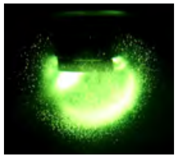
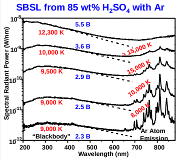
Sonoluminescence

Hangxun Xu, Brad Zieger, Rusty Conner (Dlott Group)

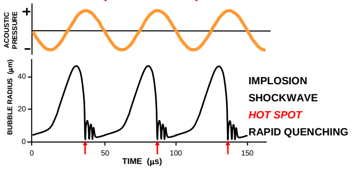


Multibubble sonoluminescence

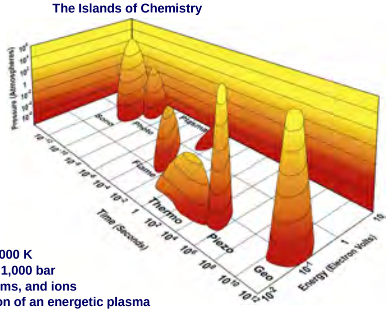
SBSL from 85 wt% H_2SO_4 with Ar



Acoustic Cavitation: Growth & Implosive Collapse of Bubbles

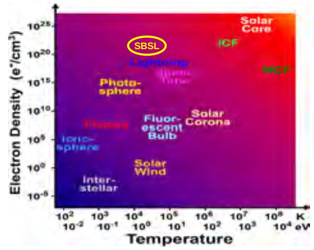


The Islands of Chemistry

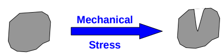


- Observable temperatures above 15,000 K
- Observable pressures approaching 1,000 bar
- Emission from small molecules, atoms, and ions
- Definitive evidence for the generation of an energetic plasma

Intense Plasma formed inside Collapsing Bubbles



Mechanoluminescence from Acoustic Cavitation

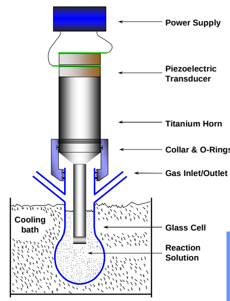


Mechanoluminescence (ML): light produced during mechanical action on a solid

Sonochemistry & Materials

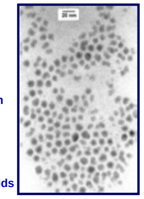
Maria Fortunato, Jinrui Guo, Maryam Sayyah, Hangxun Xu, Brad Zieger

Sonochemistry Rig

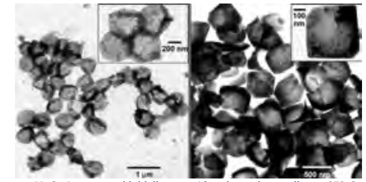


Sonochemical Synthesis of Amorphous Nanoparticles

- Sonication of $Fe(CO)_5$ in 1-hexanol, under Ar, with oleic acid, 20°C, 20 KHz, 80 W
- Amorphous on nm scale: XRD, DSC, e-beam Microdiffraction
- Superparamagnetic (i.e., single domain ferromagnet)
- High Magnetization comparable to commercial ferrofluids

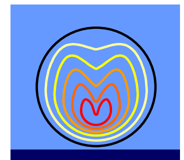


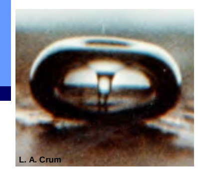
Hollow Spheres and Crystals



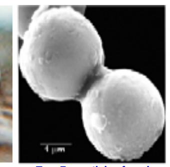
MoO_3 As prepared initially. After thermal annealing at 350°C. 1st Hollow Crystals!

Cavitation near Surfaces and Interparticle Collisions



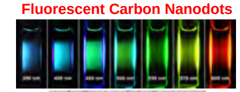


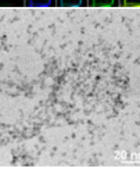
Bubble collapse near surfaces creates high velocity jet: microscopic depth charge.



Two Zn particles fused together due to shock wave from imploding bubbles.

Fluorescent Carbon Nanodots



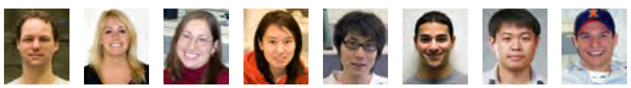


Fluorescent carbon nanodots made by sonicated Fenton Reaction of carbon nanoparticles.

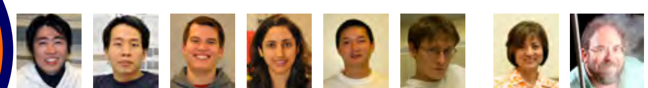
Suslick Group

Sonochemistry & Materials Chemistry
Ultrasonic Spray Pyrolysis, Nanomaterials
Sonoluminescence
Olfaction and Molecular Recognition
The Optoelectronic Nose

www.scs.uiuc.edu/suslick



Jon Askim, Katy Filson, Maria Fortunato, Jinrui Guo, Wei Jiang, Brandon Ito, Minseok Jang, Jon Kemling



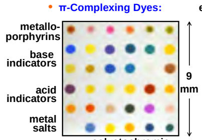
Howard Kim, Hengwei Lin, John Overcash, Maryam Sayyah, Hangxun Xu, Brad Zeiger, Nasrin Gahvari, Ken Suslick

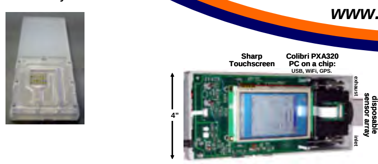
The Mammalian Olfactory System

- Olfactory epithelium
  human: 1 cm² per nostril (5 x 10^7 cells)
  dog: ~25 cm² per nostril, highly reticulated
- Even Humans can distinguish >10,000 individual scents.
- ~800 semi-specific receptors: 3% of mammalian genome!
- Olfactory receptors are GPCRs. Receptor structure speculative, but probably metalloproteins with conserved tripodal site.

Chemo-Responsive Nanoporous Pigments:

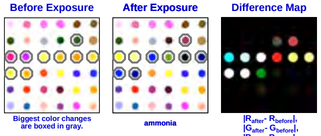
- Lewis Acid Dyes: metal ion dyes
- Brønsted Acid/Base Dyes: pH indicators
- Dyes with Large Dipoles: solvatochromic
- π-Complexing Dyes: extended π-π* dyes



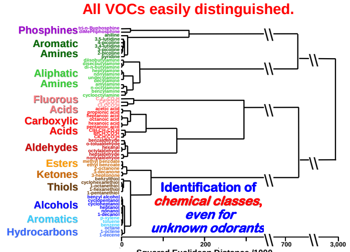


Difference Map is a "molecular fingerprint".

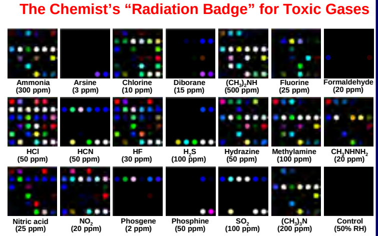
Every odorant or mixture is represented as a unique 108-dimensional vector (36 ΔR, ΔG, ΔB).



All VOCs easily distinguished.

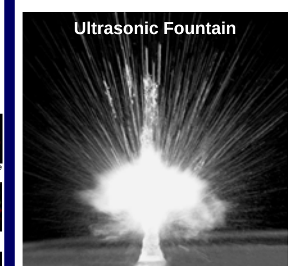


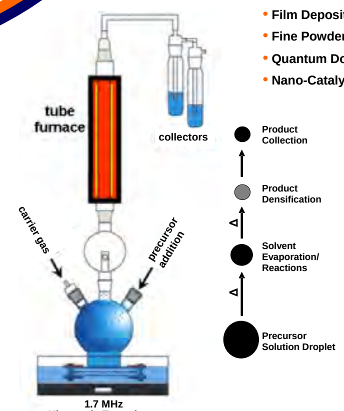
The Chemist's "Radiation Badge" for Toxic Gases



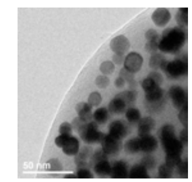
Ultrasonic Spray Pyrolysis (USP)

- Spray Drying
- Film Deposition
- Fine Powders
- Quantum Dots
- Nano-Catalysts



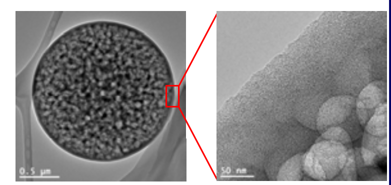


Continuous Production of Nano-Materials



TEM of Au nanoparticles embedded in porous carbon microsphere

Hierarchically Porous Carbons



microporous shell — internal macropores

Olfaction & the Optoelectronic Nose

Jon Askim, Minseok Jang, Wei Jiang, Jonathan Kemling, Hengwei Lin

New Synthetic Methods for Nanomaterials

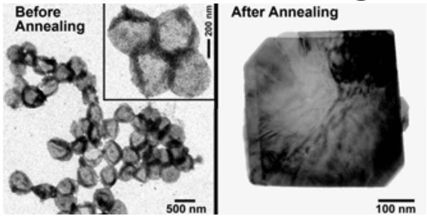
Maria Fortunato, Brandon Ito, Howard Kim, John Overcash, Maryam Sayyah

Suslick Group Overview

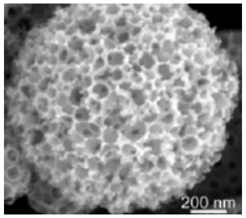
University of Illinois at Urbana-Champaign
www.scs.uiuc.edu/suslick   ksuslick@uiuc.edu

Sonochemistry: Nanomaterials from Ultrasound

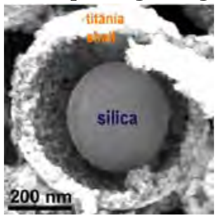
High Intensity Ultrasound and Ultrasonic Spray Pyrolysis



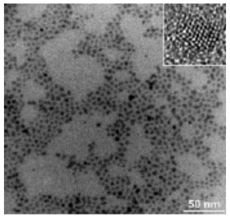
Hollow Nanocrystals



Porous Catalysts



Porous Oxides



Quantum Dots

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- Dhas, N. Arul; Suslick, K. S., "Sonochemical Preparation of Hollow Nanospheres and Hollow Nanocrystals" *J. Am. Chem. Soc.* 2005, *127*, 2368-2369.
- Toublan, F.J.J.; Boppart, S.; Suslick, K. S., "Tumor Targeting by Surface Modified Protein Microspheres" *J. Am. Chem. Soc.* 2006, *128*, 3472-3473.
- Skrabalak, S. E.; Suslick, K. S. "Porous Carbon Powders Prepared by Ultrasonic Spray Pyrolysis" *J. Am. Chem. Soc.* 2006, *128*, 12642-12643.
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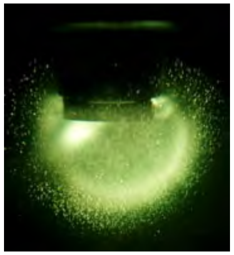
- Suslick, K. S.; Skrabalak, S. E. "Sonocatalysis" In *Handbook of Heterogeneous Catalysis, vol. 4;* Ertl, G. et al., eds.; Wiley-VCH: Weinheim, 2008, pp. 2006-2017.
- Dunkle, S. S.; Helmich, R. J.; Suslick, K. S. "$BiVO_4$ as a Visible-Light Photocatalyst Prepared by Ultrasonic Spray Pyrolysis" *J. Phys. Chem.*, C, 2009, 11980-83.
- Bang, J. H.; Suslick, K. S. "Applications of Ultrasound to the Synthesis of Nanostructured Materials" *Advanced Materials* 2010, *22*, 1039-1059 (invited review).
- Xu, H. X.; Suslick, K. S. "Sonochemical Synthesis of Highly Fluorescent Ag Nanoclusters" *ACS Nano* 2010, *4*, 3209-3214.

Sonoluminescence



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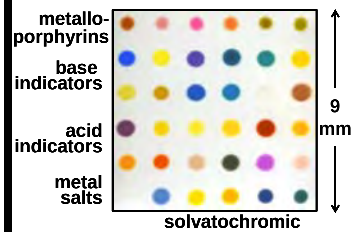
- Flannigan, D. J.; Suslick, K. S. "Plasma Formation and Temperature Measurement during Single-Bubble Cavitation" *Nature* 2005, *434*, 52-55.
- Eddingsaas, N. C.; Suslick, K. S. "Mechanoluminescence: Light from sonication of crystal slurries" *Nature*, 2006, *444*, 163.
- Suslick, K. S.; Flannigan, D. J. "Sonoluminescence" *Annu. Rev. Phys. Chem.* 2008, *59*, 659-683.
- Xu, H.; Eddingsaas, N. C.; Suslick, K. S. "Spatial Separation of Cavitating Bubble Populations: The Nanodroplet Injection Model" *J. Am. Chem. Soc.* 2009, *131,* 6060.
- Flannigan, D. J.; Suslick, K. S. "Inertially-Confined Plasma in an Imploding Bubble" *Nature Physics* 2010, *6*, 598-601.

Chemical Sensing



hand-held colorimetric reader

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- Zhang, C; Suslick, K. S., "A Colorimetric Sensor Array for Organics in Water", *J. Am. Chem. Soc.* 2005, *127*, 11548-11549.
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- Suslick, K. S. et al. "Seeing Smells: Development Of An Optoelectronic Nose" *Quimica Nova* 2007, *30*, 677-681.
- Musto, C. J.; Lim, S. H.; Suslick, K. S. "Colorimetric Detection and Identification of Natural and Artificial Sweeteners" *Anal. Chem.* 2009, *81*, 6526-6533.
- Lim, S.H.; Feng, L.; Kemling, J. W.; Musto, C. J.; Suslick, K. S. "An Optoelectronic Nose for Detection of Toxic Gases" *Nature Chemistry*, 2009, *1*, 562-567.
- Feng, L.; Musto, C. J.; Suslick, K. S. "A Simple and Highly Sensitive Colorimetric Detection of Gaseous Formaldehyde" *J. Am. Chem. Soc.*, 2010, *132*, 4046-4047.

Suslick Group Research Topics

www.scs.uiuc.edu/suslick

I. Sensors and Chemical Sensing

Mechanisms of Molecular Recognition

Chemical Sensing & Chemical Sensors: "Smell-Seeing"

Biophysics of Smell and Taste

II. Chemical Effects of Ultrasound

Sonoluminescence and Spectroscopy

Synthetic Applications of Sonochemistry

Nano-Materials and Catalytic Applications

FRENAQs™

Frequently Not-Asked Questions: Educational Philosophy

- Undergraduate education is the learning of that which is already known:
  Graduate education is the learning of that which no one knows.
- Graduate education is learning how to do what we call research: i.e.,
  Graduate education is learning how to learn the unknown.
- I expect my students to become independent researchers:
  I cannot do that if I treat you like a technician!

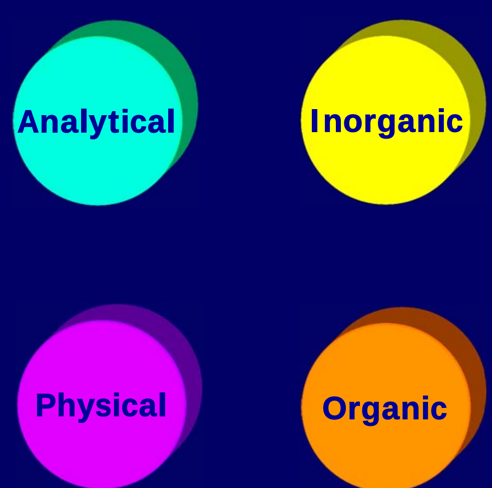
Research Philosophy

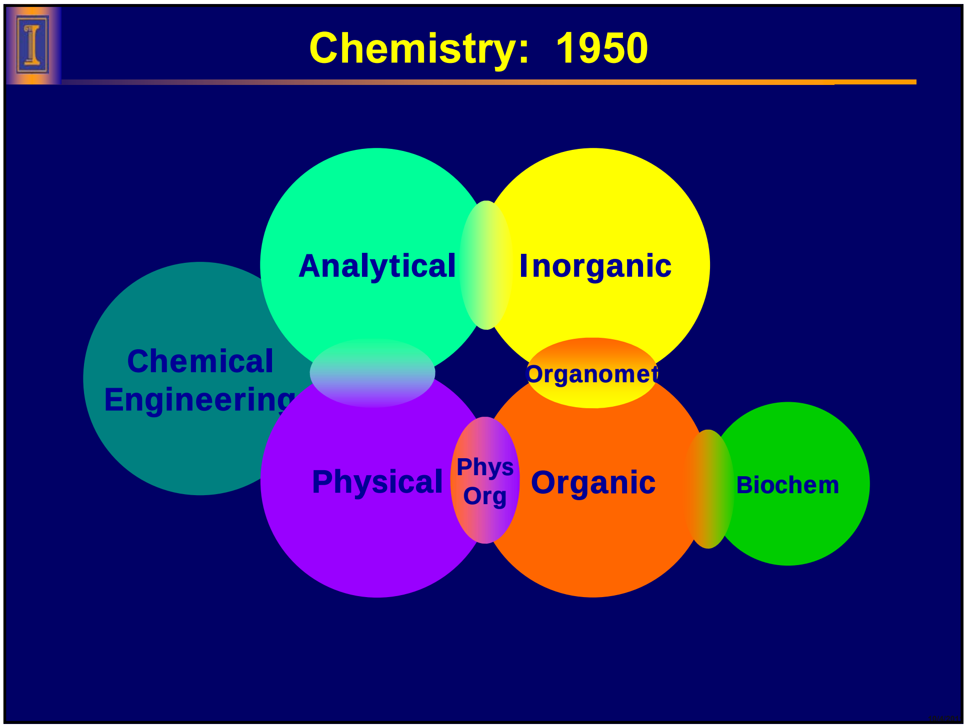
Criteria: The very best research permanently changes the way people think about some field of knowledge. If the goal of a project doesn't ultimately come up to that standard, the result will be boring.

Pure vs. Applied: Pointless distinction. More important: Is it interesting or boring?

Interdisciplinary and Multidisciplinary: Both between areas of chemistry and including elements from multiple fields of science.

Chemistry: 1900

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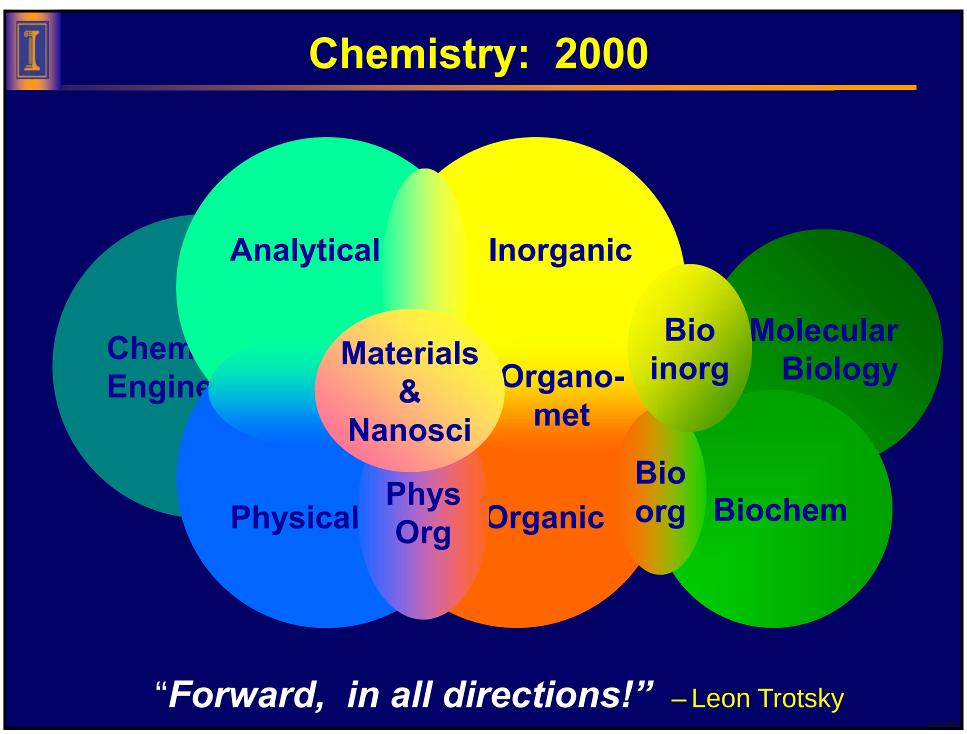
Analytical
Inorganic
Chemical Engineering
Organomet
Physical
Phys Org
Organic
Biochem


Chemistry: 2000
Analytical
Inorganic
Chem Engine
Materials & Nanosci
Organo-met
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Molecular Biology
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Phys Org
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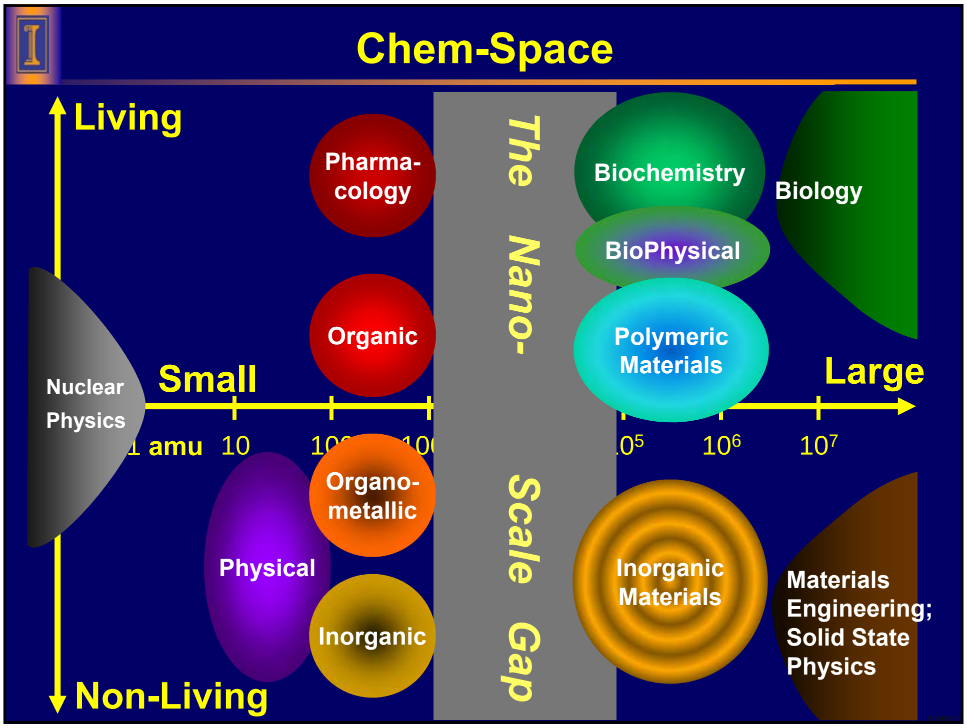
"Forward, in all directions!" – Leon Trotsky


Chem-Space
Living
Pharma-
cology
The Nano-Scale Gap
Biochemistry
Biology
BioPhysical
Organic
Polymeric
Materials
Nuclear
Physics
Small
Large
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10
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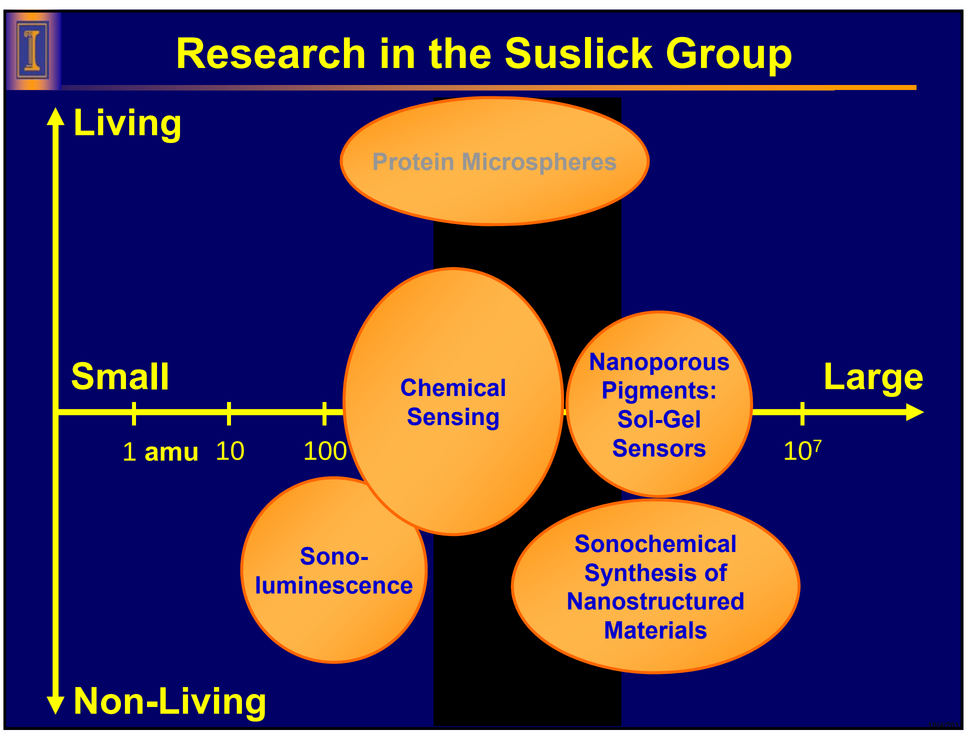
Organo-
metallic
Physical
Inorganic
Inorganic
Materials
Materials
Engineering;
Solid State
Physics
Non-Living


Research in the Suslick Group
Living
Protein Microspheres
Small
Chemical
Sensing
Nanoporous
Pigments:
Sol-Gel
Sensors
Large
1 amu
10
100
10^7
Sono-
luminescence
Sonochemical
Synthesis of
Nanostructured
Materials
Non-Living