Incorporation of Carbon Nanotubes into Microstructured Architectures for Preconcentration of Trace Gases

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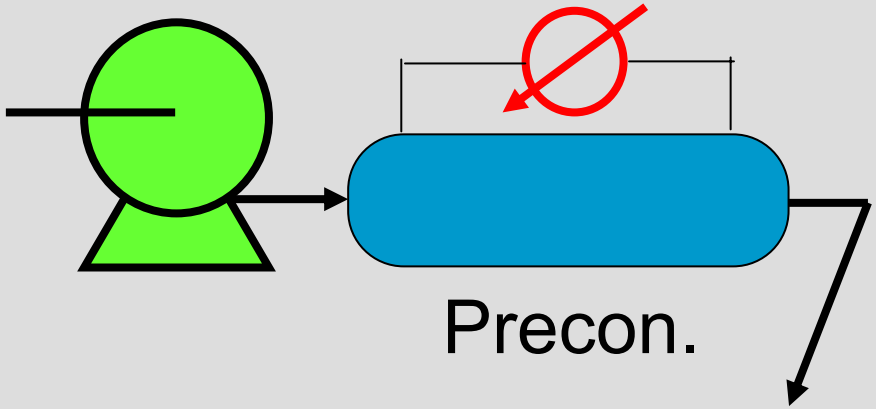
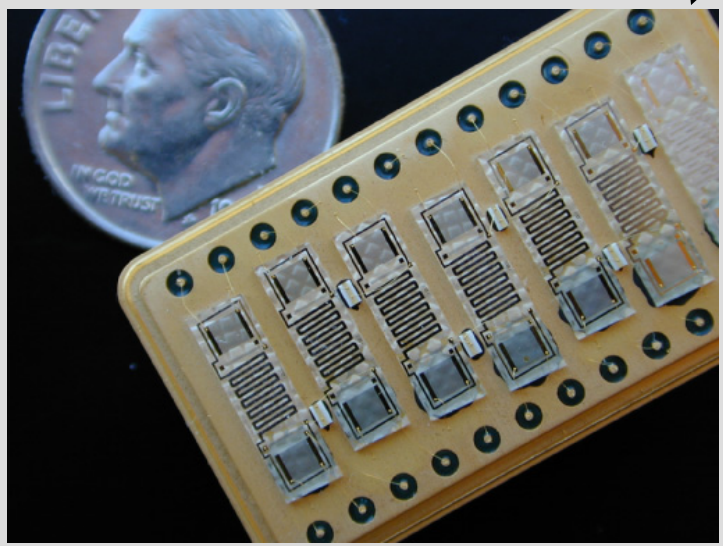
Motivation

- Needs exist for measurement of very trace organic species in the gas phase.
  - **Atmospheric chemistry**
  - Environmental health monitoring
  - **Nuclear proliferation detection**
  - **Chemical agent** & pathogen detection
- Miniature systems desired, but compact sensors (FWP, SAW, etc.) do not have needed sensitivity.

Preconcentration of Analytes

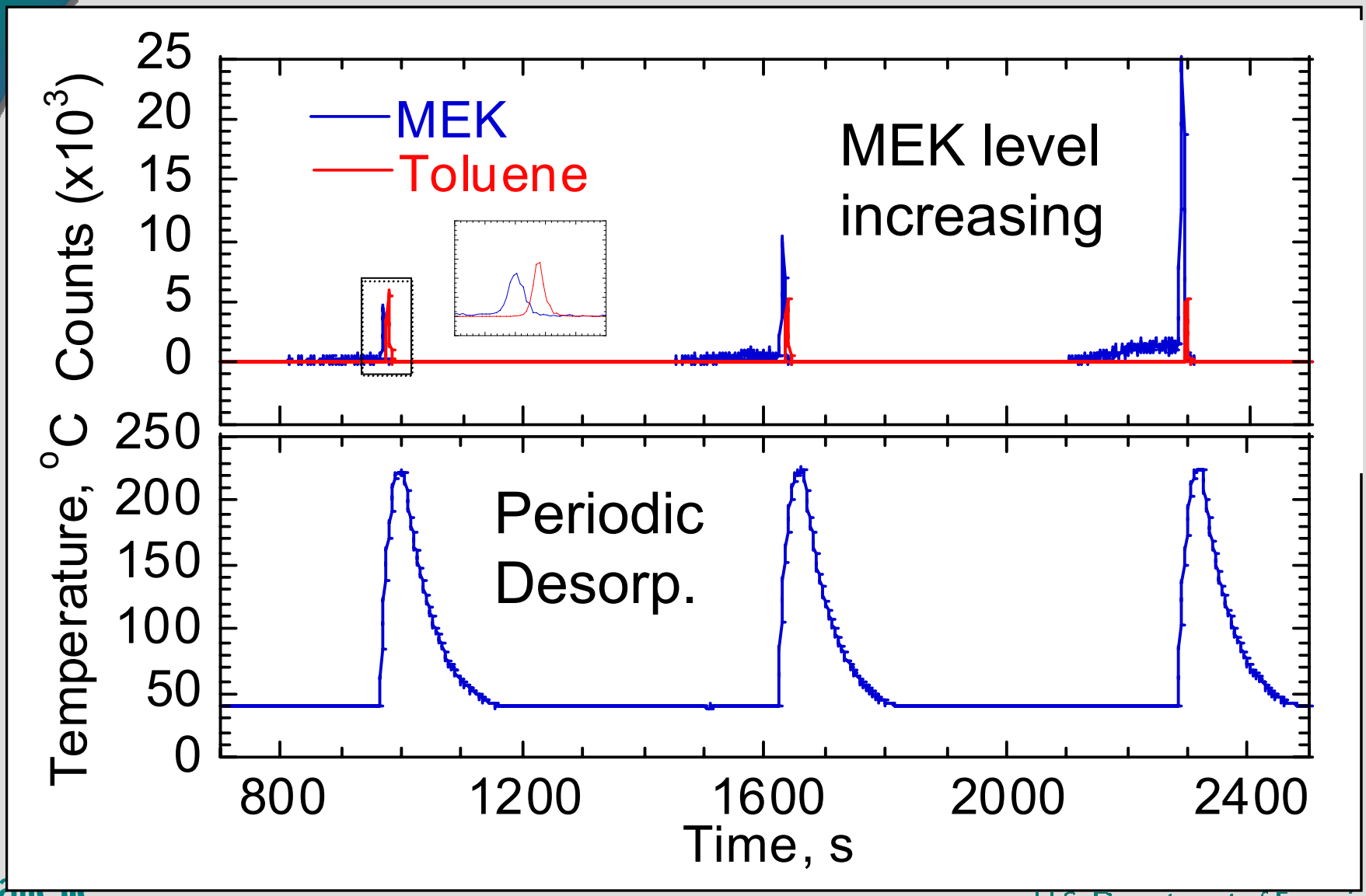
- Preconcentrator composed of sorbent media with integrated heating/cooling system
- Sorbent may be selective or relatively non-selective capture material
- Sorbent should act as thermal chromatographic media if separation desired
- Sorbent should be heated rapidly and uniformly to achieve greatest amplification of concentration





Chemical Sensor Array

Expected Result

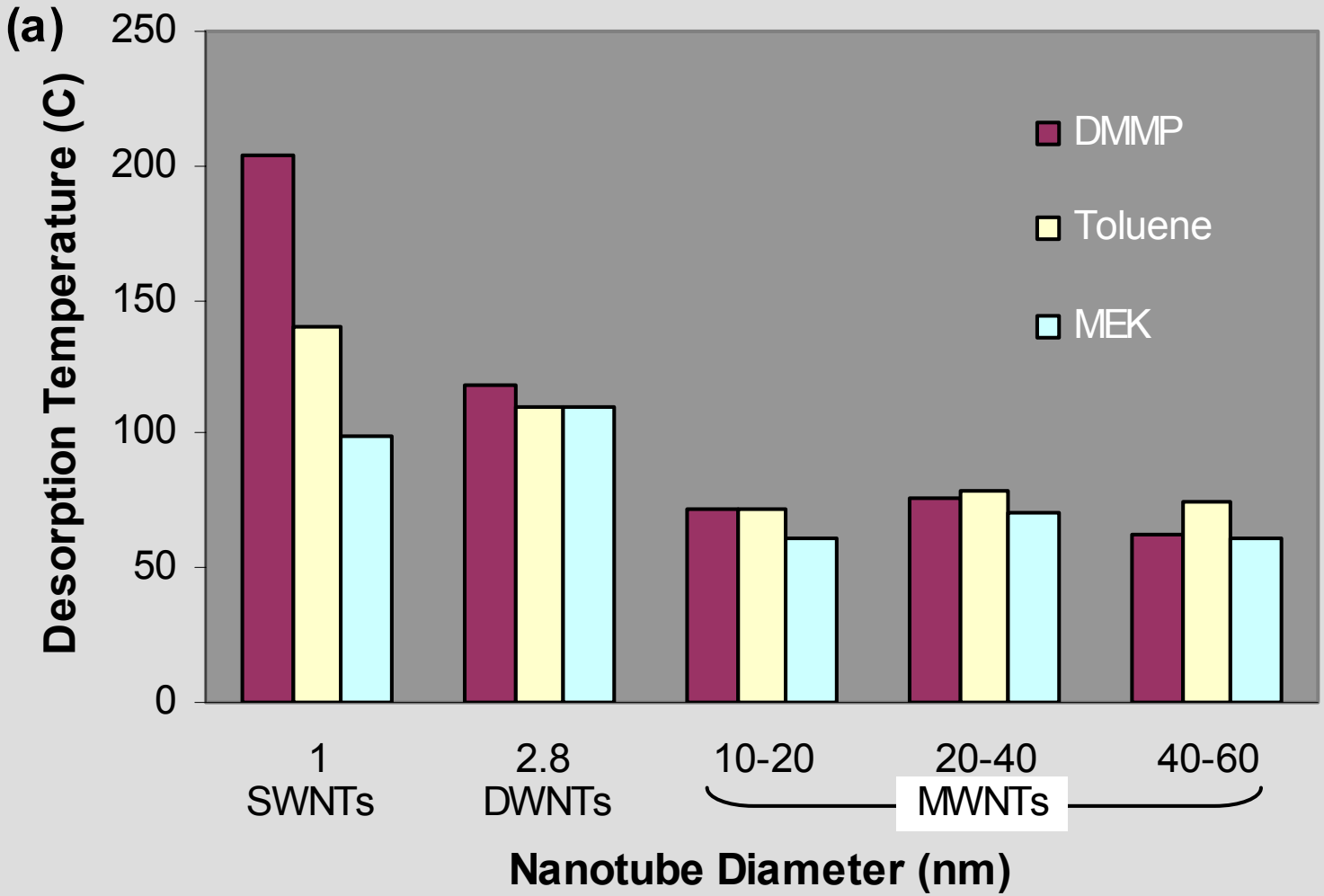


Why CNTs?: Physical Properties

- Good heat conduction potentially facilitates rapid and uniform heating.
- Relative chemical inertness leads to long term stability of sorbent characteristics.
- Surface area is ‘external’ (for closed tubes), leading to good mass transfer characteristics. Large area = high capacity.

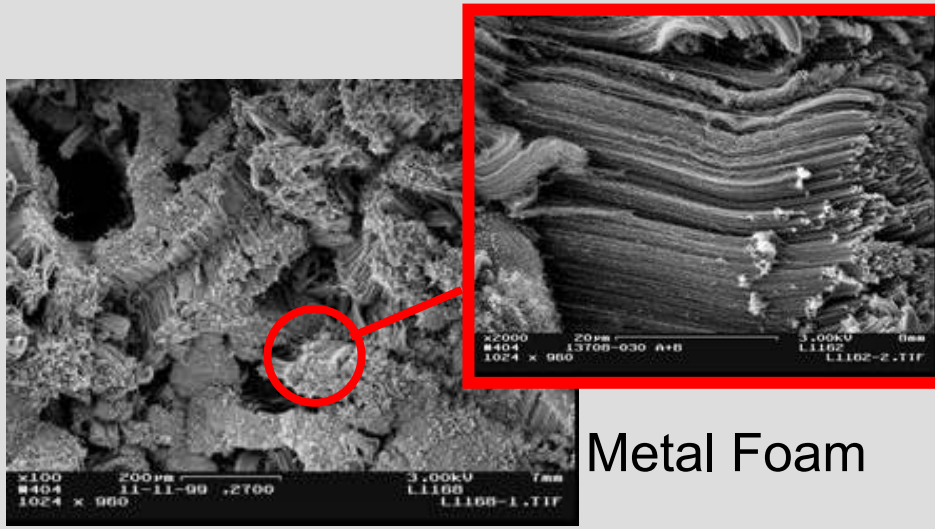
RESULT: If made miniature and in small dead volume configuration, peak broadening can be limited to only axial diffusion effects.

Why CNTs?: Organic Vapor Desorption

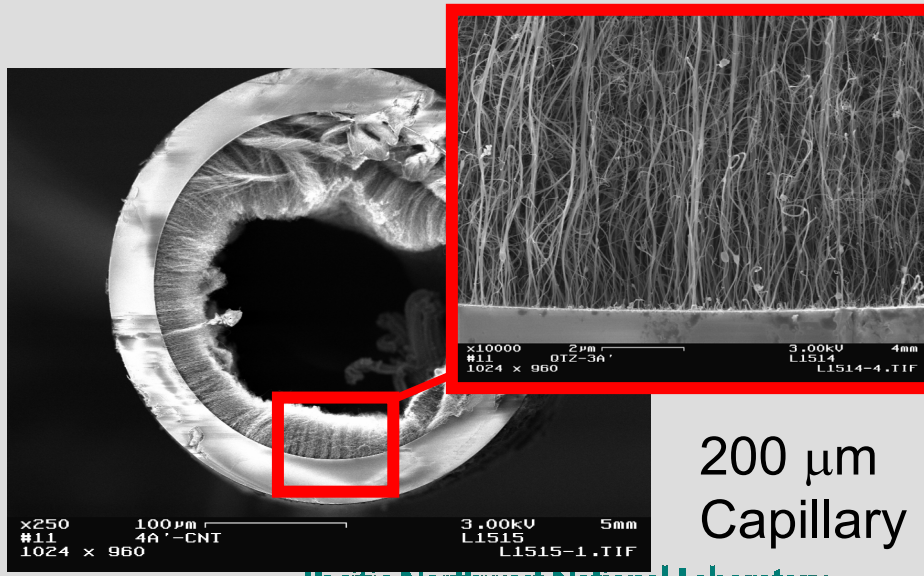


Coupling Nanostructured Materials into 'Micro' Components

- Nanomaterials must be put into a form that allows a self supported structure.
- Microtechnology is a good solution. Small dimensions allow one to take advantage of nascent properties.
- Micro-nano composites can be made by CVD or other means.

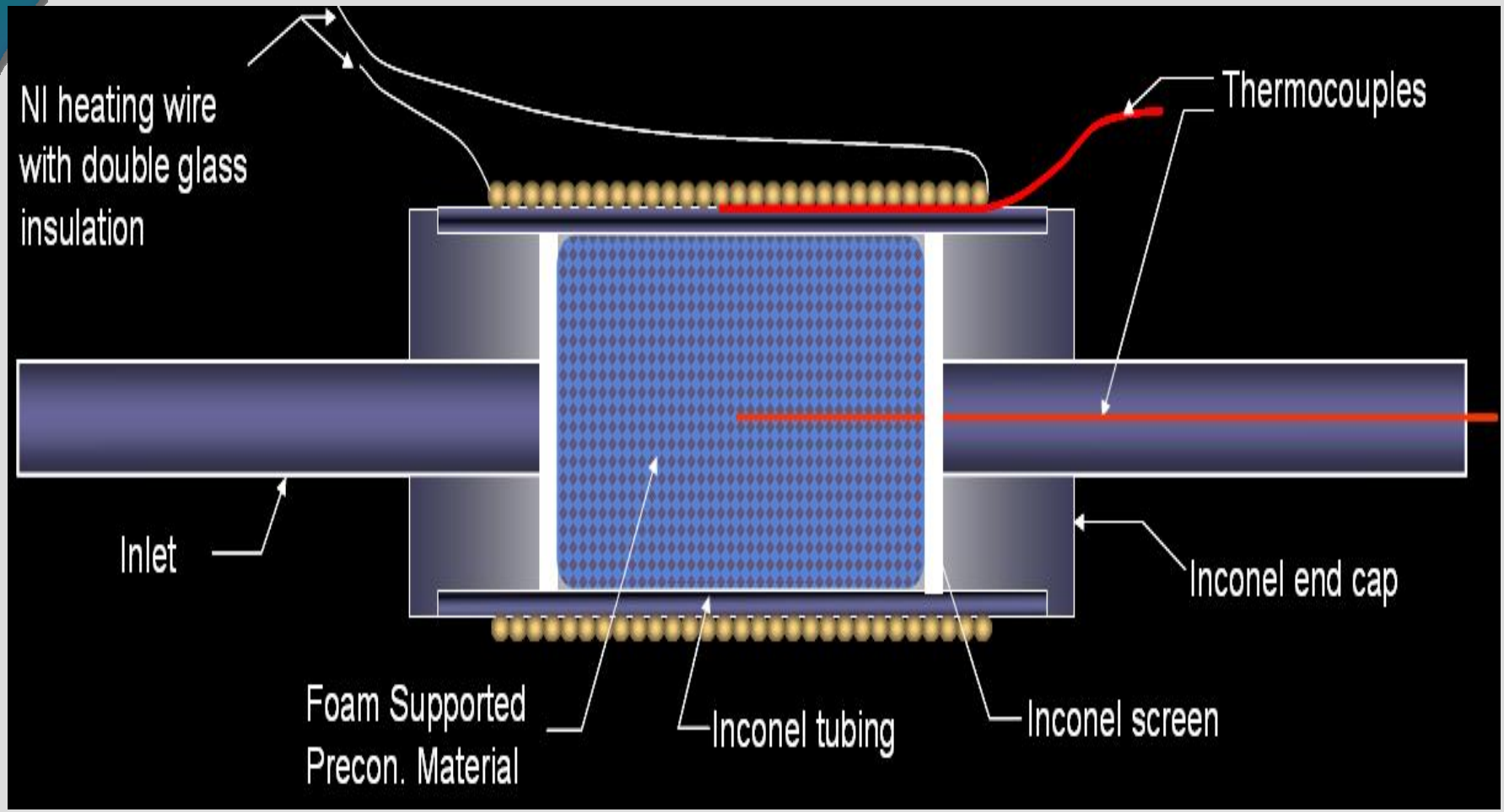


Metal Foam



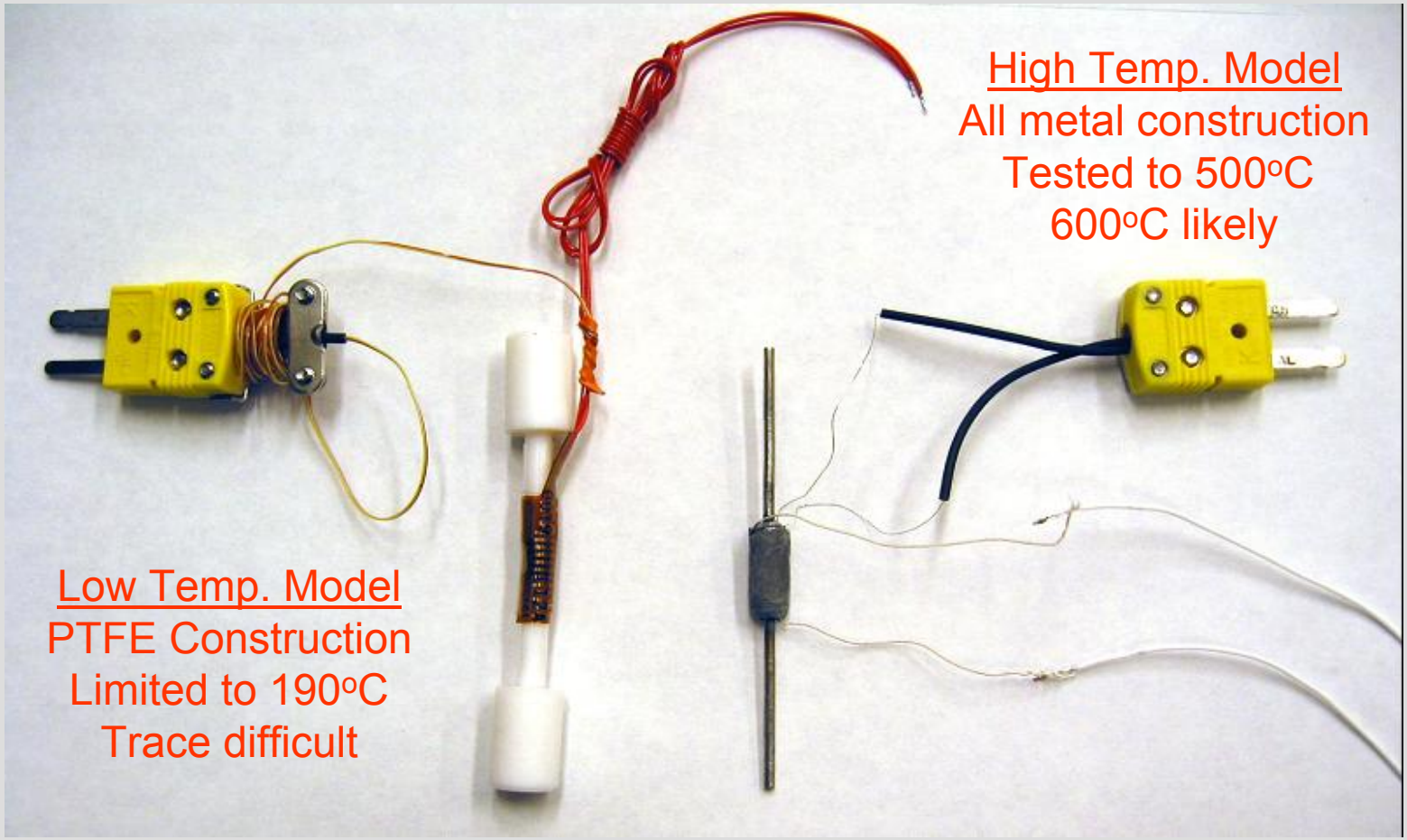
200 µm Capillary

Preconcentrator Design

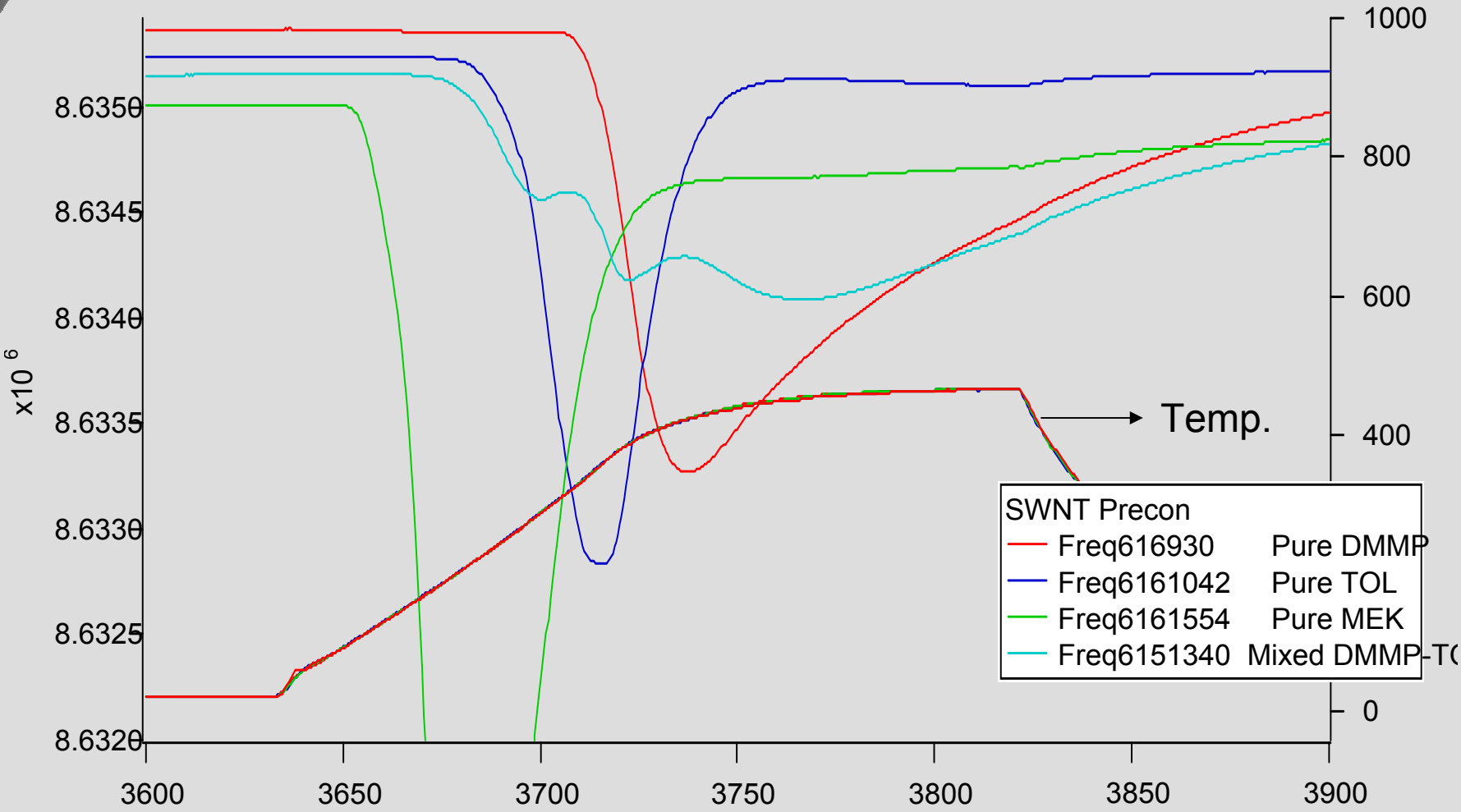


Ni Foam Cores are ϕ3.5 mm and 80 ppi

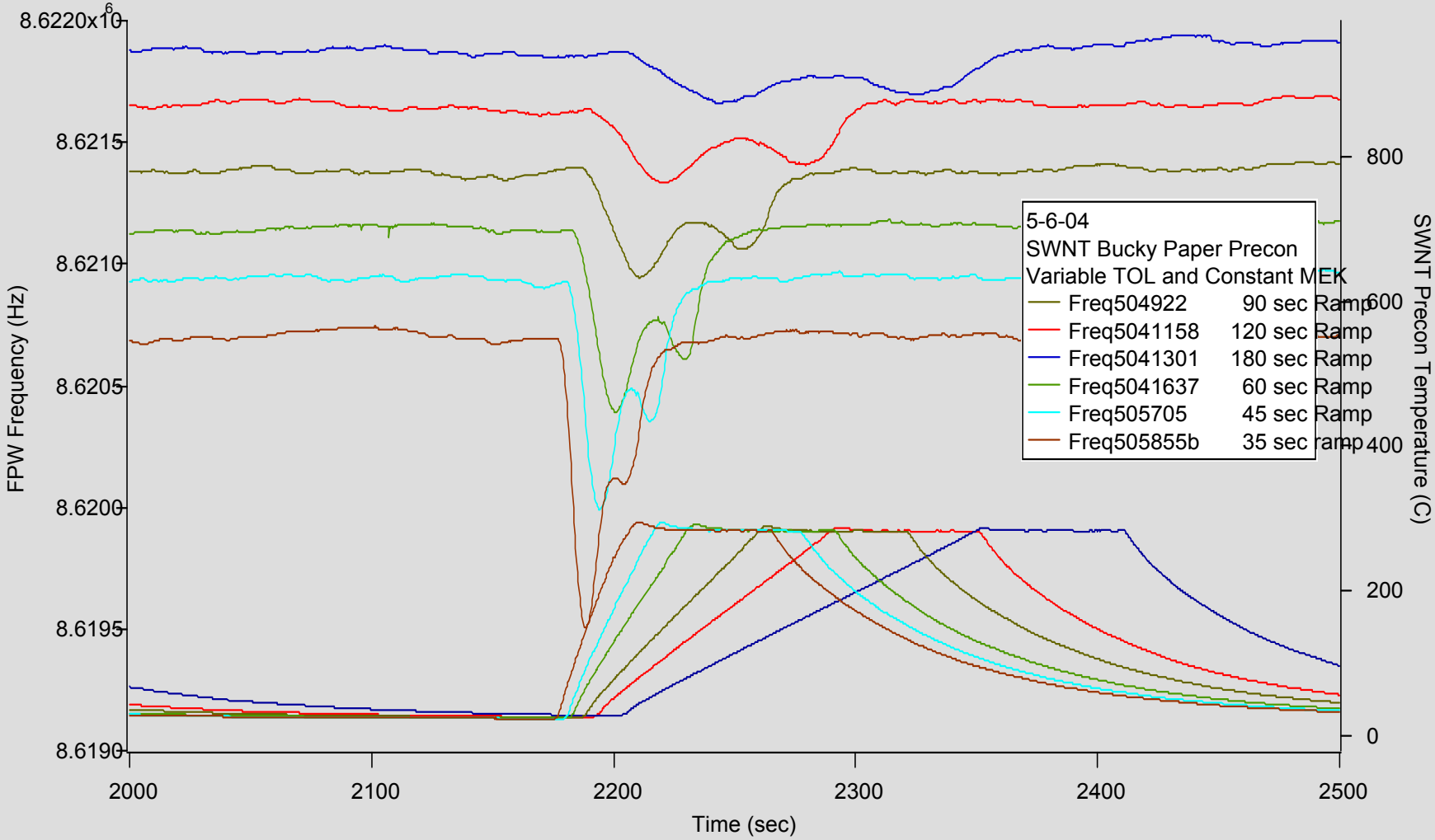
PNNL Preconcentrators



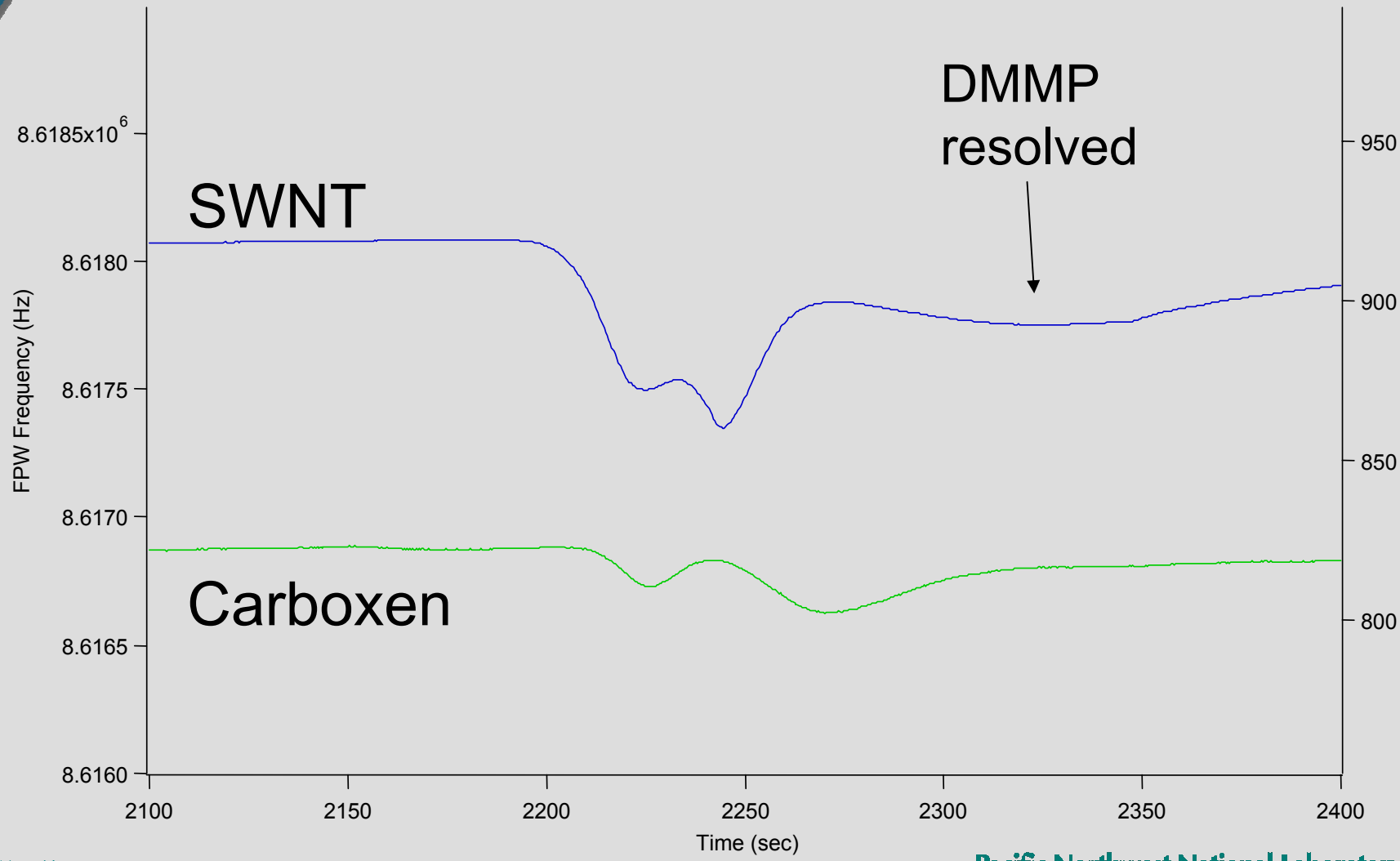
Separation of 3 Vapors (toluene, MEK, DMMP)



Temperature Ramp Effects

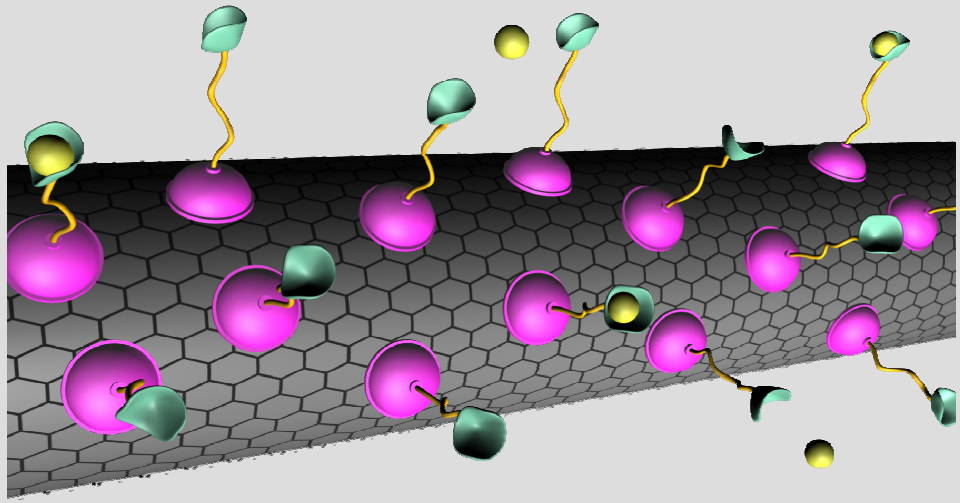


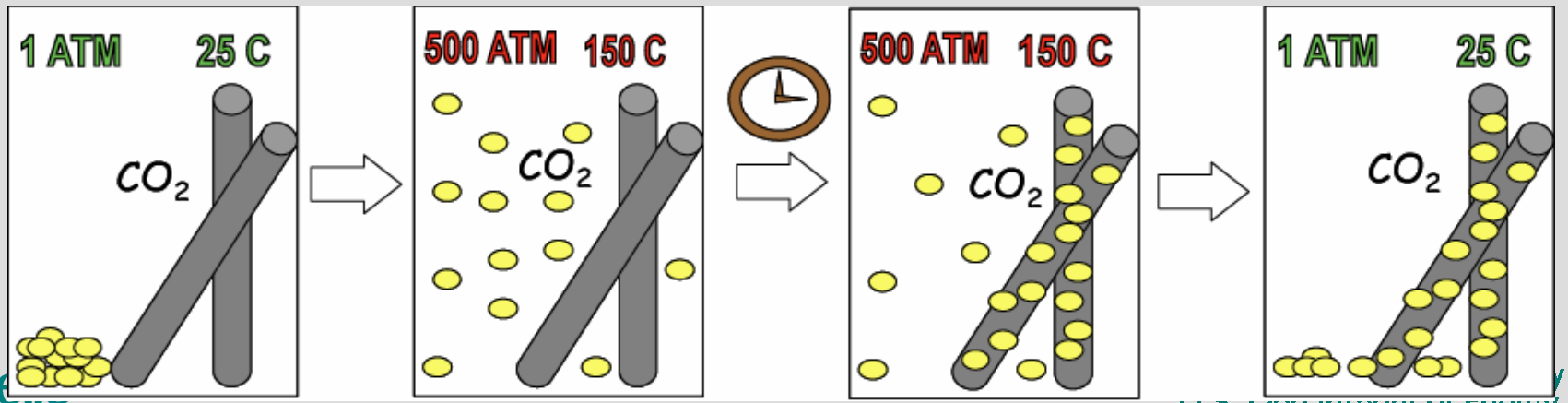
SWNT Shows Advantage Over Carbon



Another Advantage of CNTs: Anchor-Based Functionalization

- Surface is readily functionalized in supercritical fluids to obtain selectivity for target analytes.
- Can effect selectivity and desorp. temp.





Conclusions

- Functional multiscale architectures can be achieved by forming composites of nano-dimensioned materials within traditional microtechnology components such as thin films, channels, capillaries, and foams.
- Such architecture allows low pressure drop and uniform heat transfer to active materials for preconcentration of trace gases.
- Where are we going?
  - ‘Designer’ surfaces for chemical selectivity
  - Incorporation of precon material directly onto microsensors