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Aerogel Structures for Photocathodes

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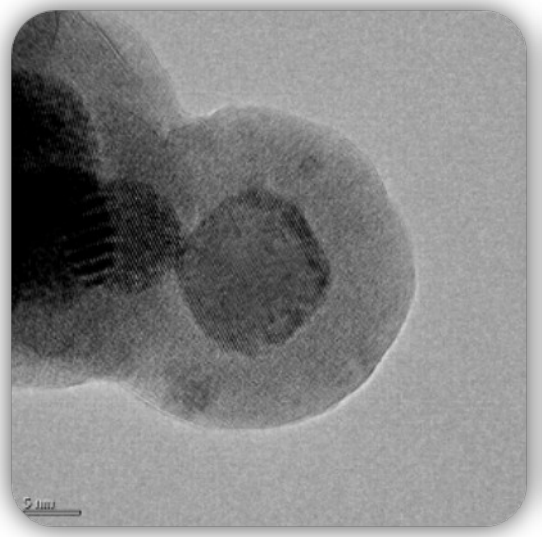
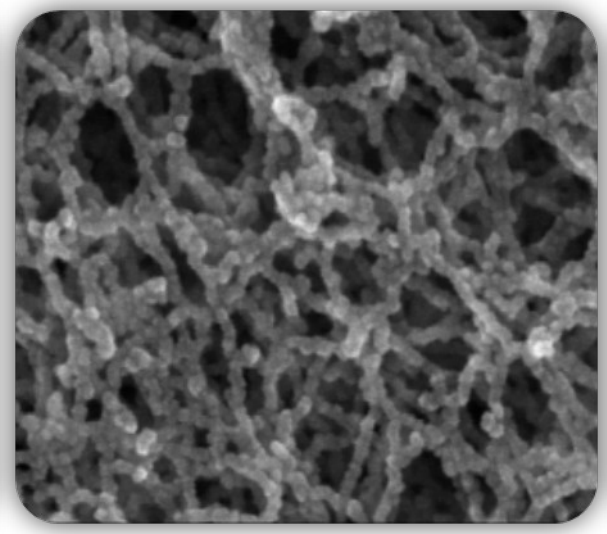
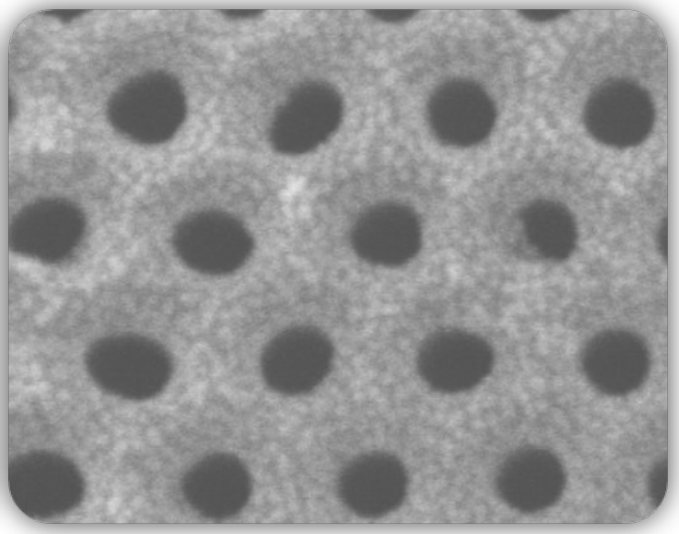
1st Workshop on Photo-cathodes: 300nm-500nm
July 20-21, 2009: University of Chicago

Atomic Layer Deposition (ALD)

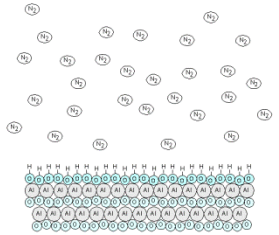
- Layer-by-layer thin film synthesis method
- Atomic level control over thickness and composition (even on very large areas)
- Precise coatings on 3-D objects
- Some unique possibilities for morphology control

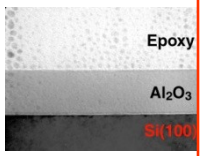




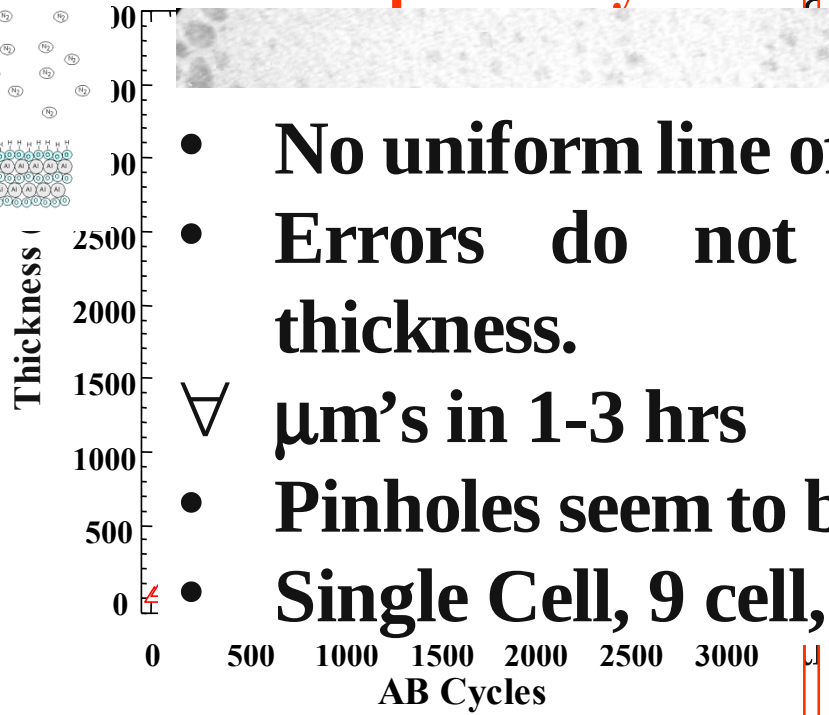


ALD Reaction Scheme





Ellipsometry



- Film growth is linear with AB Cycles

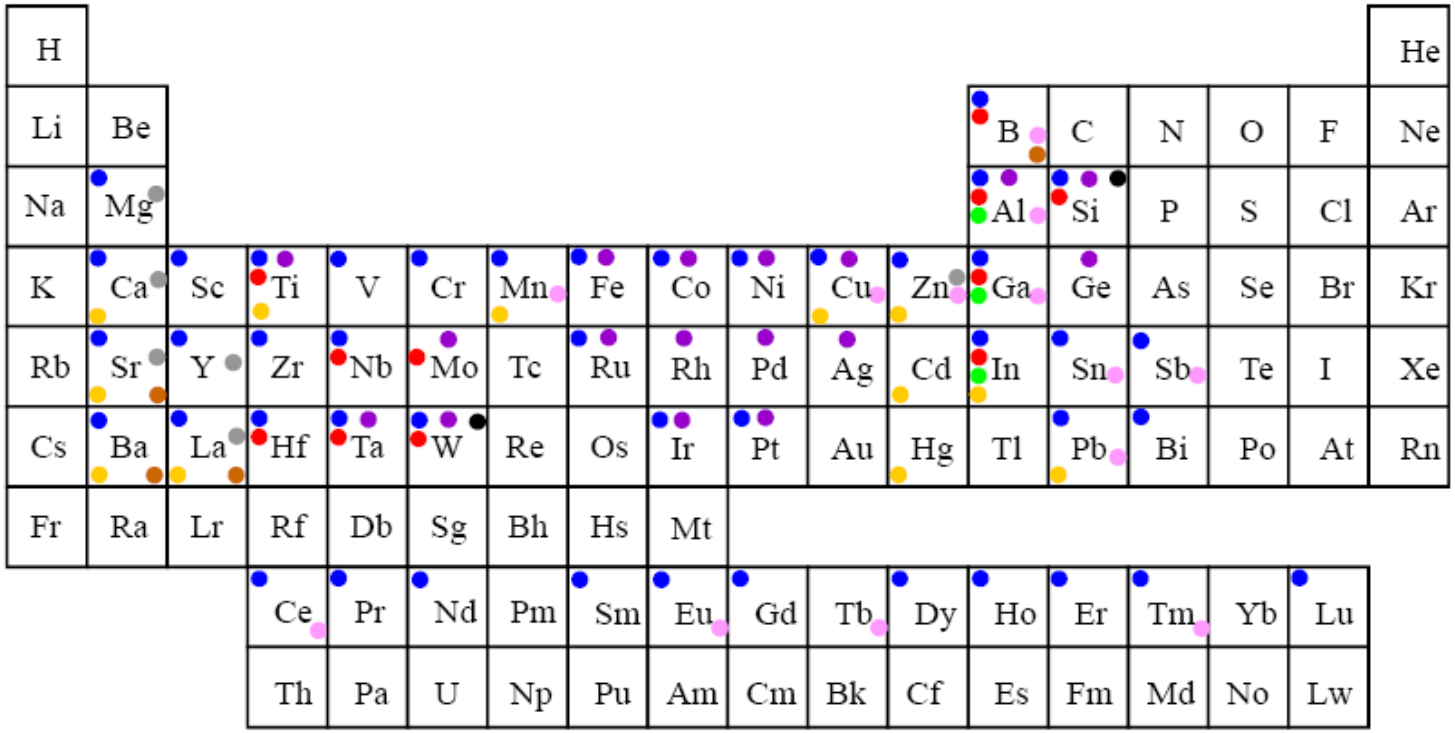
Atomic Force Microscopy

- RMS Roughness = 4 Å (3000 Cycles)
- ALD Films Flat, Pinhole free

- **No uniform line of sight requirement!**
- **Errors do not accumulate with film thickness.**
- ∀ **µm's in 1-3 hrs**
- **Pinholes seem to be removed.**
- **Single Cell, 9 cell, re-entrant, *in situ***

● Flat, Pinhole-Free Film

ALD Thin Film Materials



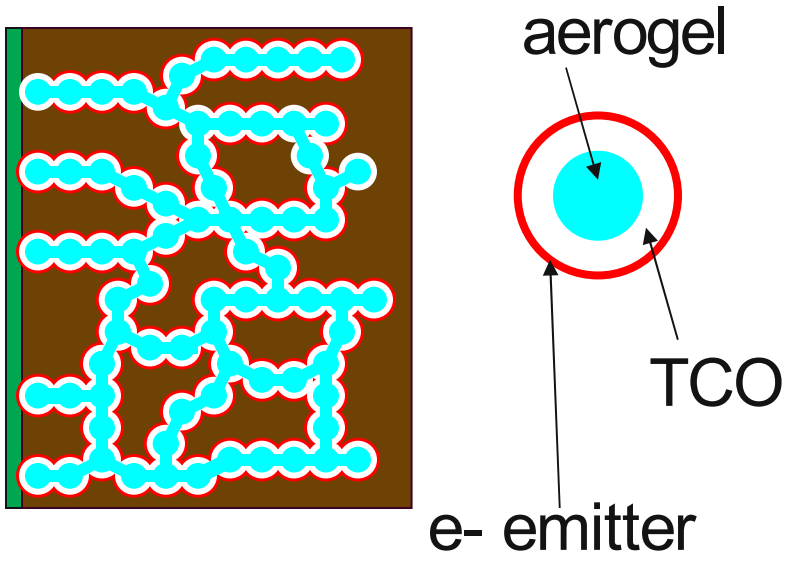
- Oxide
- Nitride
- Phosphide/Arsenide
- Sulphide/Selenide/Telluride

- Element
- Carbide
- Fluoride
- Dopant

Why Aerogels?

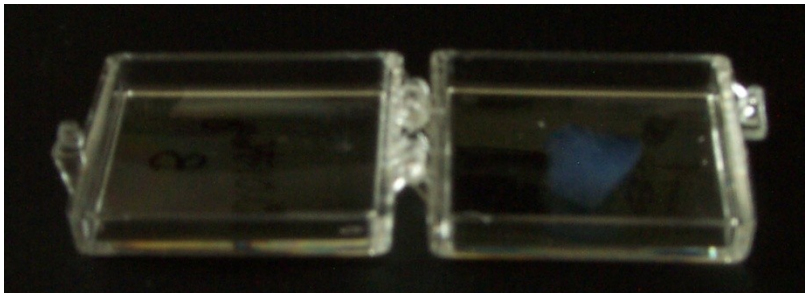
- Readily fabricated
- Extraordinary surface area and amplifying ability
- Pseudo-1D e^- transport (with many cross links)
- High porosity → improved efficiency
- Multi-component ALD → allows biasing, recharging, efficient electron emission

Dark Current vs Signal
-> everywhere the same
radius of curvature



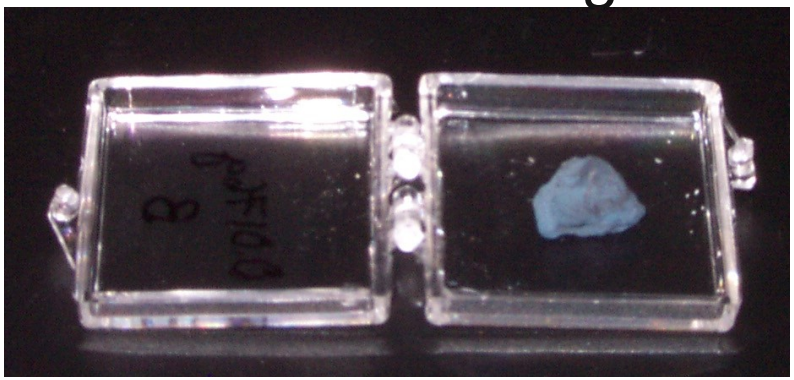
Silica Aerogel Coated with ZnO

Before Coating



Weight = 0.0176 g

After Coating



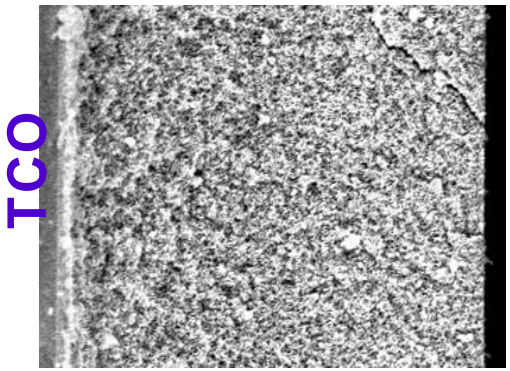
Weight = 0.1122 g

ALD Coating Conditions:
19 Cycles DEZ/H_2O
3 nm ZnO Coating
10 Torr, 100 s Exposures
T=177 °C

Weight Increase
=537%

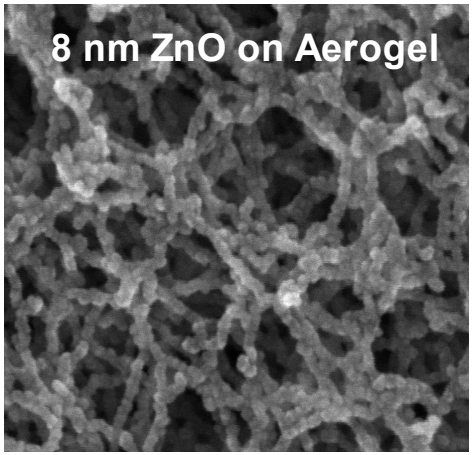
Aerogel Photoelectrodes:

- High TCO loading (=conductance)
- Continuous coating by ALD (conductivity measurements and SEM)
- Growth on TCO platforms
- High porosity



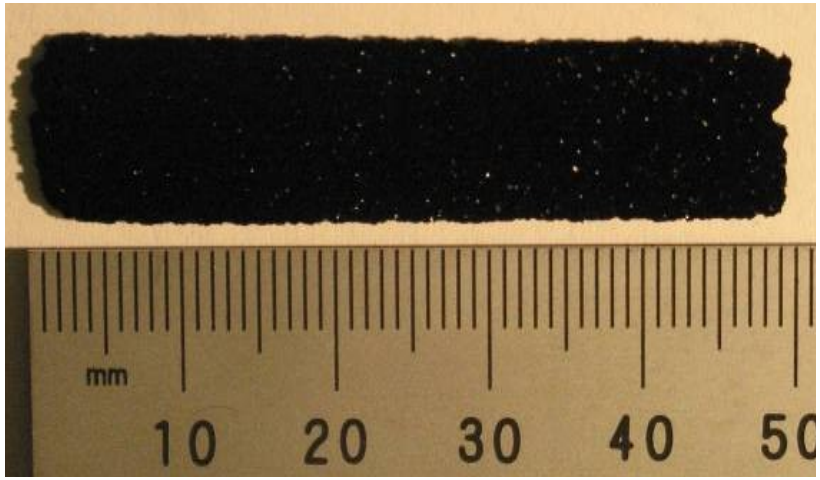
Aerogel film

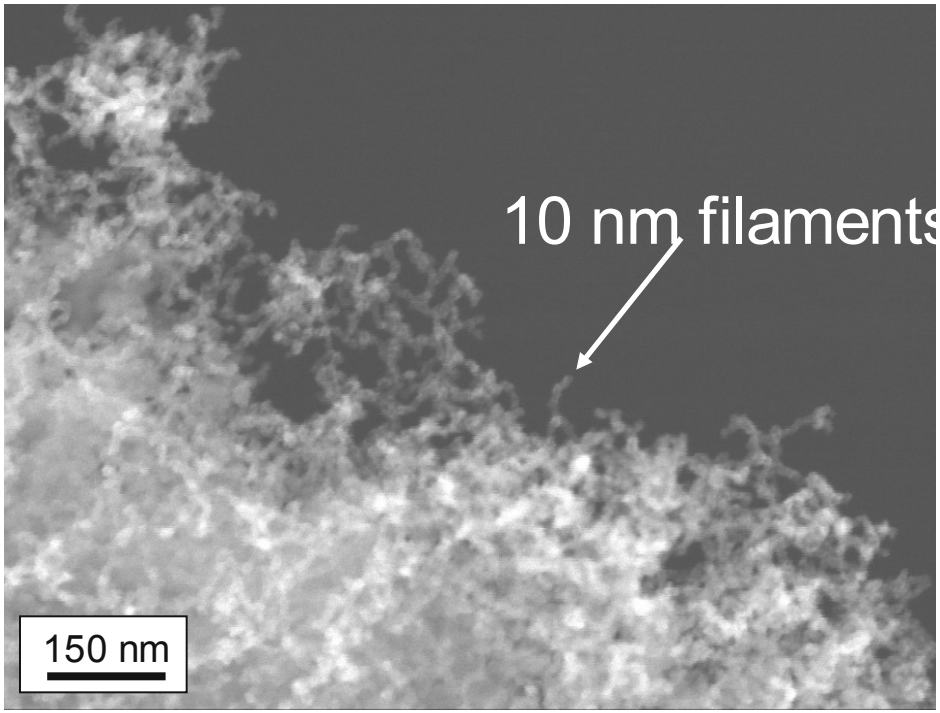
- Lower manufacturing cost than other PV technologies
- Non-vacuum, low temperature fabrication
- Very tolerant to impurities (no clean room necessary) – light absorption and charge separation occur close to interface
- Inexpensive, abundant, benign materials (e.g. TiO_2, ZnO)
- Robust nanoscale process



Carbon Aerogels

Density = 0.082 g/cc
Surface area=214 m^2/g
Manufacturer=Southern Research Institute





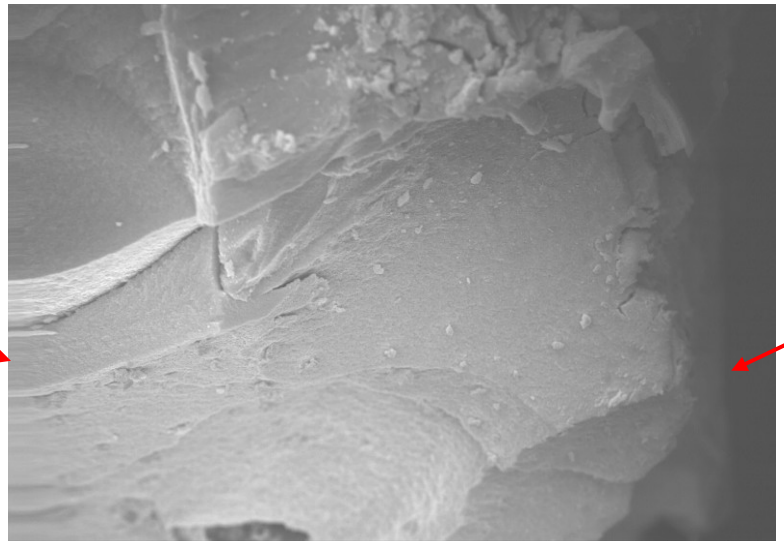
Aerogel Coating Conditions:

2) Nucleation Layer: 0.2 nm Al_2O_3
   2 Cycles TMA/H_2O 5 Torr
   600-300-600-300 s
   T=200 °C

2) Metal Layer: 4 nm W
   15 Cycles Si2H6 (5 Torr)/WF6 (10 Torr)
   600-300-600-300 s
   T=200 °C

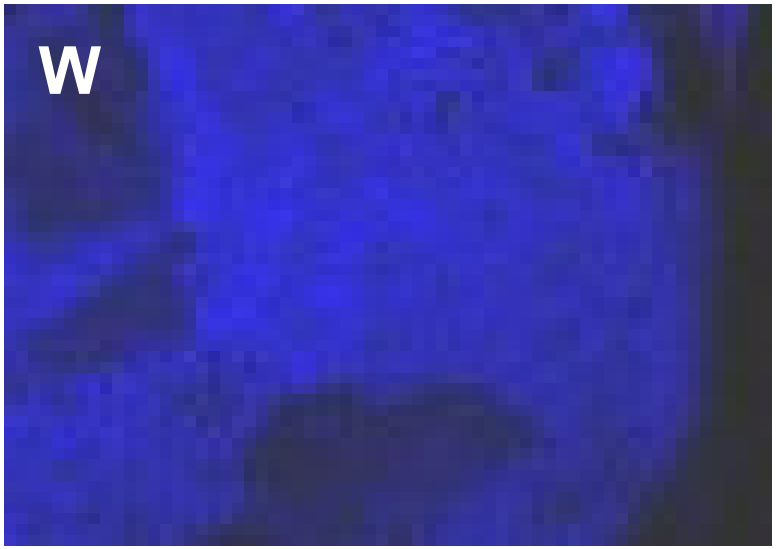
EDAX Maps of 10 nm ALD C-Aerogel

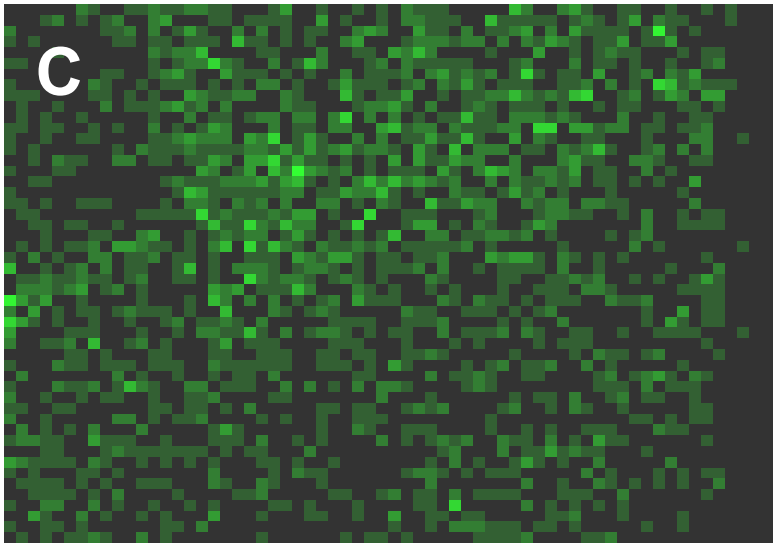
Cross section Of ALD Coated and cleaved 1 mm thick middle **C-Aerogel:**



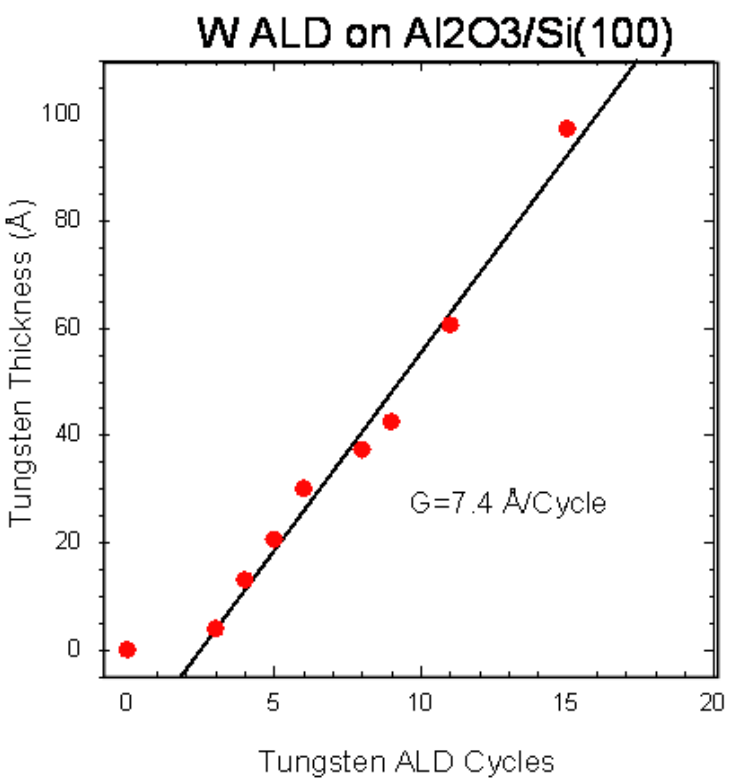
edge

- ALD W extends to middle of 1 mm thick carbon aerogel

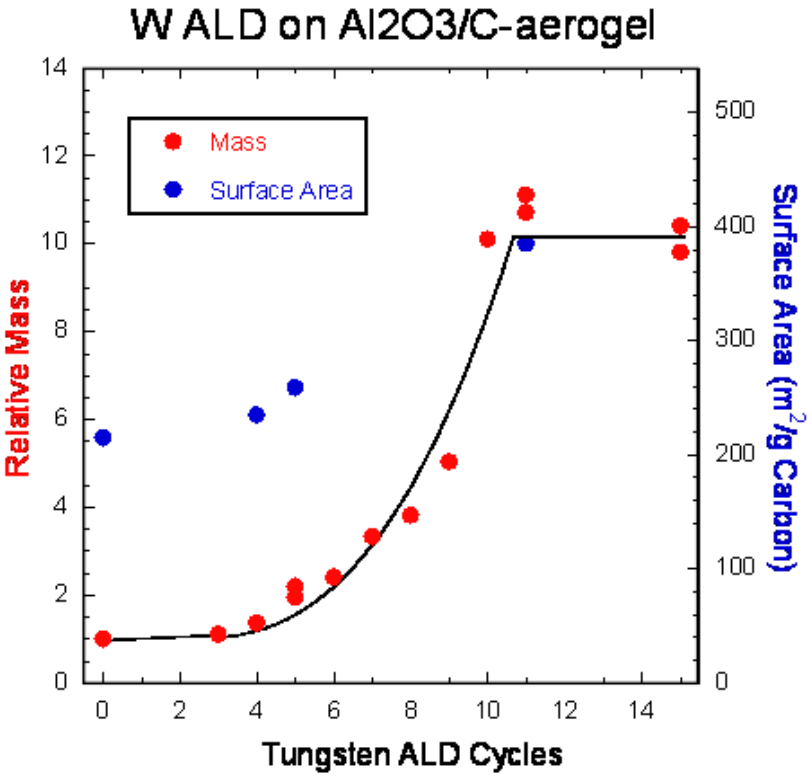




W Growth on C Aerogel



Linear growth following
3 c nucleation



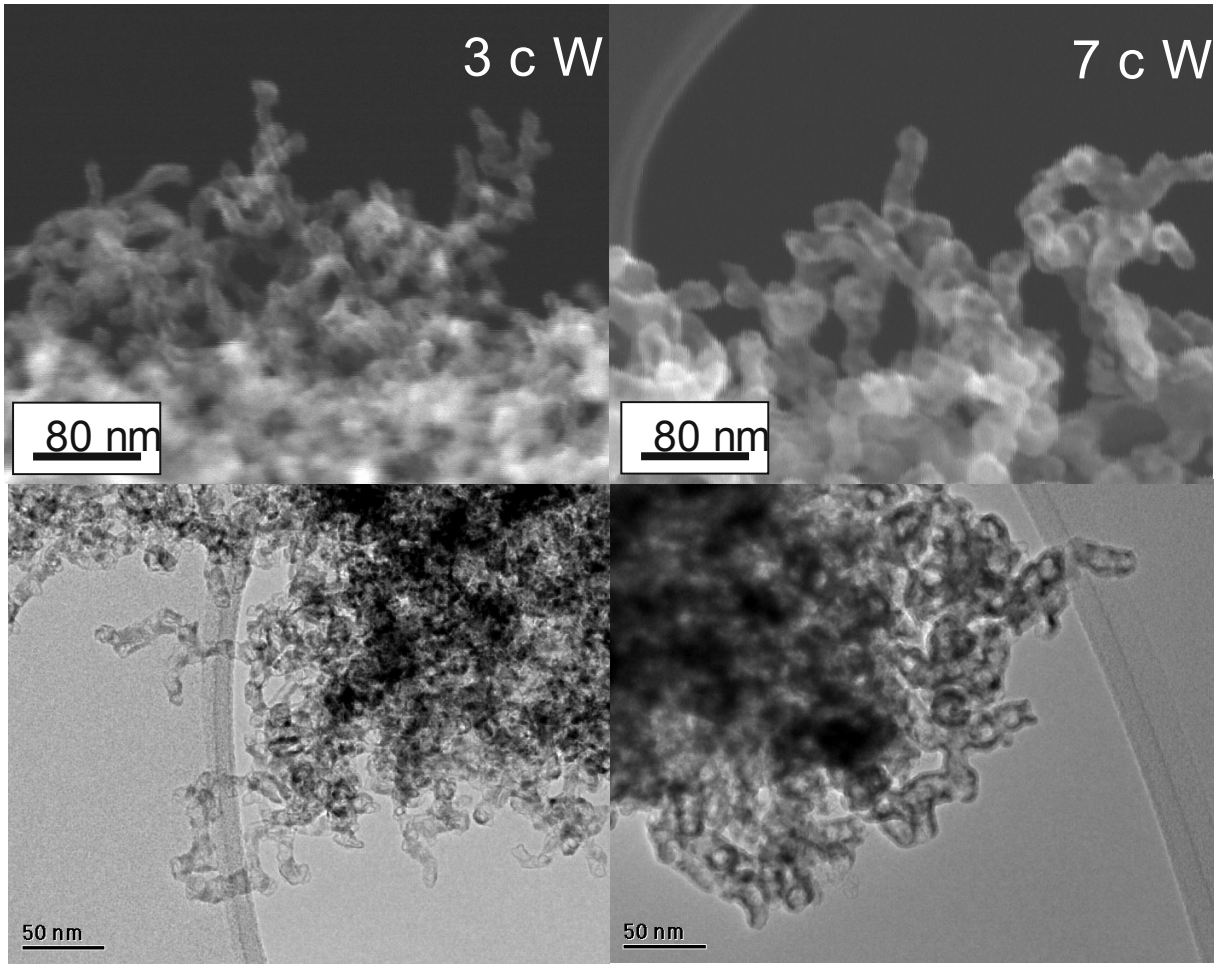
Quadratic growth after 3 c nucleation
Saturation after ~ 10 c
Surface area increases with W thickness

- Closed pore volume

Microscopy of W-Coated Carbon Aerogels

SEM

TEM



- **Aerogel filament diameter increases with ALD W Cycles**

Metal-coated aerogels are pyrophoric!

Conclusions: Aerogels

- Aerogels are one of many nanostructured materials that may be of interest to the detector community.
- Aerogels can be coated allowing the resistivity necessary to provide a kilovolt gradient.
- Abundant surface area means amplification should be achieved over relatively thin structures.
- Large areas are relatively easy to achieve + the self limiting properties of ALD encourages one to believe that these large areas can be uniformly coated.
- Interestingly
  - channel plate detectors achieve uniform flight times with very uniform structures
  - Aerogels would achieve uniformity with random structure averaging
- Remember 2ndary electrons are ejected without memory of their incoming direction.