

Self-Rolled-Up Membrane (S-RUM) tech for 3D hierarchical architectures

Formation, Functionalities, and Integration

Xiuling Li

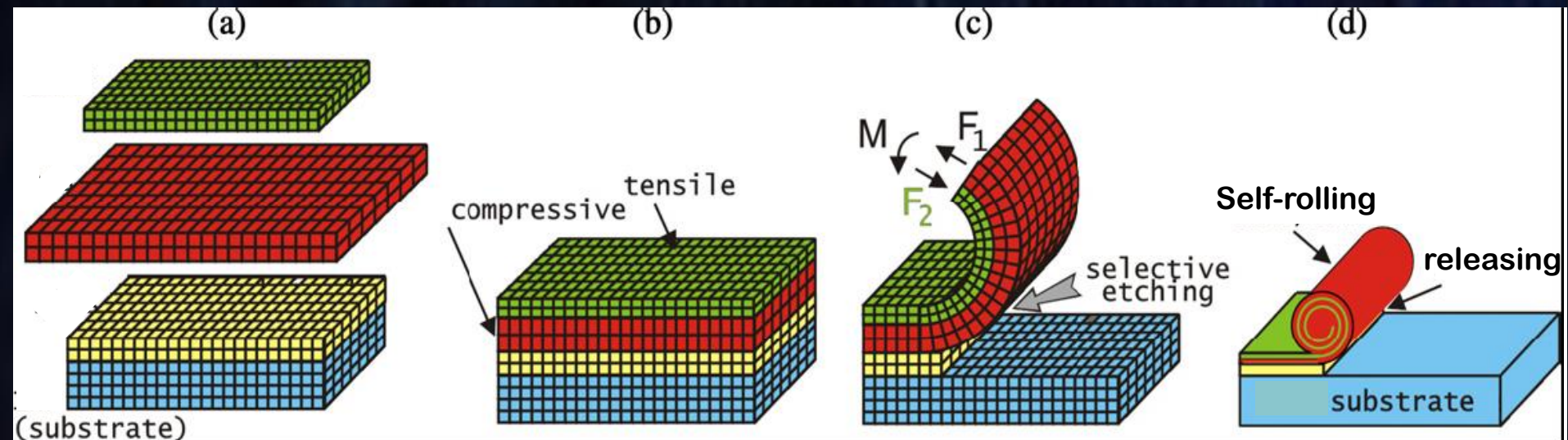
Electrical and Computer Engineering
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Strain-induced self-rolled-up membrane (S-RUM)



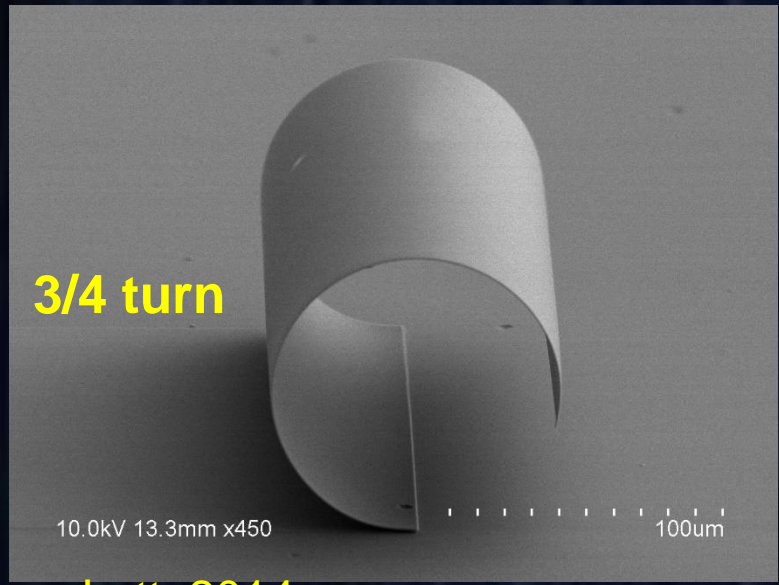
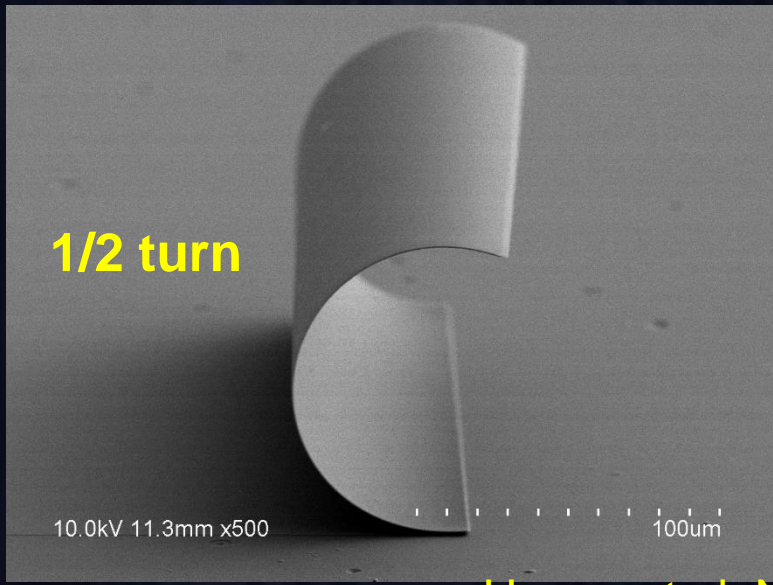
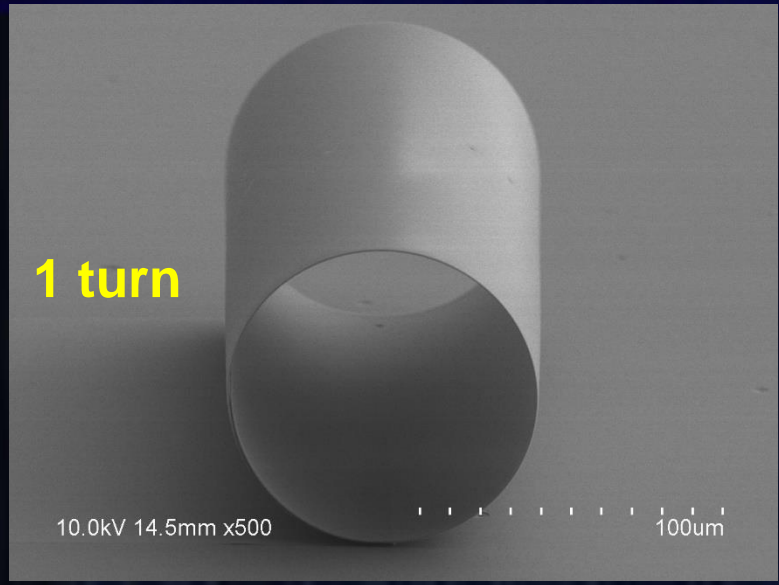
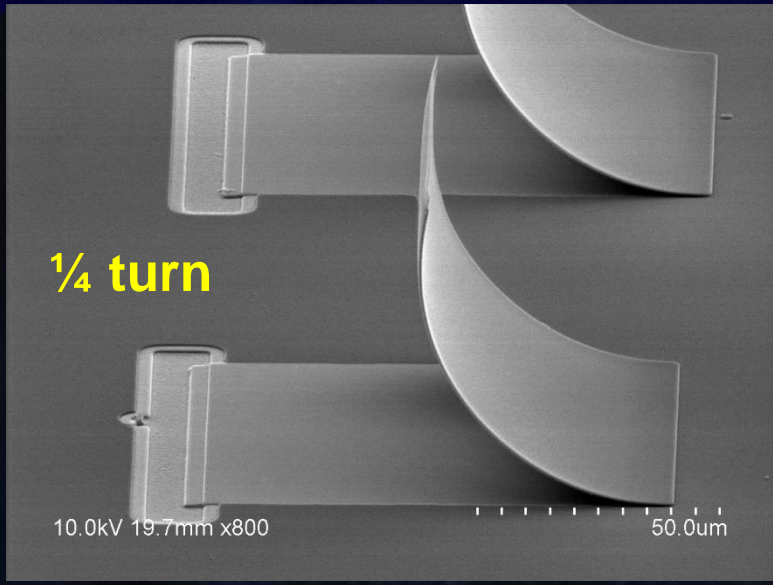
Formation Mechanism:
combination of bottom-up and top-down



- Two essential elements:
 - Strained layer
 - Sacrificial layer
- Diameter control:
 - $D \propto t/\varepsilon$
 - $\sim 2 \text{ nm}$ to $> 100 \mu\text{m}$



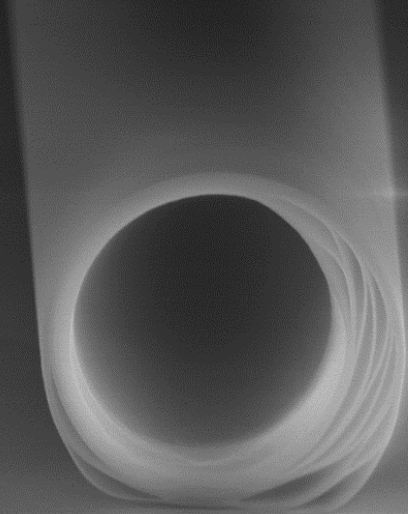
Precise Control of Fractional Rolling





Precise Control of Multiple Rolling

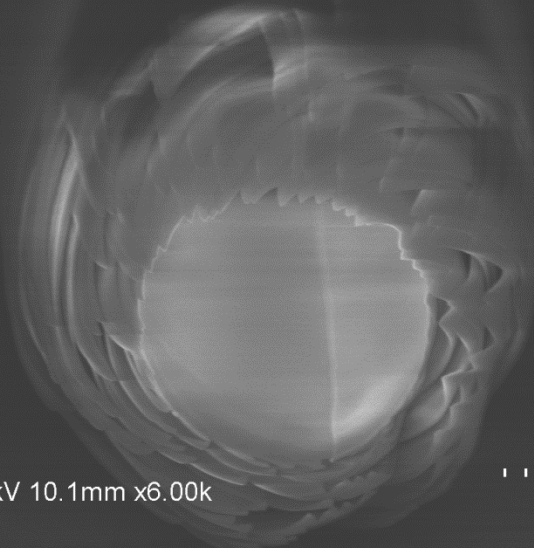
15 turns



15.0kV 8.1mm x6.00k

5.00um

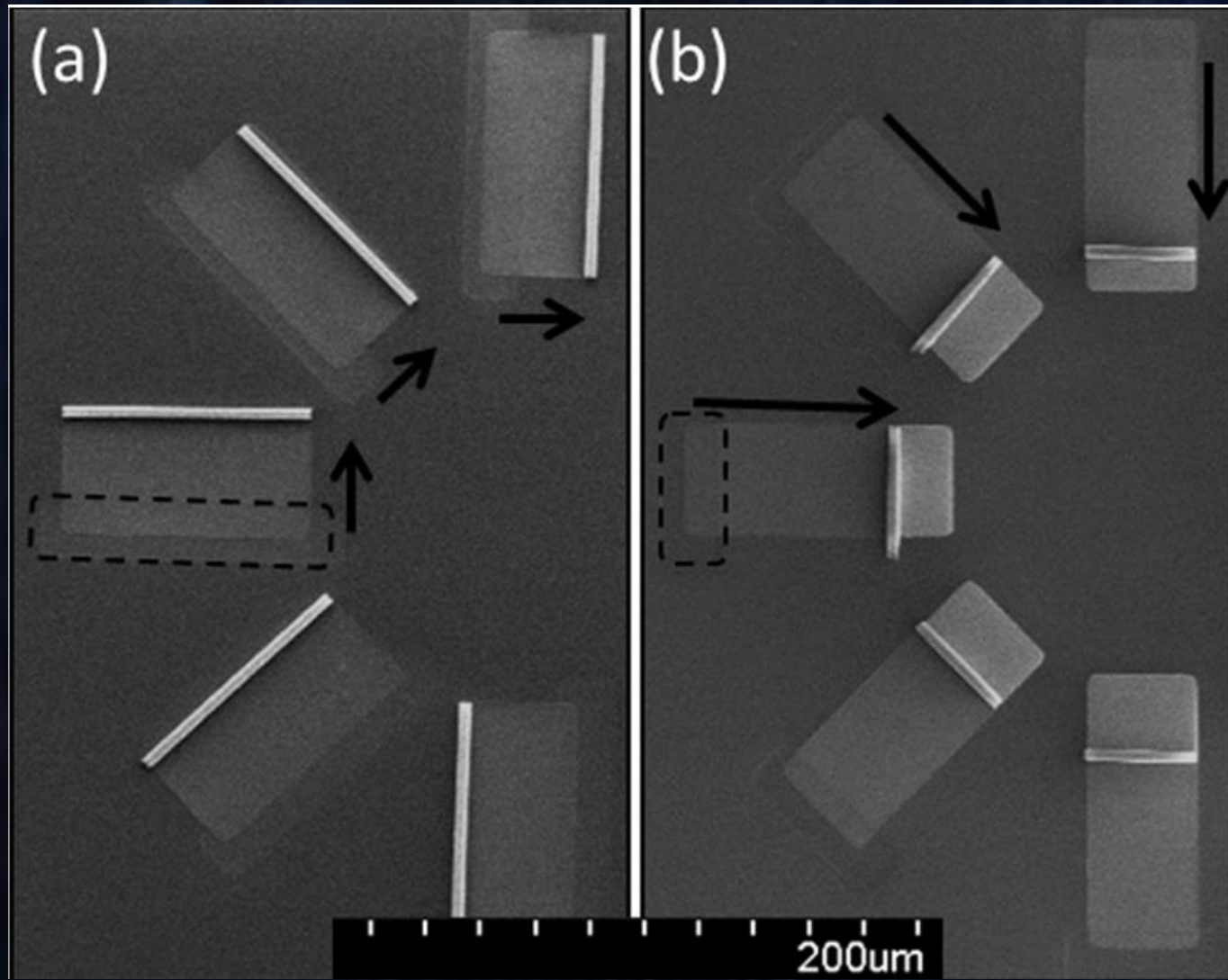
55 turns



10.0kV 10.1mm x6.00k

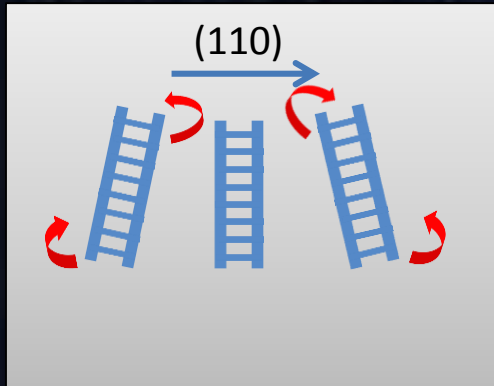
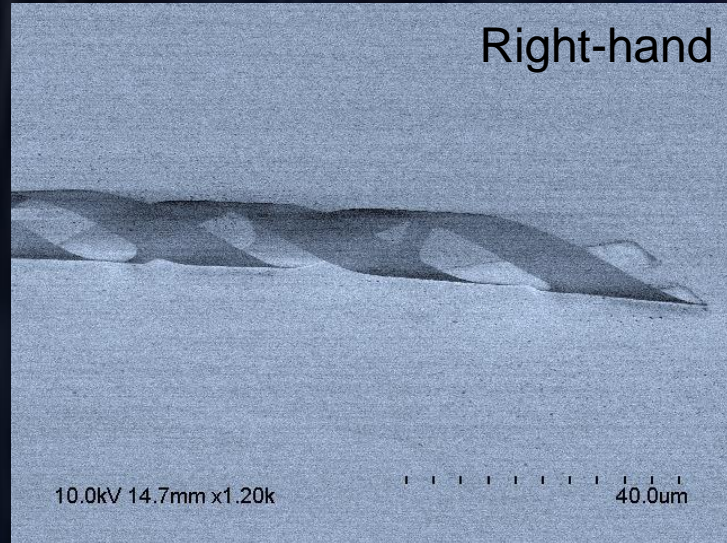
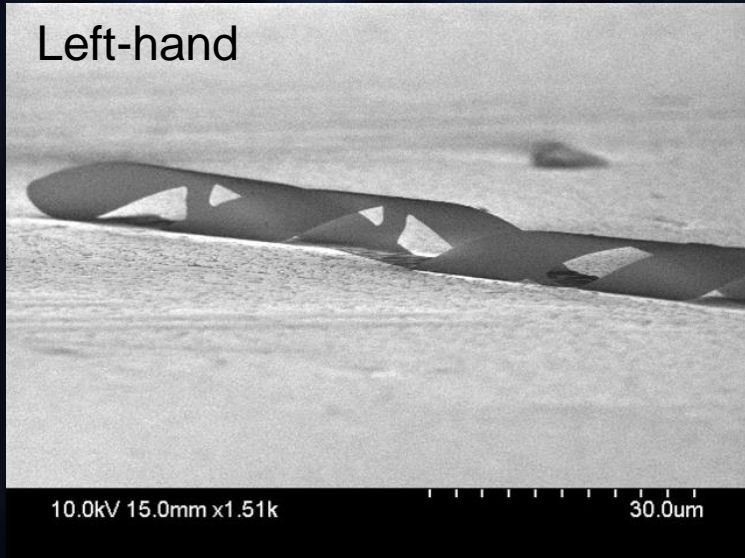
5.00um

360° control of rolling direction (SiN_x)





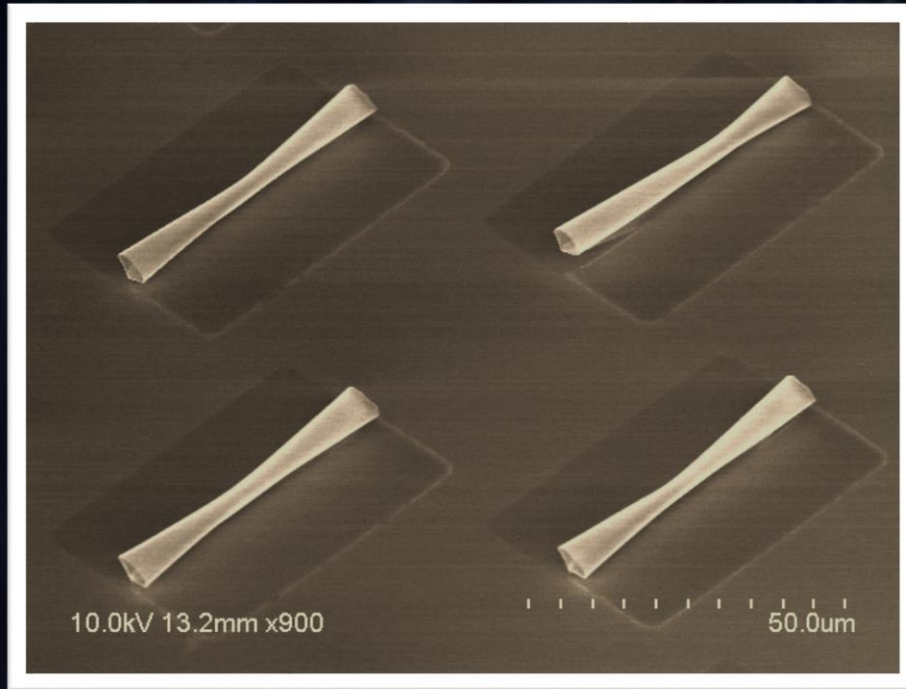
Rolling chirality control



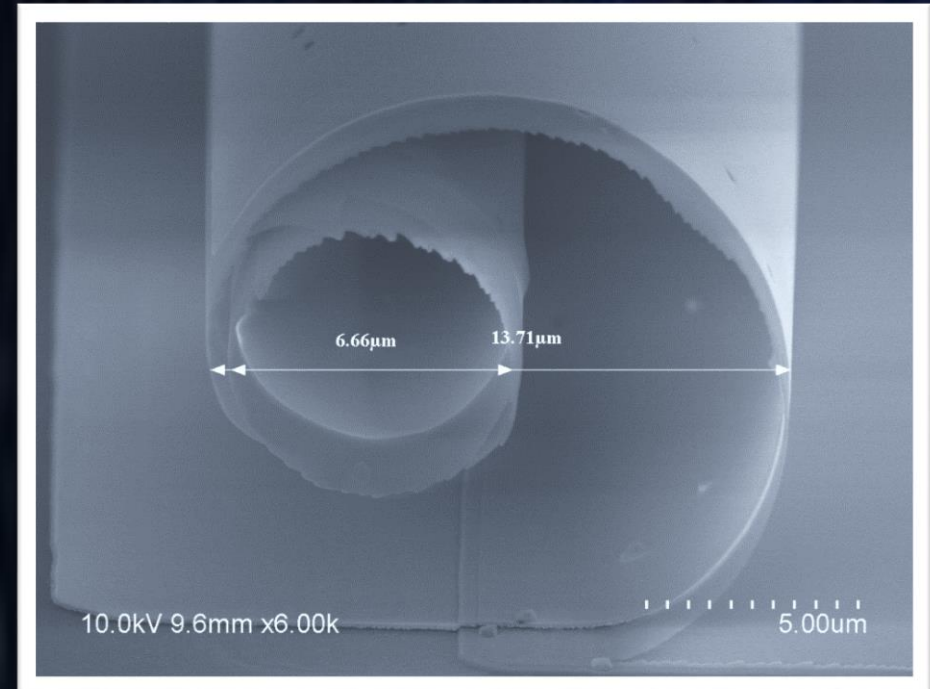


Local stress control

Tapered tubes

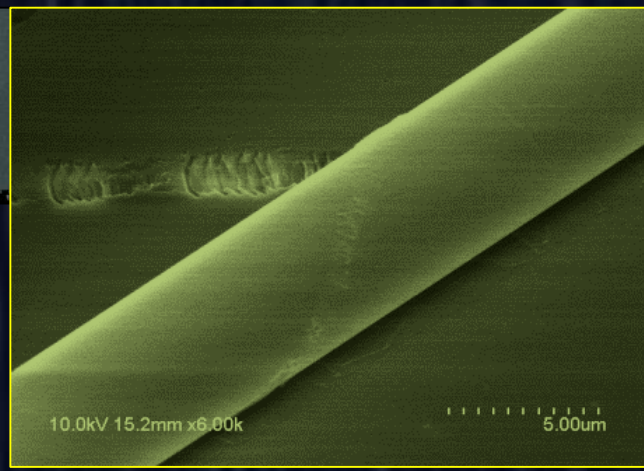
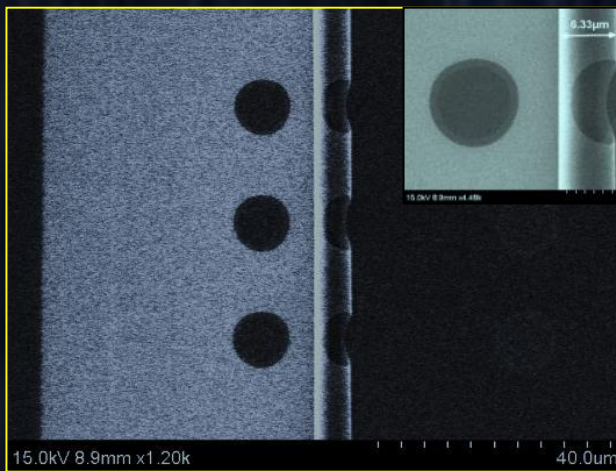
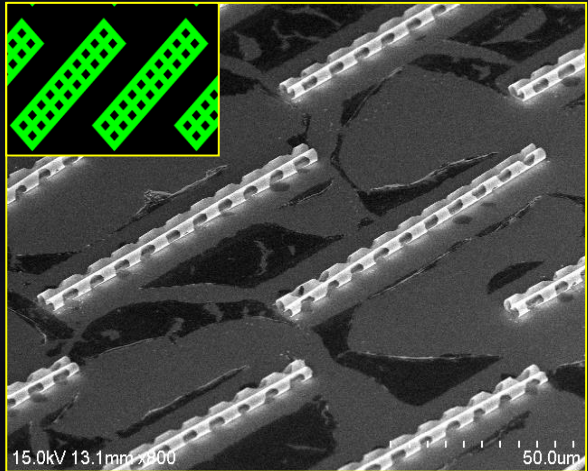
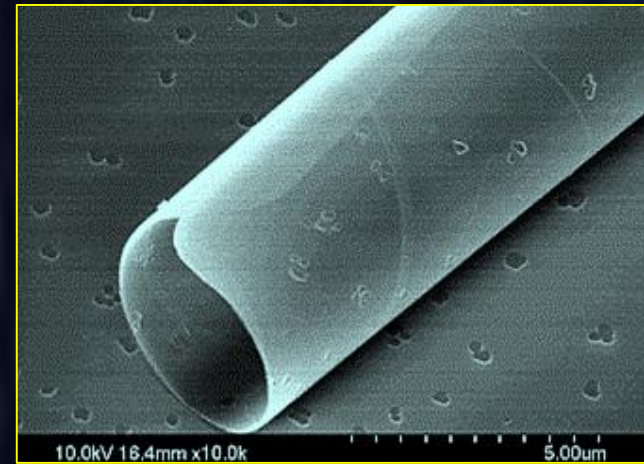
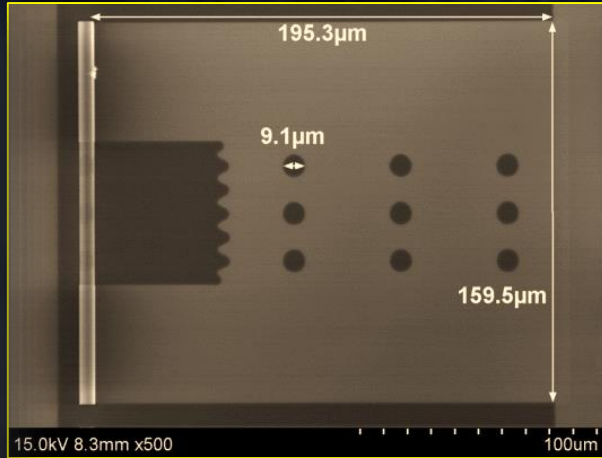
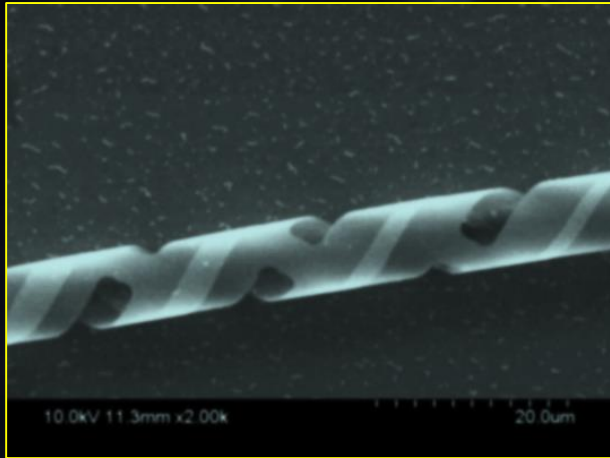


Controlled gap





Rolling patterned membranes

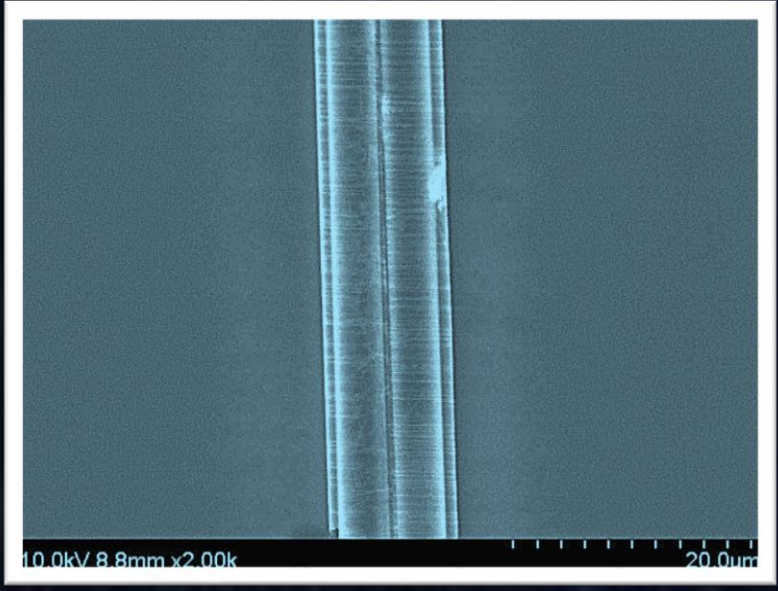
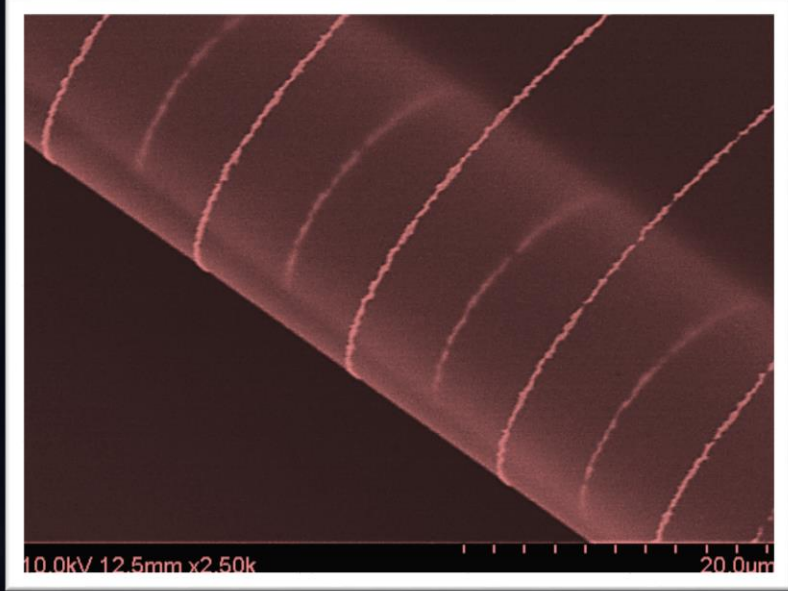
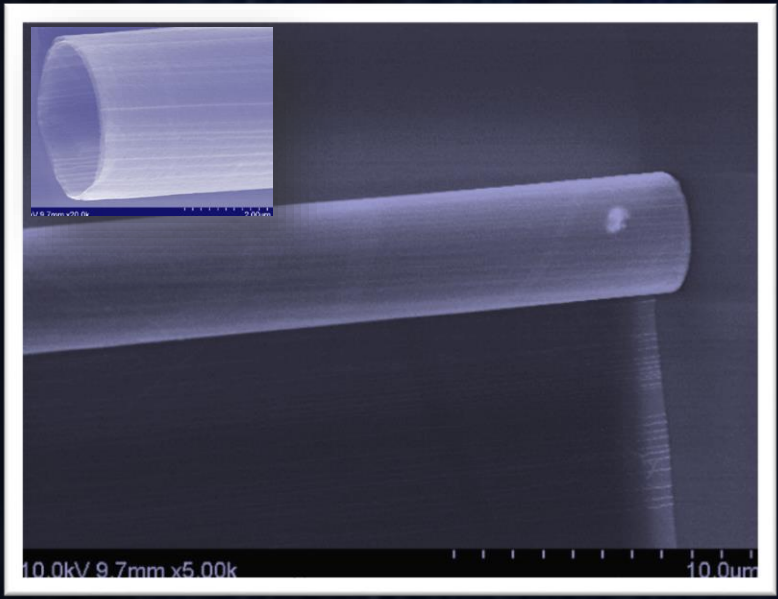
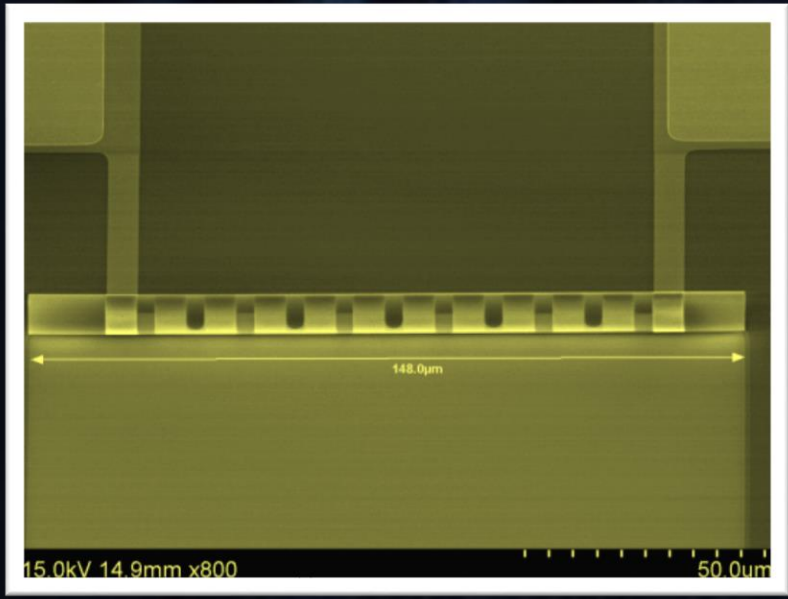


X. Li, Adv. Optics Photonics 3, 366 (2011); and Froeter et al. unpublished.



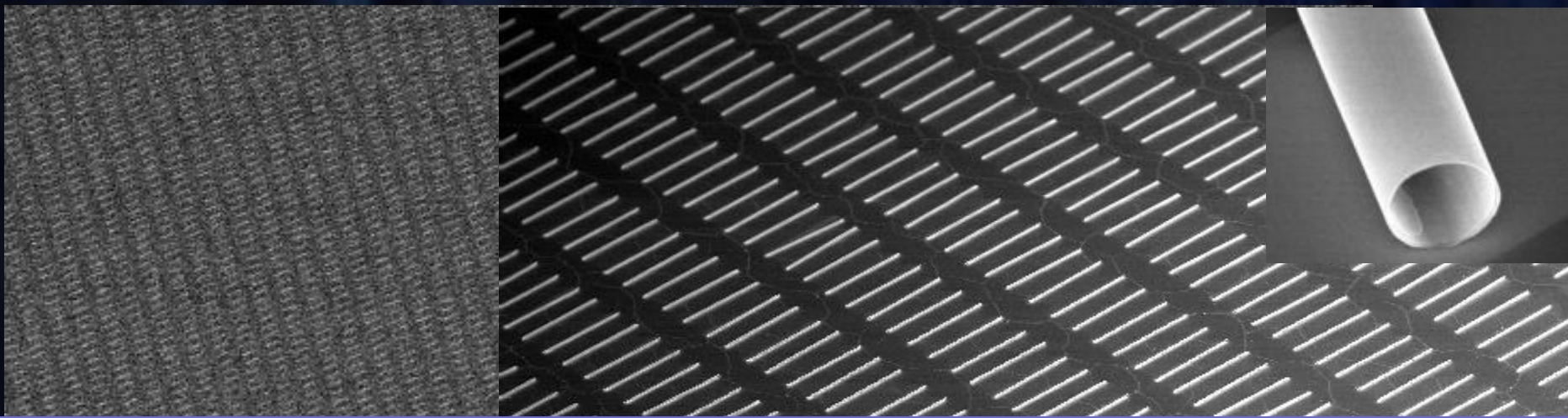
3D Hierarchical Structures

P. Froeter et al, Nanotech, 24, 475301 (2013).



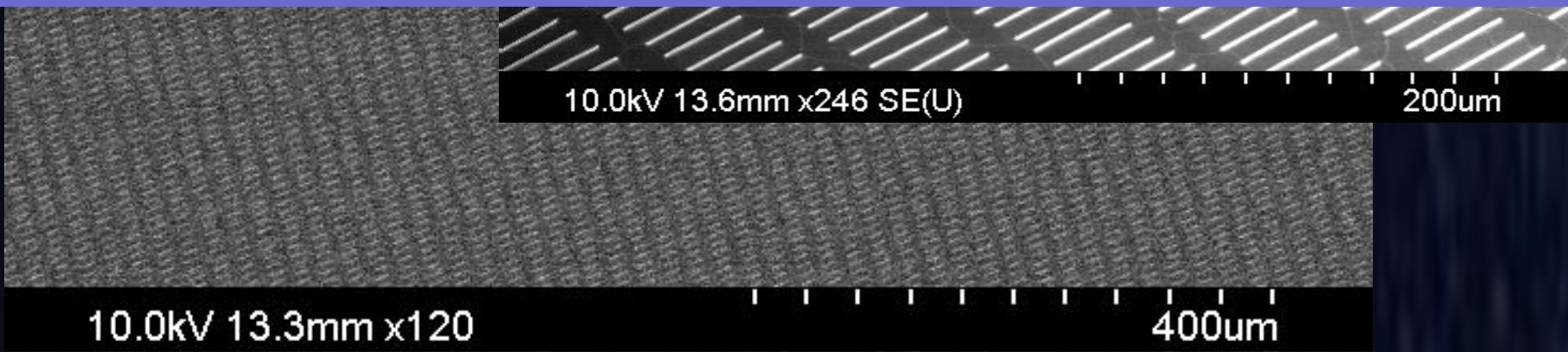


Large area assembly of ordered S-RUM tubes



- Precise placement: postgrowth lithography
- Diameter and bandgap: epitaxial structure

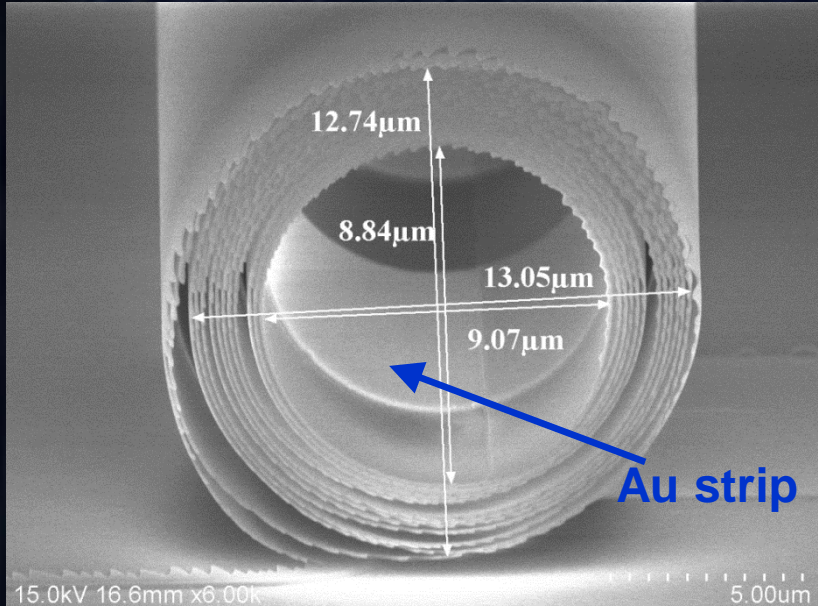
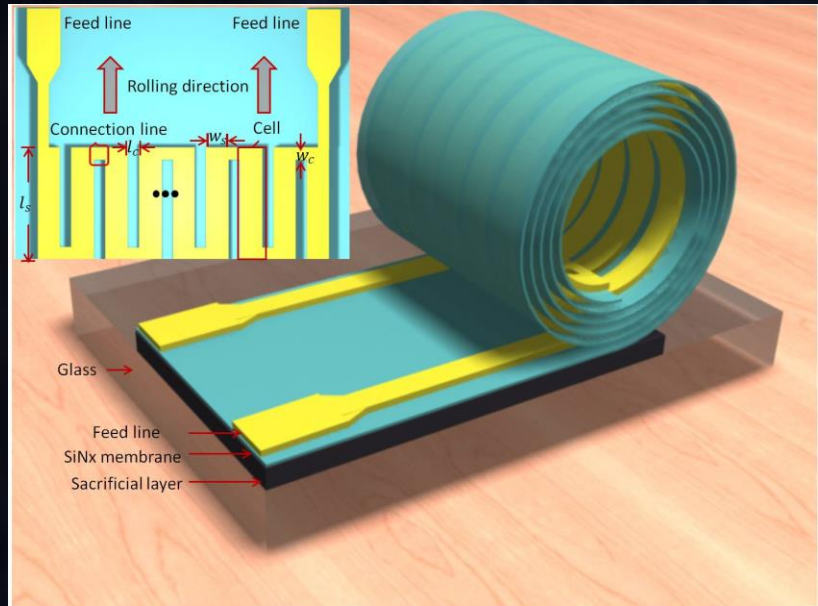
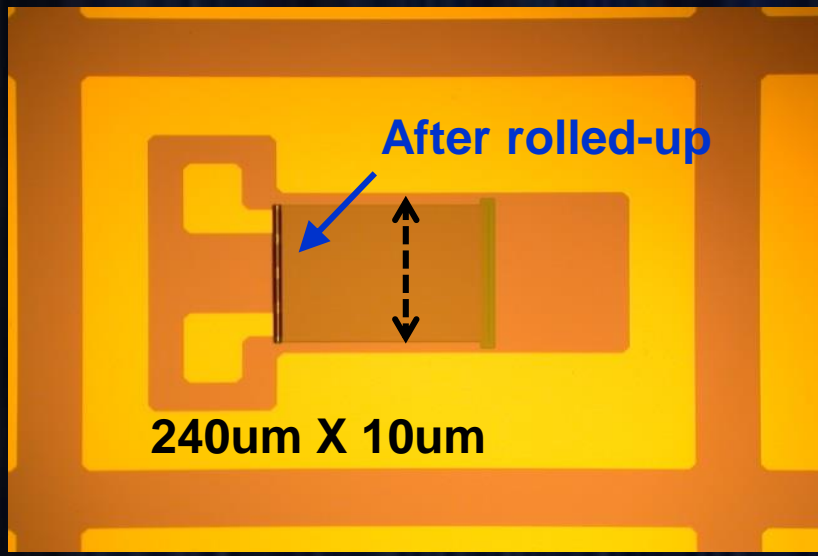
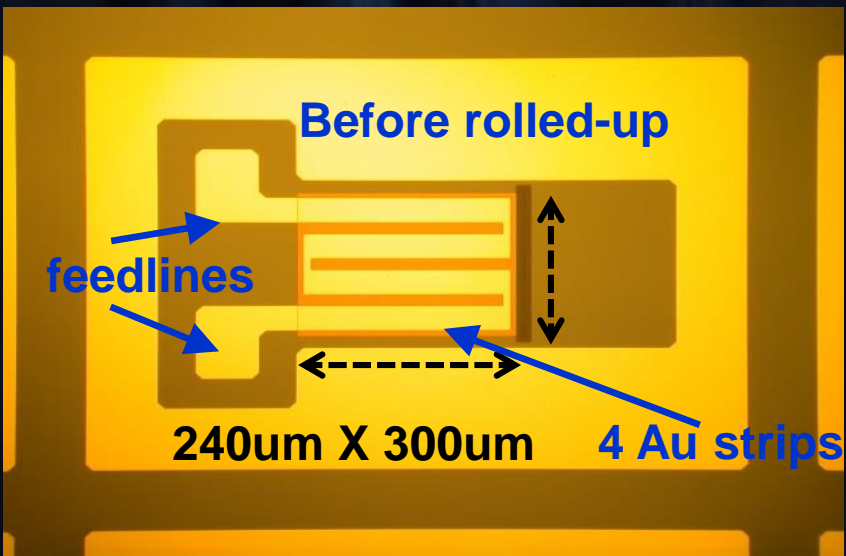
Top-down aspect
Bottom-up aspect





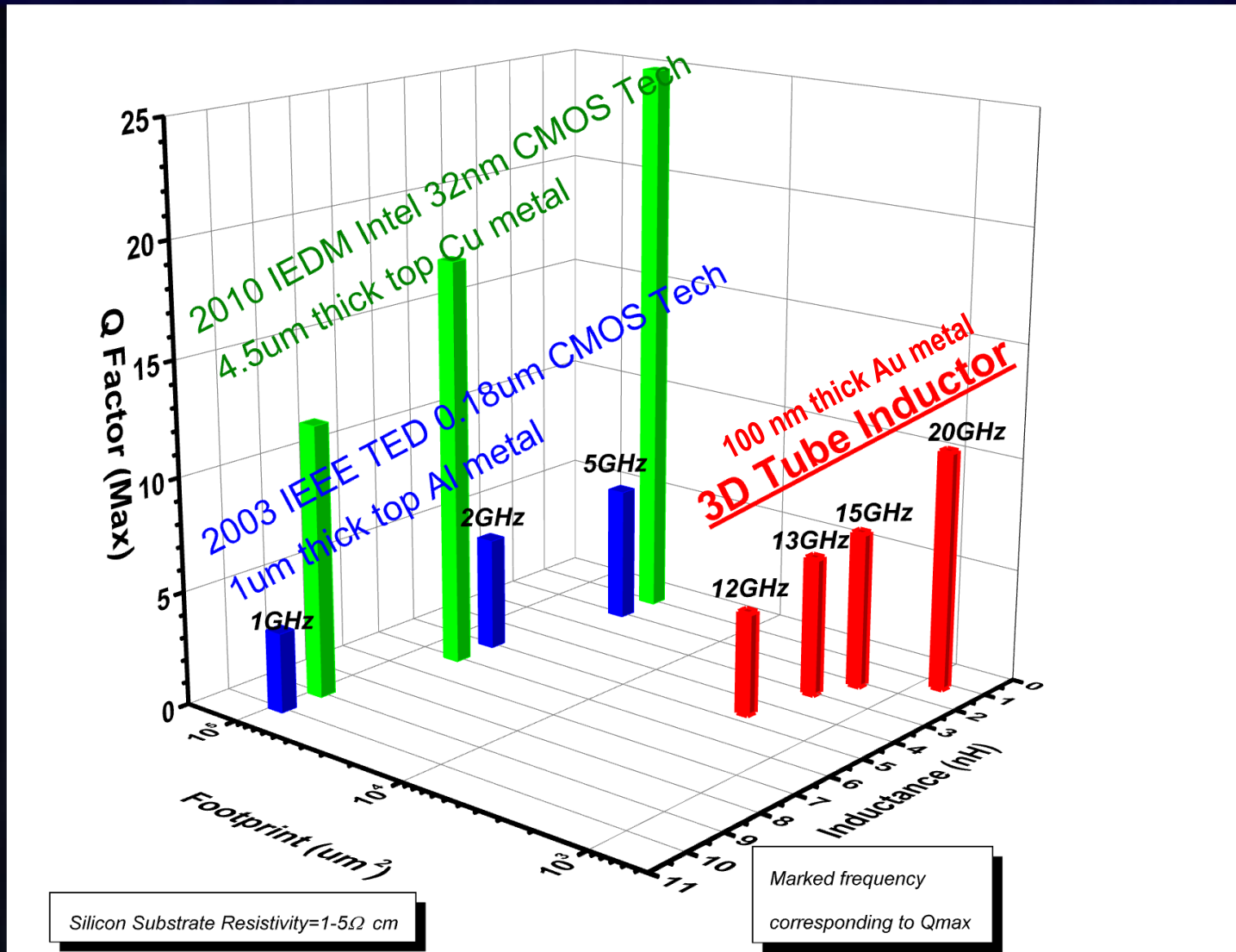
Extreme SWaP: S-RUM Inductors

W. Huang et al. Nano Lett. 2013; X. Yu et al., Scientific Reports, accepted.

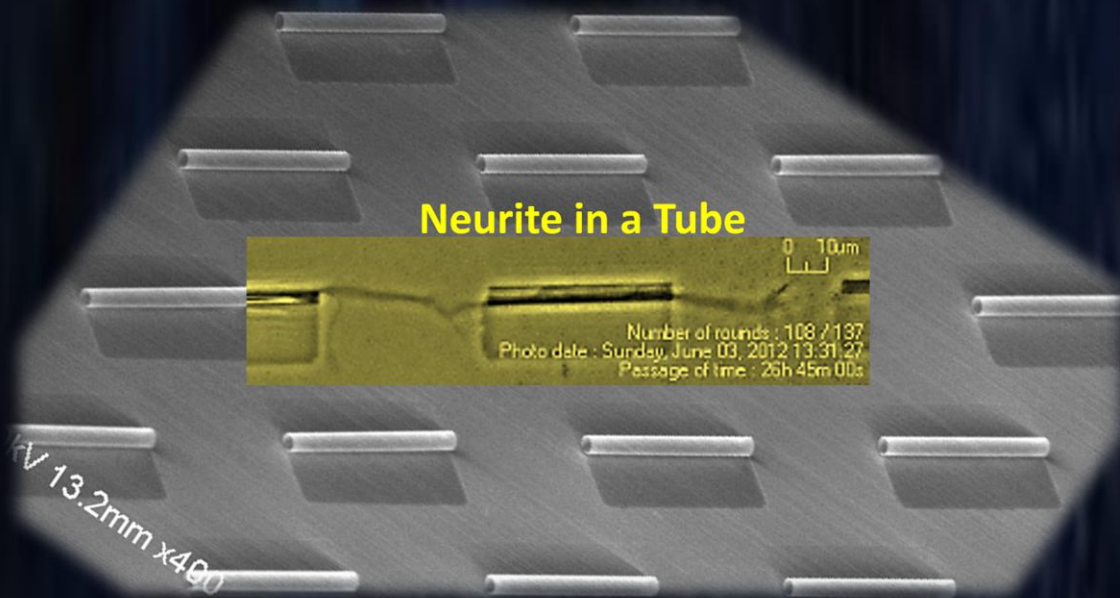




Benchmarking 3D Tubular with Planar Spiral Inductors



Guiding and Accelerating Cortical Neuron Cell Growth



- Neuron cells (axon) actively search for and extend their growth process through the microtubes.
- Record increase (20x) of growth rate inside the microtubes compared to the bare glass slide.



Self-induced Self-Rolling-up Membrane (S-RuM) Technology

Xiuling Li, University of Illinois

Mechanism: strain-induced; Scalability: whole-wafer; Integration: 3D hierarchical

Diameter: ~ 2 nm to > 100 μm

