# Hollow Fiber Sorbents for Post-Combustion $CO_2$ Capture

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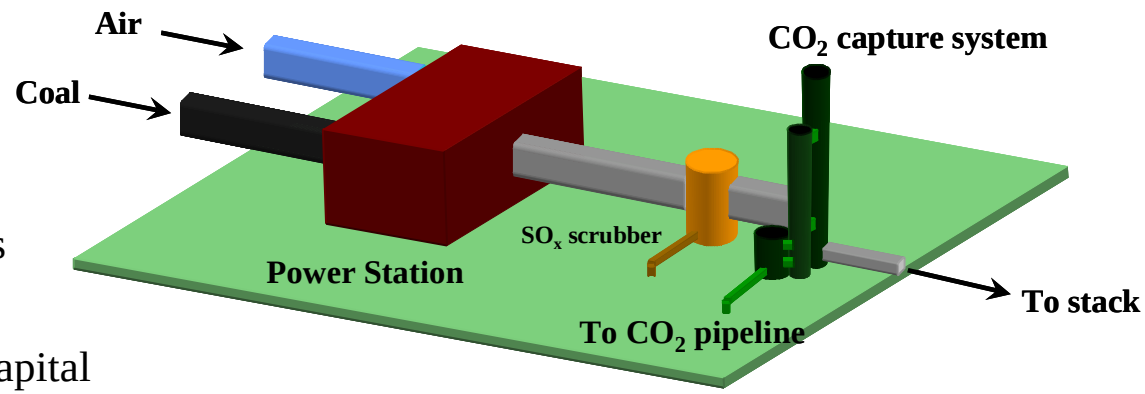
June 24th, 2009

# Motivation

- 500 MW coal power stations produce ~*9.2 tons of* $CO_2$ *per min*
- $CO_2$ mitigation seems to be a future step
- Current mitigation routes are expensive
  - Oxy-fuel
  - IGCC with pre-combustion capture
  - Post combustion (liquid amines)
- Developing low-cost approach is key for implementation

# $CO_2$ Capture Methods

- Post-Combustion Capture
  - Advantages
    - Straightforward retrofit
  - Disadvantages
    - Low $CO_2$ partial pressures
    - Large volumes of gas
    - Available technology is capital and energy intensive

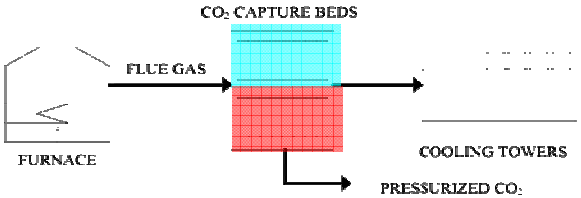



- The majority of the USA's power infrastructure cannot support other capture methods
- *Post-combustion capture is the single biggest opportunity for adoption of carbon capture and storage*

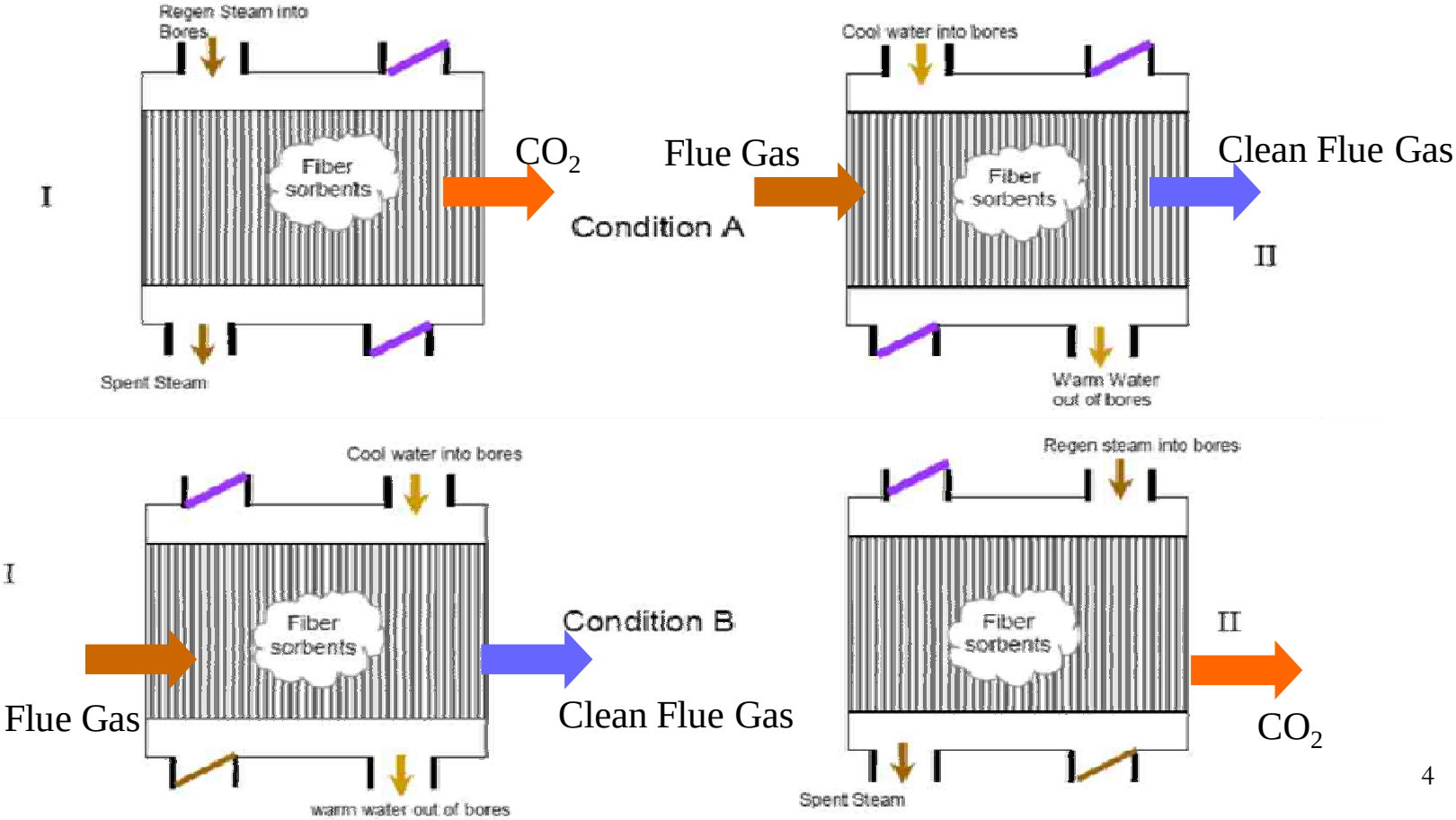
# Hollow Fiber Sorbents: Basic Approach

- **How will the $CO_2$ be captured?**

<u>Design Basis</u>: 500 MW ~ 9.2 tons $CO_2$/min, 1M SCFM, 15mol% $CO_2$

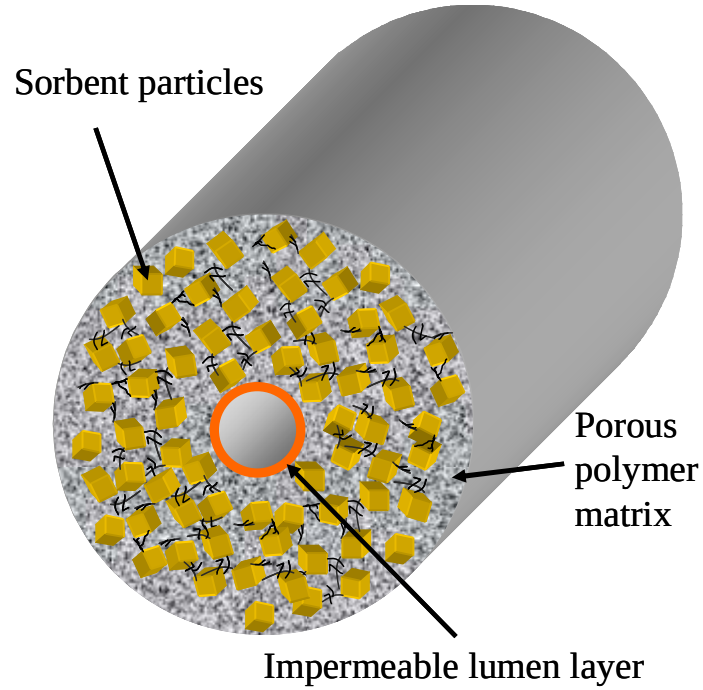


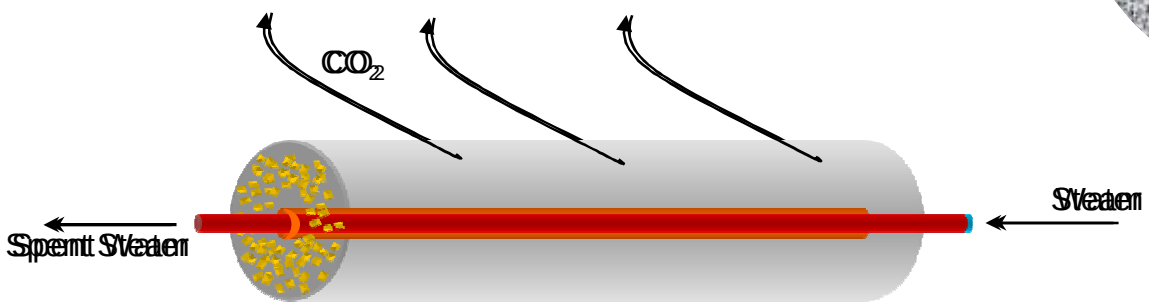

*Rapid Temperature Swing Adsorption (RTSA) based on Hollow Fiber Sorbents*



# Hollow Fiber Sorbents: Structure

- **What is a hollow fiber sorbent?**
  - Hybrid material—polymer matrix with embedded sorbent particles
    - High solids loading
  - Designed for $CO_2$ capture
  - Novel lumen layer



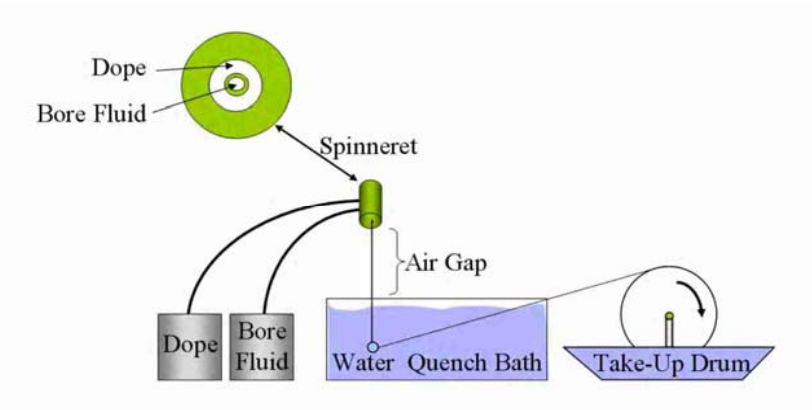



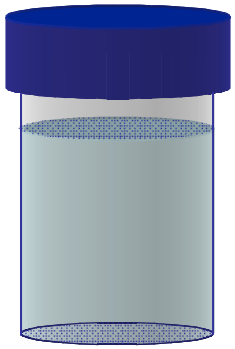

*Cooling water used to aid in <u>sorption</u> process. Plant steam used for <u>desorption</u> step.*

*Thin fiber wall allows for rapid heat transfer. Barrier layer prevents mass exchange between heat transfer agent and $CO_2$*

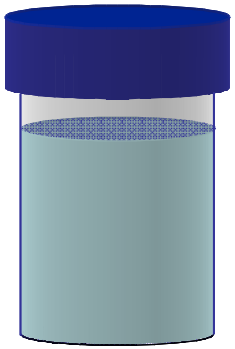
# Hollow Fiber Sorbents: Fabrication

- Extrusion through a concentric annulus
- Fiber characteristics are controlled by:
  - Extrusion rate
  - Fiber take up rate
  - Air gap height
  - Operating temperature

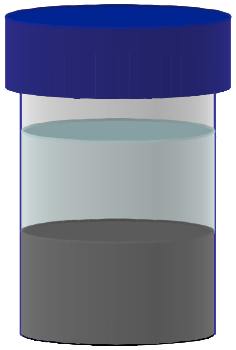


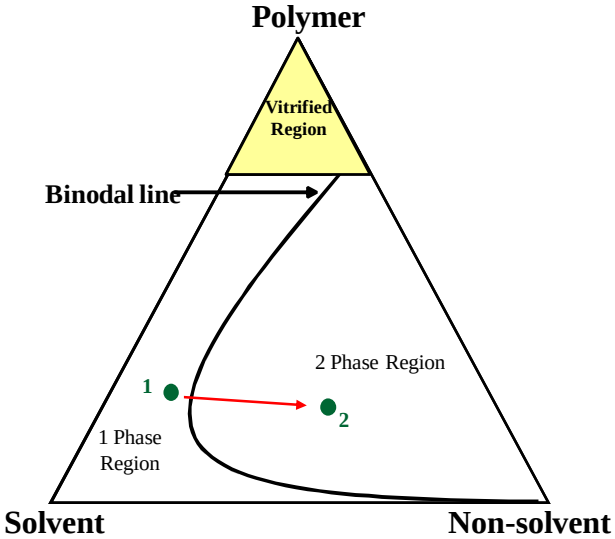
*1 phase polymer solution*



*"Cloud Point"*



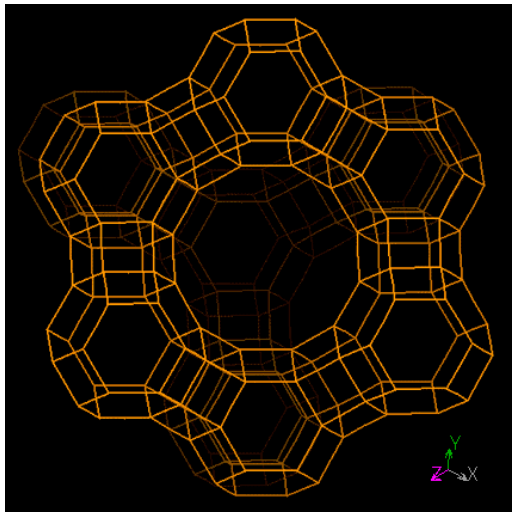
*2 phase polymer solution*

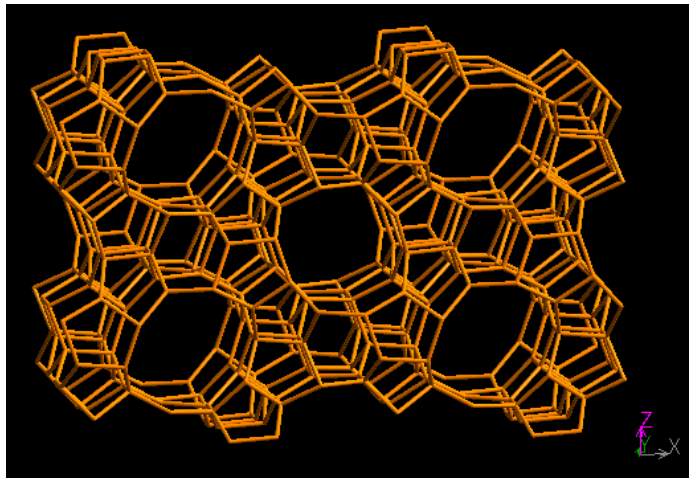


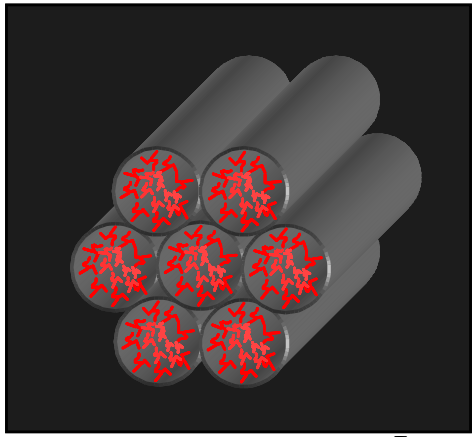

**Ternary Diagram**

# Sorbent Selection

| **Sorbent** | **Zeolite 13X** | **High Silica MFI** | **Anchored Amines** |
|---|---|---|---|
| $CO_2$ Dry Sorption Capacity 40° C | High | Medium | Low |
| $CO_2$ Wet Sorption Capacity 40° C | Very Low | -- | Medium |
| Heat of Sorption | Medium | Low | High |
| Diffusion Coefficient [$cm^2/s$] | $10^{-5}$ | $10^{-7}$ | -- |







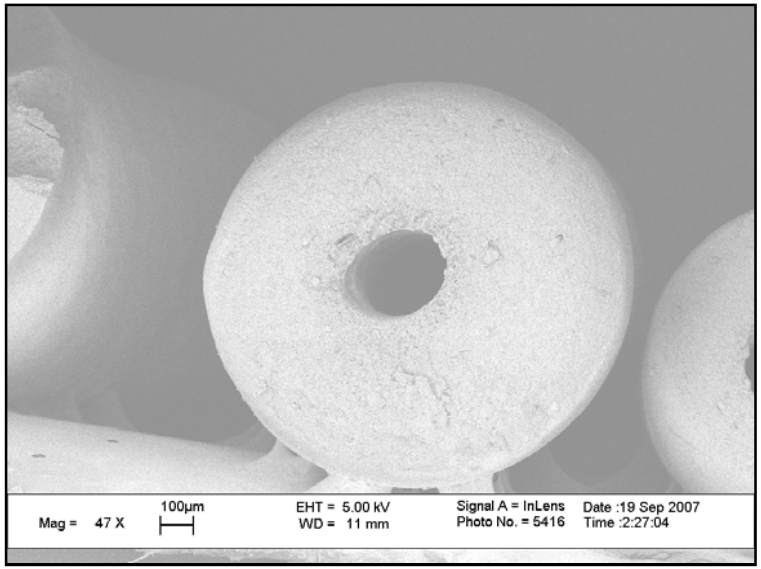
# Fiber Sorbent Spinning: 75wt% Solids

## Materials Considered

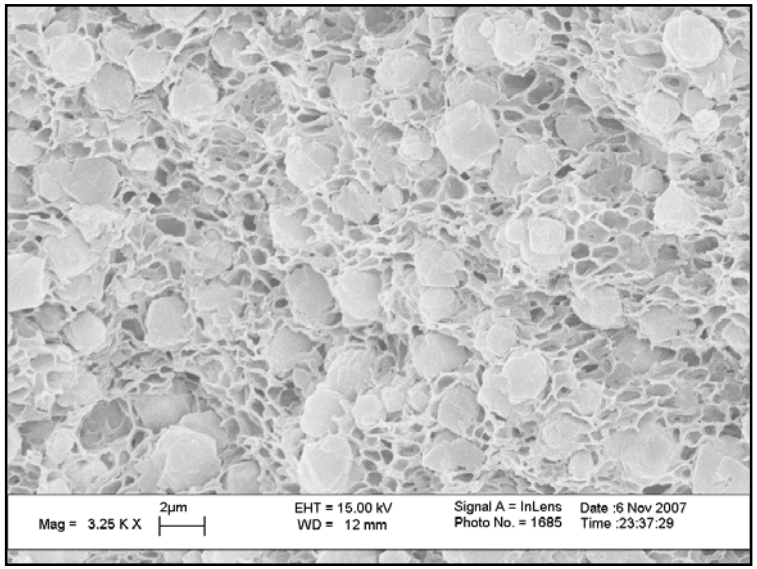
**MFI →**
Difficulty dispersing during initial attempts
**Elastomeric Polymers →**
Adhered strongly to sorbent surface
**Polysulfone →**
Could not support high inorganic loadings

## Materials Used

| | |
|---|---|
| ***Sorbent*** | Zeolite 13X |
| ***Polymer*** | Cellulose Acetate |
| ***Solvent*** | N-methylpyrrolidone |
| ***Non-Solvent*** | Water |
| ***Pore Former*** | Polyvinyl pyrrolidone |

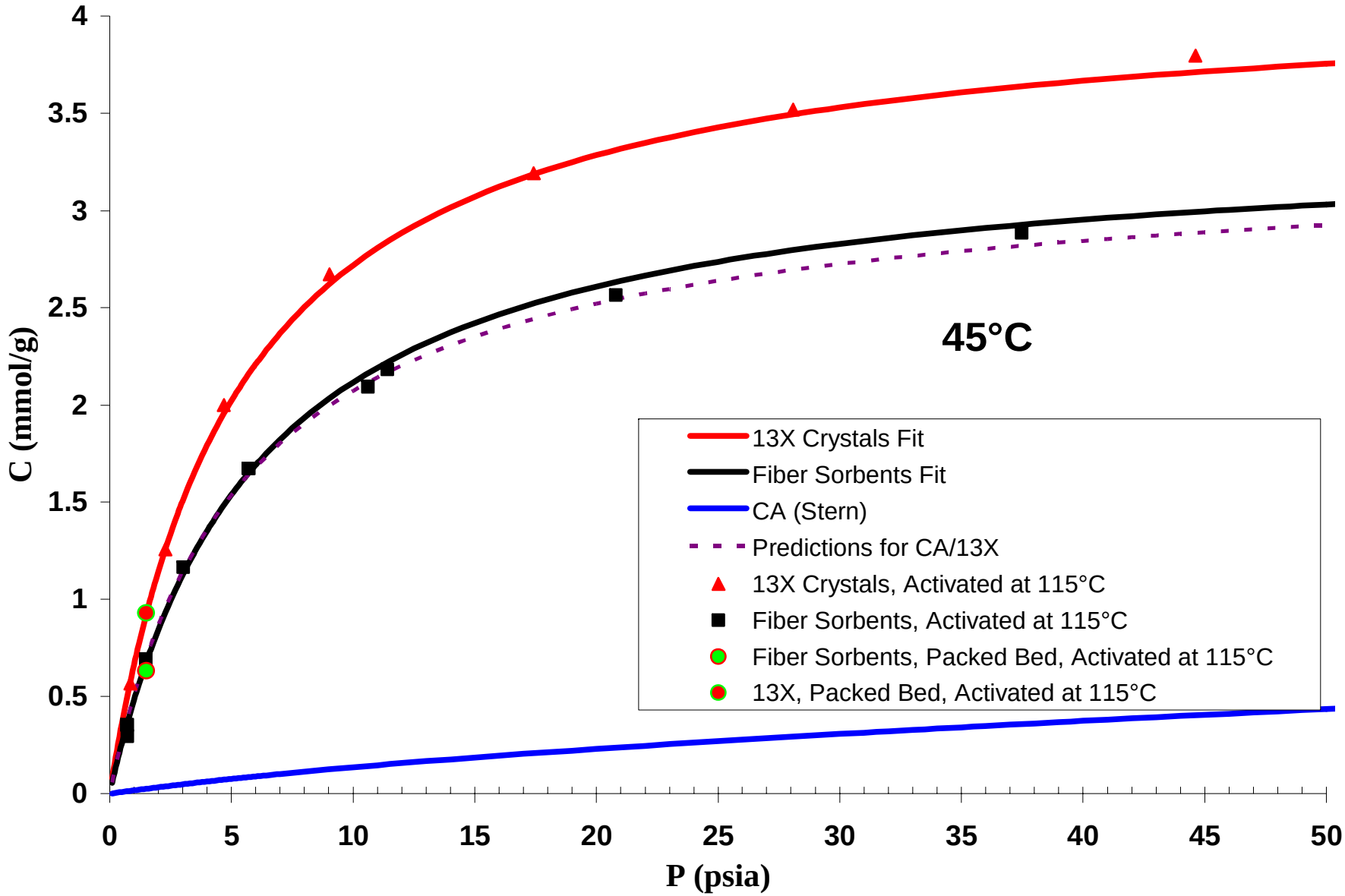



*Fiber sorbent with correct dimensions*



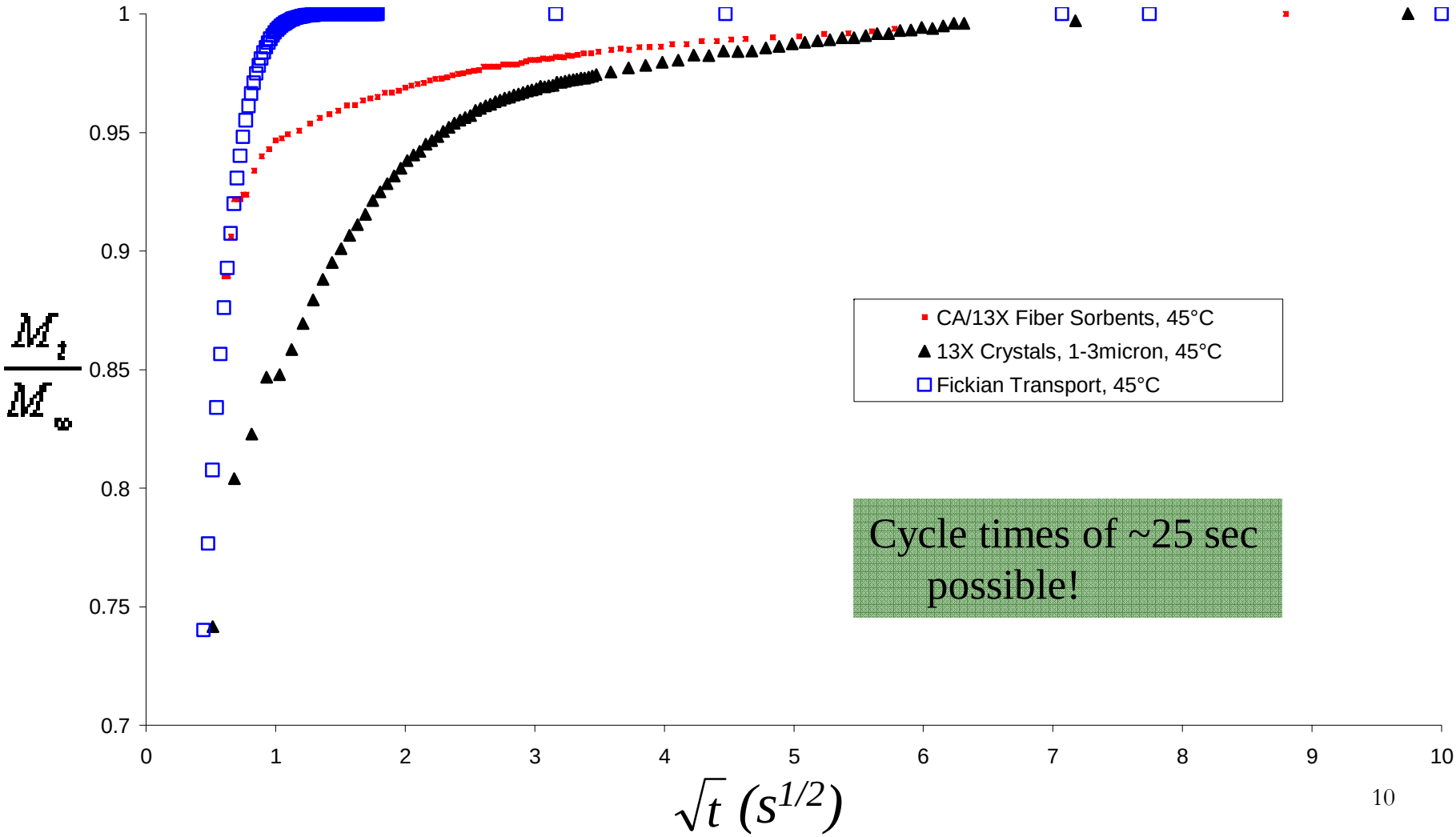

*Zeolite 13X dispersed in cellulose acetate matrix*

# Equilibrium $CO_2$ Sorption



# Response Times

## Kinetic $CO_2$ Sorption; CA/13X, Feed Pressure: 10 psia

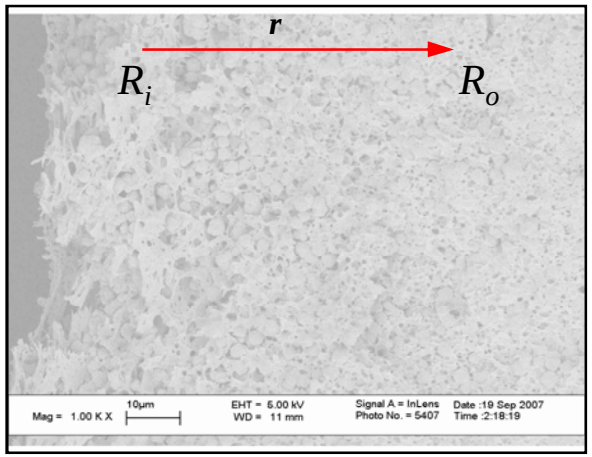



Cycle times of ~25 sec possible!

# Barrier Layer Construction

Decreasing porosity in r-direction

- ~30 microns
- Gradient serves as a backstop for latex




*Porosity "gradient" in fiber sorbents*

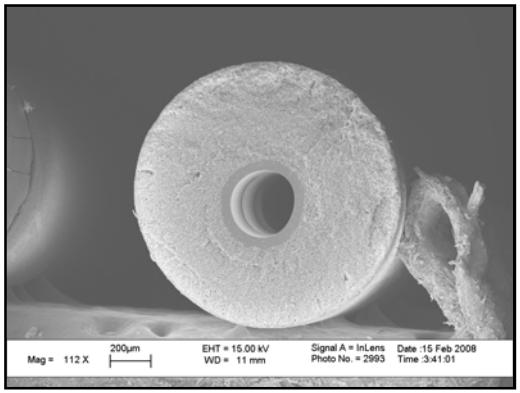
Permeation Results:

Uncoated: $N_2$~60,000 GPU

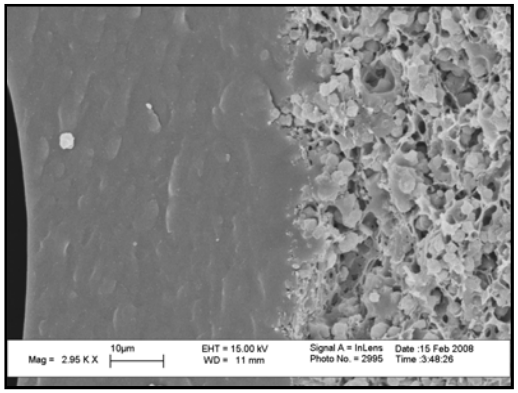
Coated: $N_2$~0.01-3.0 GPU

$CO_2/N_2$ selectivity ~ 1

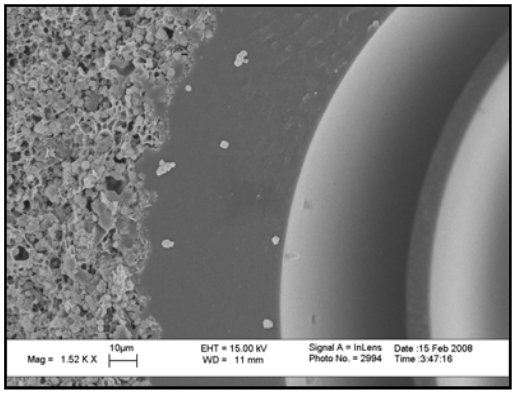
→ Pinhole defects!



*PVDC lumen layer on fiber sorbents*



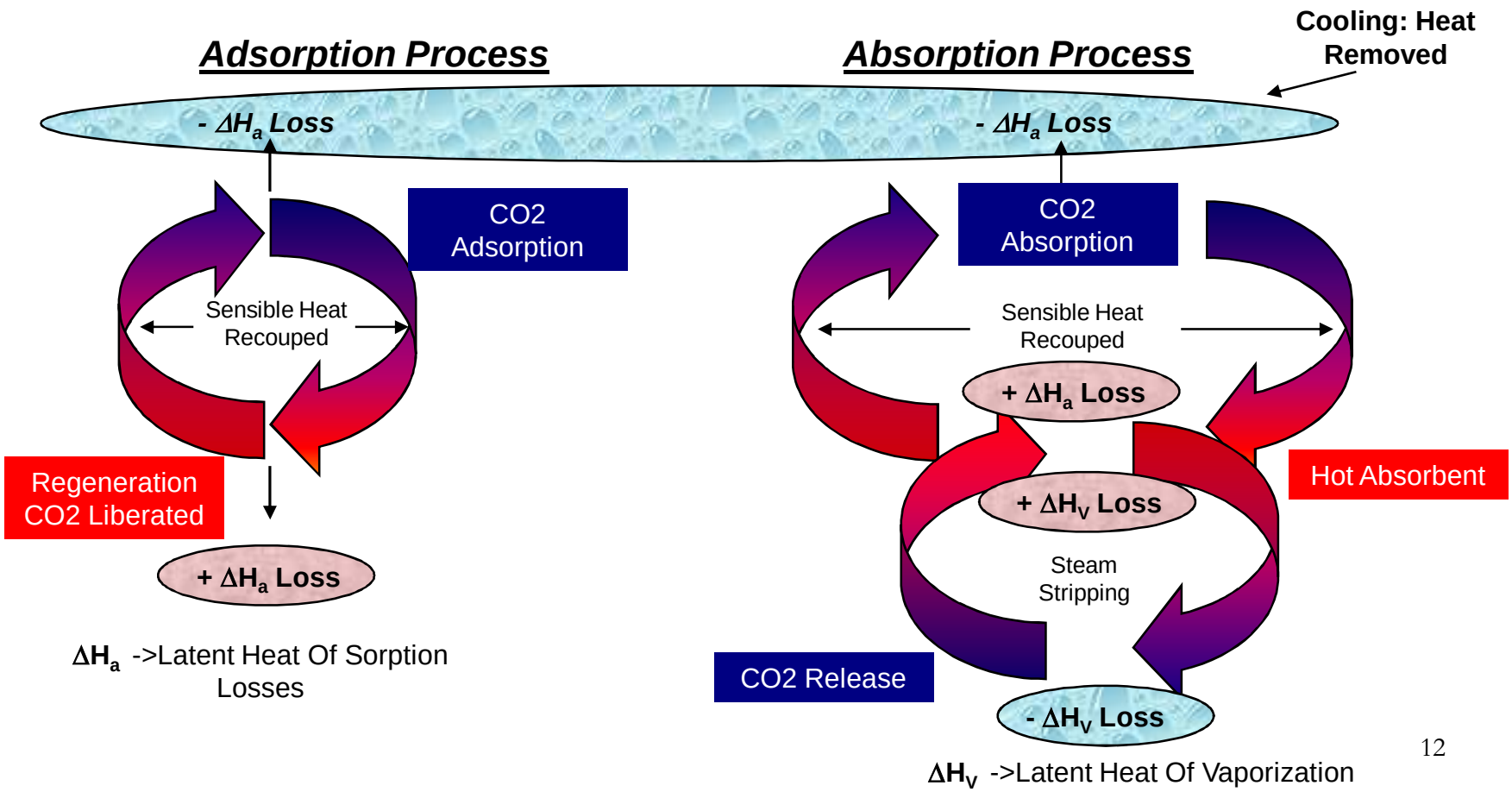
*Polymer/Polymer adhesion*



*Lumen layer surface*

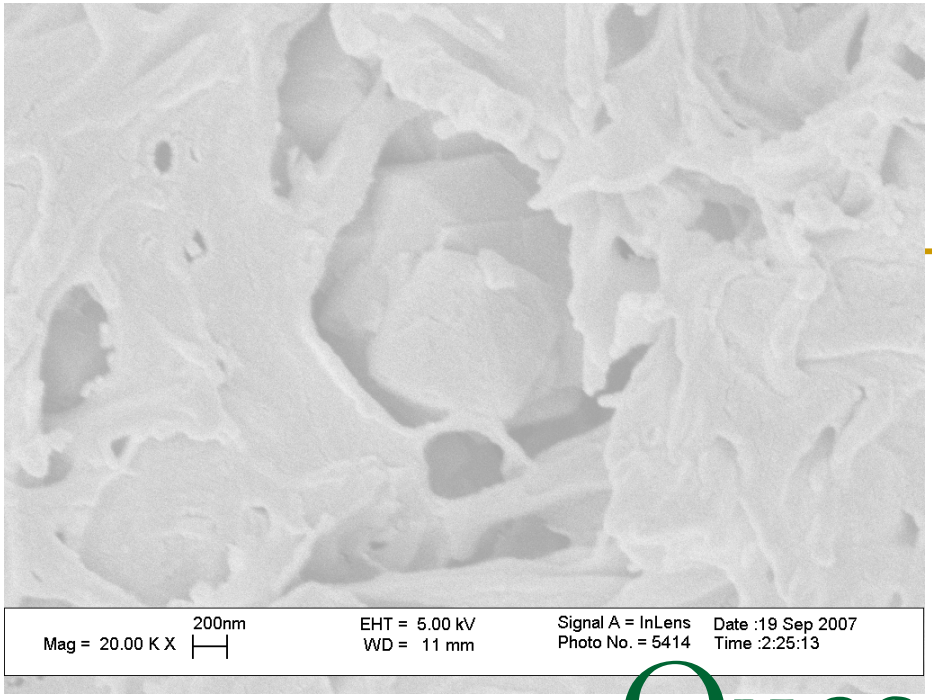
# *Simplified Comparison Of Adsorption versus Absorption Processes:* Thermal Cycles And Heat Loss

- Key Difference In Thermal Cycles Comes During Regeneration
  - Steam Stripping Used To Regenerate Absorbent



# Technology Comparisons

- Comparison of Hollow-Fiber Sorbents to Fixed-Bed sorbents
  - Advantage: Lower pressure drop
  - Advantage: Faster response times
  - Advantage: Integration of non-interacting heat transfer fluid
  - Disadvantages: More complicated fabrication, new technology
- Comparison of Hollow-Fiber Sorbents to Liquid-based (absorption) systems
  - Advantage: heat exchanger is integral part of hollow fiber
  - Advantage: factor of two to four less heat required
  - Disadvantage: poisoning, other fouling unknown
  - Disadvantage: new technology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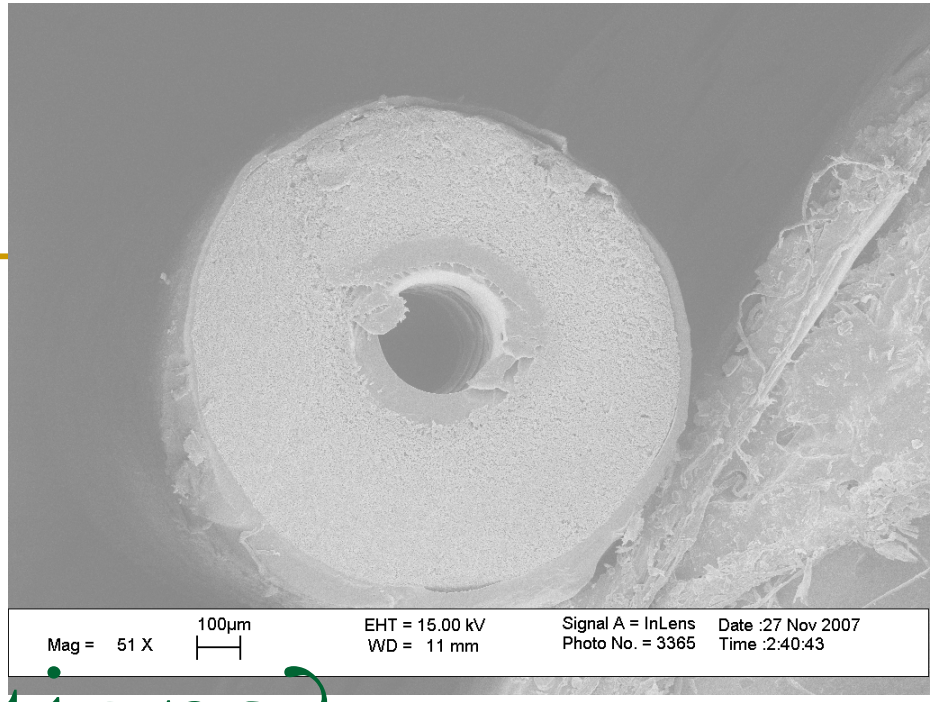
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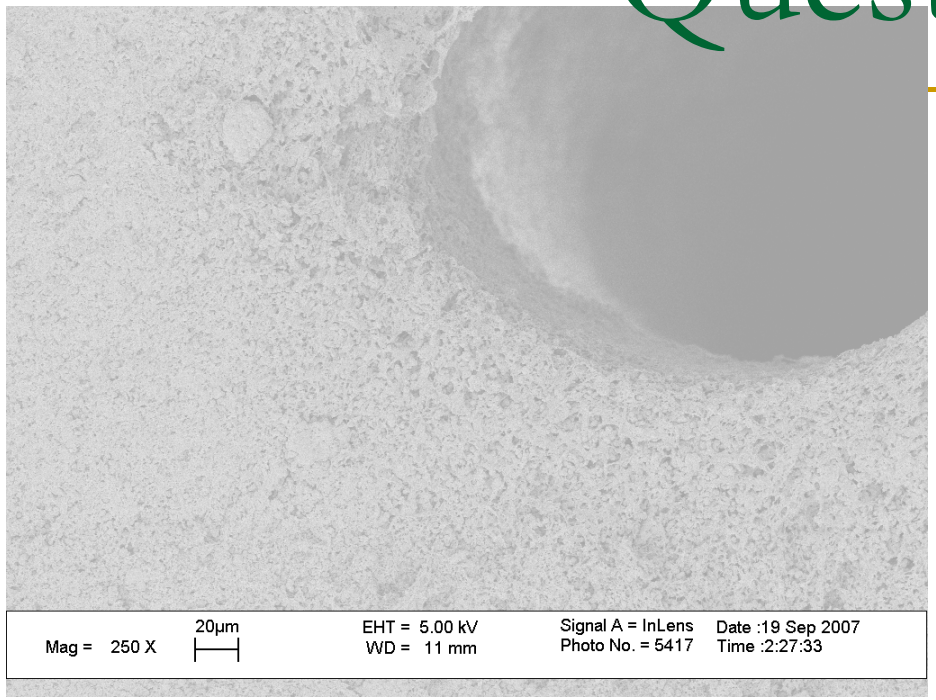
# Questions?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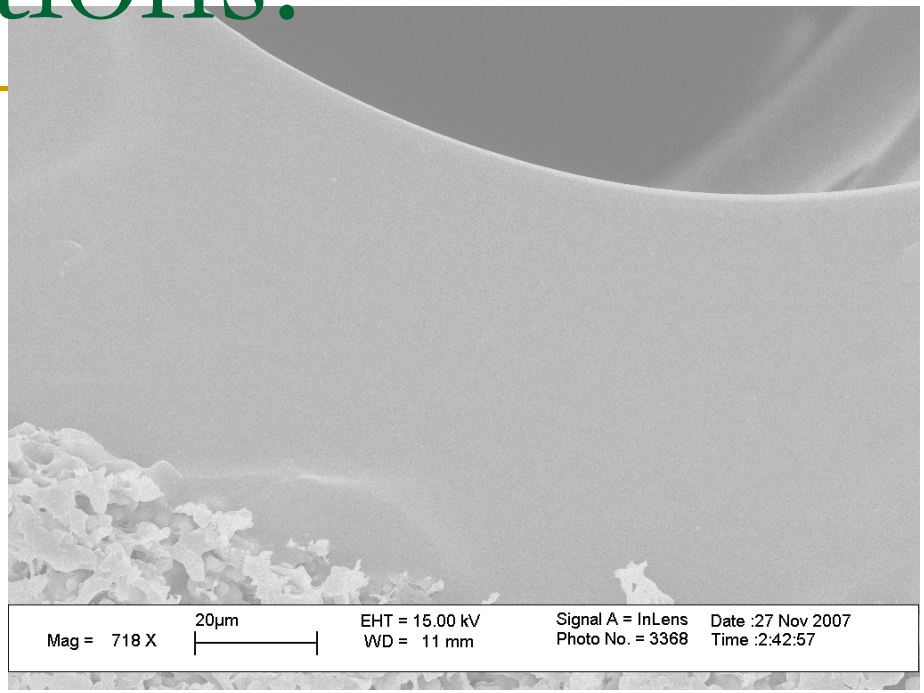
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