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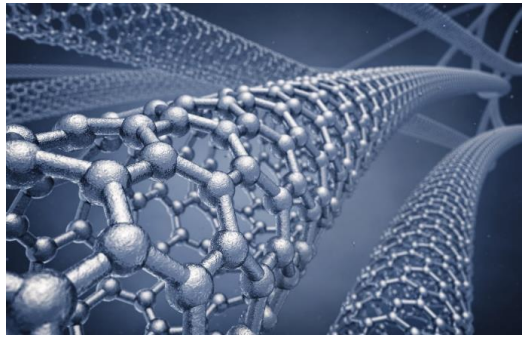
Carbon nanotube membranes for EUV lithography – a versatile material platform

SEMICON Europa 2023 *Presentation A-161* *Emma Salmi*

Canatu creates the most advanced carbon nanotubes (CNT)



Background

- *HQ, R&D and Production in Finland*
- *100 employees from 22 nationalities*

Technology

- *Canatu **Builds, Develops**, and **Licenses** CNT synthesis reactors*

Commercial development

- *EUV membrane mass production since 2021*
- *In-house manufacturing & technology licensing*

Focus

- ***Semiconductor:** particle filters and optical filters*
- *EUV pellicles*
- *EUV debris filters*
- *X-ray filters*

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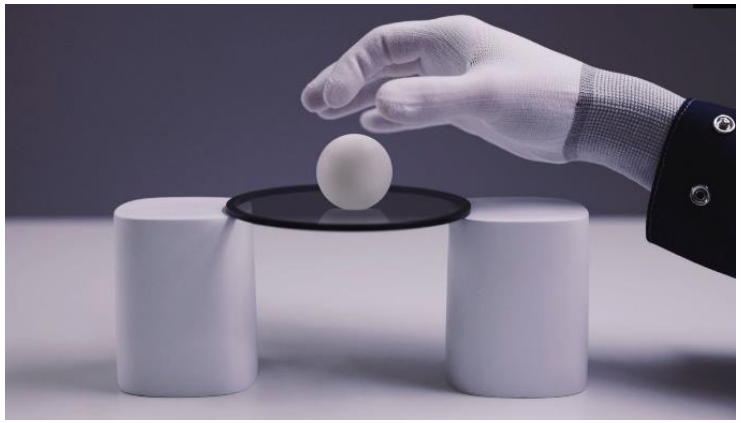
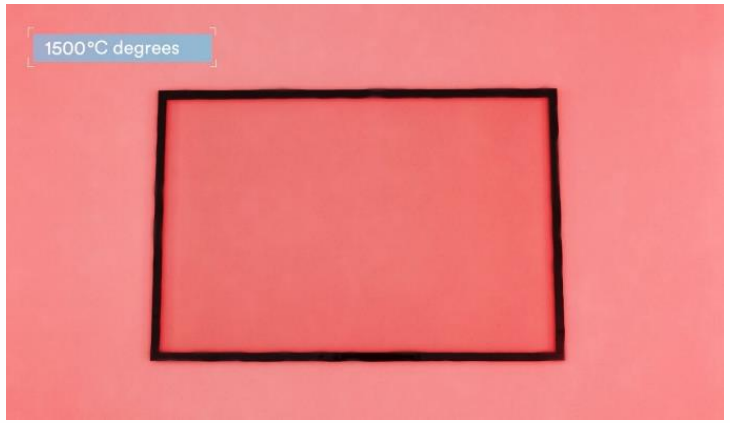
General properties of free-standing CNT films



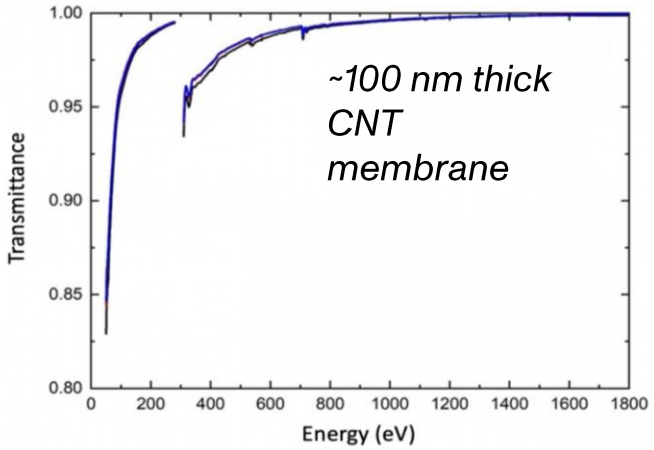
MECHANICAL ROBUSTNESS

- High tensile strength
- Ultra flexible
- Gas filtration



HIGH HEAT RESISTANCE

- High thermal stability in vacuum
- Chemically inert graphitic structure



HIGH TRANSPARENCY

- More than 97%T at EUV / X-Ray
- Low flare (scatter)
- Low EUV reflectivity

Data courtesy of doi: 10.1117/12.2631516

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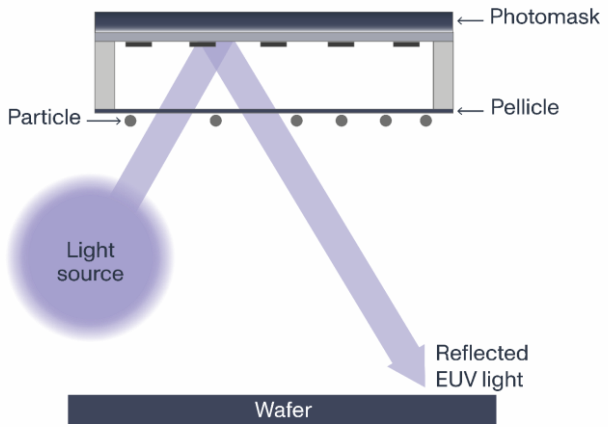
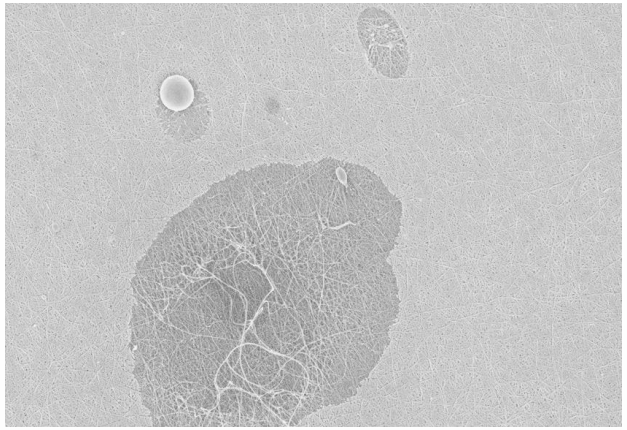
Canatu CNT membrane focus applications



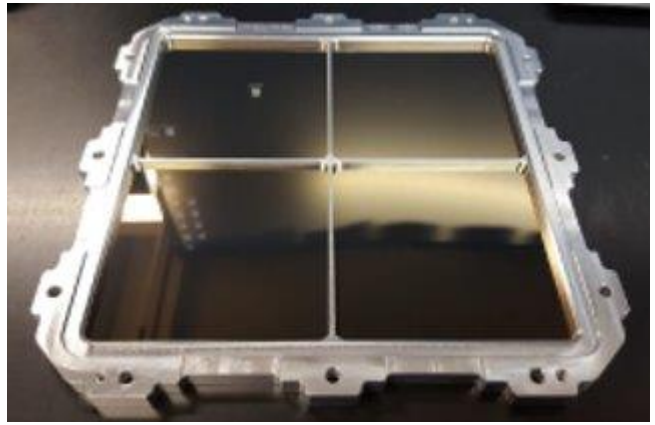
EUV pellicle

- A key enabling technology for achieving higher yields in sub-7nm chip EUV manufacturing.
- Key customers: market leaders
- Status: in pilot production



EUV debris filter

- A key enabling technology for better mask detection performance in sub-7nm chip manufacturing.
- Key customers: market leader
- Status: in mass production since 2021



Optical filter

- Blocks the UV/VIS/IR radiation while offering high X-ray and EUV transmittance
- Key customers: ESA, SEMI
- Status: under development

Carbon nanotube synthesis

Free-standing film manufacturing

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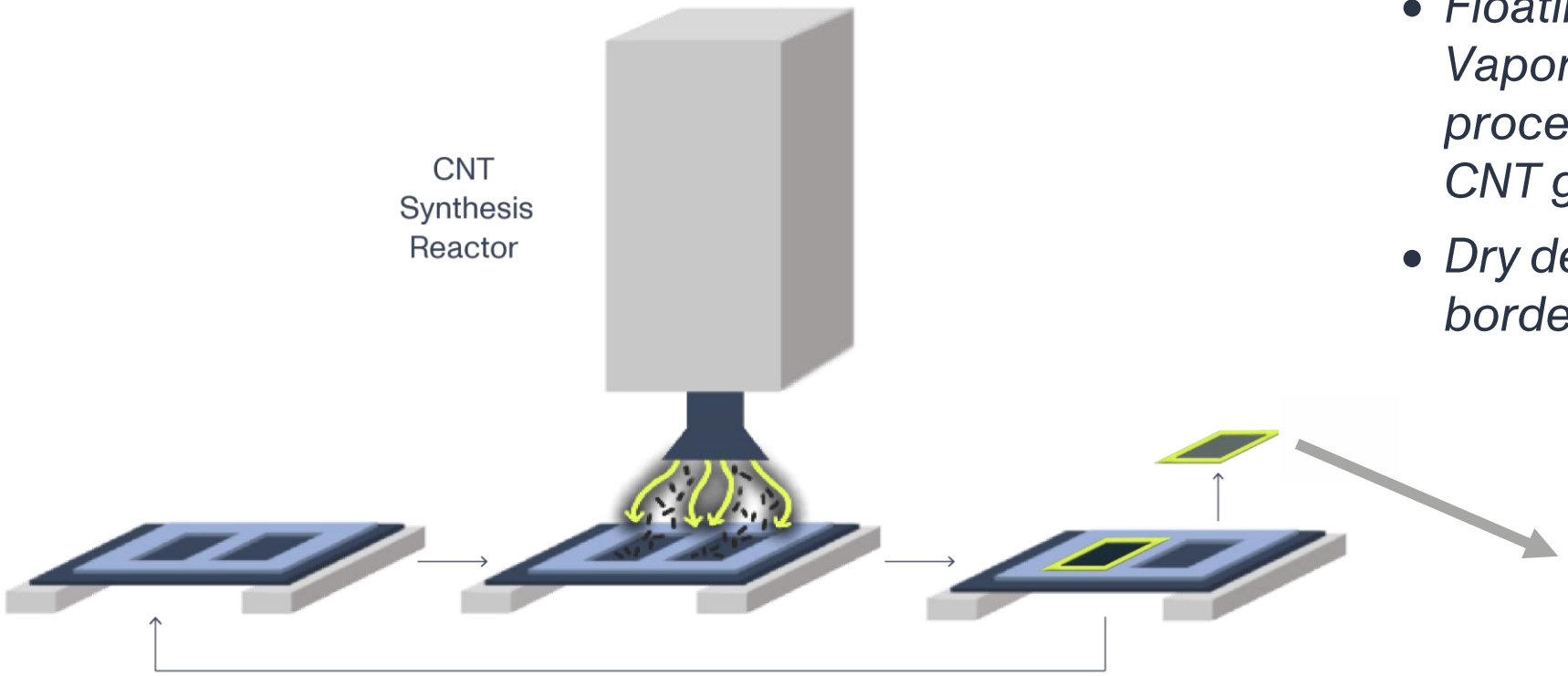
Unique Dry Deposition for long and clean CNTs



- *Floating Catalyst Chemical Vapor Deposition (FC-CVD) process providing control over CNT growth*
- *Dry deposition and transfer to border or substrate*

Application-specific post processing

- *EUV Pellicle*
- *EUV Debris filter*
- *X-ray filter*

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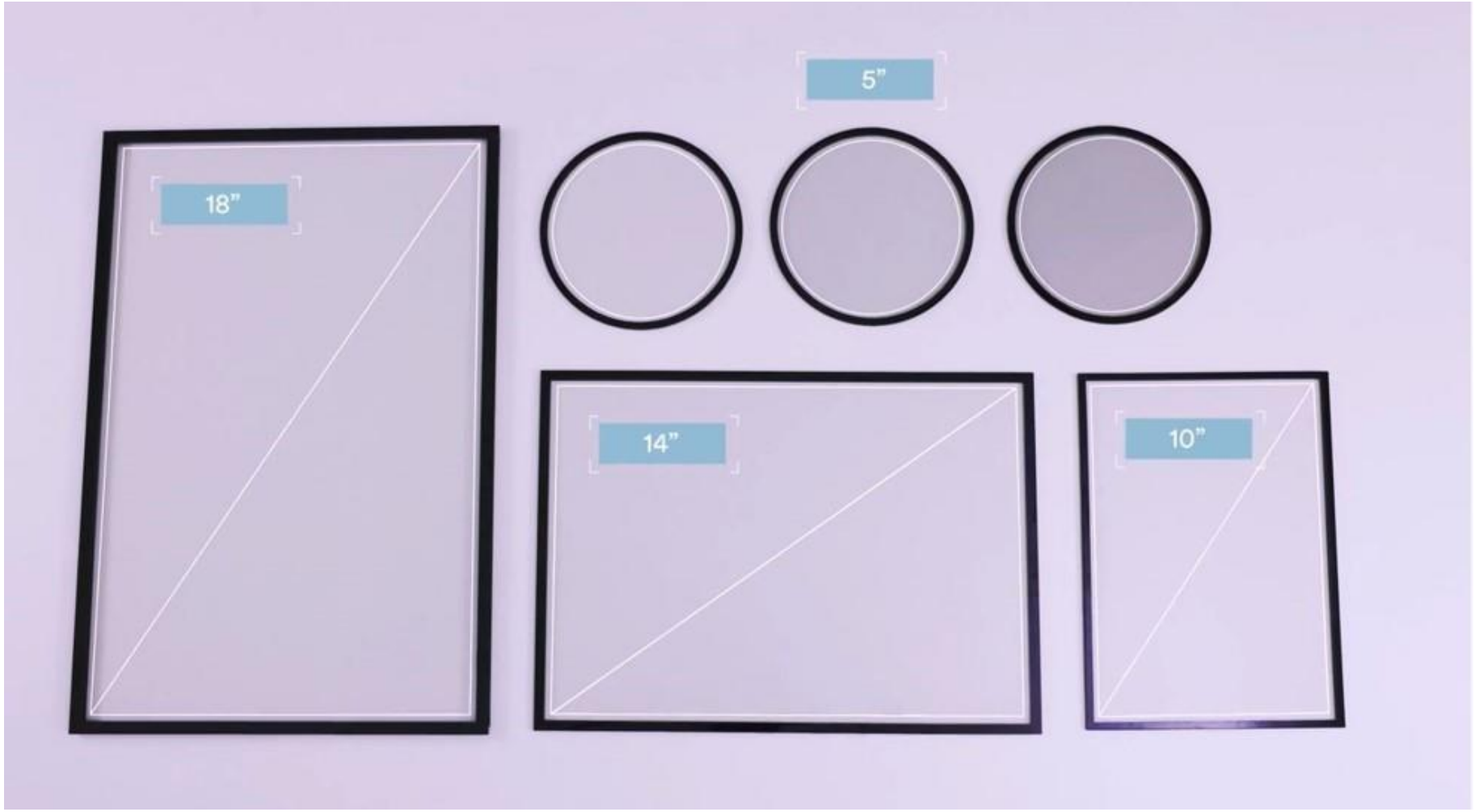
Application-specific membrane shapes, sizes & thicknesses



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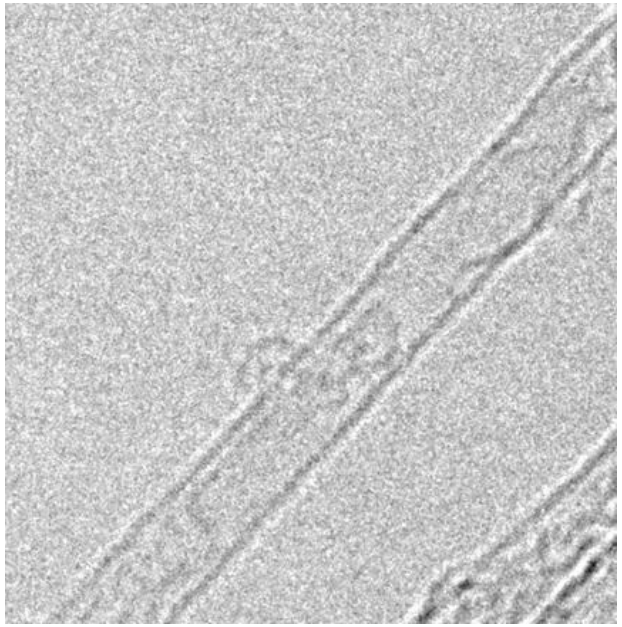
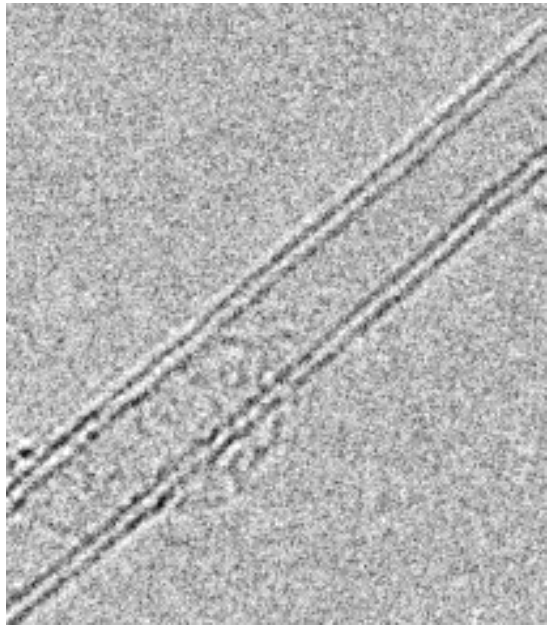
CNT synthesis: wall count

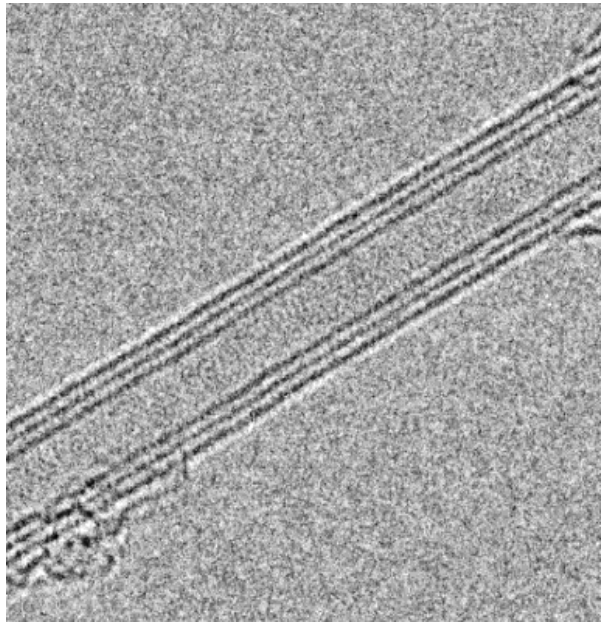
The number of walls can be tuned for application requirements



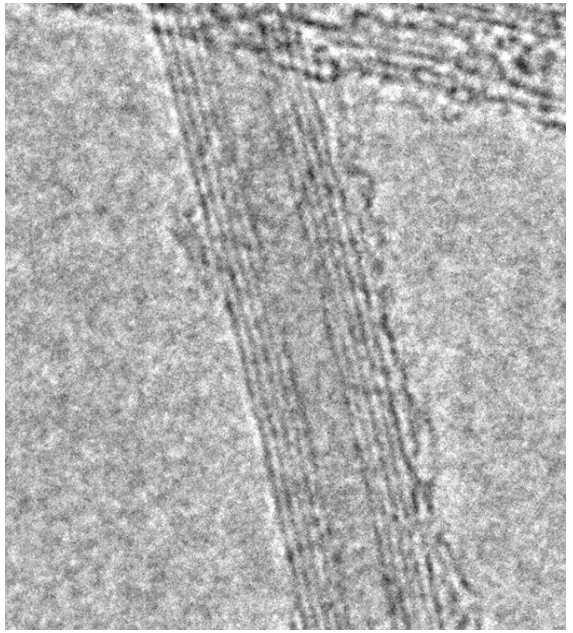
1-wall CNT



2-wall CNT



3-wall CNT



5-wall CNT

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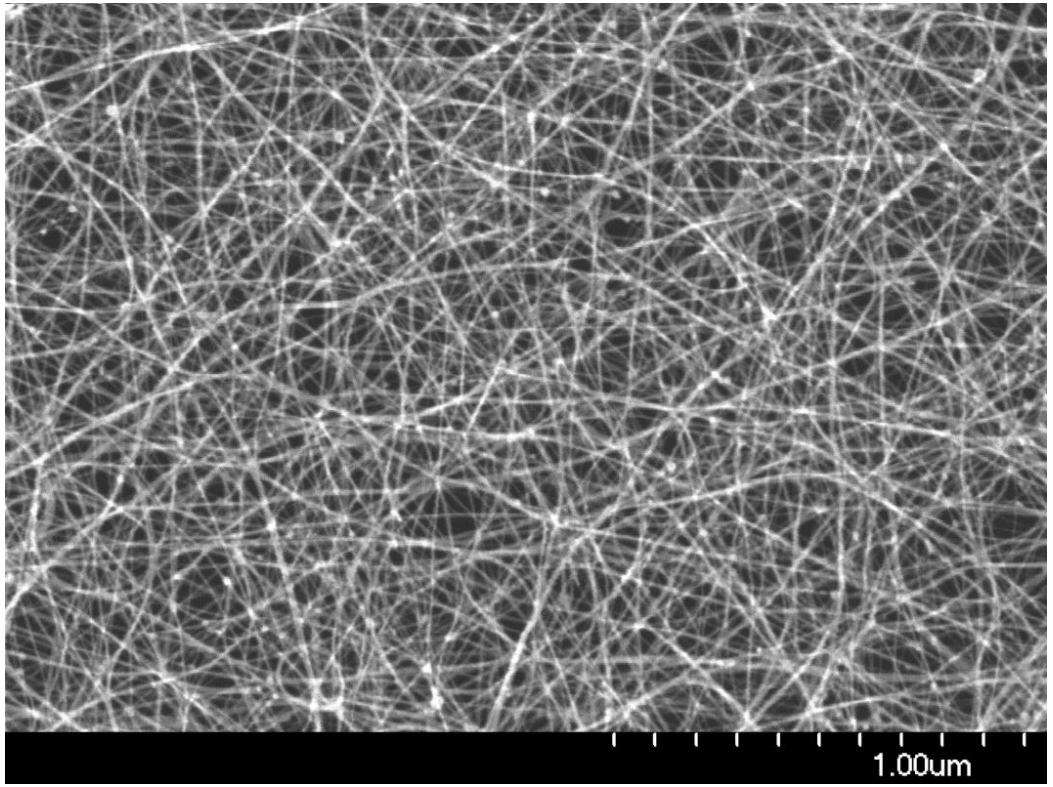
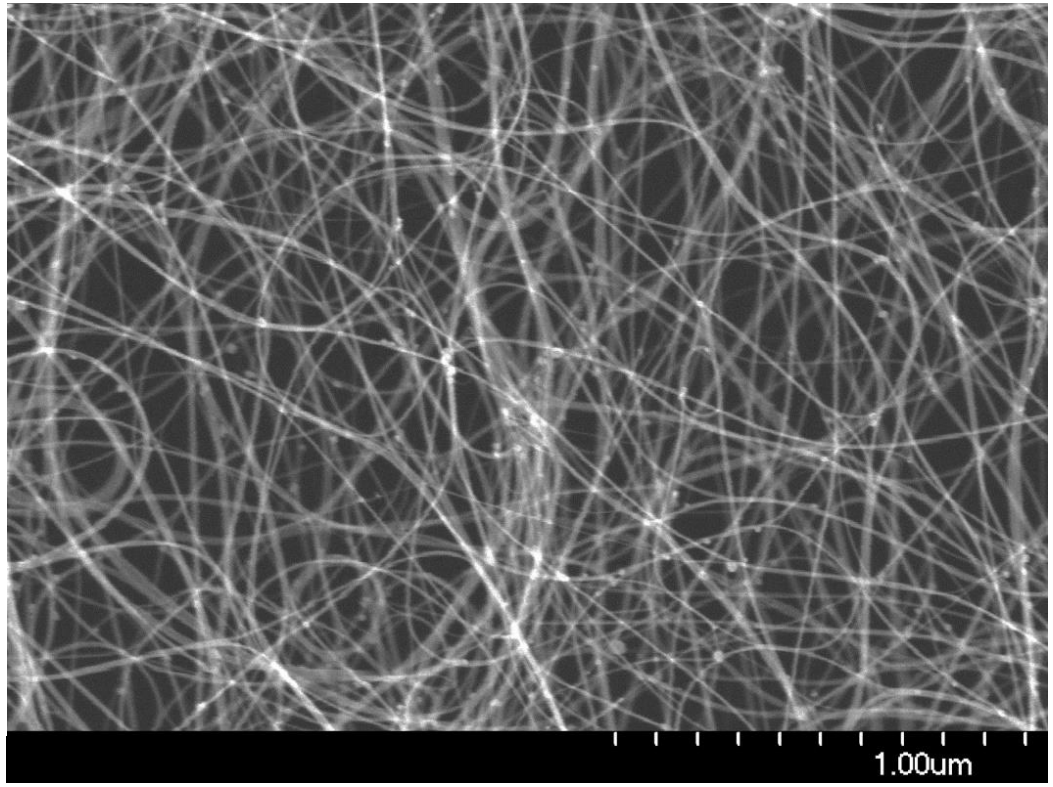
CNT synthesis: bundle size control

Same %T transmittance



Small bundles



Large bundles

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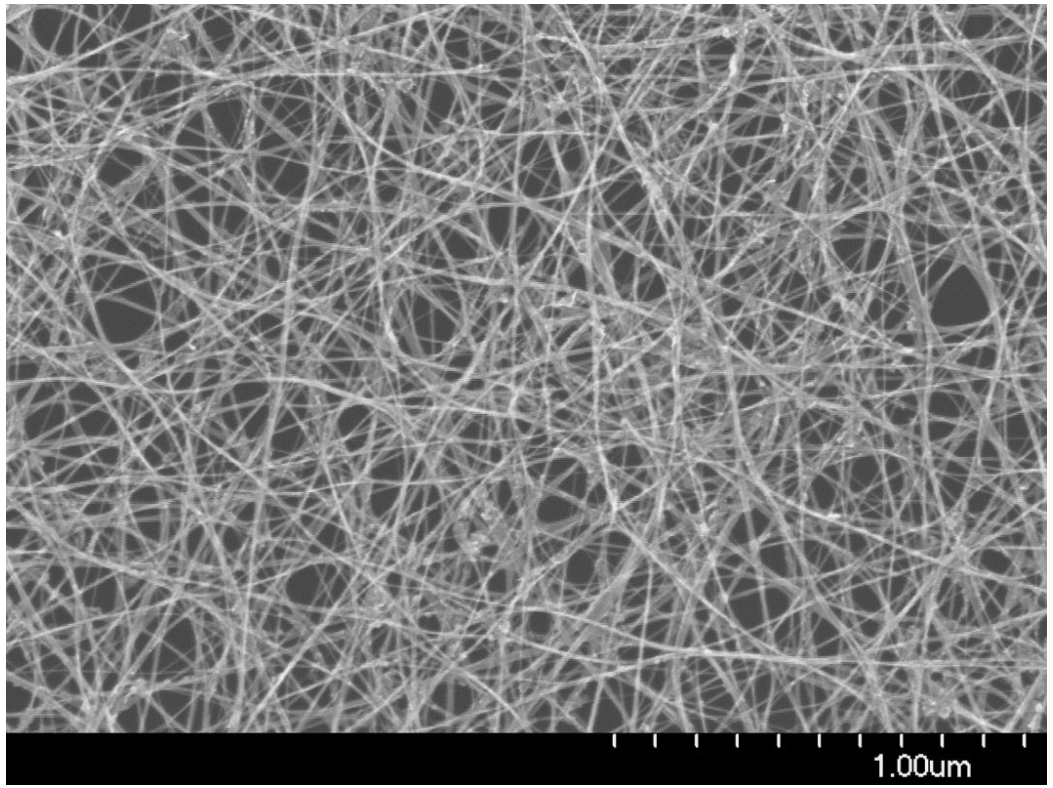
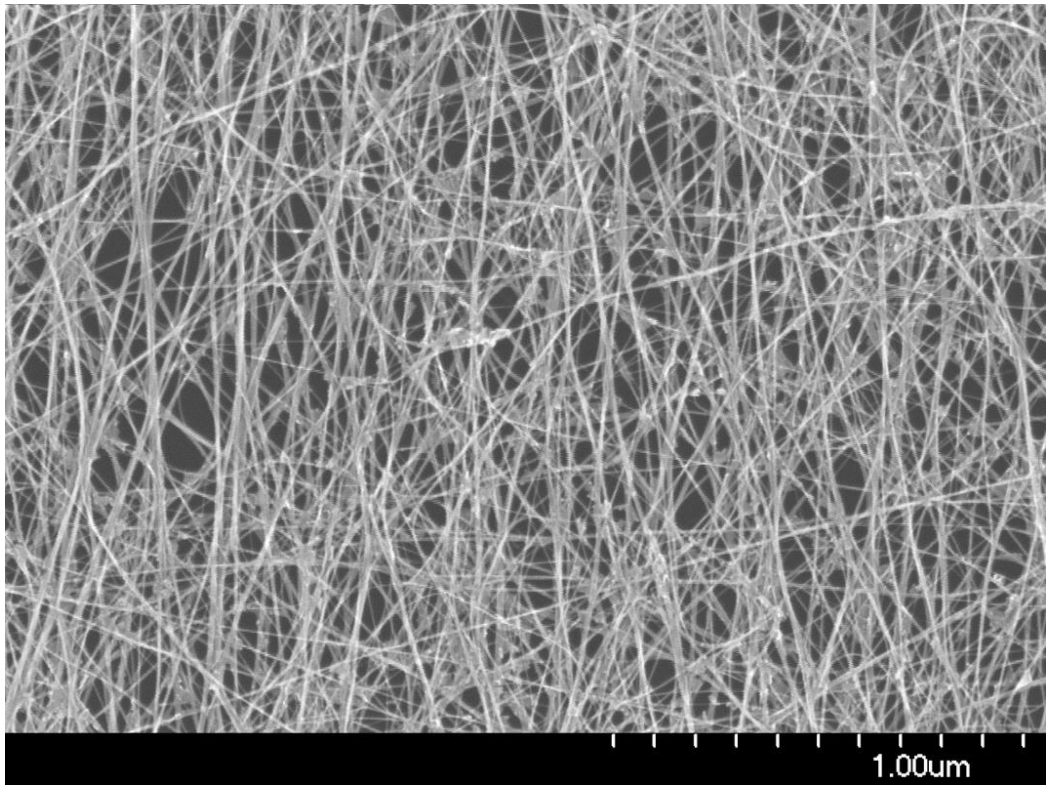
CNT synthesis: orientation

Anisotropic properties



Isotropic CNT network



Anisotropic CNT network

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Post processing

Freestanding film manufacturing

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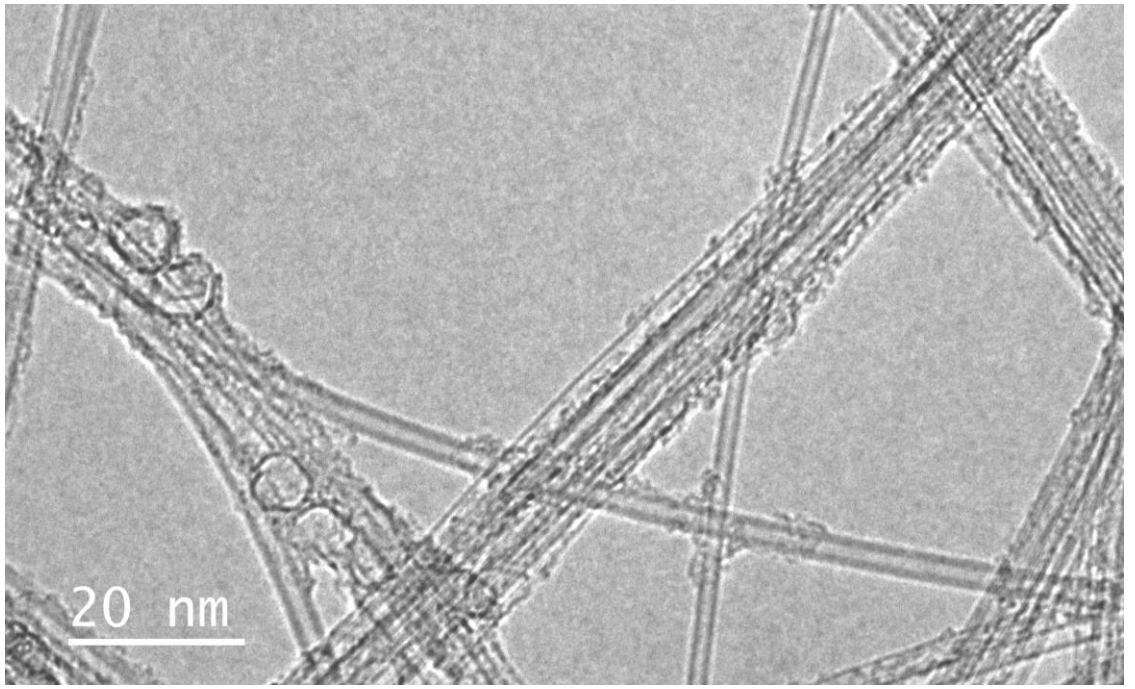
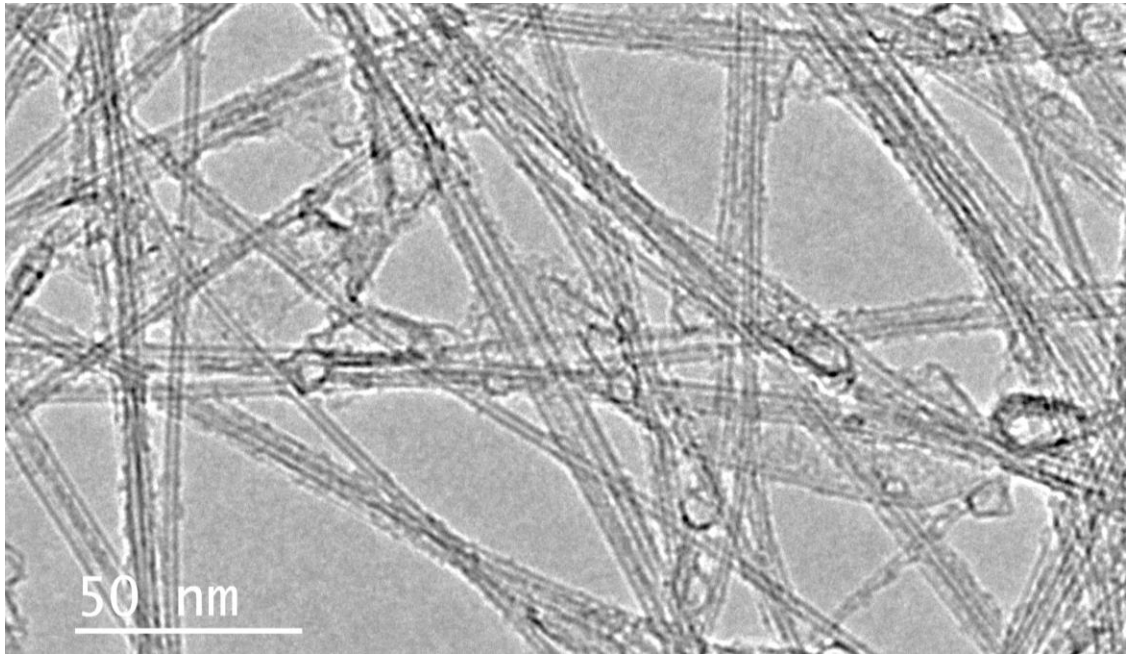
CNT membrane purification

- *A high-temperature vacuum purification process*

Rutherford backscattering (RBS), courtesy of imec

After purification	at-%
C	98.19
O	1.78
Catalyst	0.03





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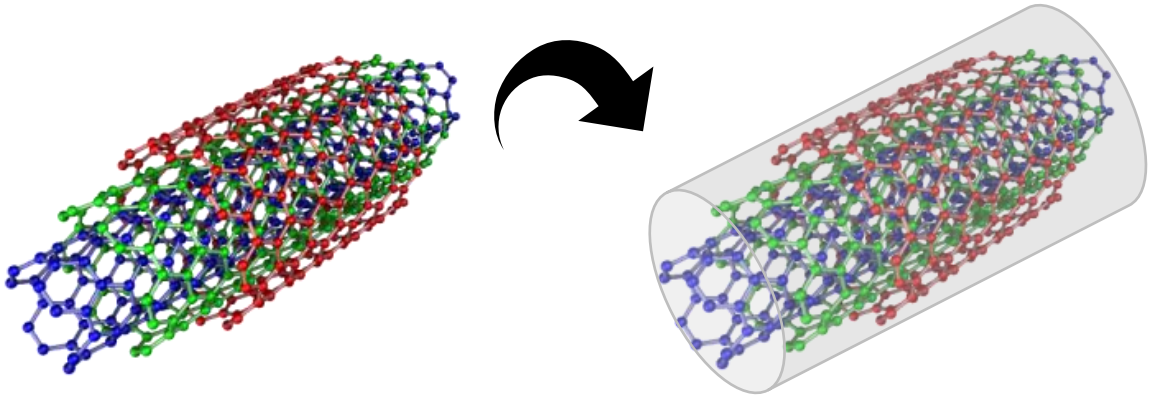
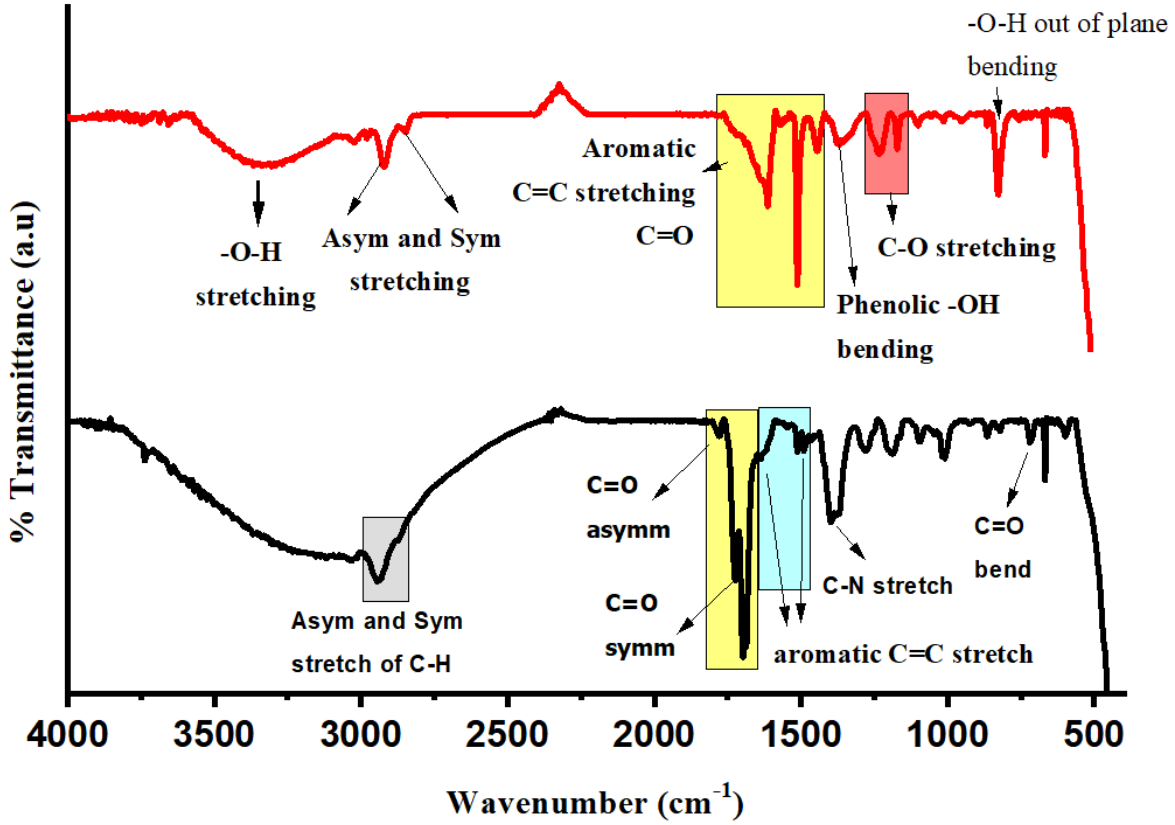
Functionalization

Wet or dry functionalization matches the CNT surface chemistry to the specific chemistry used in ALD, CVD, or PVD deposition

- *High coating conformality*
- *Better coating thickness control*



CNTs *Functionalized-CNTs*



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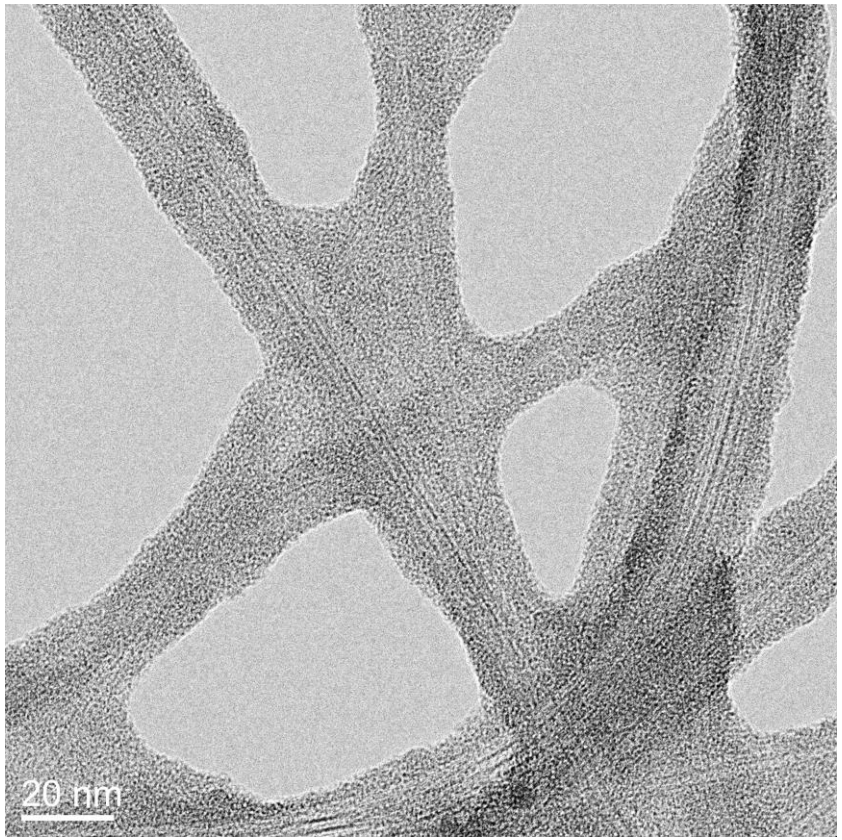
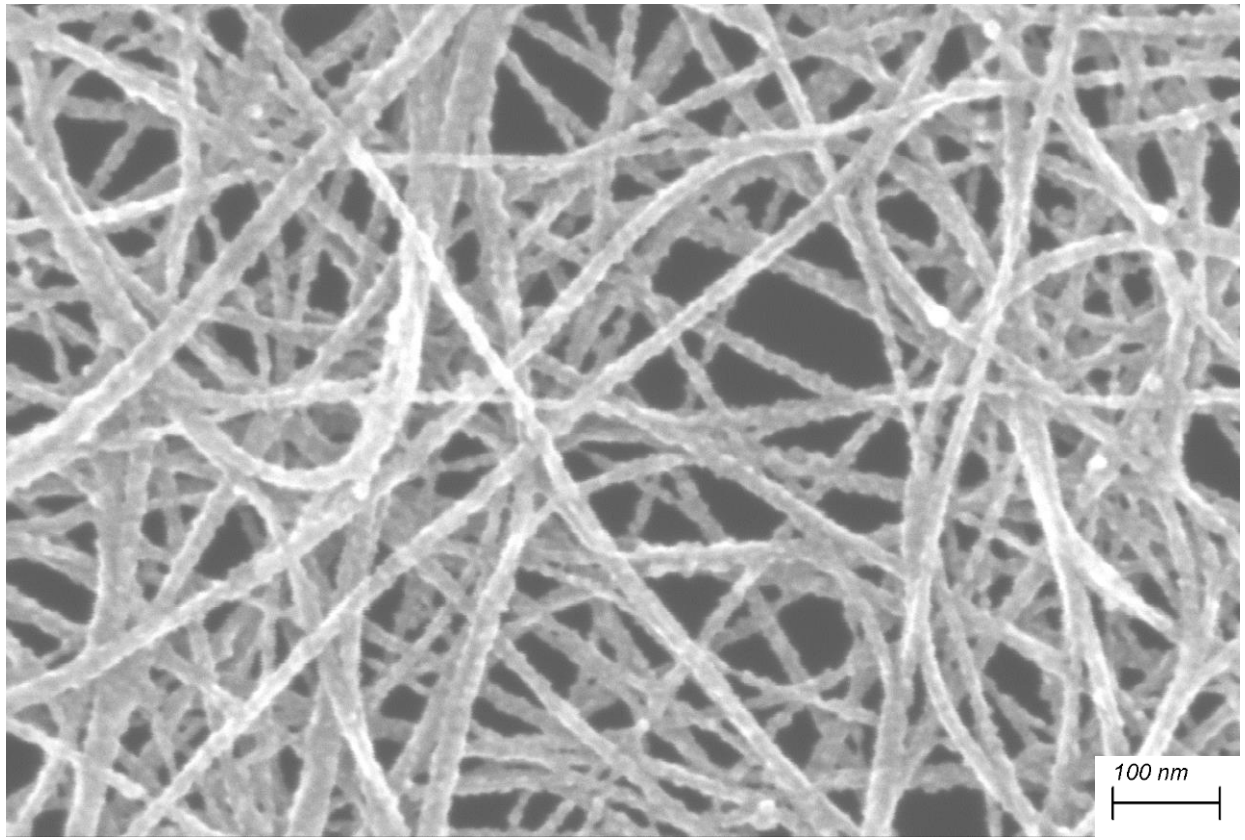
Coatings

A novel electrochemical coating method for freestanding CNT membranes (patents pending)

- *Coating conformality control*
- *Thickness control*





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Application example

EUV Debris filter

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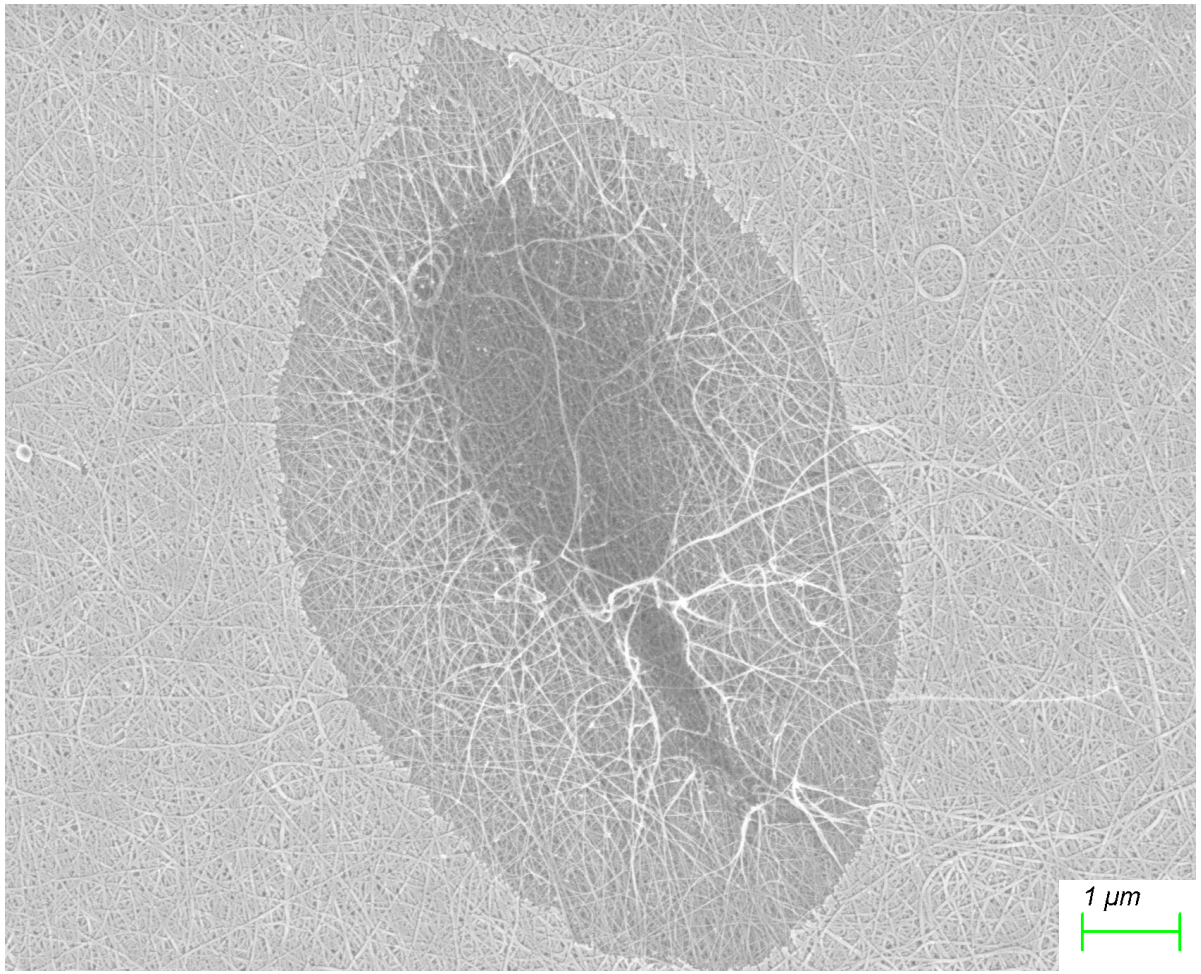
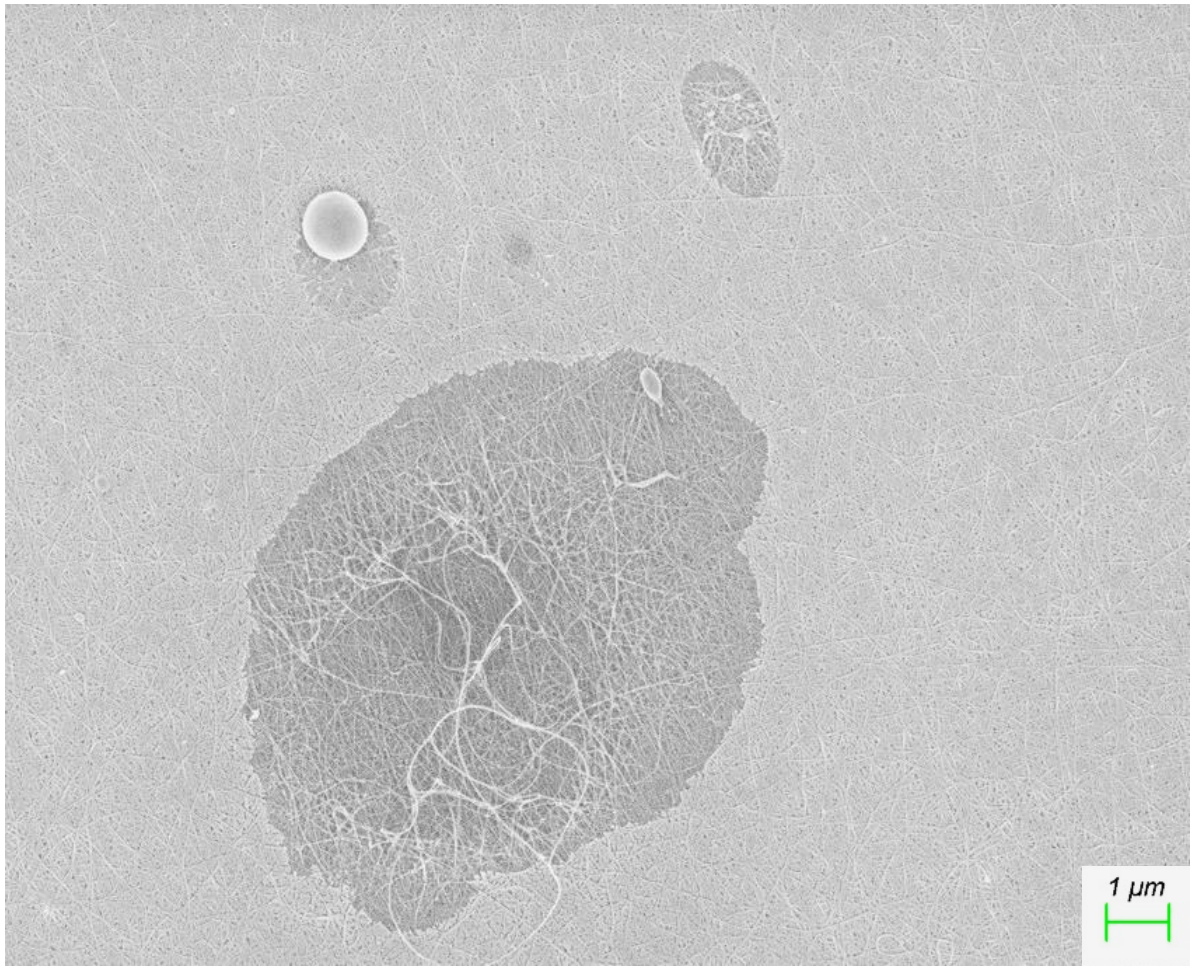
Debris filtering – Particle stopping





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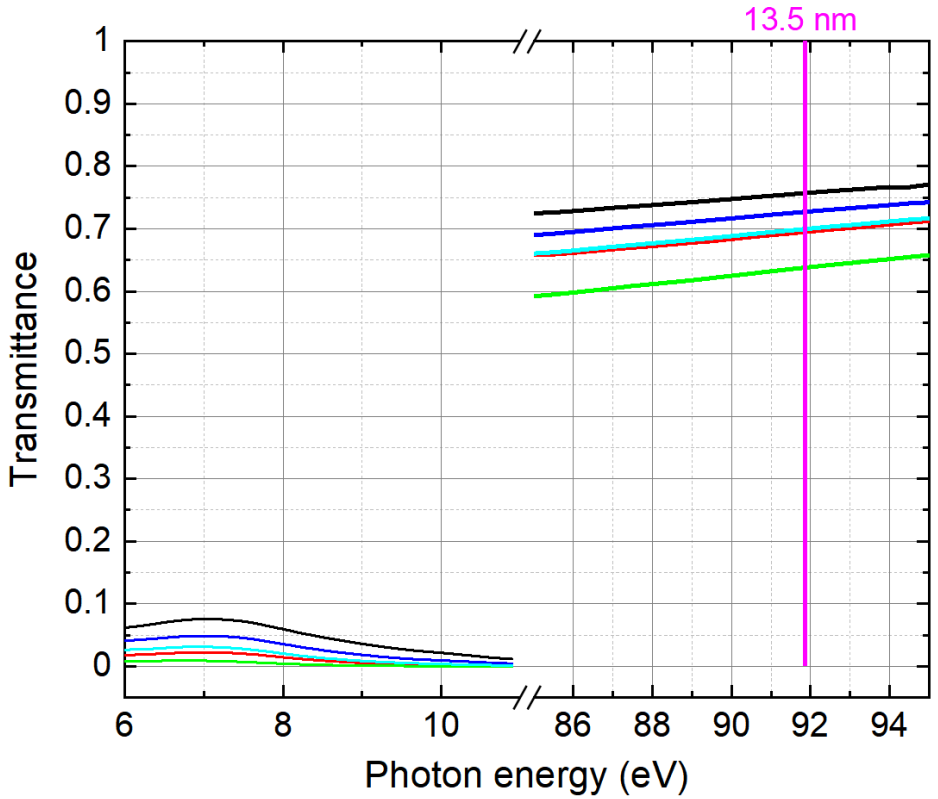
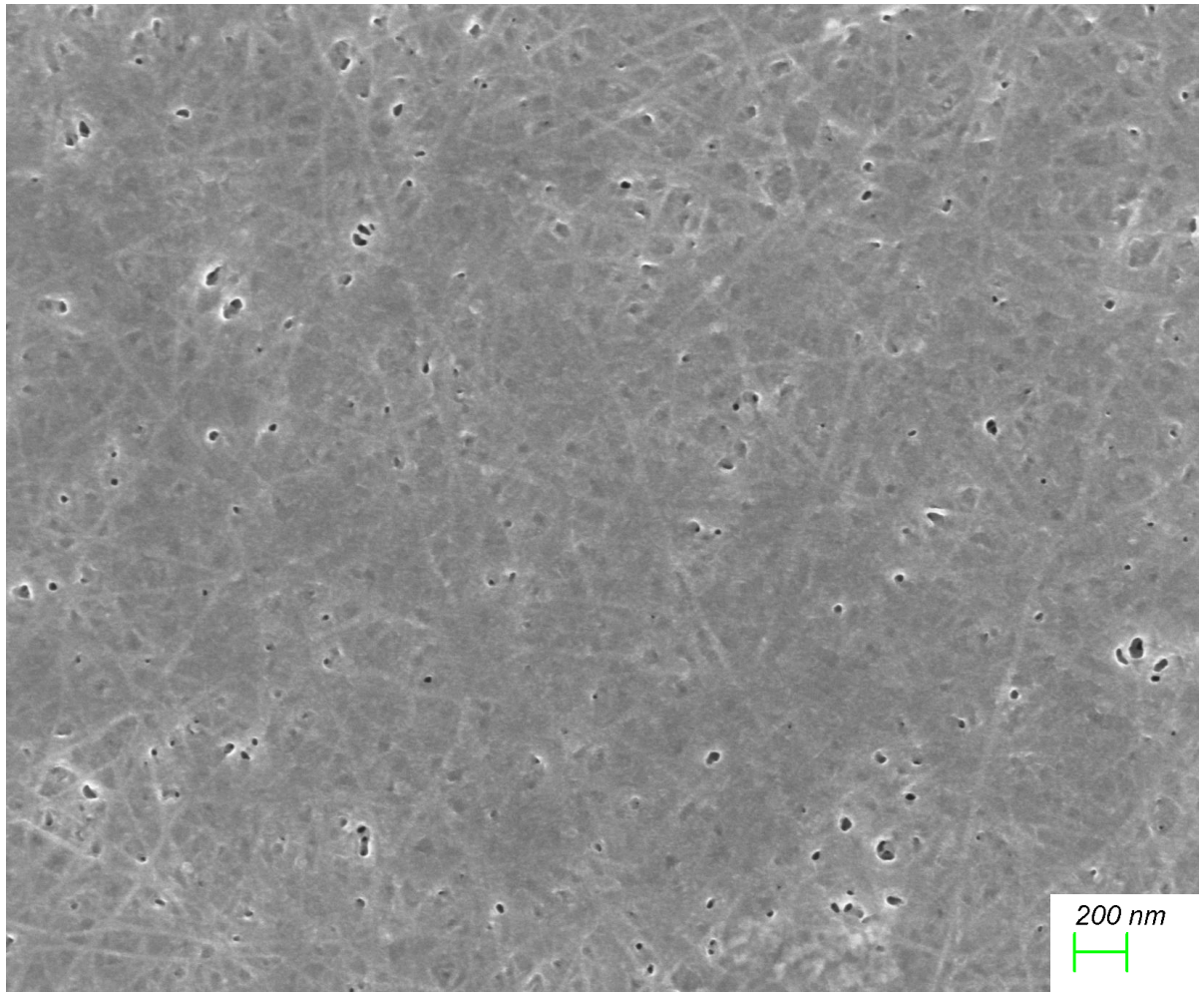
DUV filtering

The appropriate coating on CNT enables the removal of DUV photons – while keeping EUVT high





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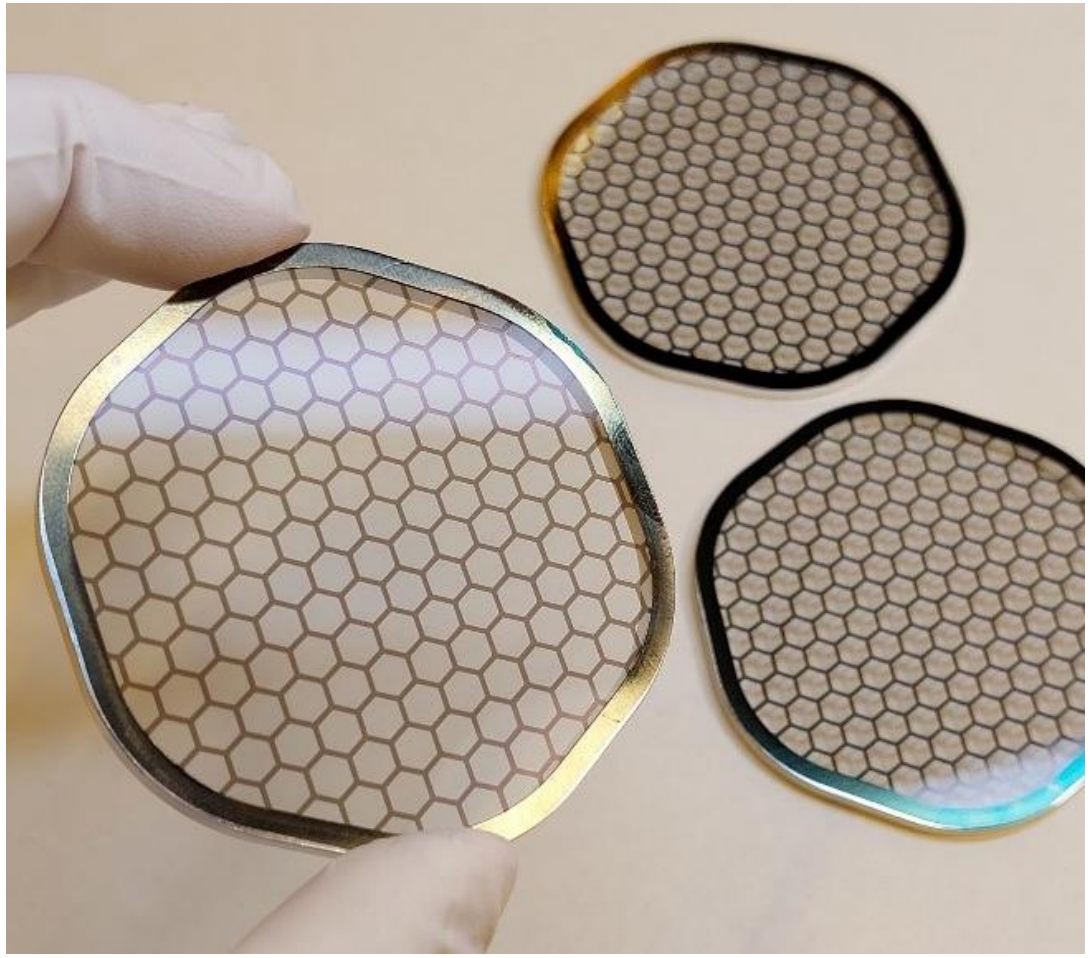
Carbon nanotube support mesh

A novel mesh structure manufactured from Canatu CNTs provides an alternative to conventional metal meshes

- *Enhanced mechanical properties*
- *Excellent film-to-mesh adhesion*
- *Stops film tear propagation after puncture*
- *A wide range of shapes and dimensions to minimize EUVT loss*
- *Retains spectral purity in X-ray applications*



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Canatu

- *Builds and develops CNT synthesis reactors*
- *Manufactures free-standing CNT membranes*
- *Develops CNT post-processing*

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I want to thank my co-authors:
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