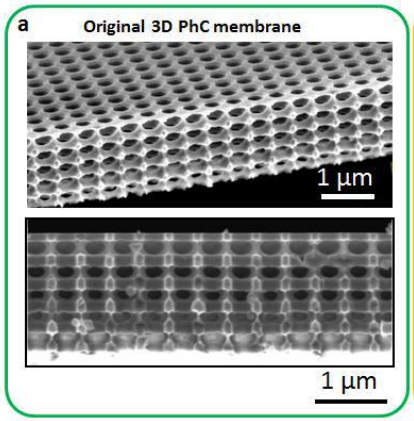


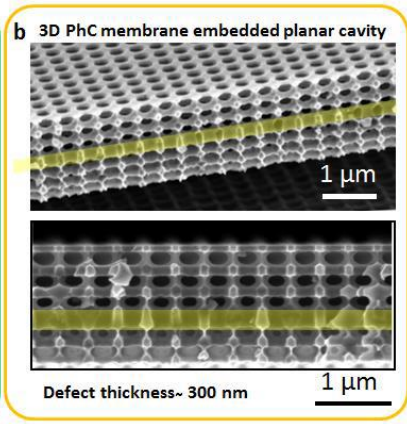


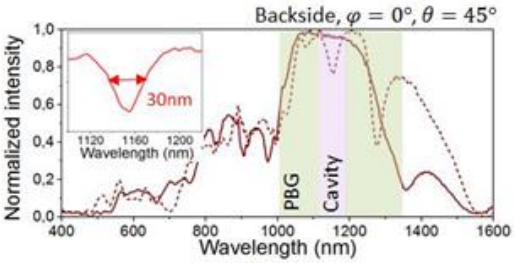
- Applications with embedded planar cavities

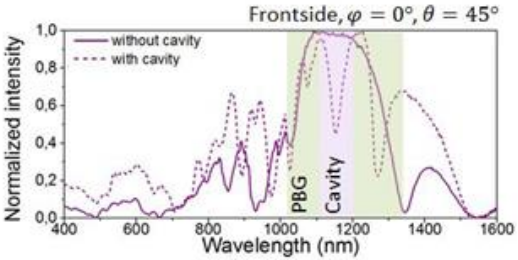


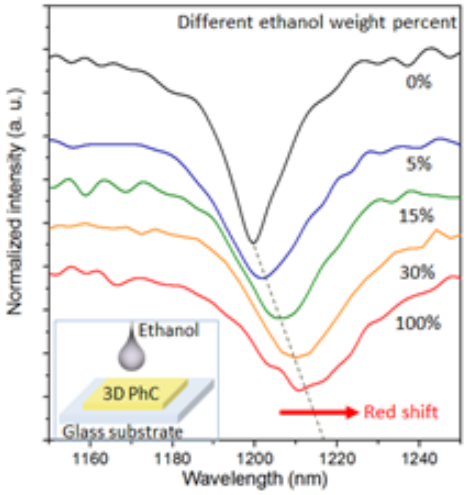
Rinne, S.A., et al. 2008.

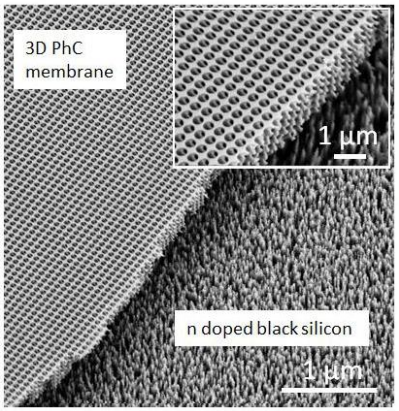












FULL PAPER

ADVANCED OPTICAL MATERIALS

3D Photonic Crystals

www.advopticalmat.de

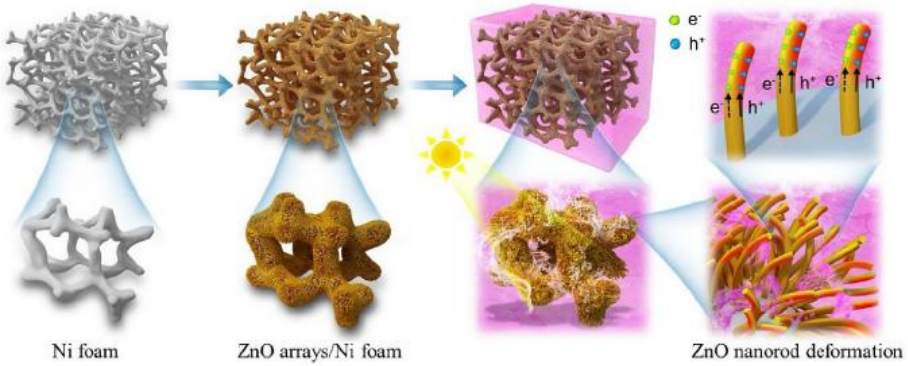
Large Area Three-Dimensional Photonic Crystal Membranes: Single-Run Fabrication and Applications with Embedded Planar Defects

Bingdong Chang, Chen Zhou, Abebe Tilahun Tarekegne, Yuanqing Yang, Ding Zhao, Flemming Jensen, Jörg Hübner, and Henri Jansen*

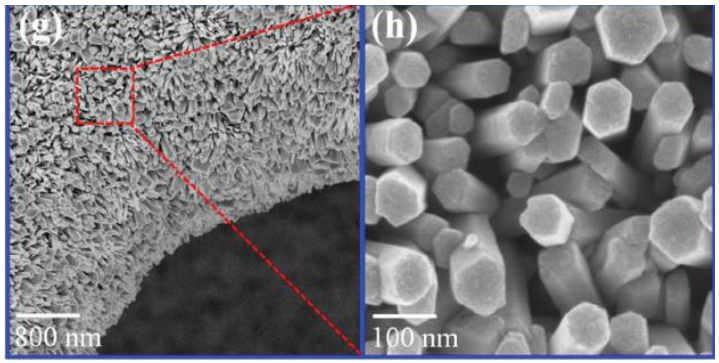
Nordic Nanolab Network

3. Applications of fabricated 3D silicon micro- and nanostructures

Integration of 3D silicon micro-mesh structures with ZnO nanowires for photodegradation and photocurrent generation

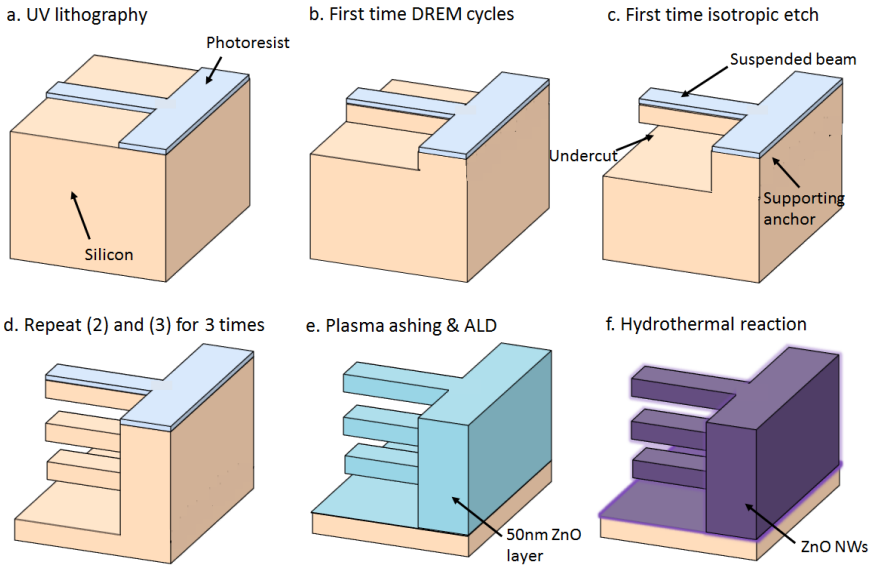


Chen, X., et al. 2017.

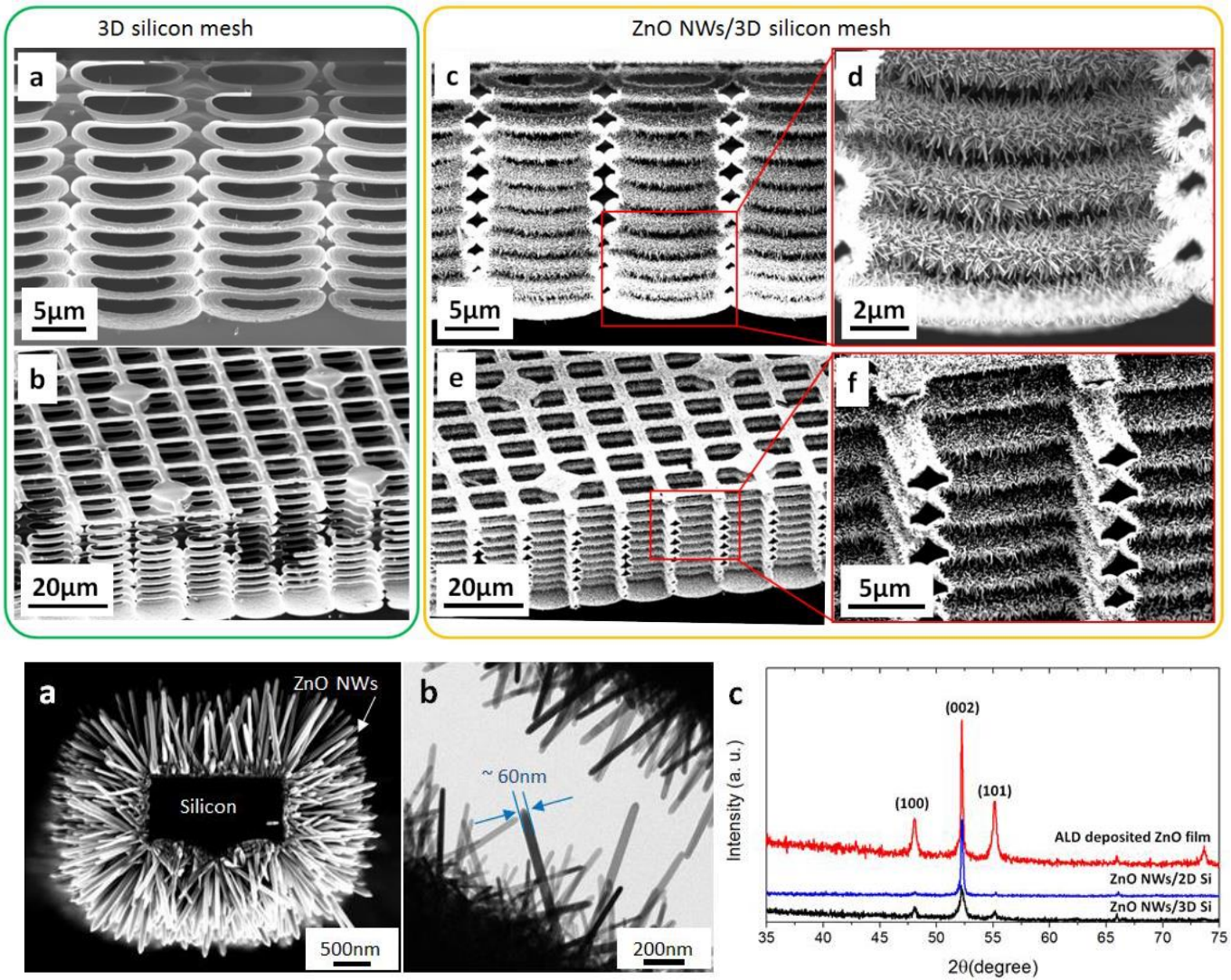


Shao, D., et al. 2015.

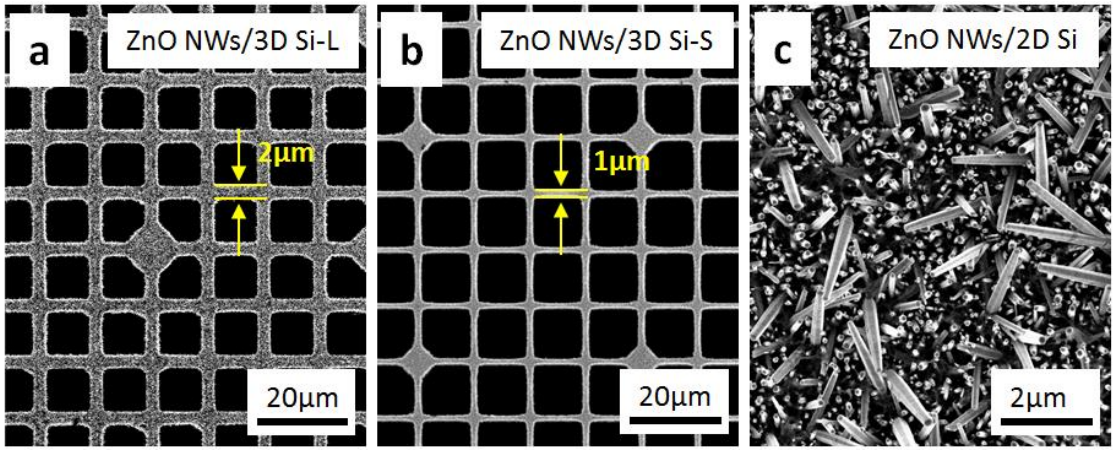
Ko, S. H., et al. 2011.

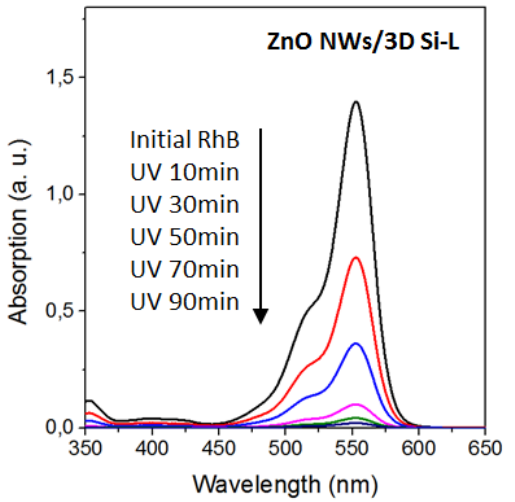


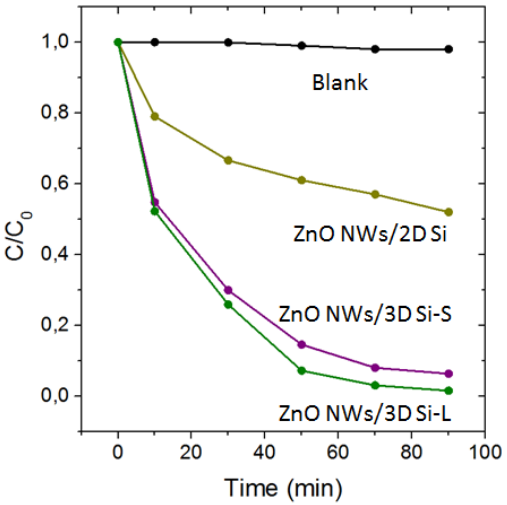
- ZnO nanowires density increased by around 1 magnitude.

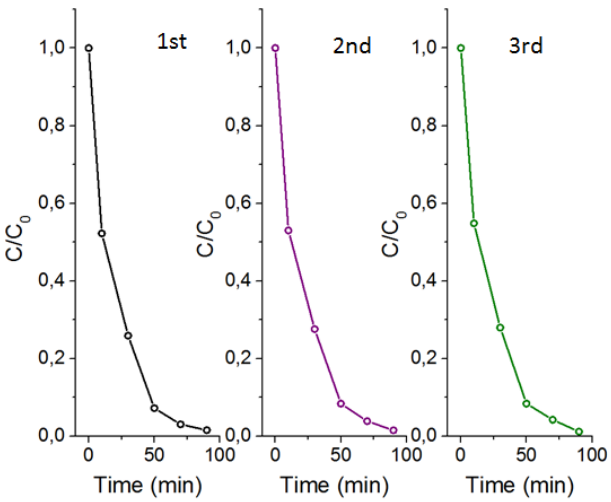


- Improved photodegradation rate of RhB dyes under UV light irradiation

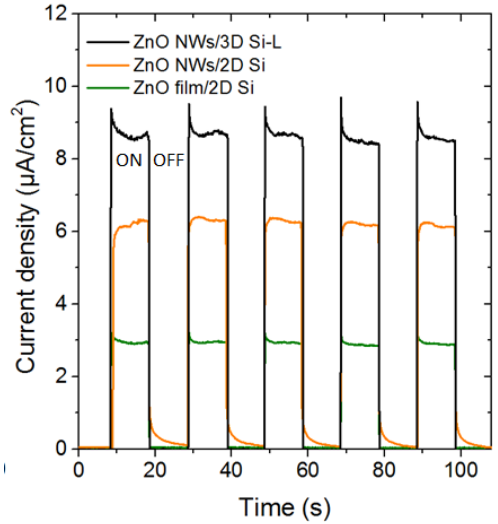


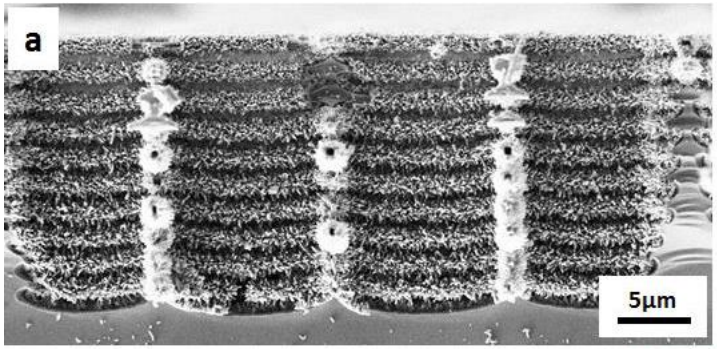


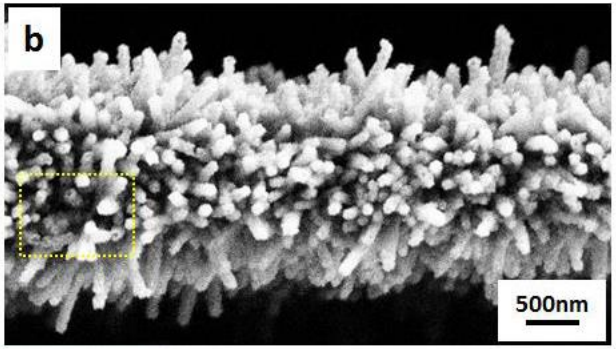


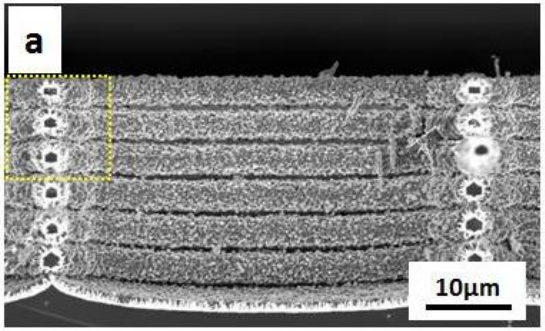


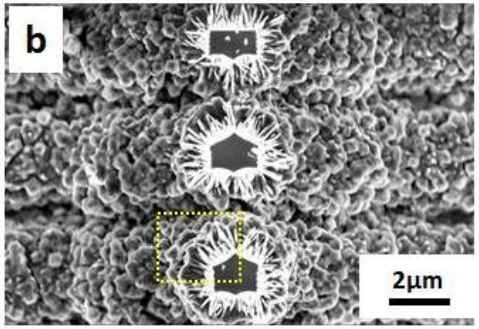
- Improved photocurrent generation;
- conversion of ZnO for other materials (ZnS, ZIF-8).











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CHEMNANOMAT
Full Paper

Photocatalysis

Highly Ordered 3D Silicon Micro-Mesh Structures Integrated with Nanowire Arrays: A Multifunctional Platform for Photodegradation, Photocurrent Generation, and Materials Conversion

Bingdong Chang,*[a] Yingying Tang,[b] Mingli Liang,[b] Henri Jansen,[a] Flemming Jensen,[a] Bo Wang,[c] Kristian Mølhave,[d] Jörg Hübner,[a] and Hongyu Sun*[d]

1. Introduction of the etching tool

   • Etching machine: DRIE-Pegasus (SPTS);
   • Real time monitoring system: OEI/OES, Claritas EPD, Oscilloscope, etc.

2. Introduction of the etching strategy

   • DREM process;
   • 3D DREM process.

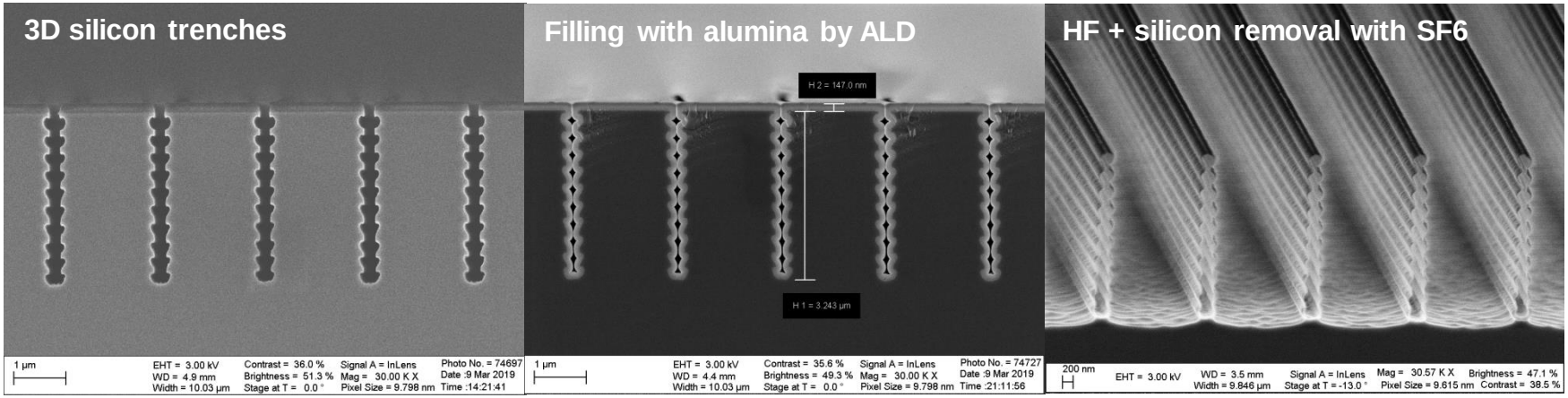
3. Applications of fabricated 3D silicon micro- and nanostructures

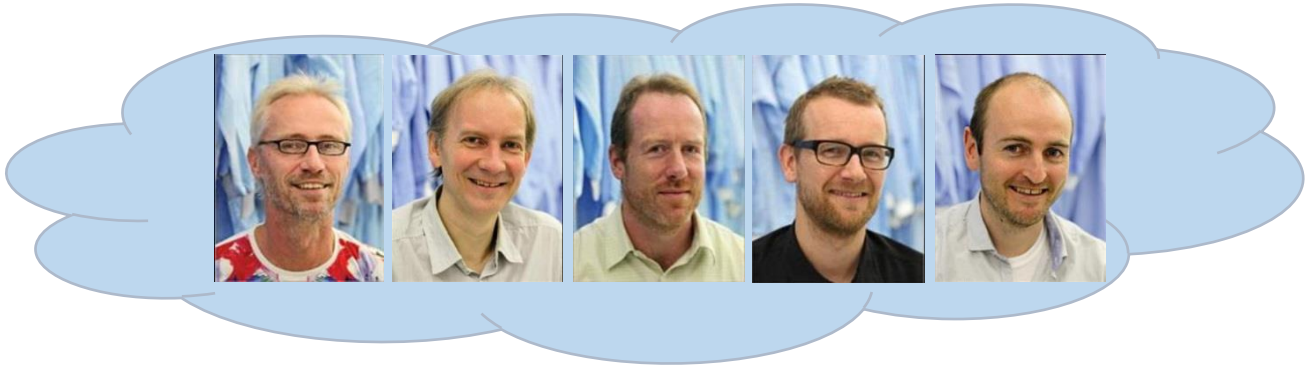
   • 3D photonic crystal membranes;
   • ZnO nanowires/3D silicon micromesh for photocurrent and photocatalysis

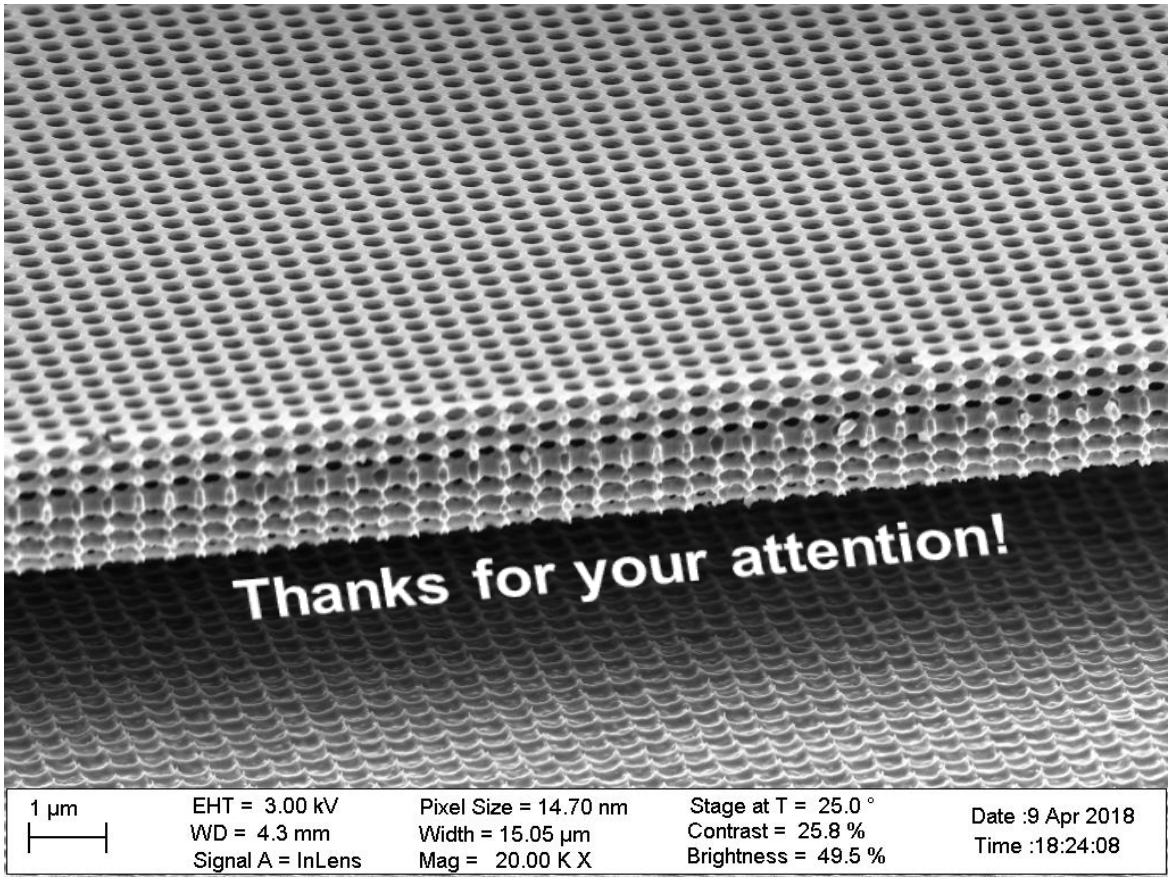
4. Conclusions and perspectives

4. Conclusions and perspective

- Transferring 3D silicon structures into other matierlas;
- Postprocess of 3D structures (e.g. annealing, laser reshaping, etc).



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Date :9 Apr 2018
Time :18:24:08