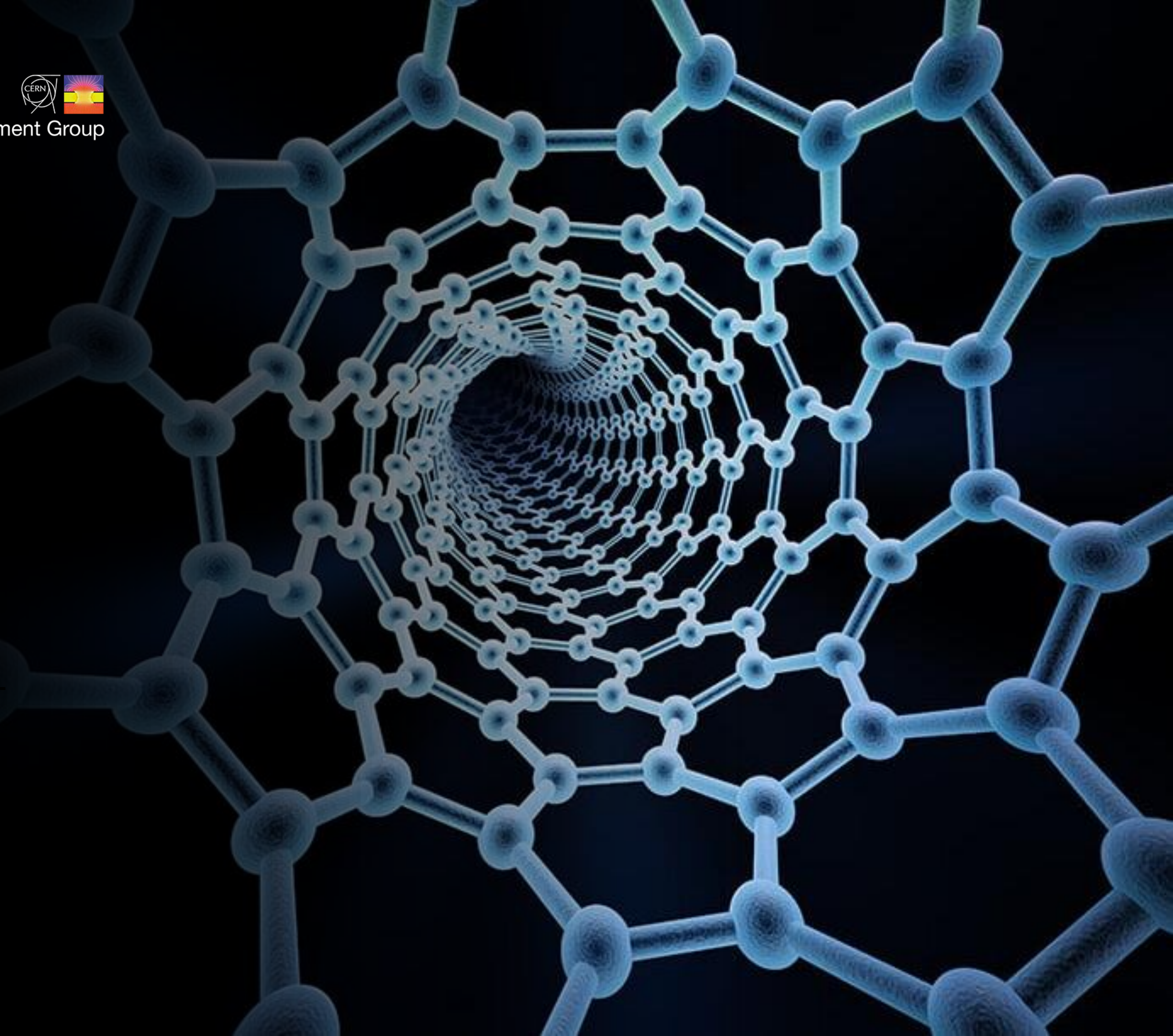
GDD
Gas Detectors Development Group

Nano-Pattern Gas Detector (NPGD)



Yalçın KALKAN

The 8th International Conference on Micro-Pattern Gaseous Detectors
Oct.14th - Oct.18th 2024 USTC·Hefei, China

Nano-tube Structures

- Carbon nanotubes (CNTs)
- Titanium dioxide (TiO_2) nanotubes
- Zinc oxide (ZnO) nanotubes
- Boron nitride (BN) nanotubes
- Aluminium oxide nanotubes (Al_2O_3)

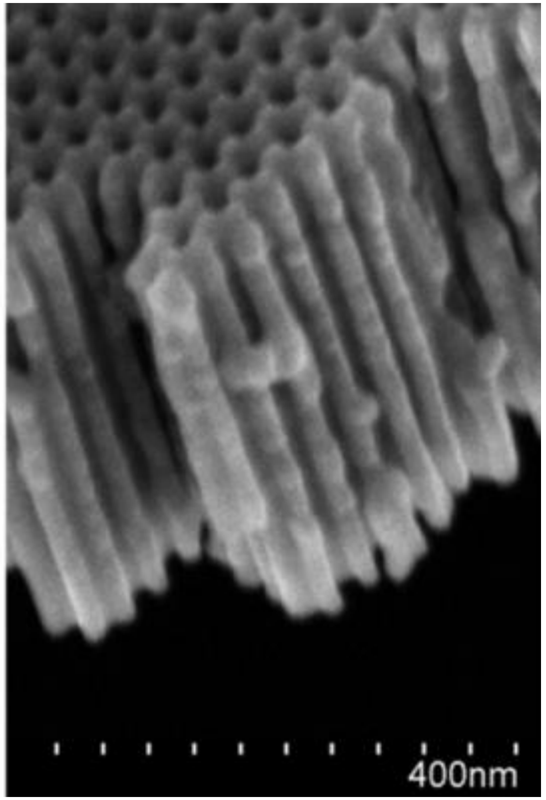
Anodic Aluminium Oxide (AAO)

Unique properties:

- Exceptional mechanical strength
- High electrical and thermal conductivity/resistivity
- Large surface area to volume ratio
- Hole (pore) geometry

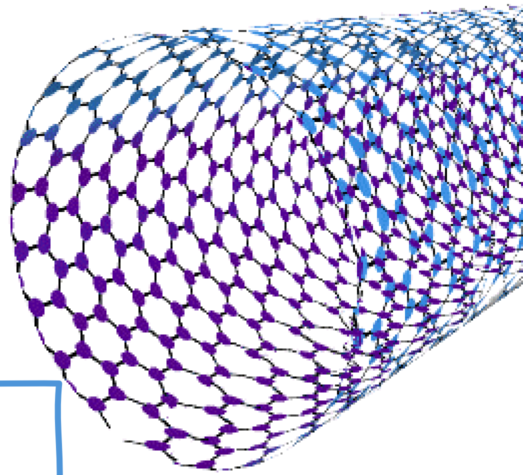
Synthesis methods:

- Chemical vapor deposition (CVD)
- Arc discharge
- Laser ablation
- Template-assisted methods



[Al-Haddad, Ahmed et al. (2020). AIP Conference 20046.]

Nano-tube Structures



Applications:

Electronics (transistors, sensors)

Energy storage (batteries, supercapacitors)

Composite materials for aerospace and automotive industries

Water purification and desalination

Medicine delivery systems

Cutting-edge research:

Self-healing nanotubes

Nanotube-based artificial muscles

Quantum computing applications

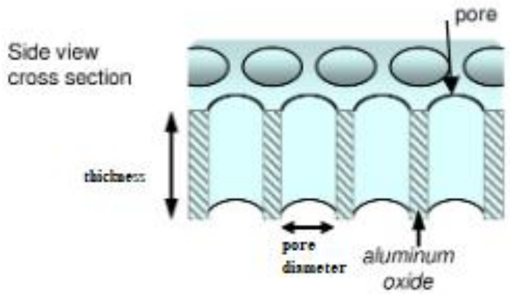
Challenges:

- Large-scale production issues
- Purification and sorting
- Health and environmental concerns

Future prospects:

- Integration in flexible electronics
- Space elevator concept (using CNTs)
- Nanorobots for medical applications
- Particle detector applications (why not?)

Anodic Aluminum Oxide (AAO)



Definition and basic structure:

- Self-organized nanoporous material
- Hexagonal array of cylindrical pores

Fabrication process:

- Two-step anodization method
- Control parameters (voltage, electrolyte, temperature)

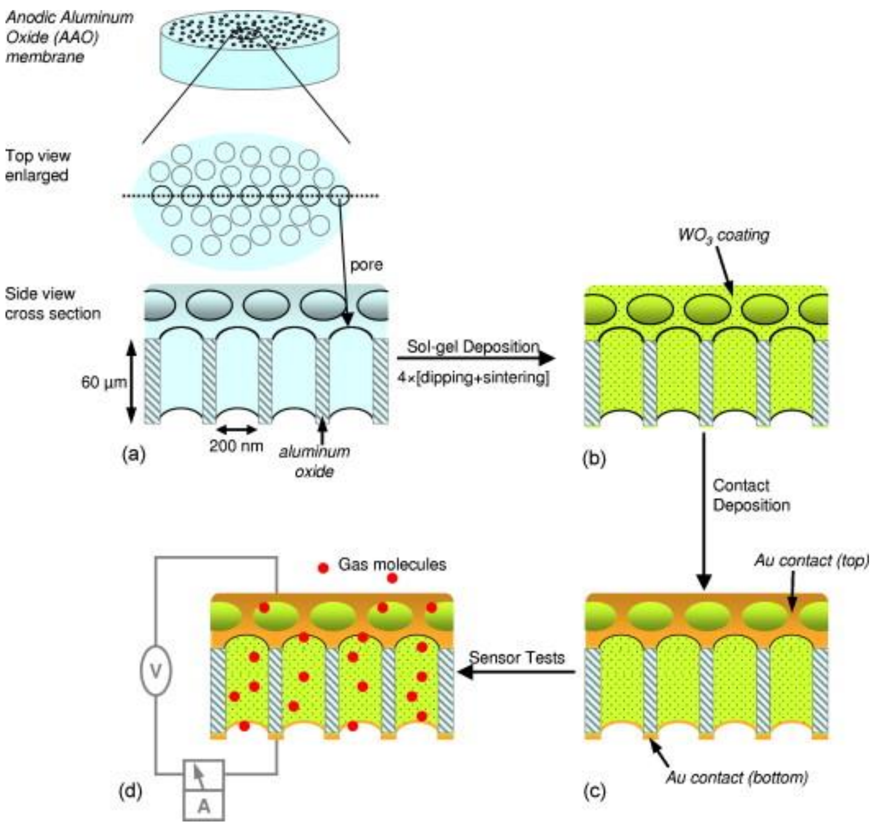
Unique properties:

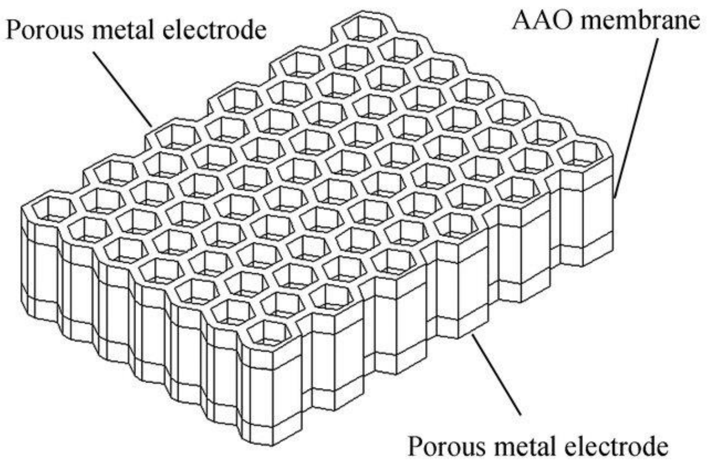
- Highly ordered pore structure
- Tunable pore size (10-400 nm) and interpore distance
- High aspect ratio (length to diameter)
- Chemical and thermal stability

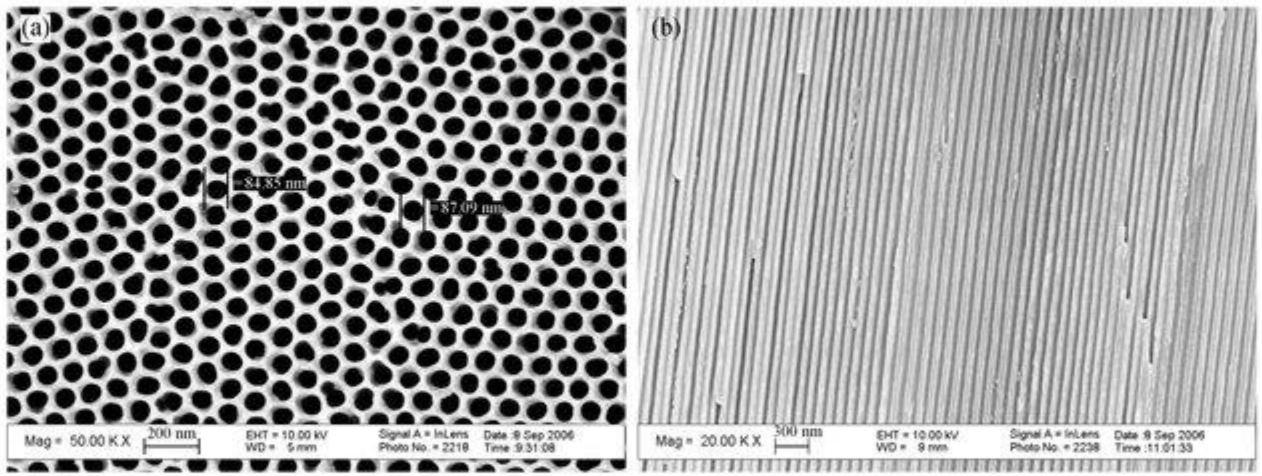
Customization possibilities:

- Pore diameter control
- Interpore distance adjustment
- Thickness variation

The idea: **AAO GEM foil**







[R. Artzi-Gerlitz et al. / Sensors and Actuators B 136 (2009) 257–264]

[Z. Ling et al. / Chin. Sci. Bull. 53, 183–187 (2008)]

Coating Process

Cleaining:

Ultrasonic bath in alcohol+pure water mixture

Method:

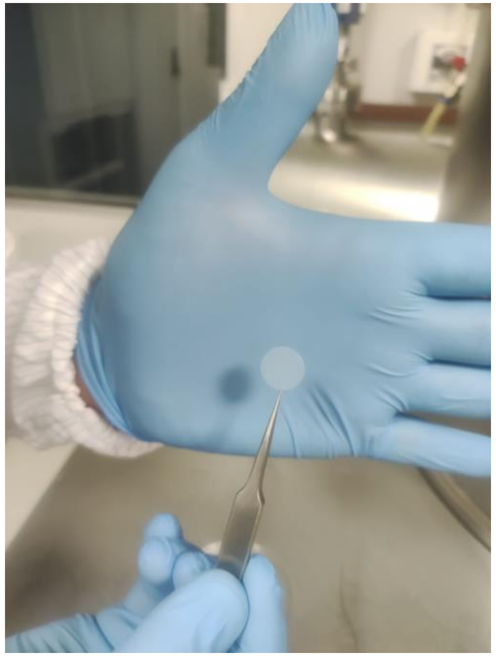
Thermal Evaporation

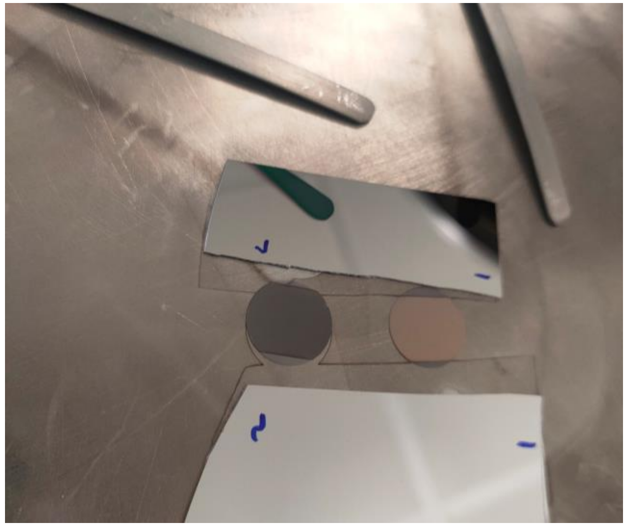
e-beam

DC-RF Sputtering

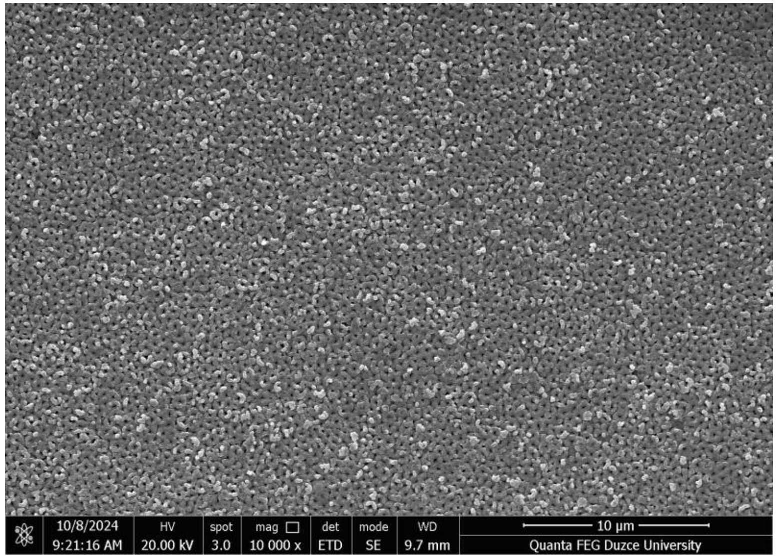
Annealing:

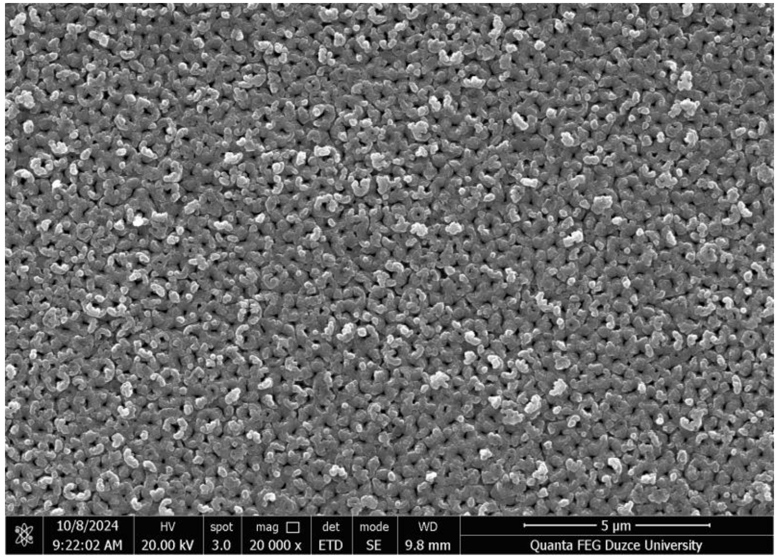
300 degrees after coating

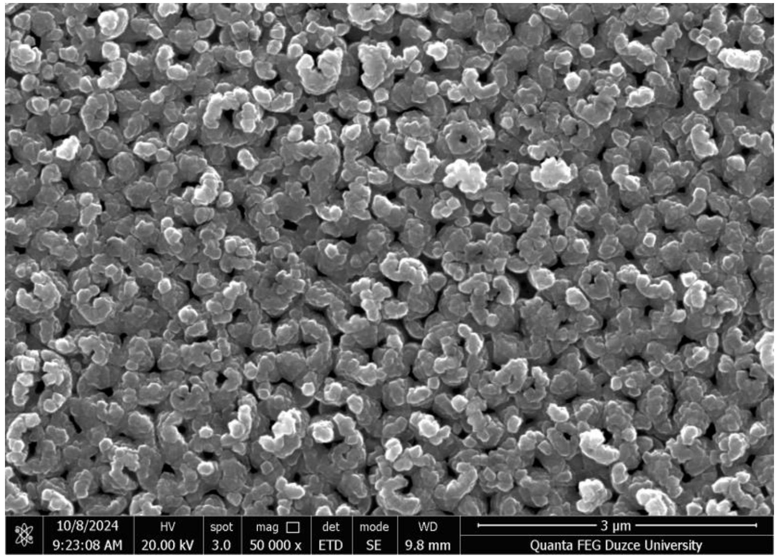


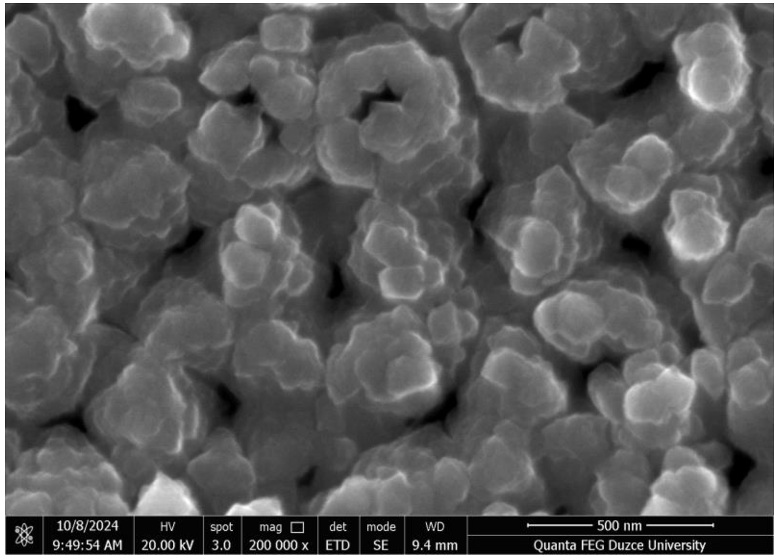


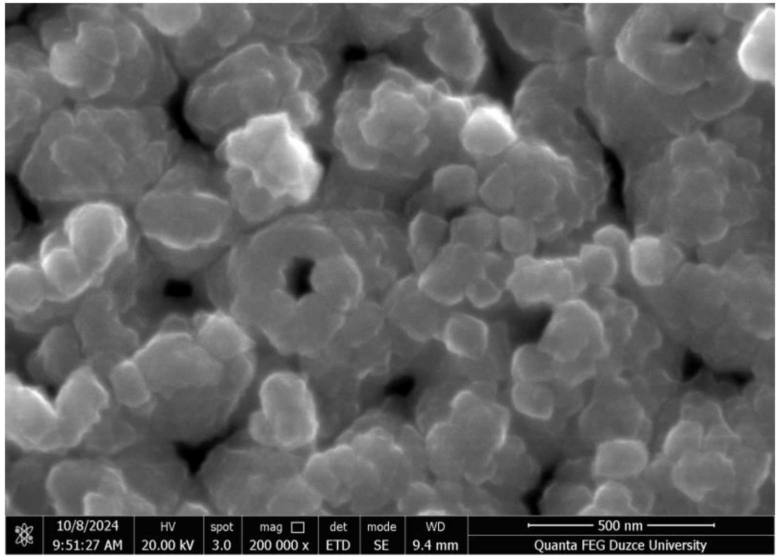
SEM Analysis





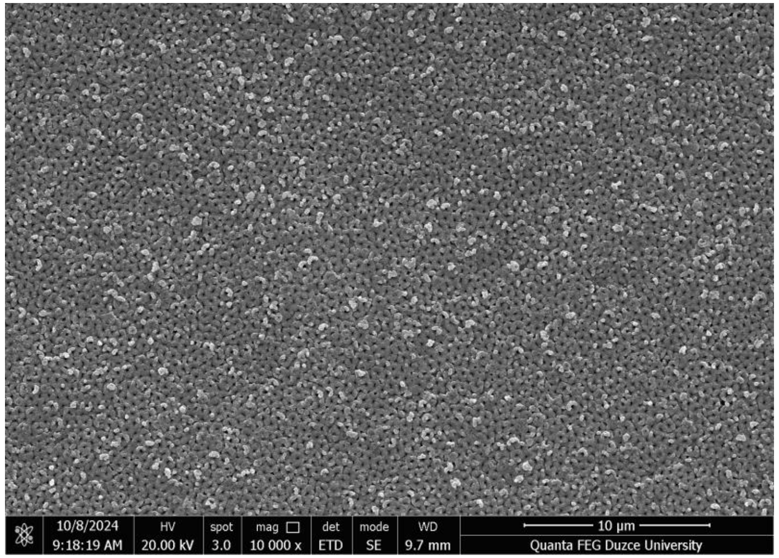




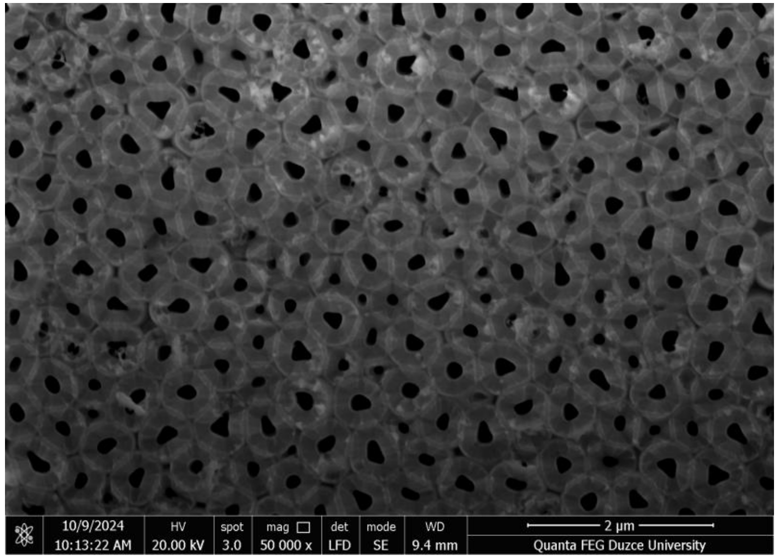


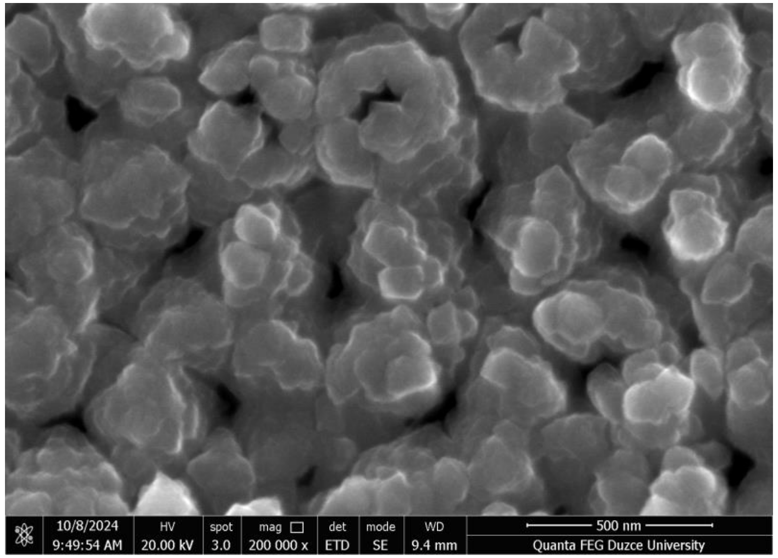
SAMPLE 1

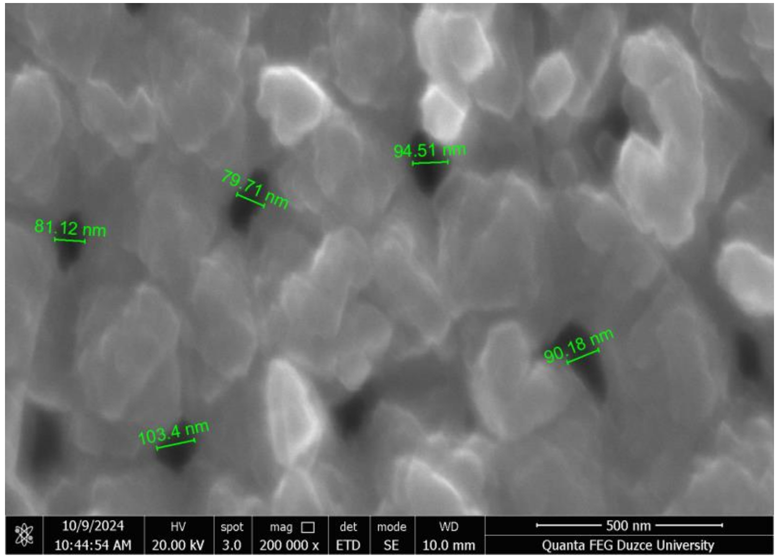
SEM Analysis

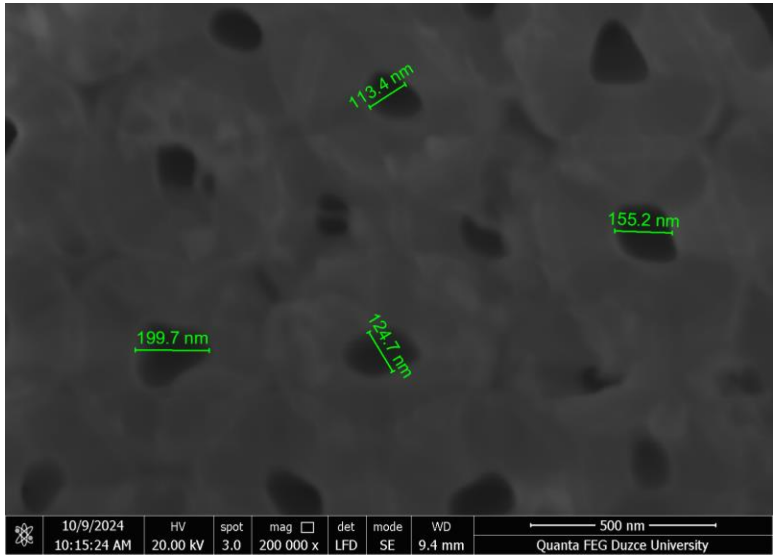


SAMPLE2

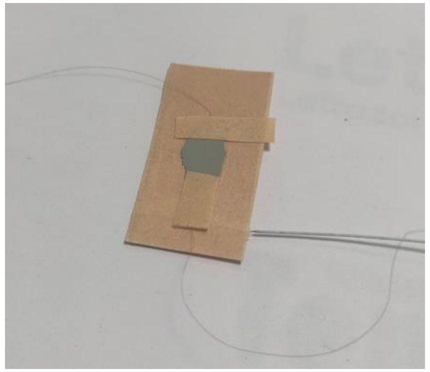


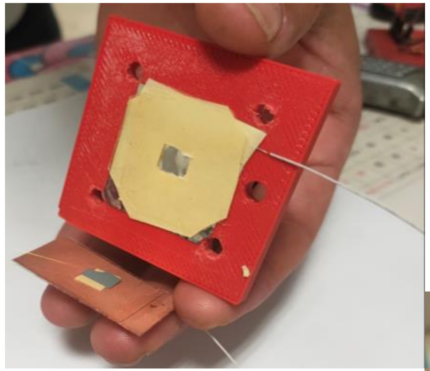


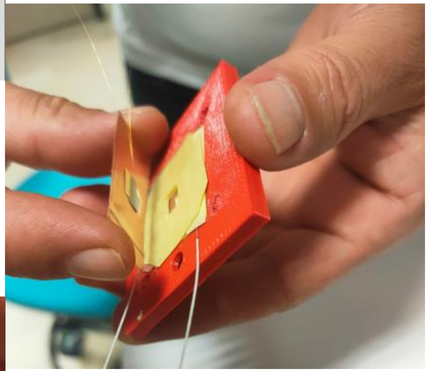


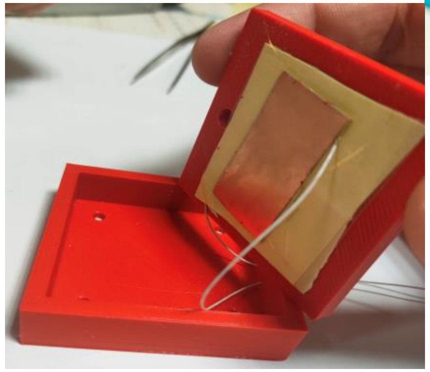


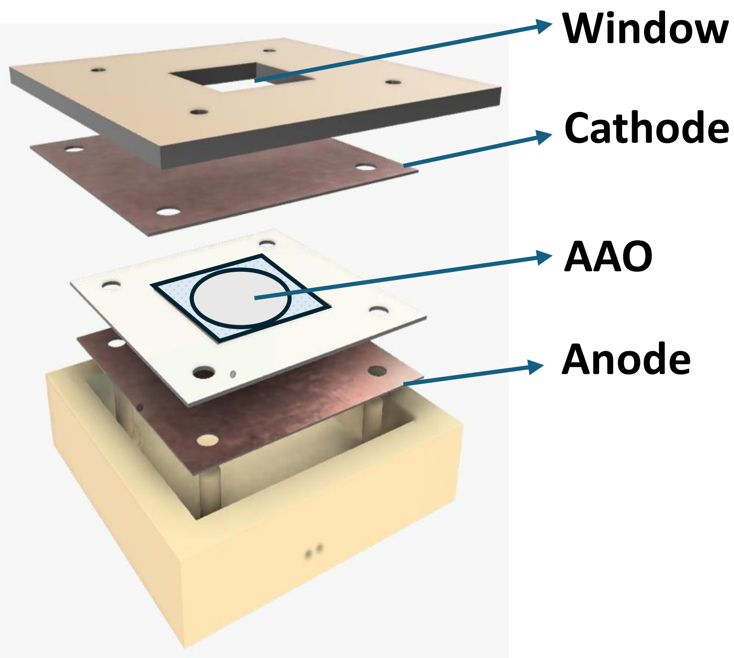
Prototyping

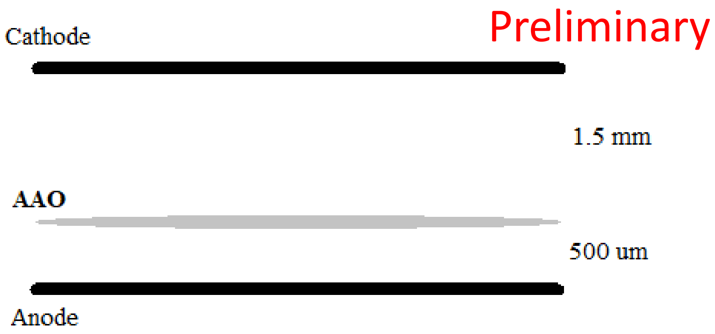




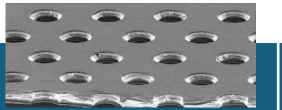
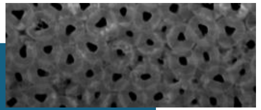




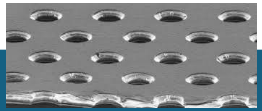
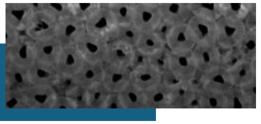




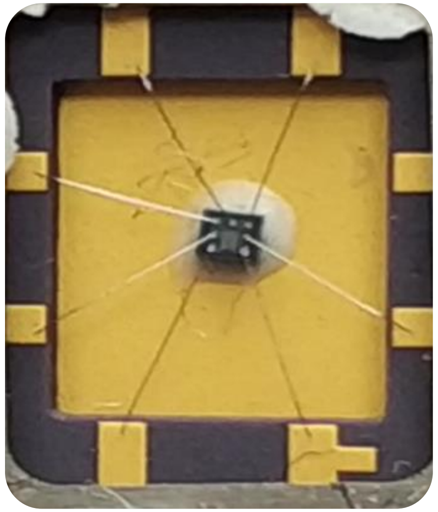
Comparision

Parameter	Standart GEM Foil 	Nano-structured GEM Foil 
Material Composition	Polyimide (Kapton) with copper layers	Anodized Aluminum Oxide (AAO) with aluminum coating
Surface Coating (Electrodes)	Copper (both sides)	Aluminum (top and bottom)
Hole Size (Diameter)	Typically 50–70 µm	Nano-structured holes (~10–50 nm range)
Hole Pitch (Distance between holes)	140 µm	Custom-designed (potentially smaller due to nano-structuring)
Hole Shape	Cylindrical	Nano-structured, possibly more tailored or irregular
Electrical Field Uniformity	Moderate	Enhanced due to nano-scale coating
Charge Gain (Typical values)	$\sim10^3$ to 10^4	Potentially higher due to nano-structuring enhancing charge collection
Electron Transparency	Typically ~80–90%	Could be improved due to more controlled nano-scale geometry
Mechanical Strength	Good (depends on substrate)	Likely increased due to AAO's rigidity
Radiation Hardness	High	Comparable or potentially higher due to material properties

Comparison

Parameter	Standart GEM Foil 	Nano-structured GEM Foil 
Operating Gas	Typically Ar/CO_2, other noble gases	Same or customized gas mixtures based on nano-structure design
Hole Density (Holes per mm^2)	~500–600 holes/mm^2	Higher due to smaller hole size, potentially 10,000+ holes/mm^2
Cost	Relatively affordable (mass production)	Likely higher due to specialized fabrication techniques
Production Method	Photolithography	Nano-fabrication and surface coating techniques
Surface Resistivity	~10^{16} Ω/sq	~10^{8} to 10^{12} Ω/sq
Electron Affinity	1.9 eV	2.7 – 3.5 eV
Gas Box Volume	Higher due to larger hole size and spacing	Lower due to nano-scale holes, enabling reduced gas consumption

Key Benefits



- Enhanced Charge Gain
- Improved Field Uniformity
- Superior Radiation Hardness and Durability
- Better Electron Transparency
- Higher Insulating Performance with Tunable Conductivity
- Customized Gas Compatibility
- Mechanical and Structural Strength
- Enhanced Radiation Shielding and Signal Integrity

R&D Unknowns

- Results for the double, and triple models
- Effects of foil or wall thicknesses, pore diameters, pore density, porosity
- Effects on ions/cluster ions behavior (mobility, diffusion etc.)

[V. Pelenovich et al., Size determination of Ar clusters formed in conical nozzles, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Volume 450, 1 July 2019, Pages 131-134.]

- Advance applications

Conclusion

- Nanotube structures promise the potential in gas radiation detectors.
- The electrode coating processes was completed and a prescription was obtained.
- The results can be the first steps for possible NPGDs.
- 1 cm^2 prototype is ready

  Electrical and signal characterization is coming soon…

Thanks.

Yalçın KALKAN
yalcin.kalkan@cern.ch
yalcin.kalkan@ibu.edu.tr