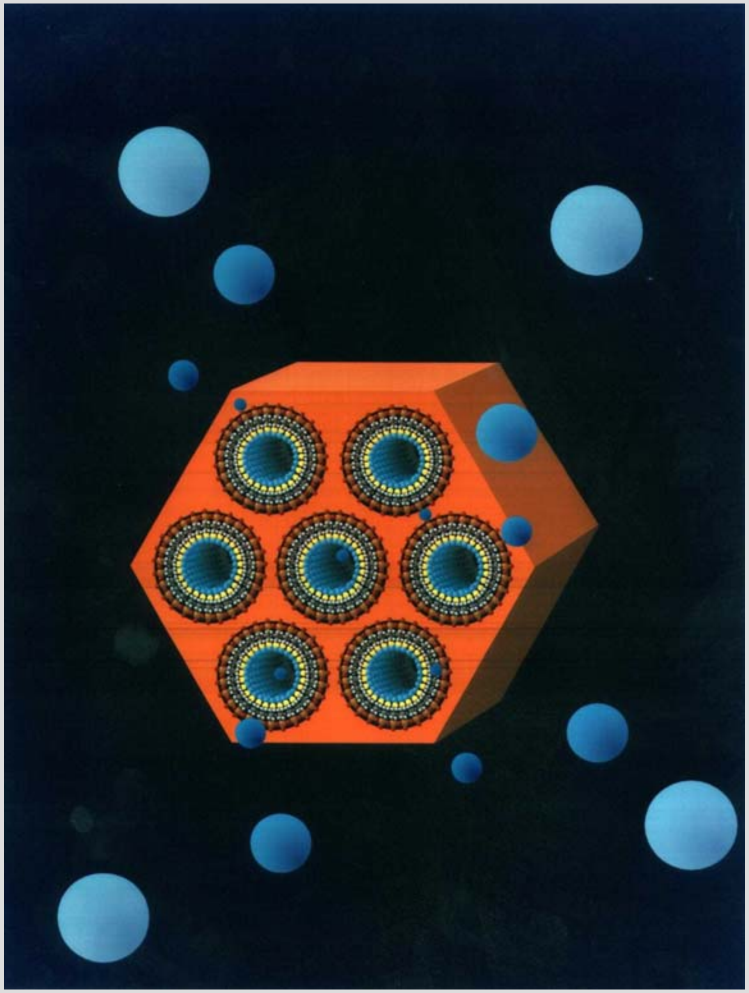
Nanomaterials for Environmental Remediation

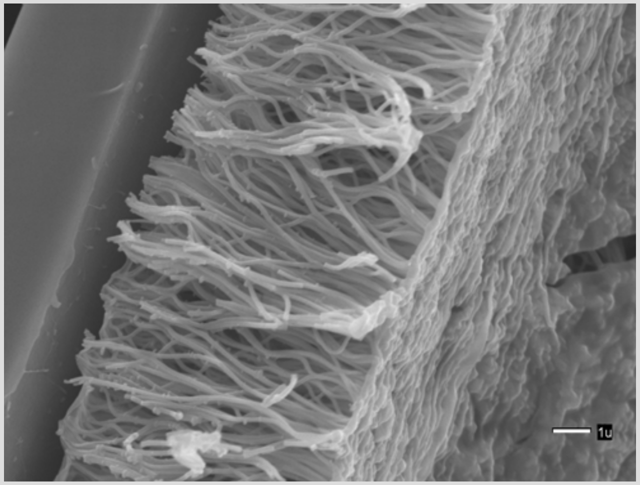


Glen E. Fryxell
Pacific Northwest National Laboratory
Richland, WA

glen.fryxell@pnl.gov

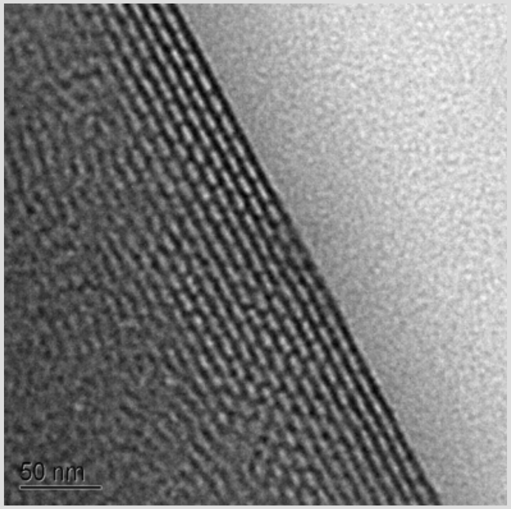
Battelle

Advantages of nanomaterials



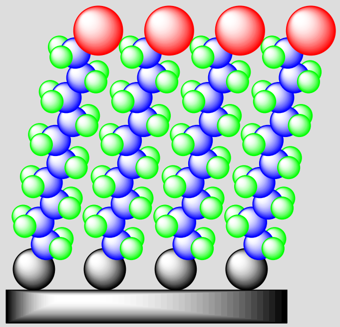
Nanomaterials provide:

- High surface area (capacity)
- Well defined structure
- High reactivity
- Easy dispersability
- Readily tailored for application in different environments
- Chemistry/materials developed for remediation processes are readily tailored to sensing/detection



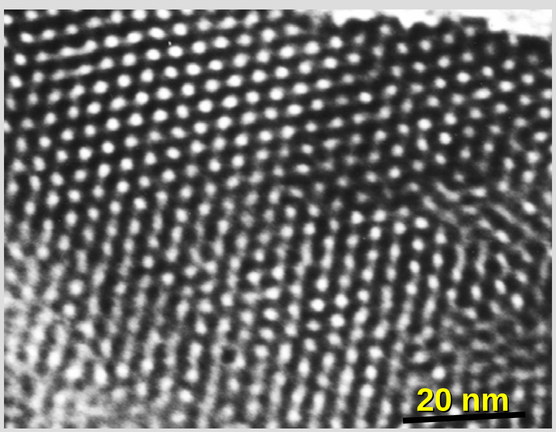
SAMMS: Self-Assembled Monolayers on Mesoporous Supports

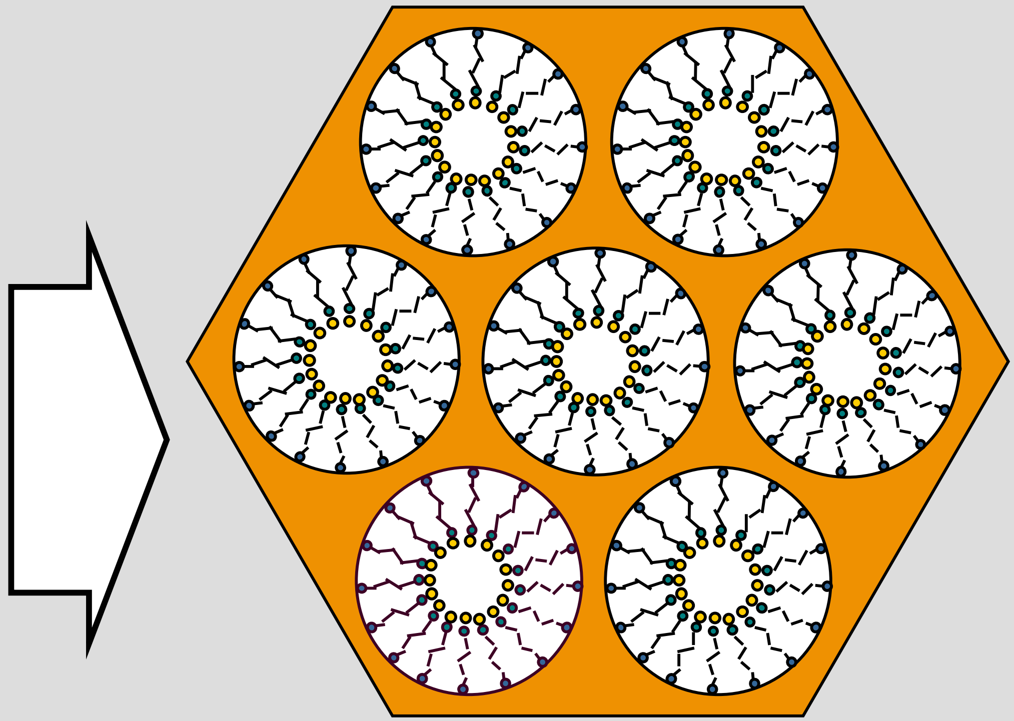
A. Self-assembled monolayers



+

B. Ordered mesoporous oxide



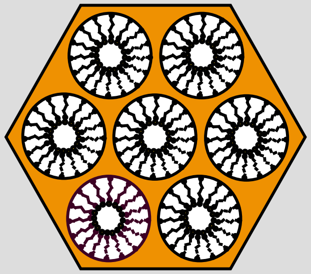


First reported in:

Science 1997, *276*, 923-926.

SAMMS in a Nutshell

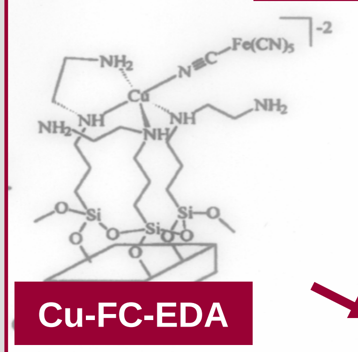
- Extremely high surface area = high capacity
- Rigid, open pore structure provides for fast sorption kinetics
- Chemical specificity dictated by monolayer interface
- Easily modified for new target species
- Sequestration can be driven either by metal/ligand affinity or by adduct insolubility
- Good chemical and thermal stability
- Easily regenerated/recycled



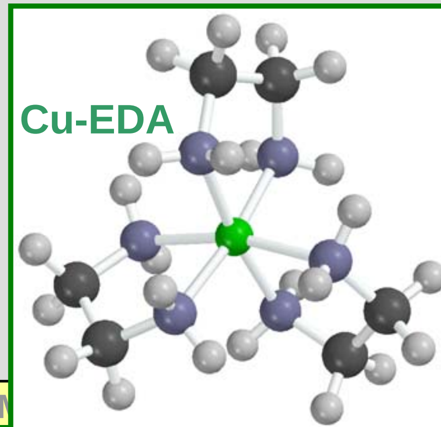
"Designing Surface Chemistry in Mesoporous Silica" in "Adsorption on Silica Surfaces"; pp. 665-687, Marcel-Dekker, 2000.

Tailoring SAMMS interfacial chemistry to the periodic table

Env. Sci. & Tech. 2001, 35, 3962-3966.

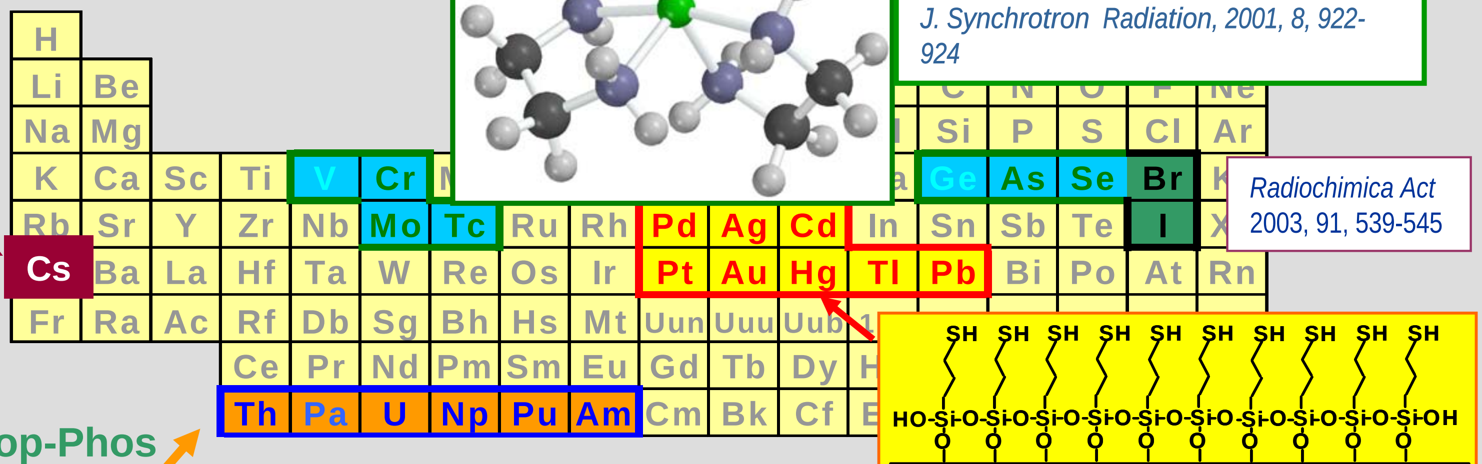


Cu-FC-EDA



Cu-EDA

Chemistry of Materials 1999, 11, 2148-2154
J. Physical. Chem. B. 2001, 105, 6337-6346.
J. Synchrotron Radiation, 2001, 8, 922-924

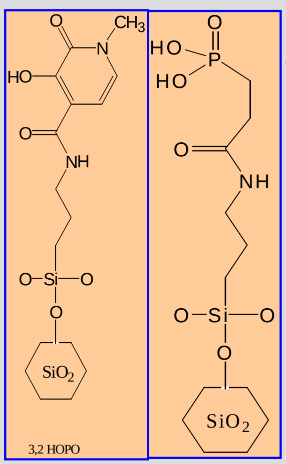


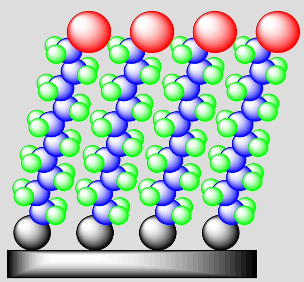
Radiochimica Act 2003, 91, 539-545

thiol

HOPO Prop-Phos

Chem. Comm. 2002, 1374-1375.

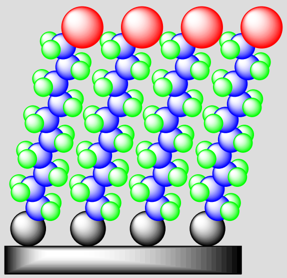




Science, 1997, 276, 923-926.
J. Synchrotron Radiation, 1999, 6, 633-635
Sep. Sci. & Technol. 1999, 3411, 2329-2345
Mat. Tech. Adv. Perf. Mat. 1999, 14, 183-193
Surf. Sci. & Catalysis, 2000, 105, 729-738.

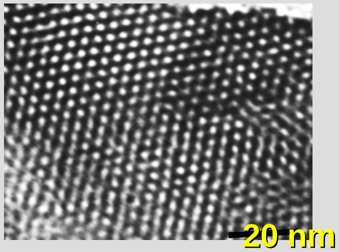
….all by varying the monolayer ligand field.

Functional Nanomaterials for analytical preconcentration



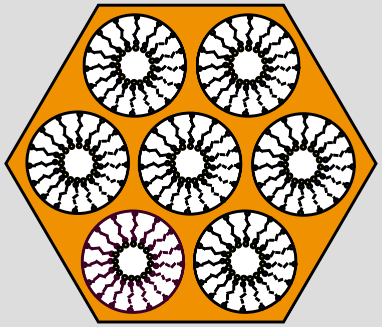
Self-assembled monolayers

- Dense surface coverage
- Chemical specificity



Mesoporous materials

- High surface area
- Rapid sorption kinetics

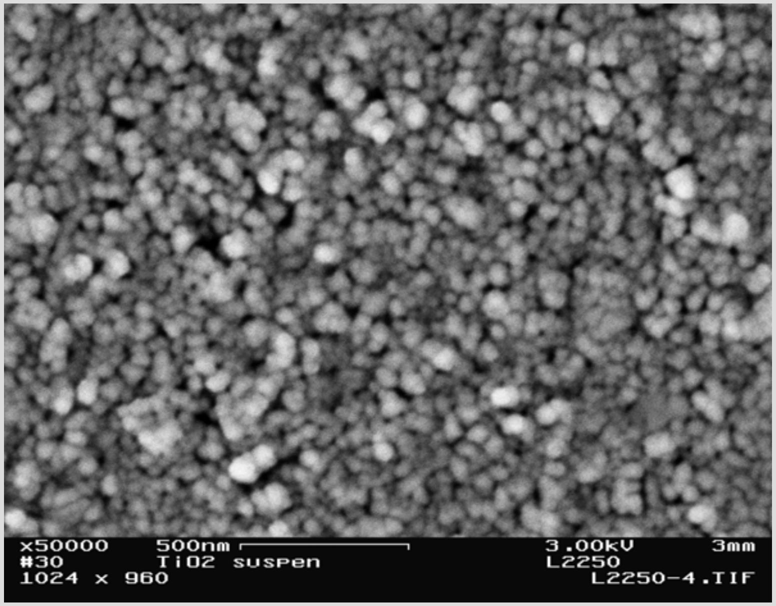


High-performance preconcentrators

"Self-Assembled Monolayers on Mesoporous Supports (SAMMS): Environmental Clean-up and Enhanced Sensing Capability" *Encyclopedia of Nanoscience and Nanotechnology*, Marcel-Dekker, 2004

POC: Shane Addleman

Functionalized TiO_2 Nanoparticles for Subsurface Injection



TiNano40TM Characteristics

Surface Area (BET)	51.2 m2/g
Particle Density	3.88 g/cm3
Particle Size	40 – 60 nm
TiO2	99.8%
Impurities (ZrO2, SiO2, Cl, P2O5, ZnO)	0.2%
Crystalline Phase	Anatase

Anatase Nanoparticle Injection Tests

An aqueous suspension of anatase (ammonium carboxylate ~ 2 wt %) was successfully injected in to a 100 cm long, 20 – 30 mesh sand column (~35% porosity).

The inlet pressure after injection of 3 pore volumes of suspension remained low (<14 psi).

An average of 4 wt % of anatase was uniformly distributed throughout the sand column.

Tc-99 Adsorption Experiment

Adsorbent: Cu-EDA anatase nanoparticles

Contact Solution: Hanford GW spiked with 49.5 pCi/ml of Tc-99

Hanford Ground Water (mg/l)

Ca	49.5
NO3	8.6
Mg	14.6
SO4	64.7
K	1.7
Si	16.5
Na	13.2
CO3	60.8
Cl	16.4
pH	8.3 (SU)
EC	0.47 mS/cm

Solution:Solid Ratio (ml/g) :
25, 50, 100, 500, 100, 5000, 10000

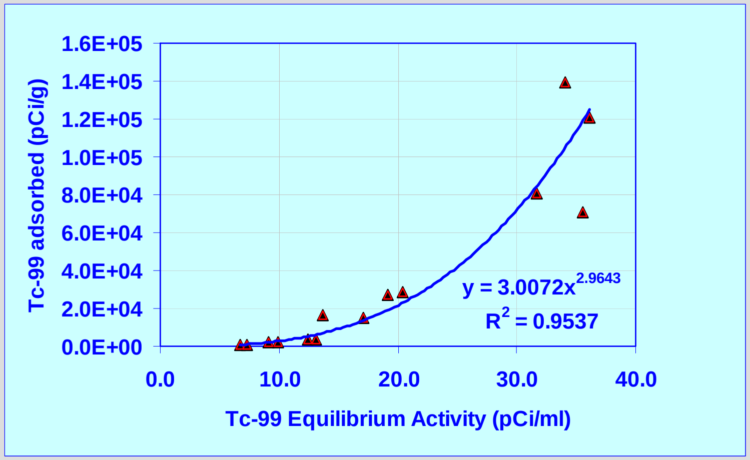
POC: Shas Mattigod

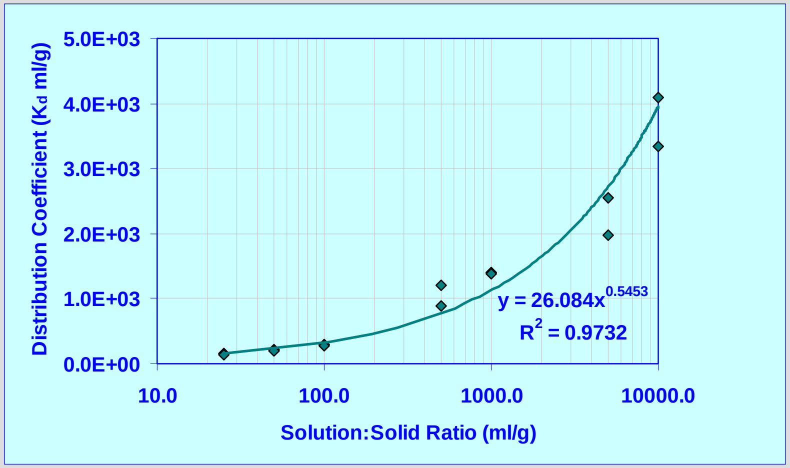
Tc-99 Sequestration by Functionalized TiO_2 Nanoparticles

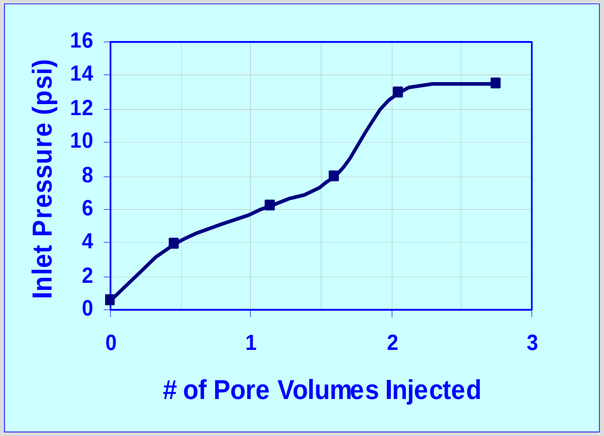
Tc-99 Adsorption Experiments

Maximum Tc-99 loading: ~1.3 x 10^5 pCi/g.

Tc-99 Kd: 1.5 x 10^2 – 4.0 x 10^3 ml/g.







Inlet Pressure Change as a Function of Pore Volume

Summary

Anatase nanoparticles were successfully functionalized with Cu-EDA monolayers.

Cu-EDA anatase selectively adsorbed Tc-99 from spiked Hanford ground water.

Successful injection of an aqueous suspension of anatase nanoparticles into a sand medium was demonstrated.

POC: Shas Mattigod