Development of a nanomaterial anode for a low voltage proportional counter for neutron detection

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Outline

- Company overview
- Objectives
- Modeling
- Design
- Experimental
- Upcoming work

NanoTechLabs

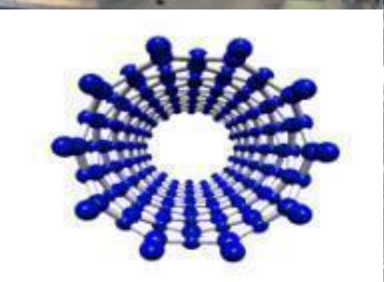
Bigger innovations through smaller materials

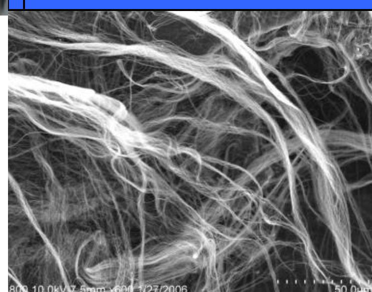
www.nanotechlabs.com

Located in Yadkinville, NC

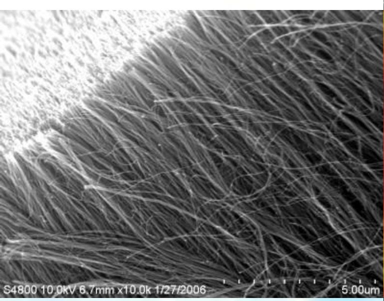
- Small business
- Veteran-owned
- Founded in 2004

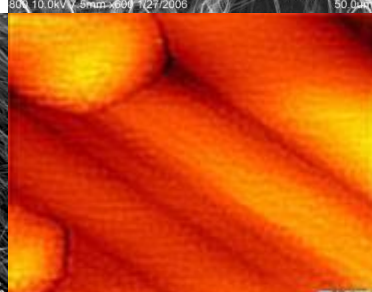
Sealants, Composites, EMI shielding, Thermal Interface Material



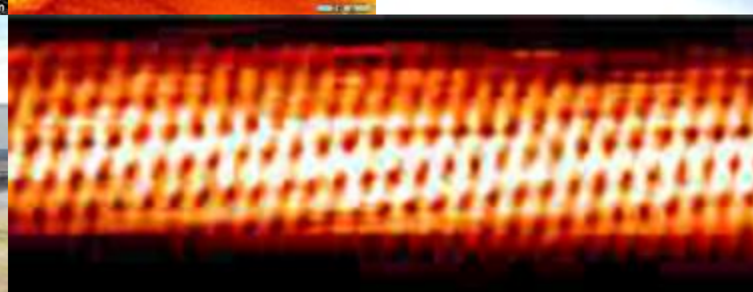


Nanotubes and high aspect ratio materials





Green ionic liquids for phase change, batteries, lubricants



Synthetic specialty chemicals, oil and gas, remediation, water treatment

Program Objectives

- Develop and test a B_{10} coated nanoscale proportional counter as an alternative to current He-3 detectors
- Determine the pitch vs. height parameters to yield the highest efficiency
- Pattern, fabricate, and densify controlled CNT arrays
- Model the proportional volume
- Fabricate and test prototype

Relevance to Nuclear Physics

- Roughly 1300-1500 Radiation Portal Monitors in use in the USA
- He-3 is expensive, and in a shortage
- Current detectors need high operating voltages
- There exists a potential threat that needs more detectors

Advantages

- Nano-Proportional counter utilizes lower voltages
- An opportunity to increase sensitivity
- Decreased size and cost
- Better selectivity

Schedule and Deliverables

Task/Description	Months											
	2	4	6	8	10	12	14	16	18	20	22	24
1. Nanotube Array Growth and Densification												
2. Boron Coating for Neutron Detection												
3. Screening of Densified Arrays												
4. Modeling Detector Configuration												
5. Neutron Detection												
6. Prototype Fabrication and Testing												

Electrostatic Modeling

- Electric field E is governed by:

$$\nabla \cdot (\varepsilon_0 \varepsilon_r E) = \rho$$

- And

$$E = -\nabla V$$

- Electric field at the top of nanopost in the parallel plate configuration

$$E = \left(\frac{h}{r}\right)\frac{V}{d}$$

- ε_r is the relative permittivity of the material, ε_0 is the electric constant, and *V* is the electric potential
- *h* is the nanopost length, *r* is nanopost radius, and *d* is the distance between the parallel plates

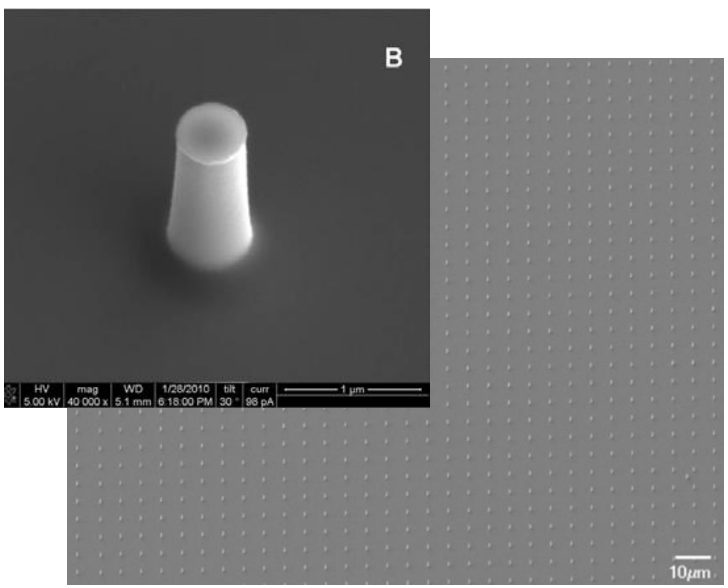
Theoretical performance for neutron detection

- The neutron is converted through the nuclear reaction:
- $^{3}He + n \rightarrow {}^{3}H + {}^{1}H + 764$ KeV
- Thermal neutron's reaction with ^{10}B:
- $^{10}B + n \rightarrow {}^{7}Li + \alpha + \gamma$, 2300 KeV (94%)
- $^{10}B + n \rightarrow {}^{7}Li + \alpha$, 2780 KeV (6%)

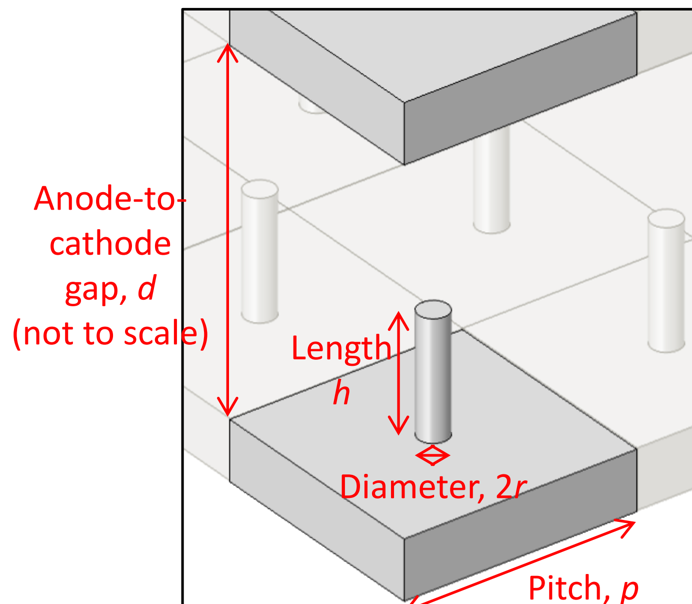
- The thermal neutron (n) is absorbed by the ^{3}He and decays to produce tritium (^{3}H) and protium (^{1}H) with 764 KeV of kinetic energy going into tritium and protium which then are detected by creating a charge cloud in the stopping gas of a proportional counter.
- Excess energy is associated with kinetic energy of the recoil nucleus (^{7}Li), gamma ray (γ) and alpha particle (α)

Model setup

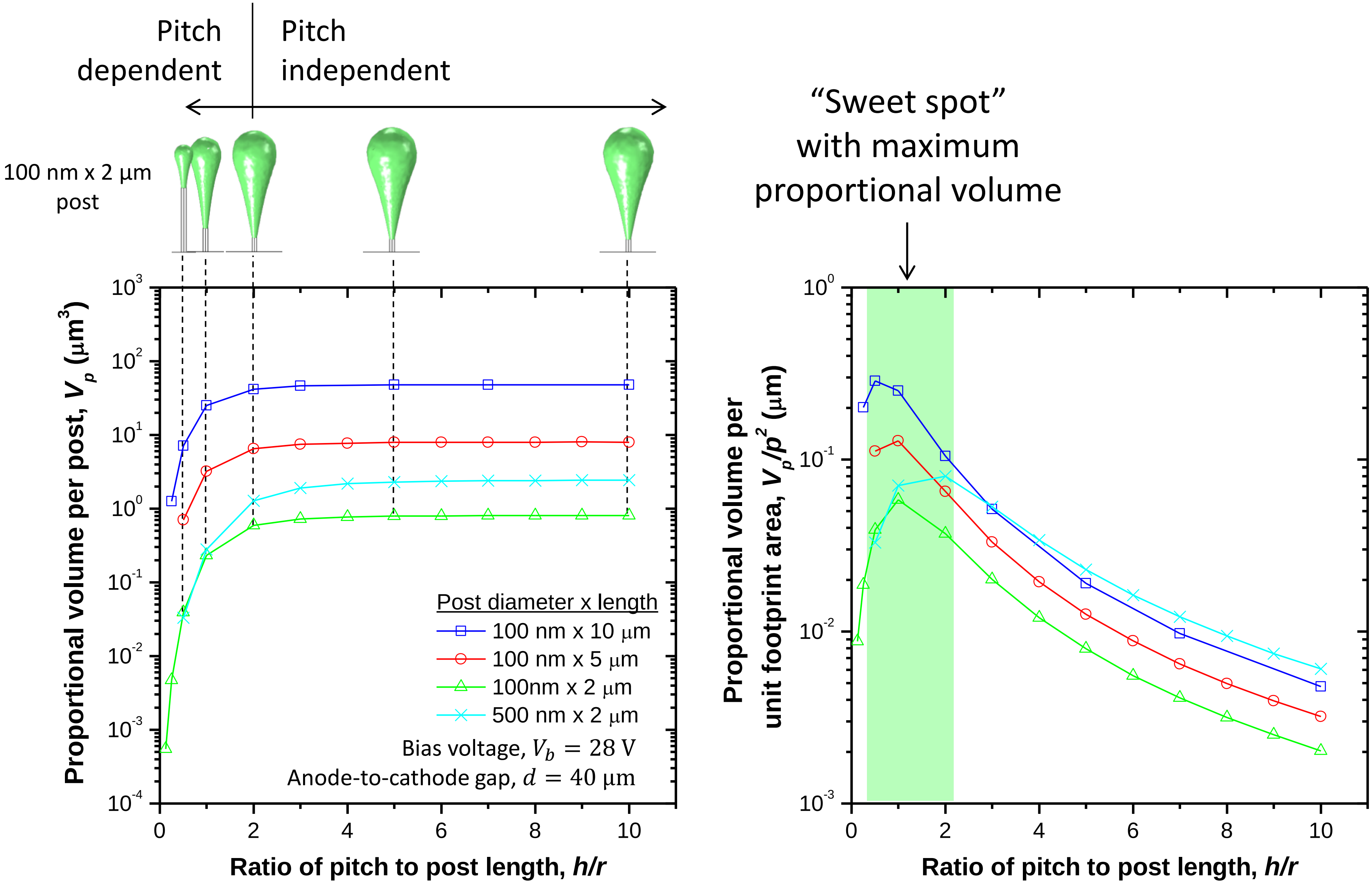
- Experimental array
  - Silicon posts are approximately cylindrical
  - Large arrays of posts in square grid pattern with controlled pitch



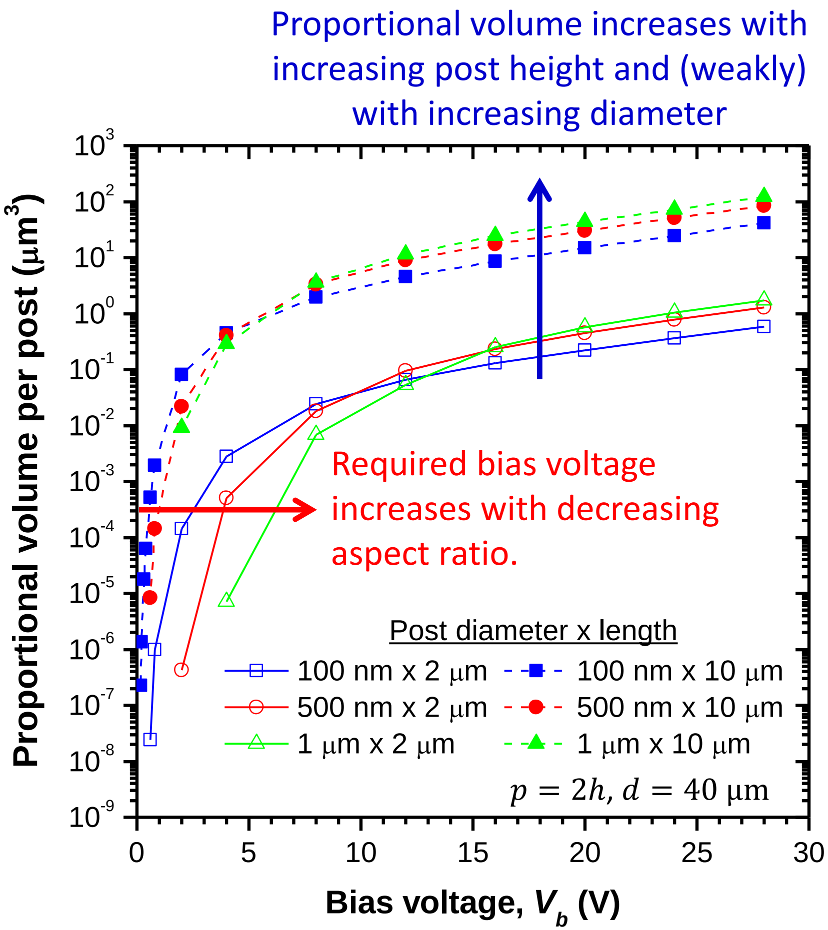
- Simulated array
  - Cylindrical posts
  - Single post with symmetry conditions represents infinitely large array

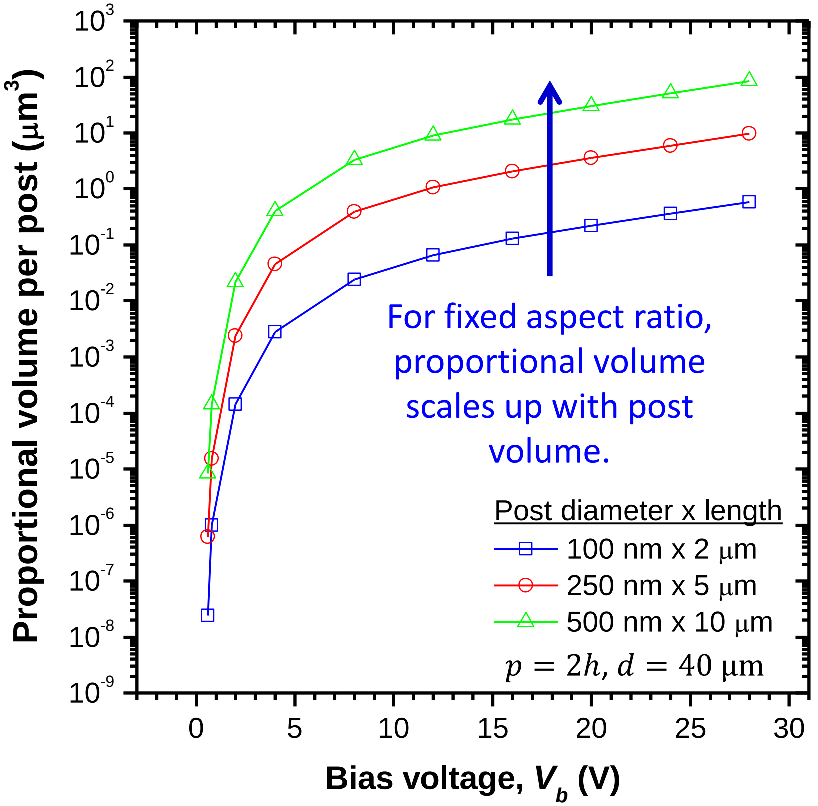


Effect of Pitch



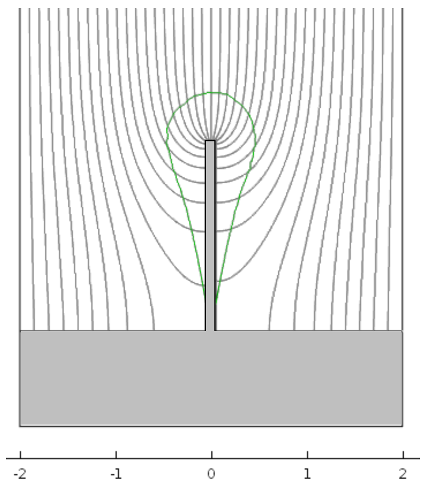
Effect of Post Dimensions





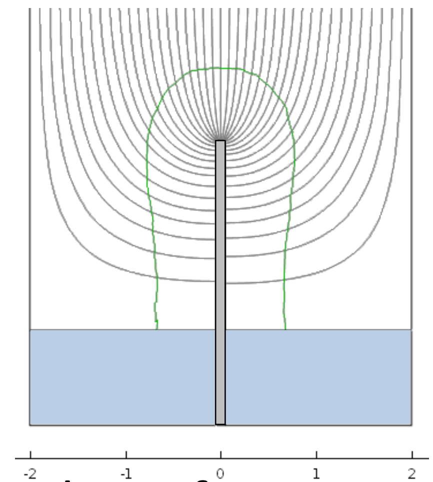
Alternative Anode Design

- Conductive post and substrate as single unit



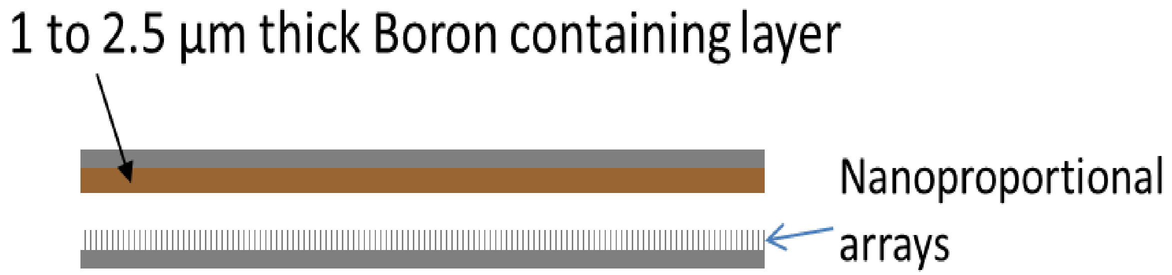
  - Teardrop-shaped proportional volume
  - Many field lines/electron paths bypass proportional volume

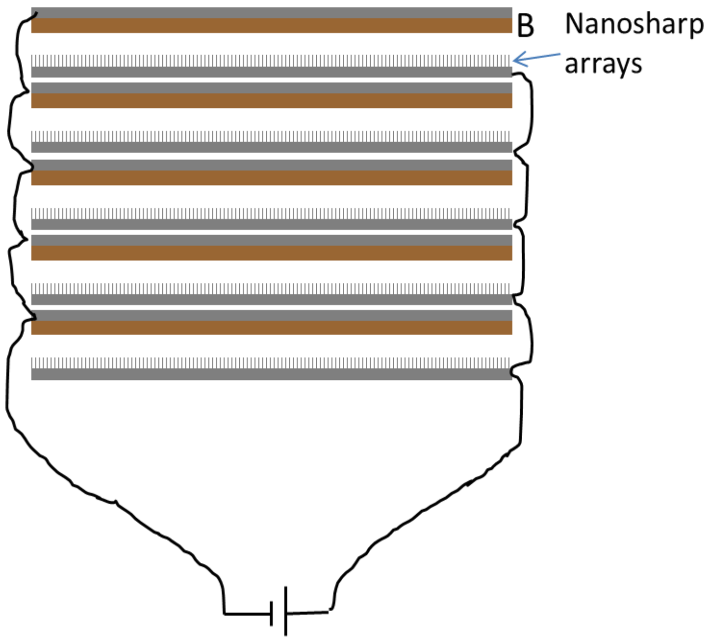
- Anode wires through insulating substrate

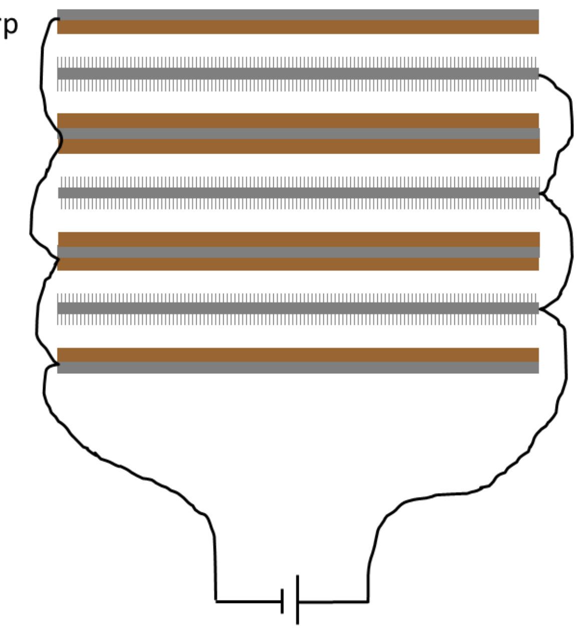


  - Fairly uniform proportional volume thickness over post
  - All field lines lead through proportional volume
  - Better detection?

Parallel Plate Design



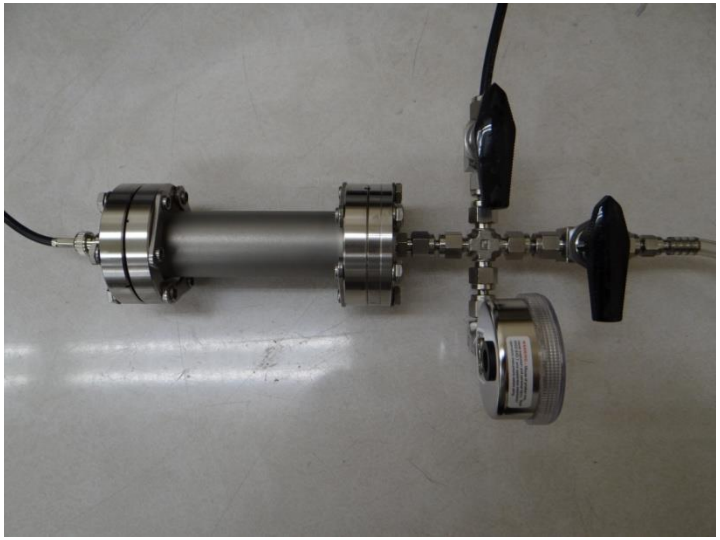


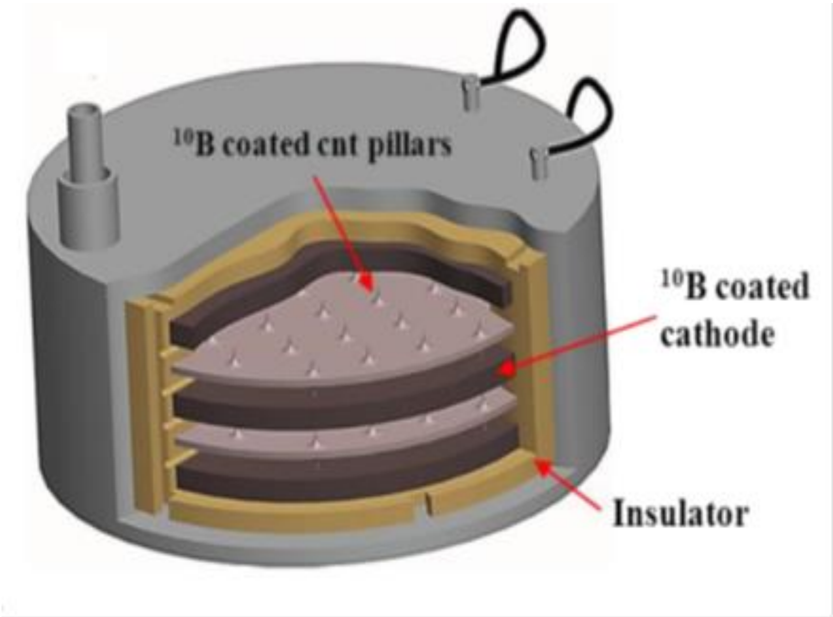


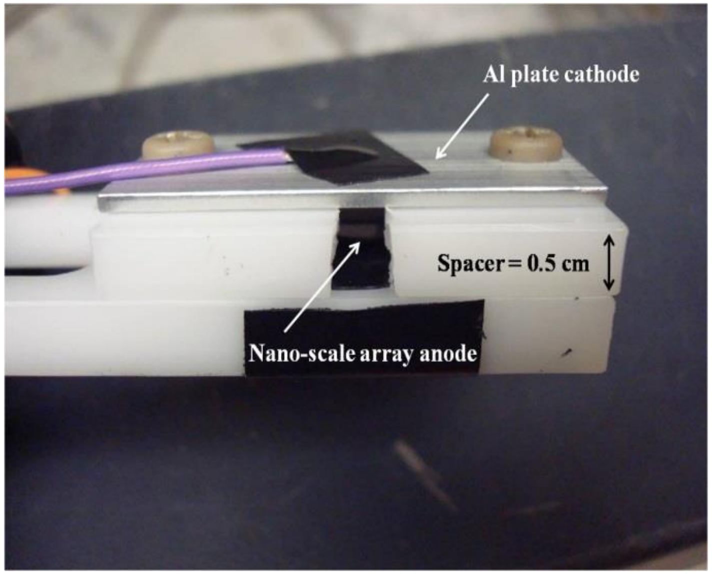
An example of 5 2mm thick Nanoproportional counters stacked. Need nonconducting spacer

An example of 6 Nanoproportional counters stacked in an alternating pattern. No need for spacer, can share electrodes, and get additional B layer and gas fill volume in total volume.

Device Design

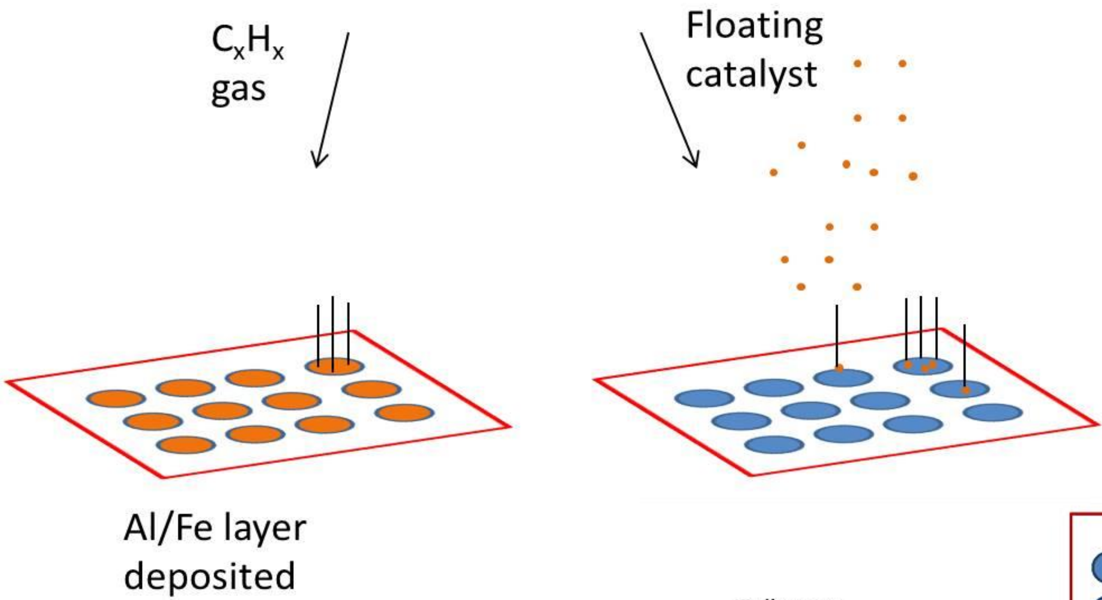


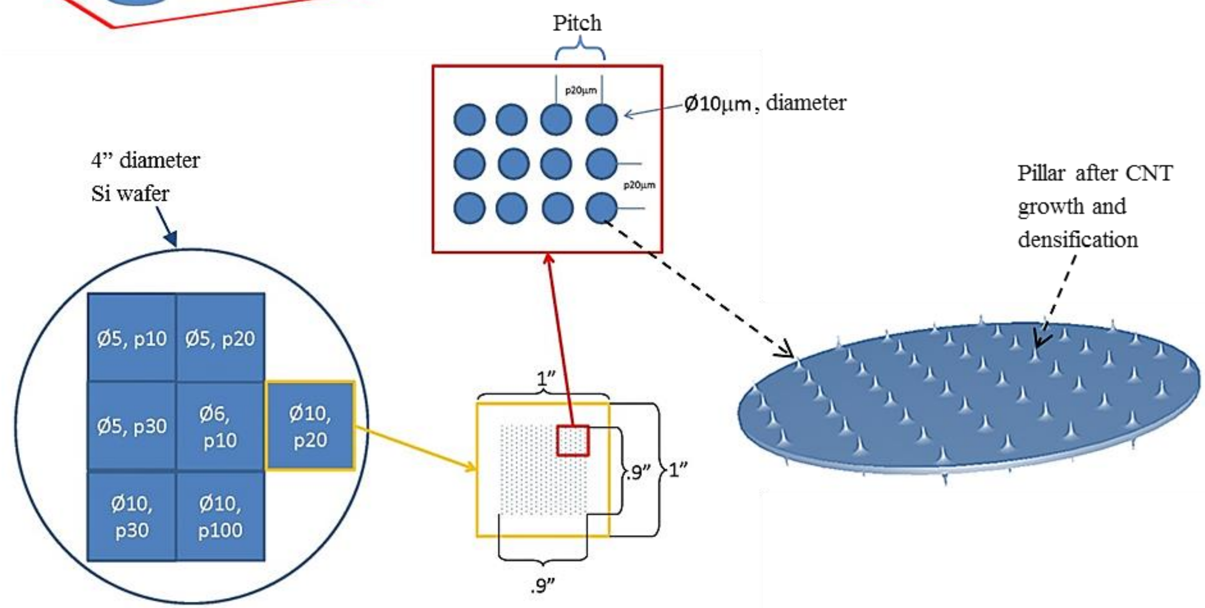




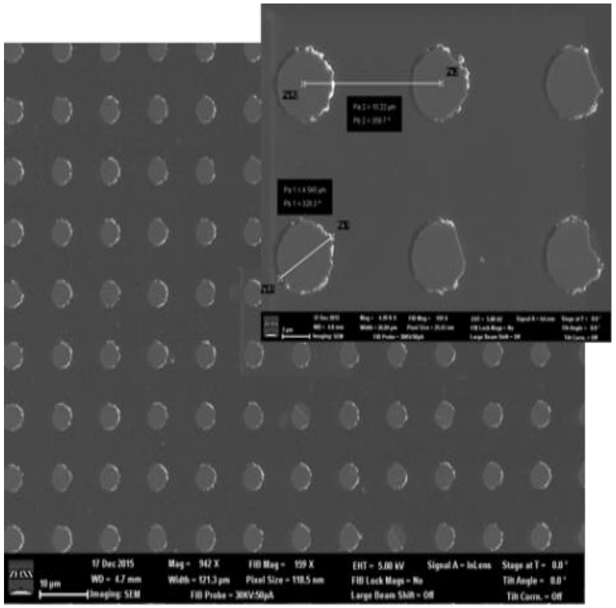
- Current nano-PC packaging
- Prototype of parallel plate detector

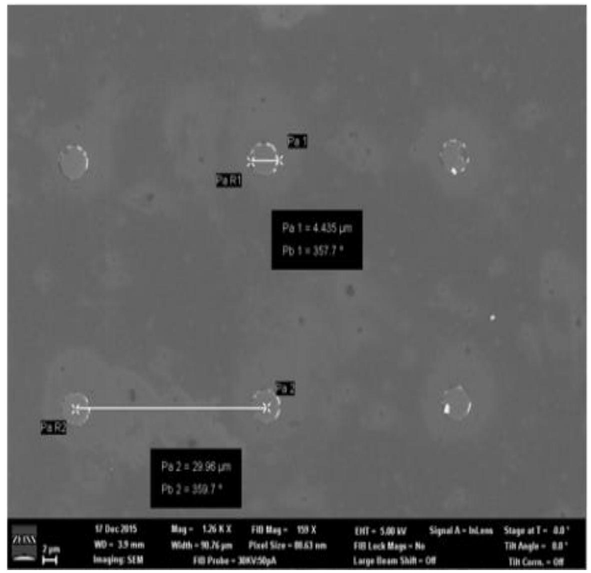
Catalyst Deposition

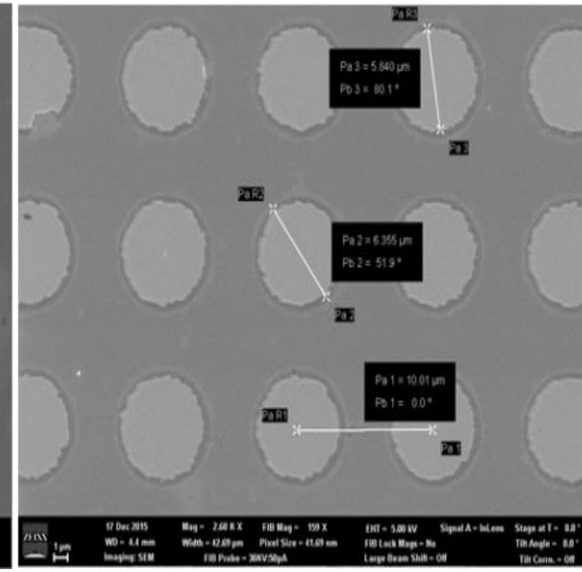


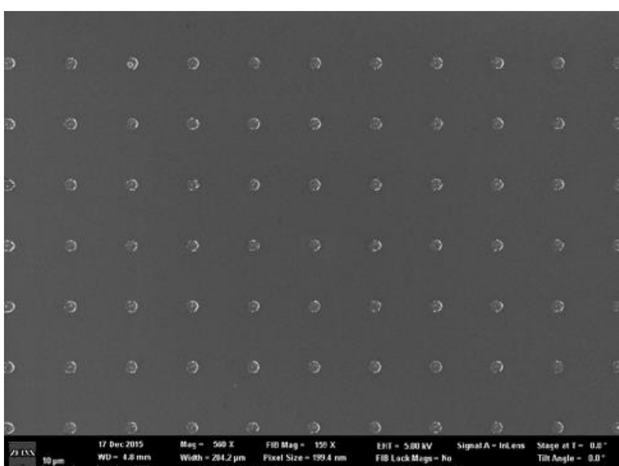


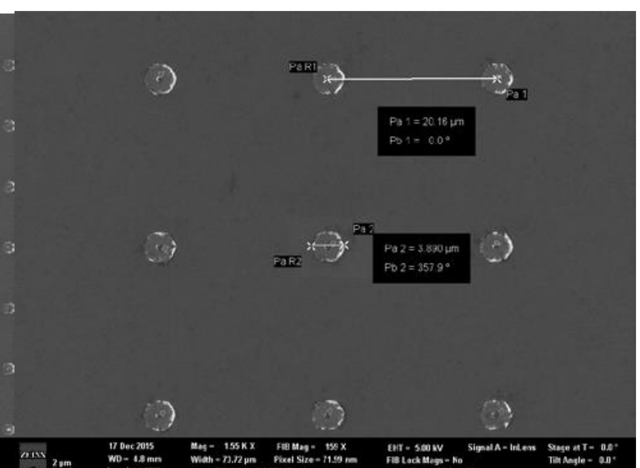
SEM of Catalyst Islands



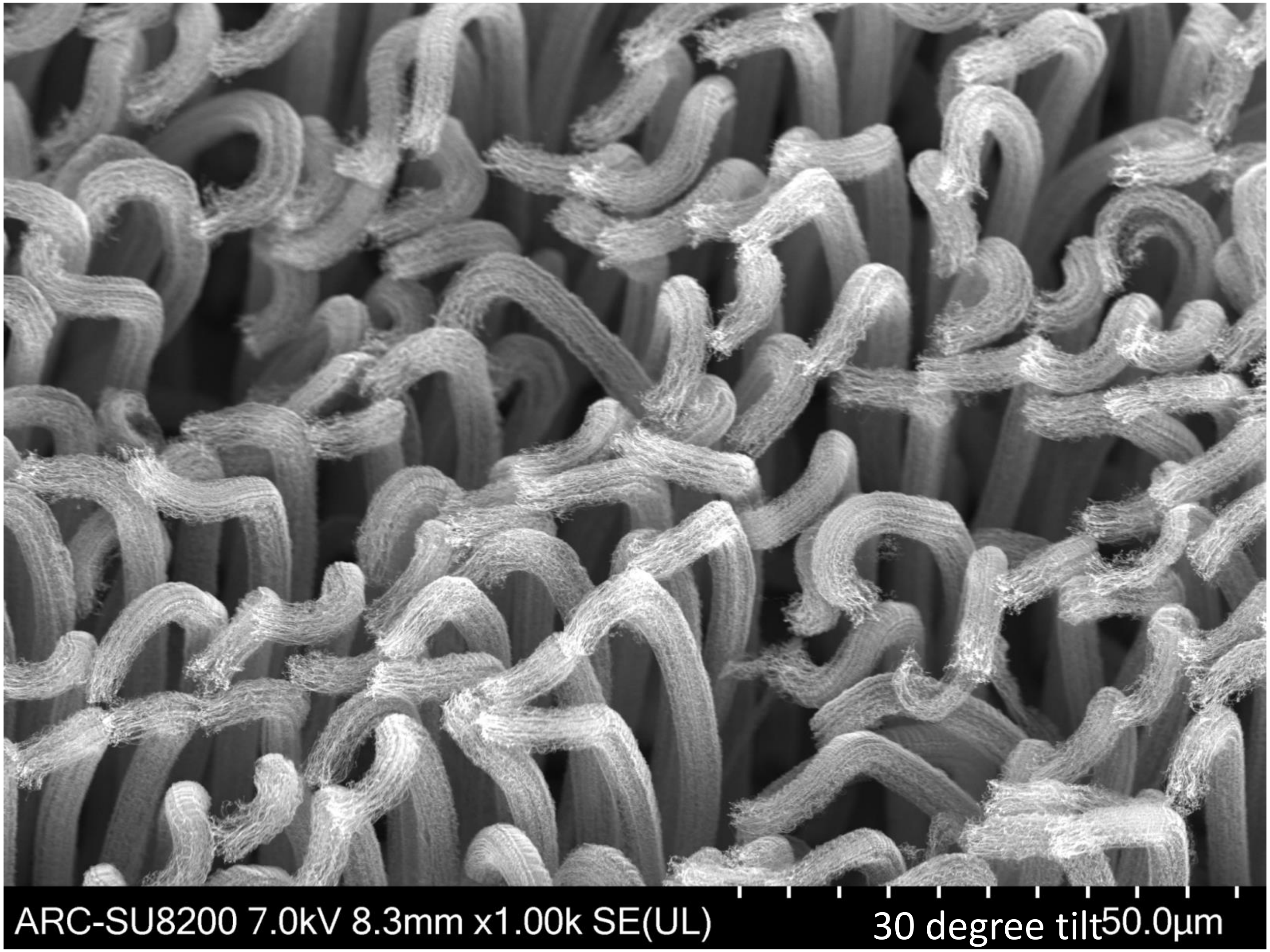




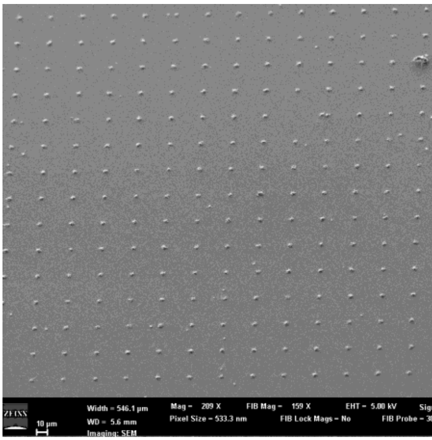


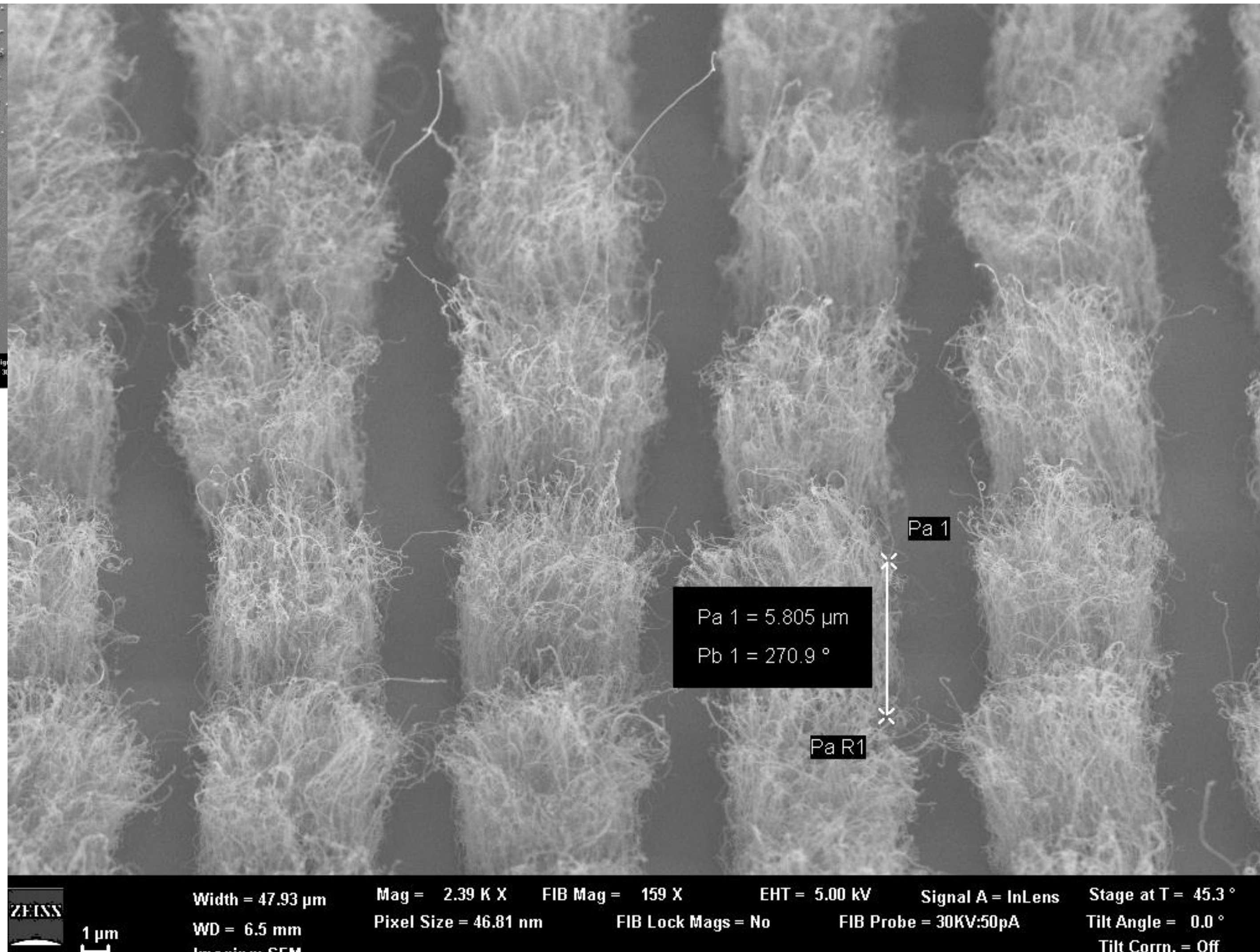


CNT growth

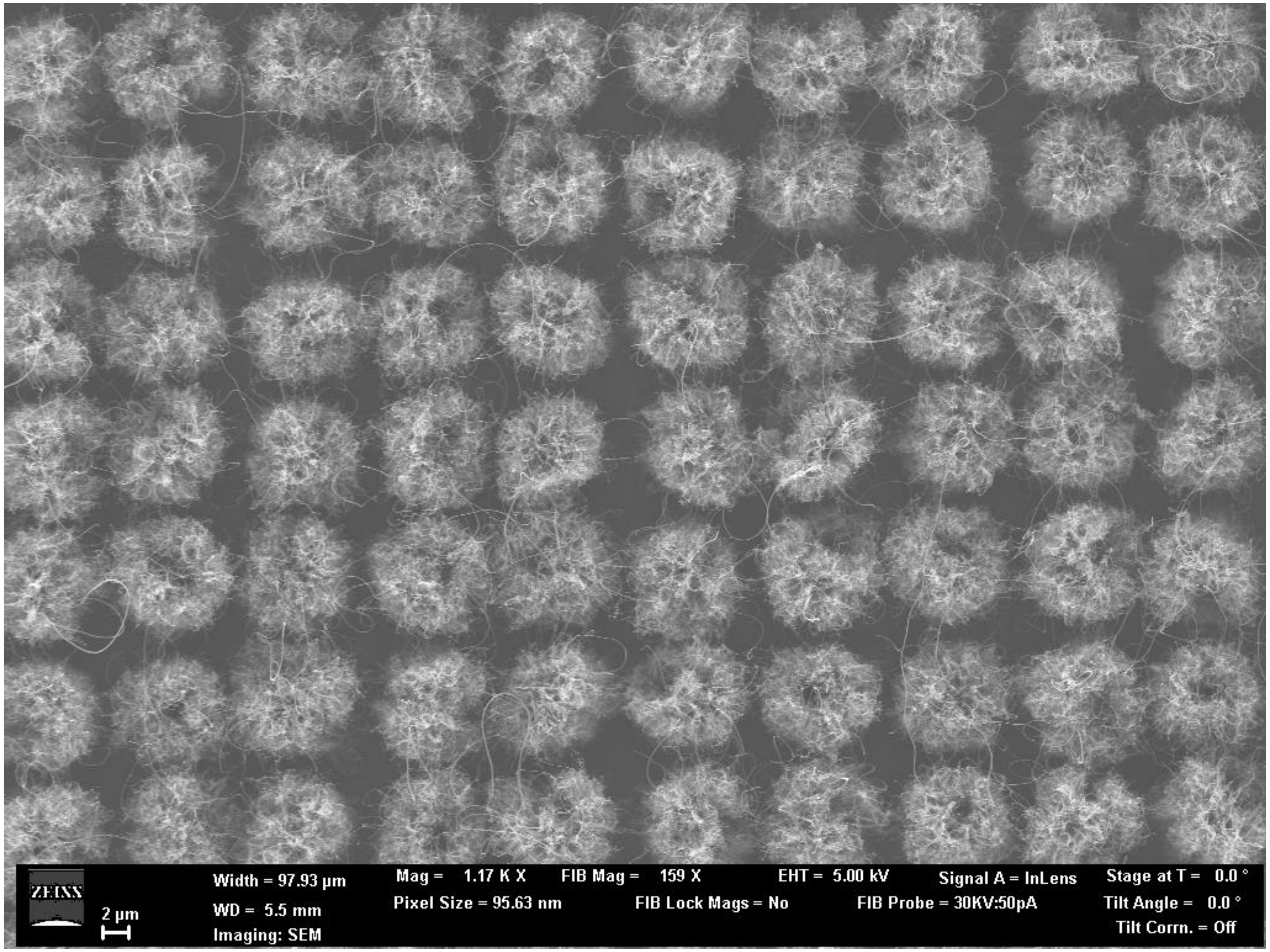


CNT Array growth

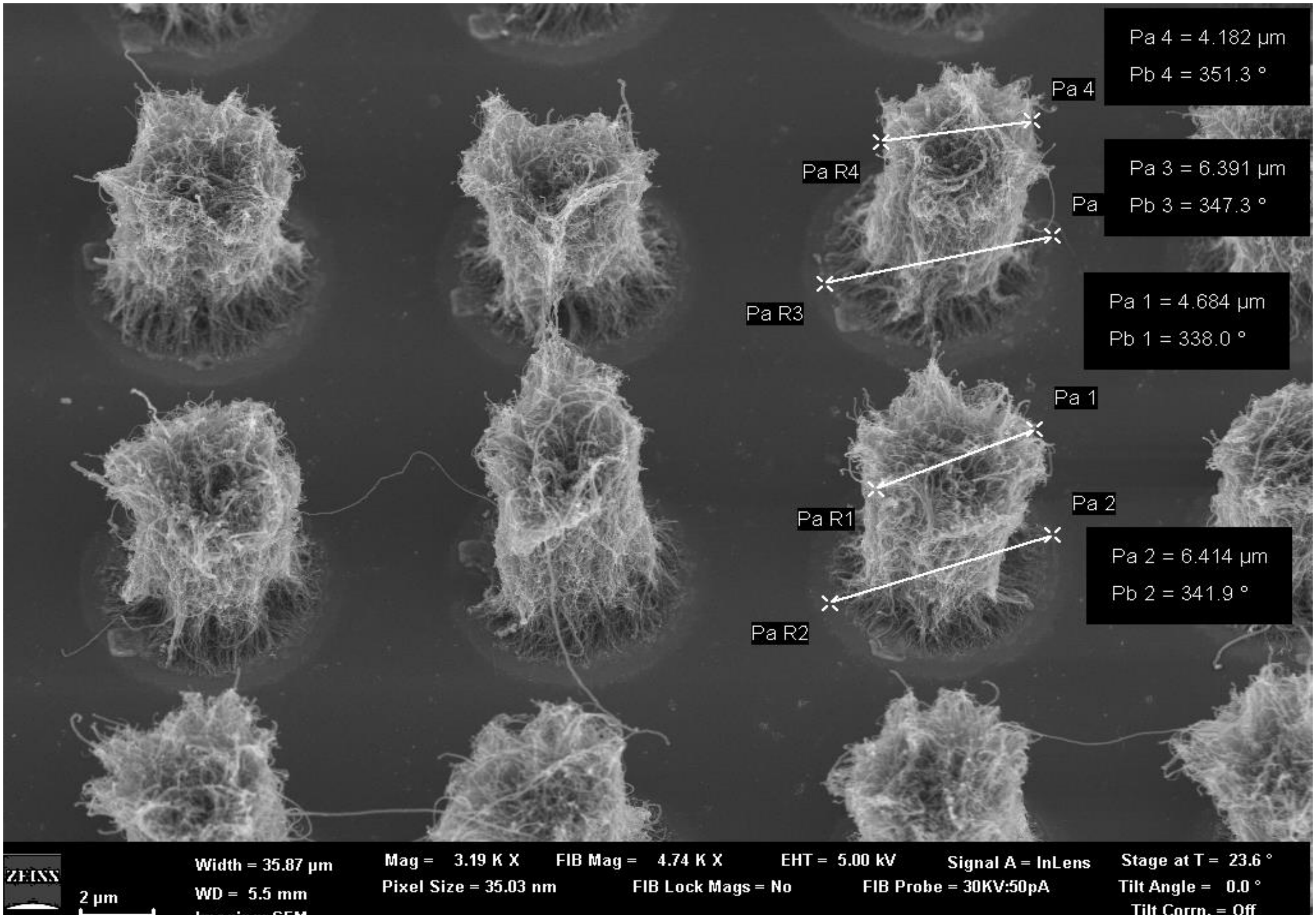




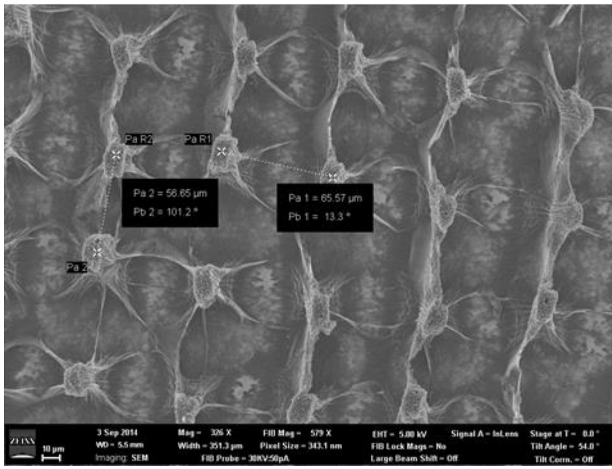
6 micron diameter x 10 micron pitch x 10 micron tall

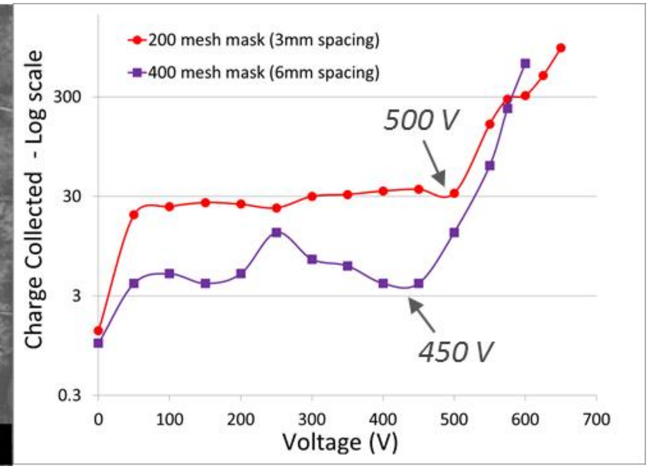


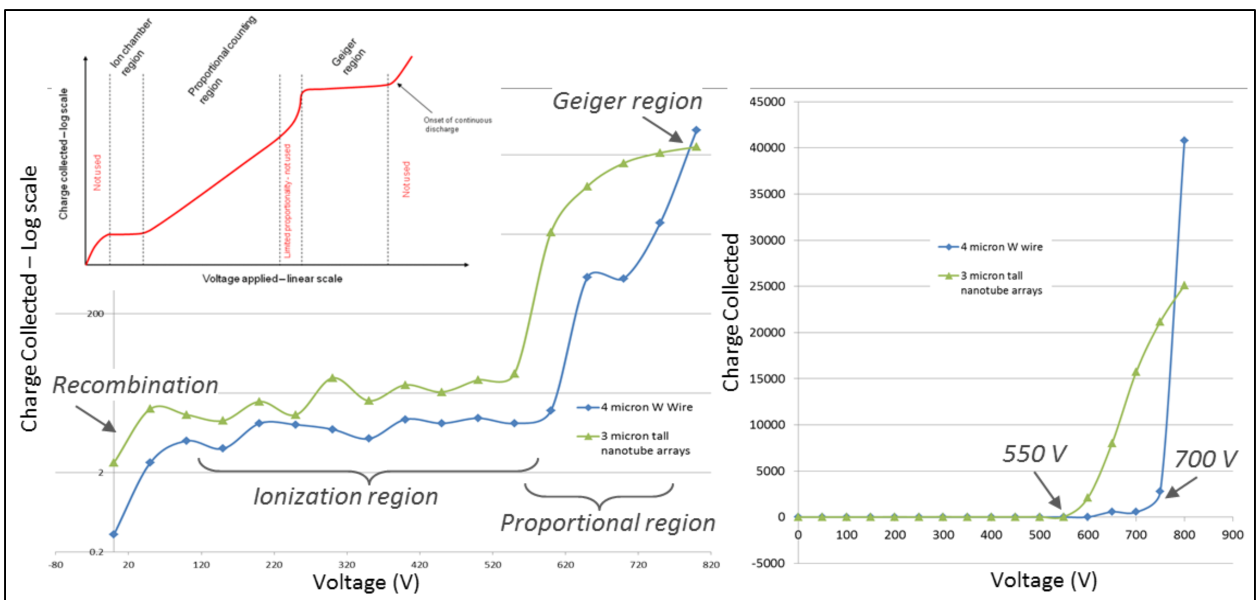
Densification of the 6x10x10 CNT Arrays



Preliminary results







Summary

- Modeling to determine pitch to height ratio
- Patterning
- Deposition
- Synthesis
- Densification
- Testing

Upcoming work

- Thinner catalyst layers
- Water vapor
- Densification
- SOP’s
- Testing
- Prototype build
- Further modeling

Acknowledgements

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Thank You

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Questions?