Living in a Material World

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UW-Stout

Applied Science Seminar Nov. 20, 2014

San Francisco, CA

http://www.photoeverywhere.co.uk/west/usa/san_francisco/san_francisco_cityscape5699.jpg

What is Materials Chemistry?

- The Chemistry of Solids
  - Relationship between structure and properties of solids
  - Chemical transformations affecting solids
  - Synthesis and processing of solids

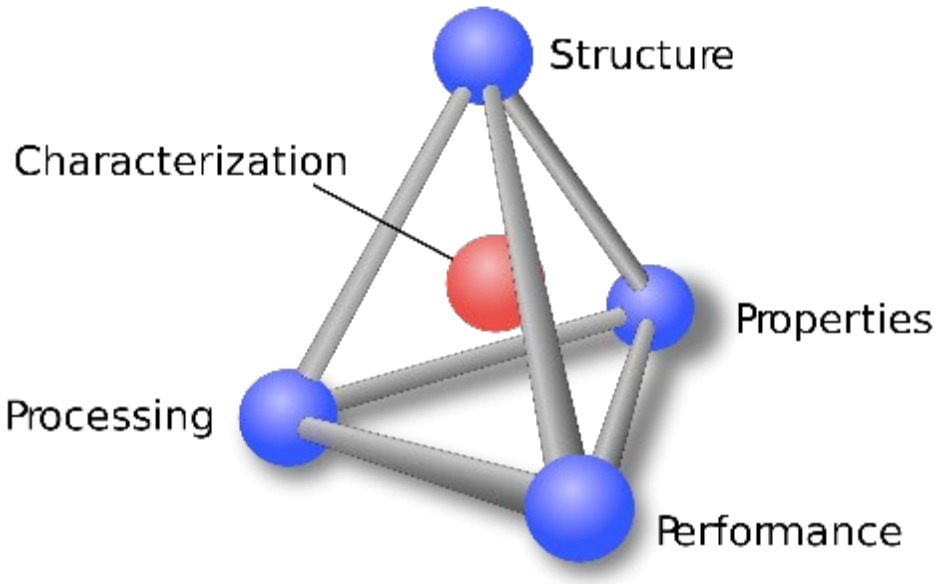
Materials and Nanoscience

- Structure

-Property-Performance-Processing-Characterization

- Size

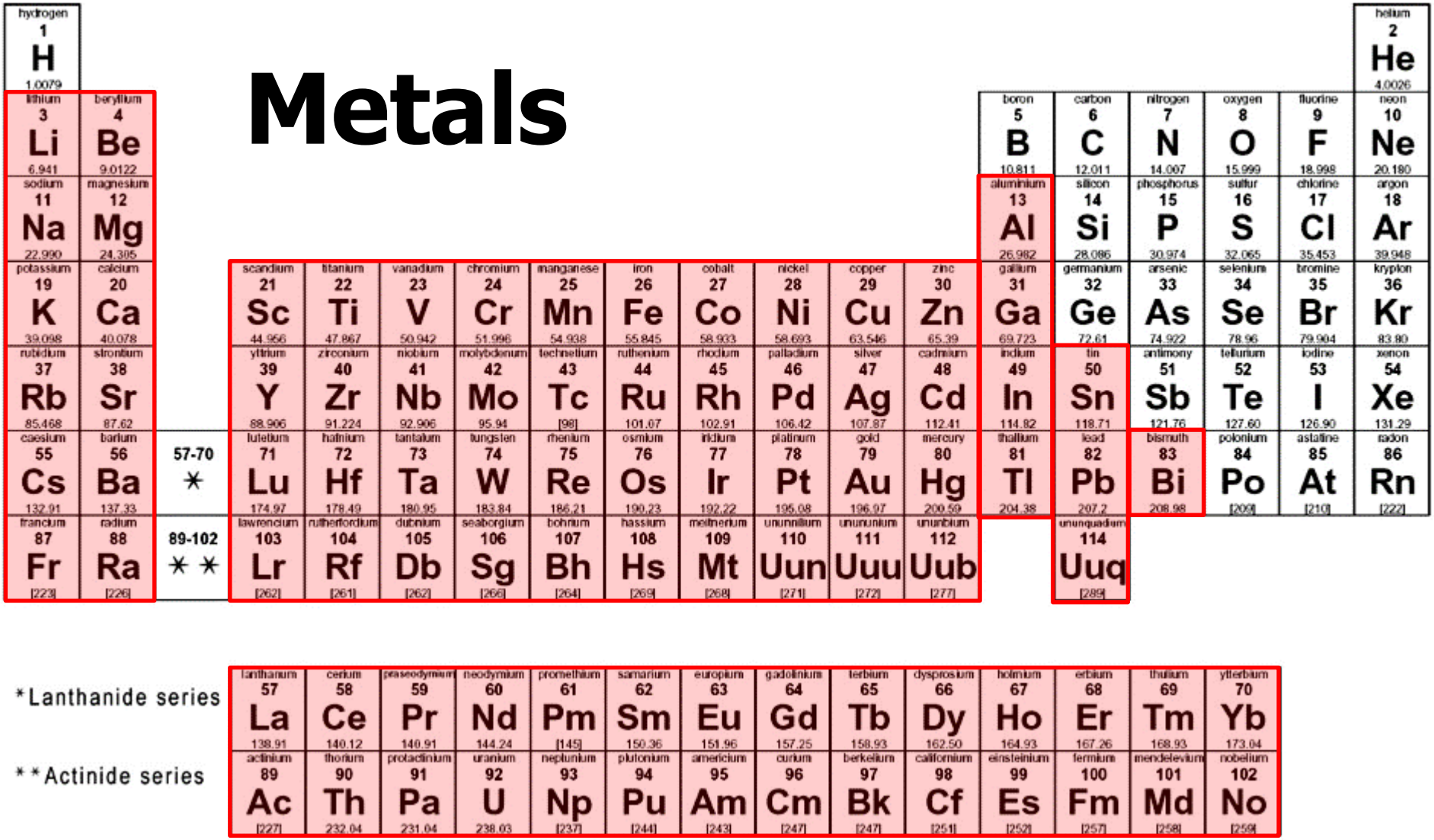
-Property-Performance-Processing-Characterization



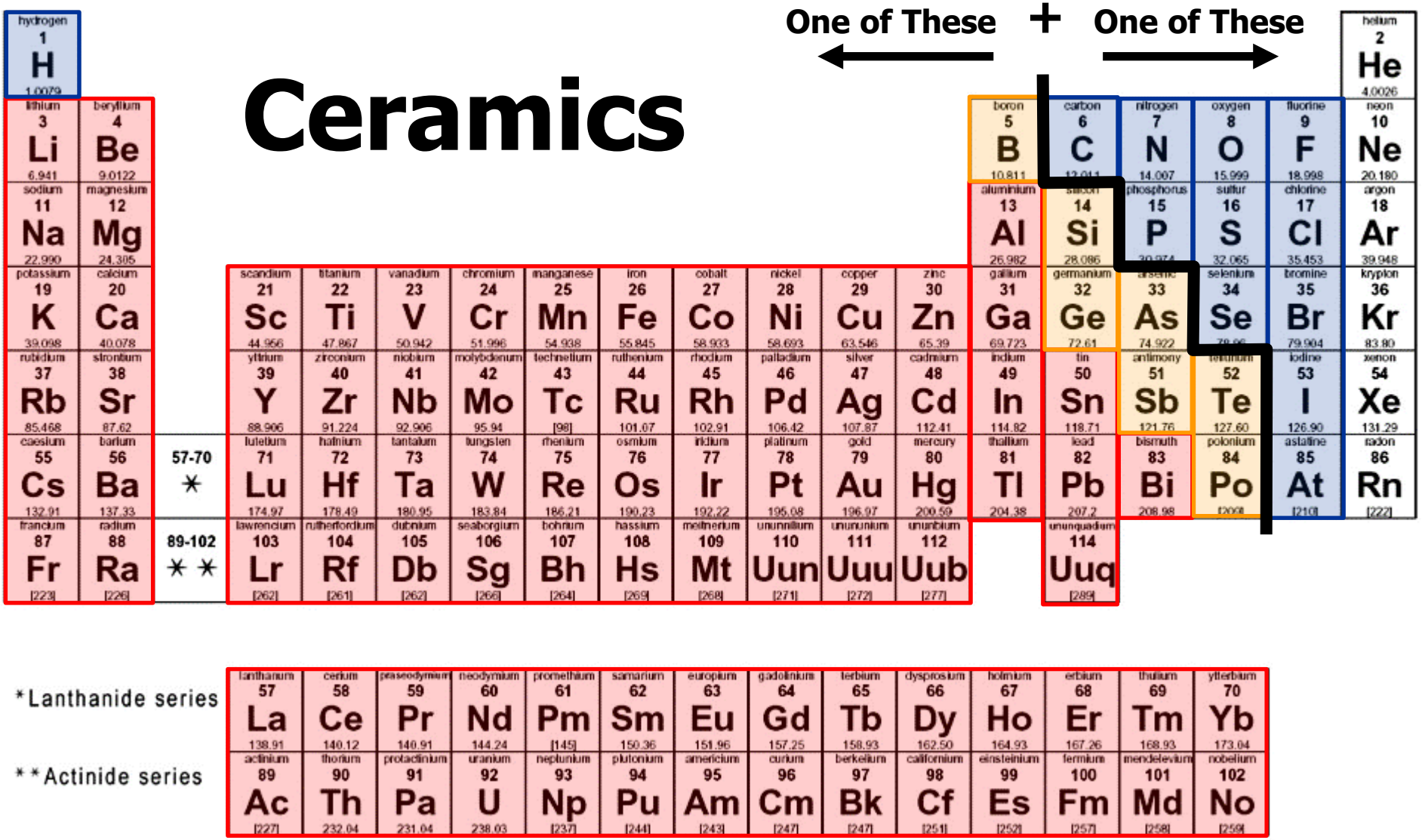
How Do We Classify Materials?

- **Metals** – pure metallic elements or mixtures of metallic elements
- **Ceramics** – compounds of metals and non-metals semiconductors are often types of ceramics
- **Polymers** – (Plastics) very large molecules made up of many parts or mers
- **Composites** – materials composed of two or more of the above

The Elements



The Elements



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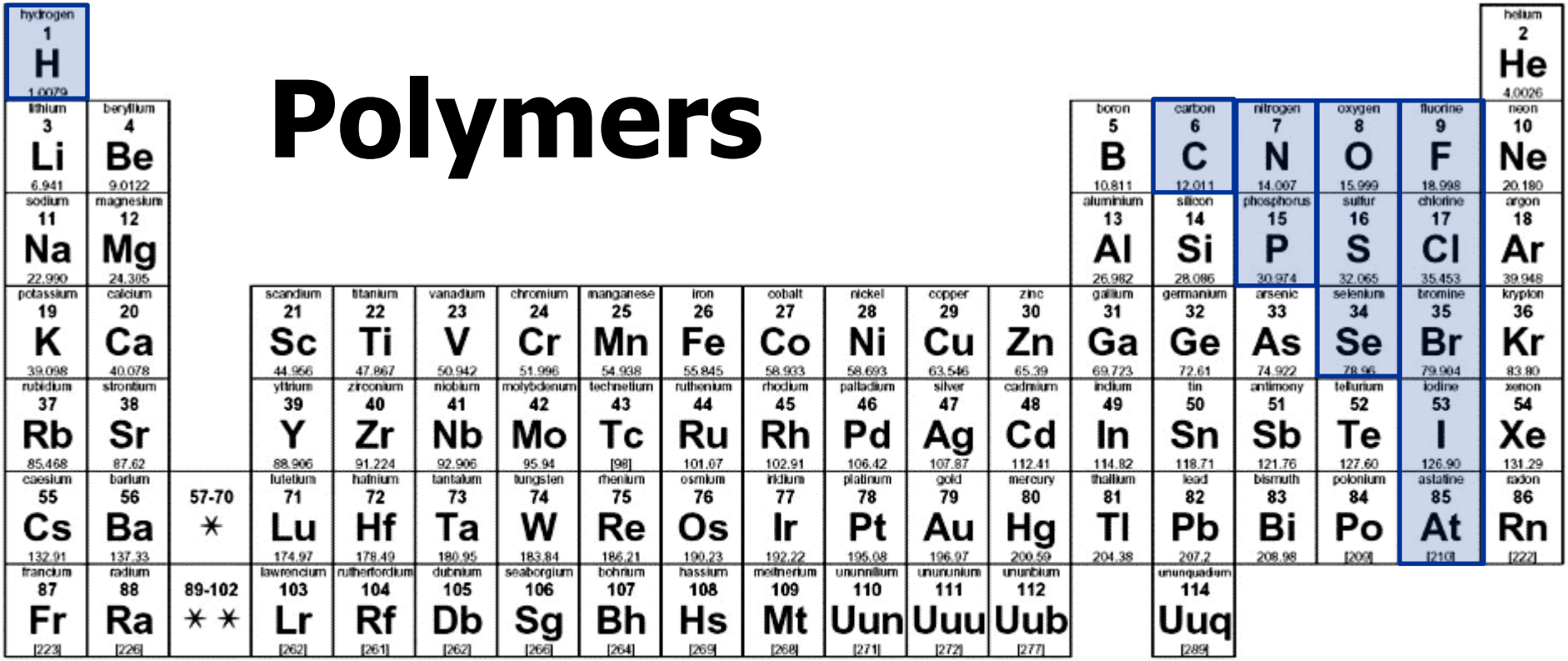
The Elements

Polymers



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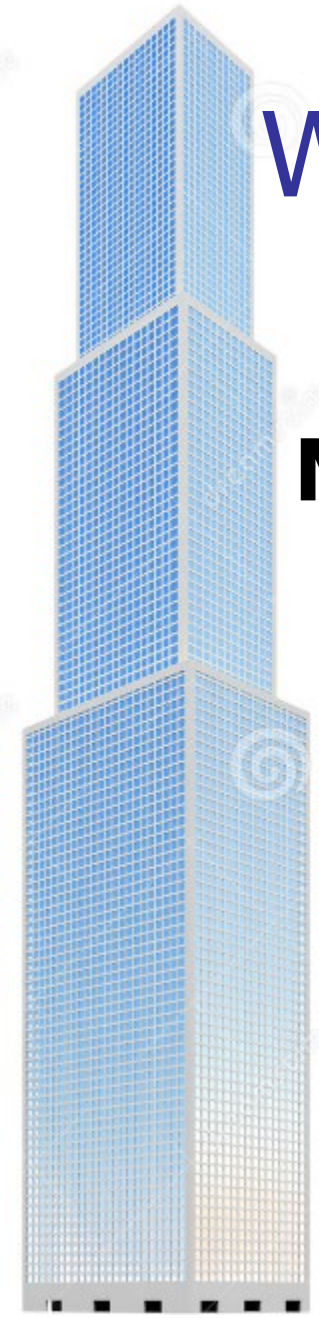
What Makes Materials Differ?



Macrostructure

Depends on . . .

Microstructure

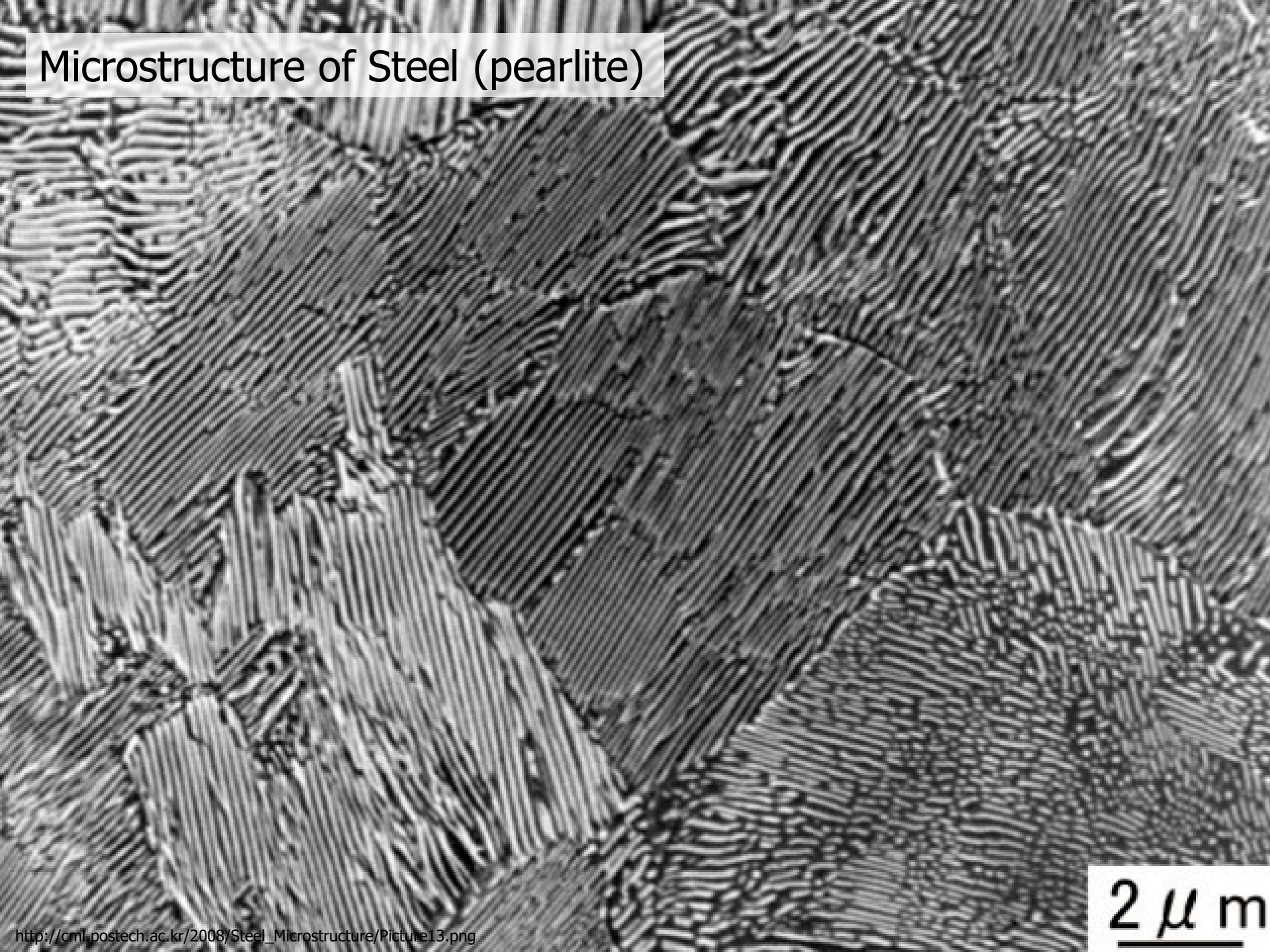
San Francisco, CA

http://www.photoeverywhere.co.uk/west/usa/san_francisco/san_francisco_cityscape5699.jpg

Steel I-Beam

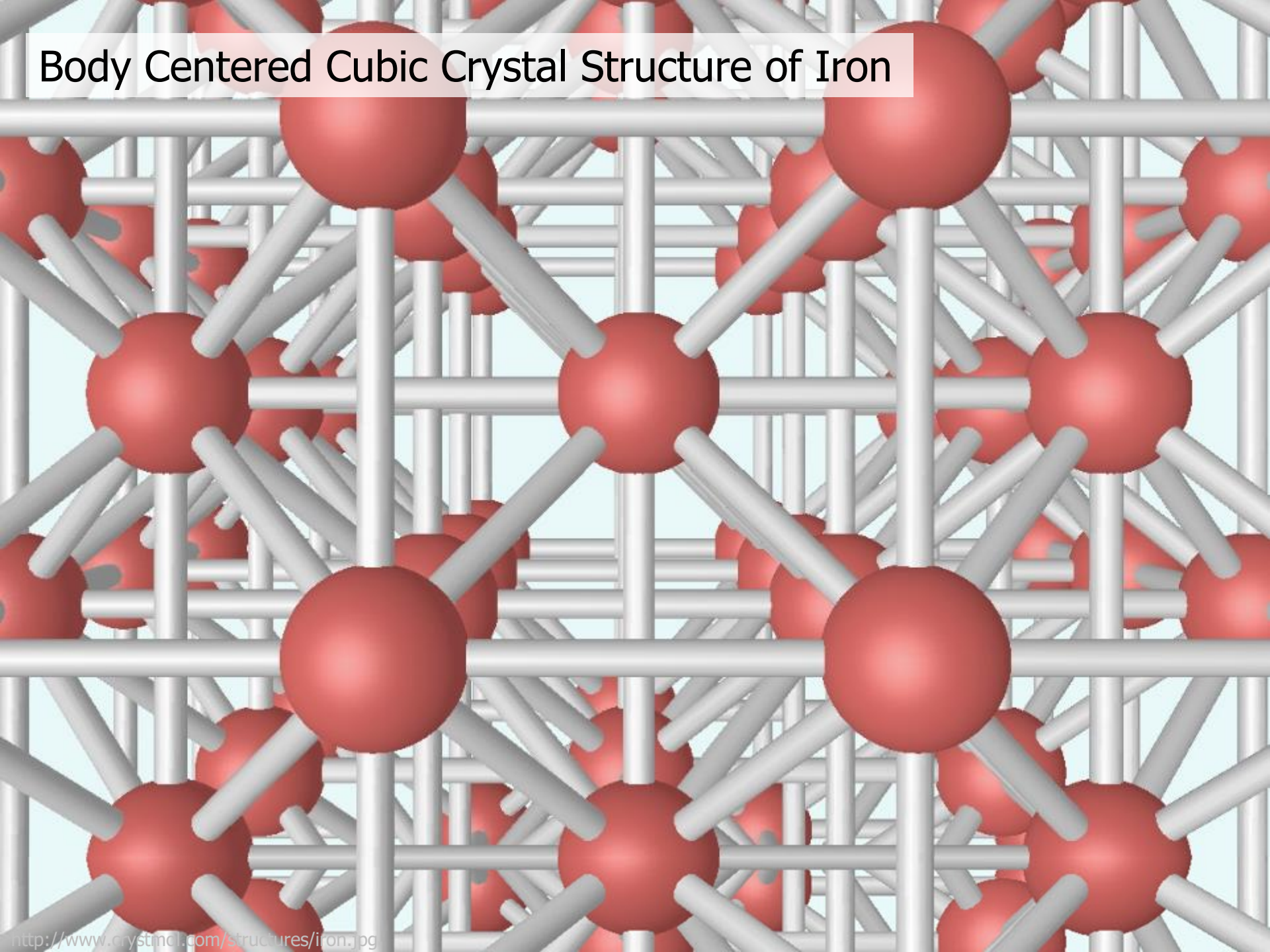
http://www.imscoatings.com/media/catalog/category/shutterstock_1820378.jpg

Microstructure of Steel (pearlite)



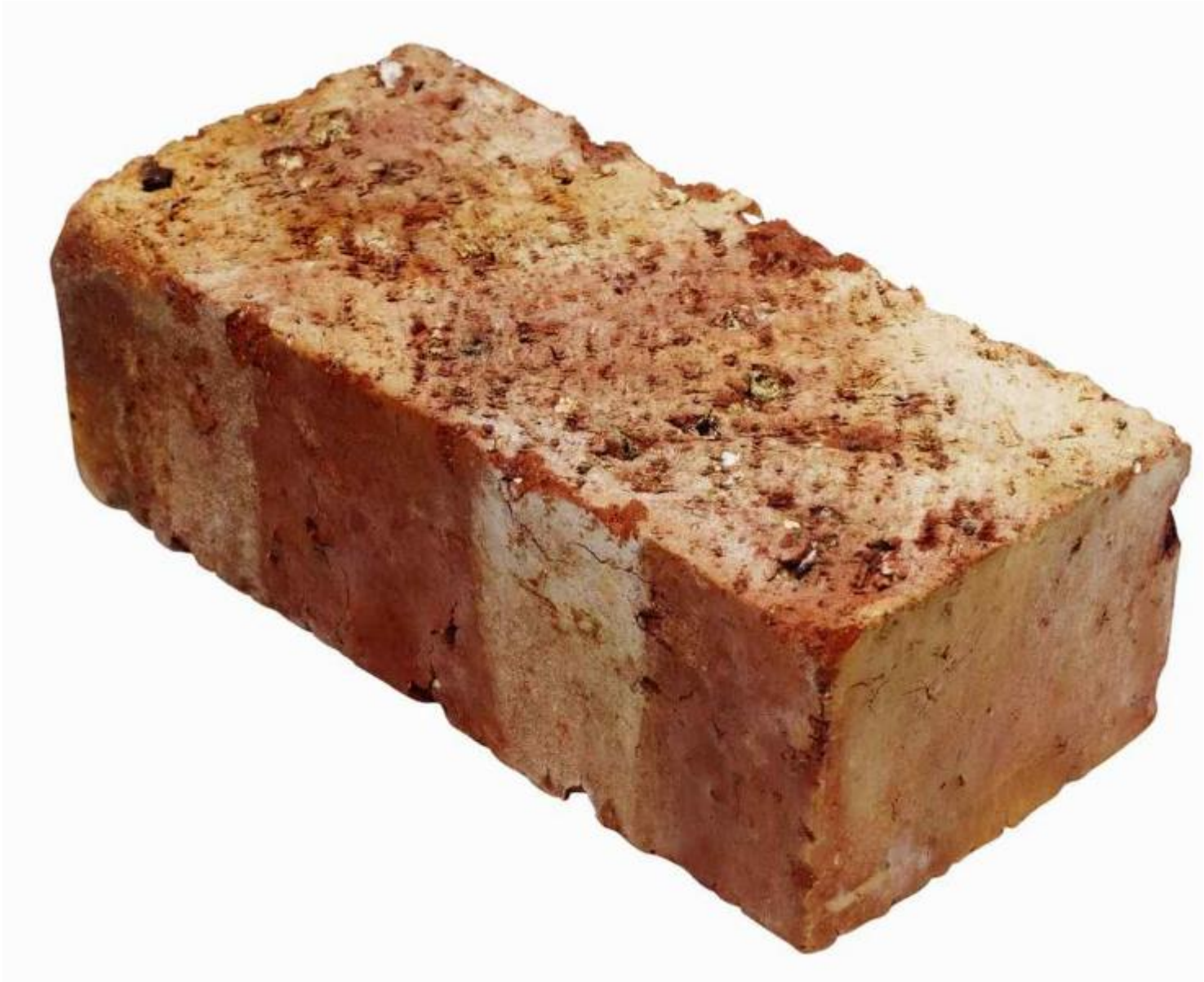
http://cml.postech.ac.kr/2008/Steel_Microstructure/Picture13.png

Body Centered Cubic Crystal Structure of Iron



http://www.crystmol.com/structures/iron.jpg


ENGINE HOUSE
-N°5-



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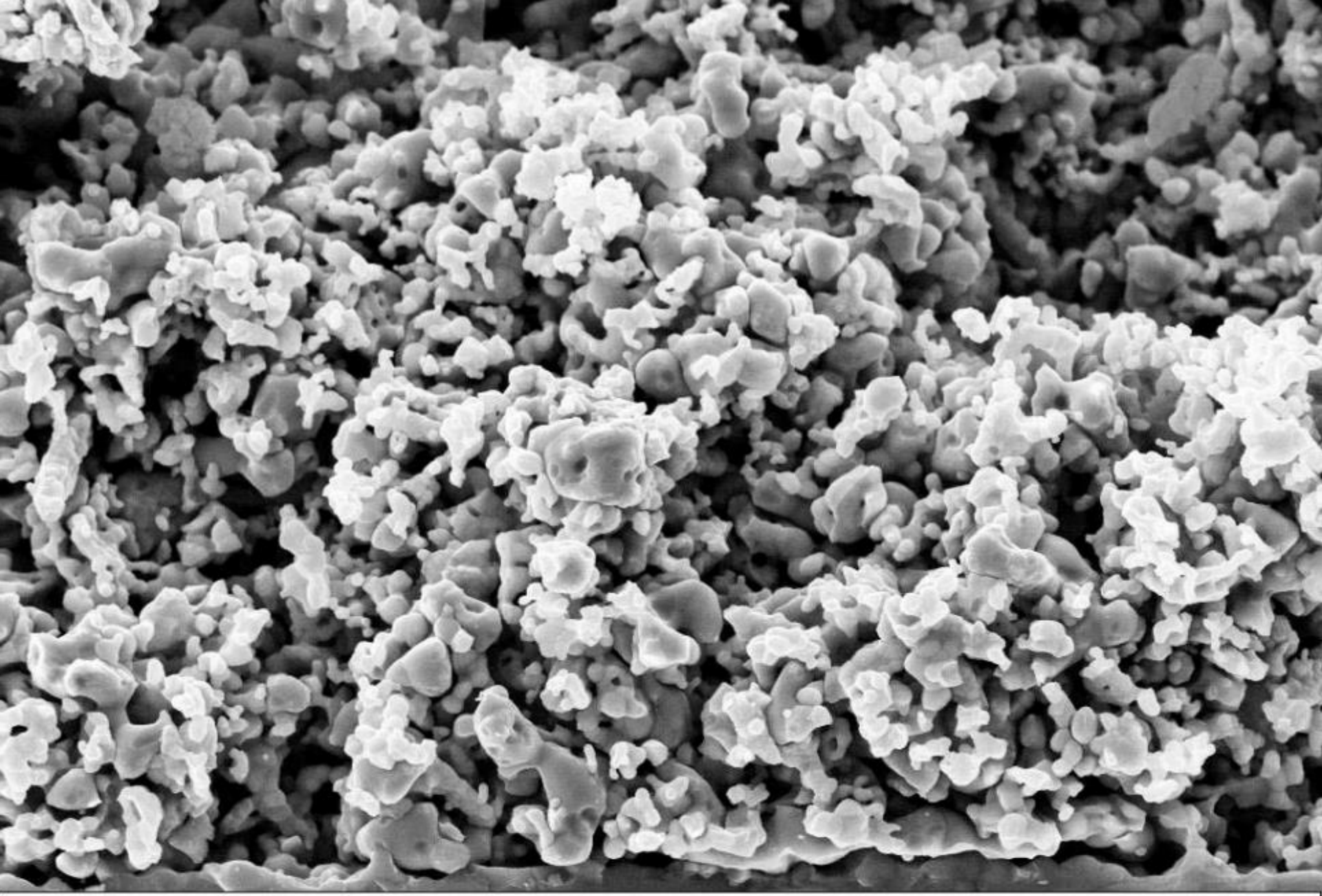

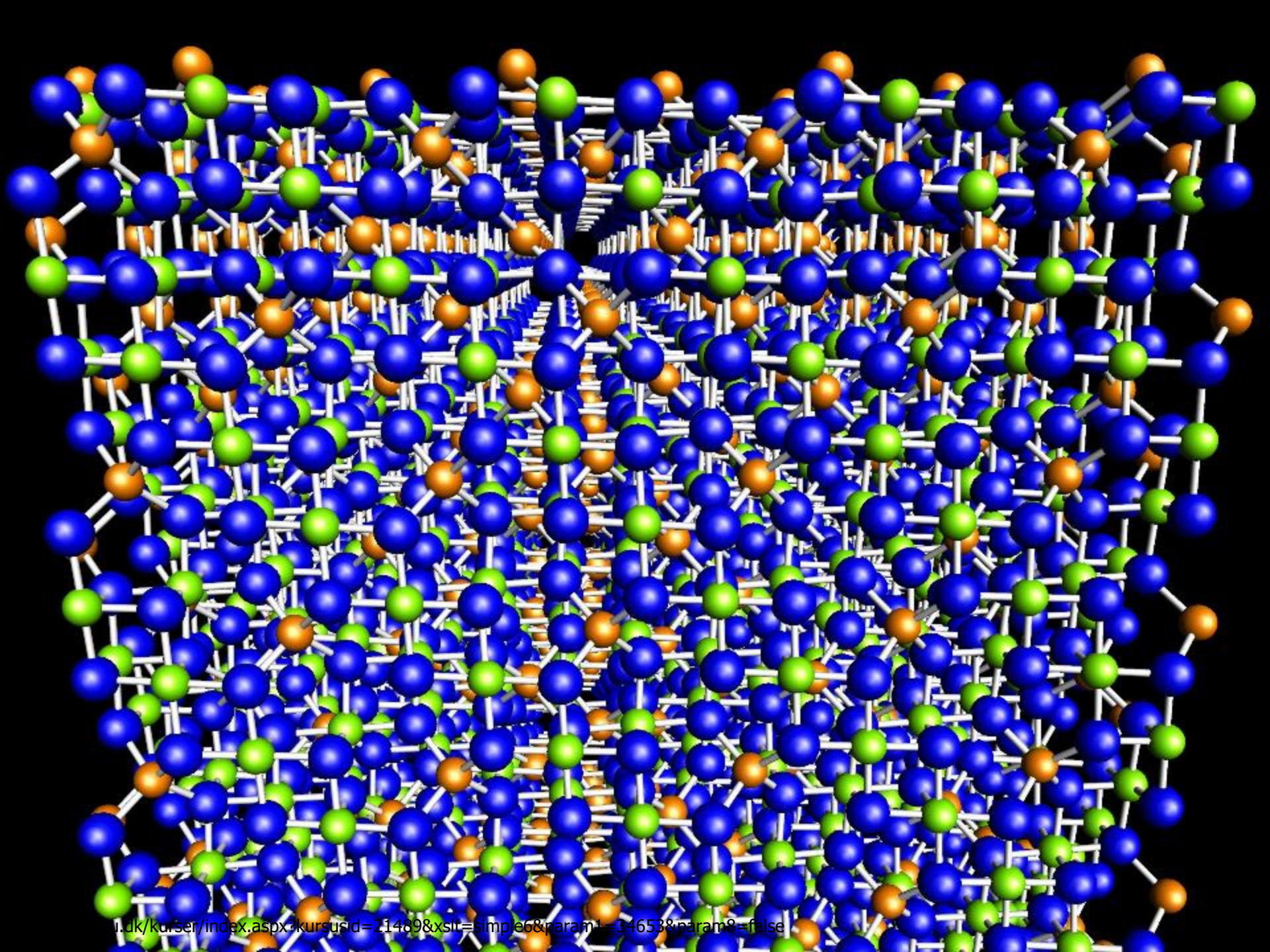
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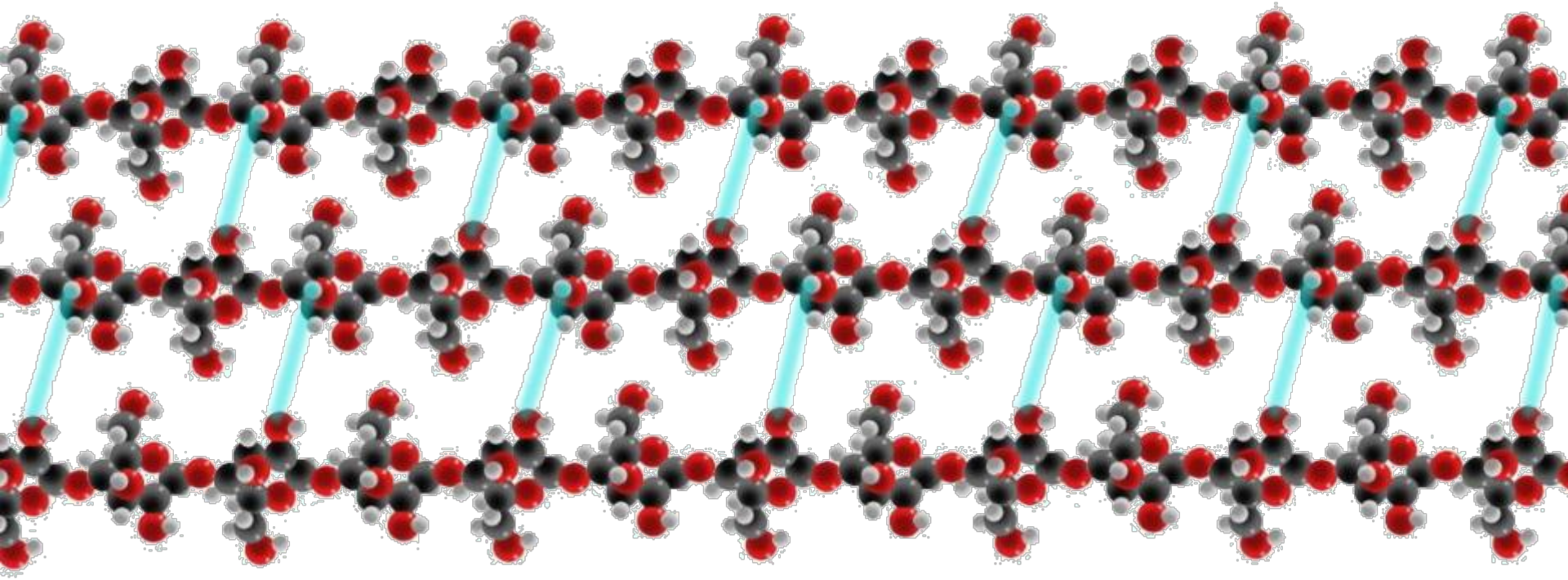
http://www.foodfunandfacts.com/canstockphoto2443478colorteasclotheline.jpg

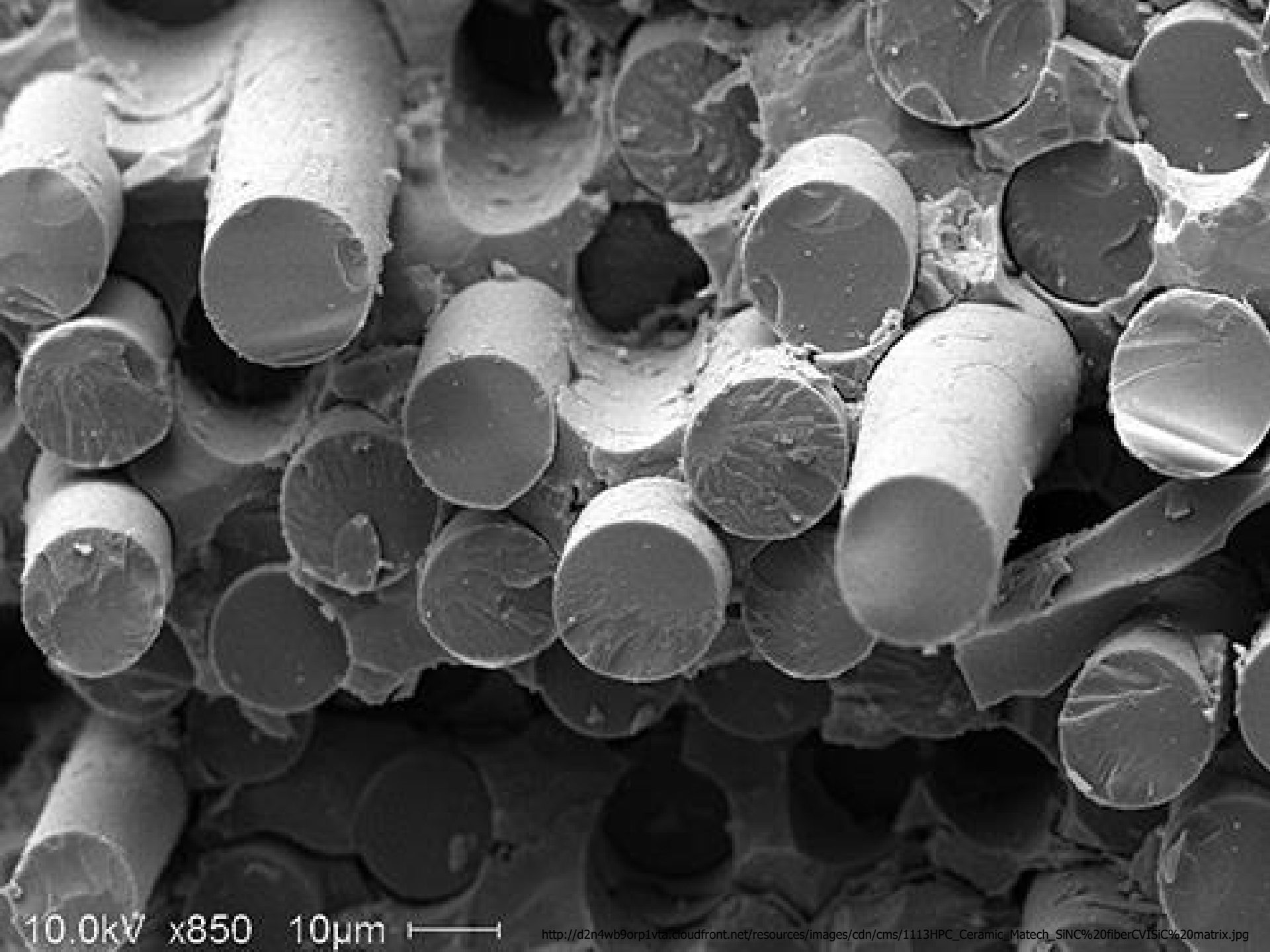
http://www.uwo.ca/fab/resources/Images/SEM/fabric.jpg



http://en.wikipedia.org/wiki/Cellulose

http://www.marineproducts.net/content/images/Birdsall/birdsall_1.jpg

http://www.boatdesign.net/forums/attachments/materials/50871d1291586763-heat-treated-fiberglass-mat-p1010129.jpg
http://www.easycomposites.co.uk/images/products/large/EF80-Flexible-Epoxy-Resin.jpg



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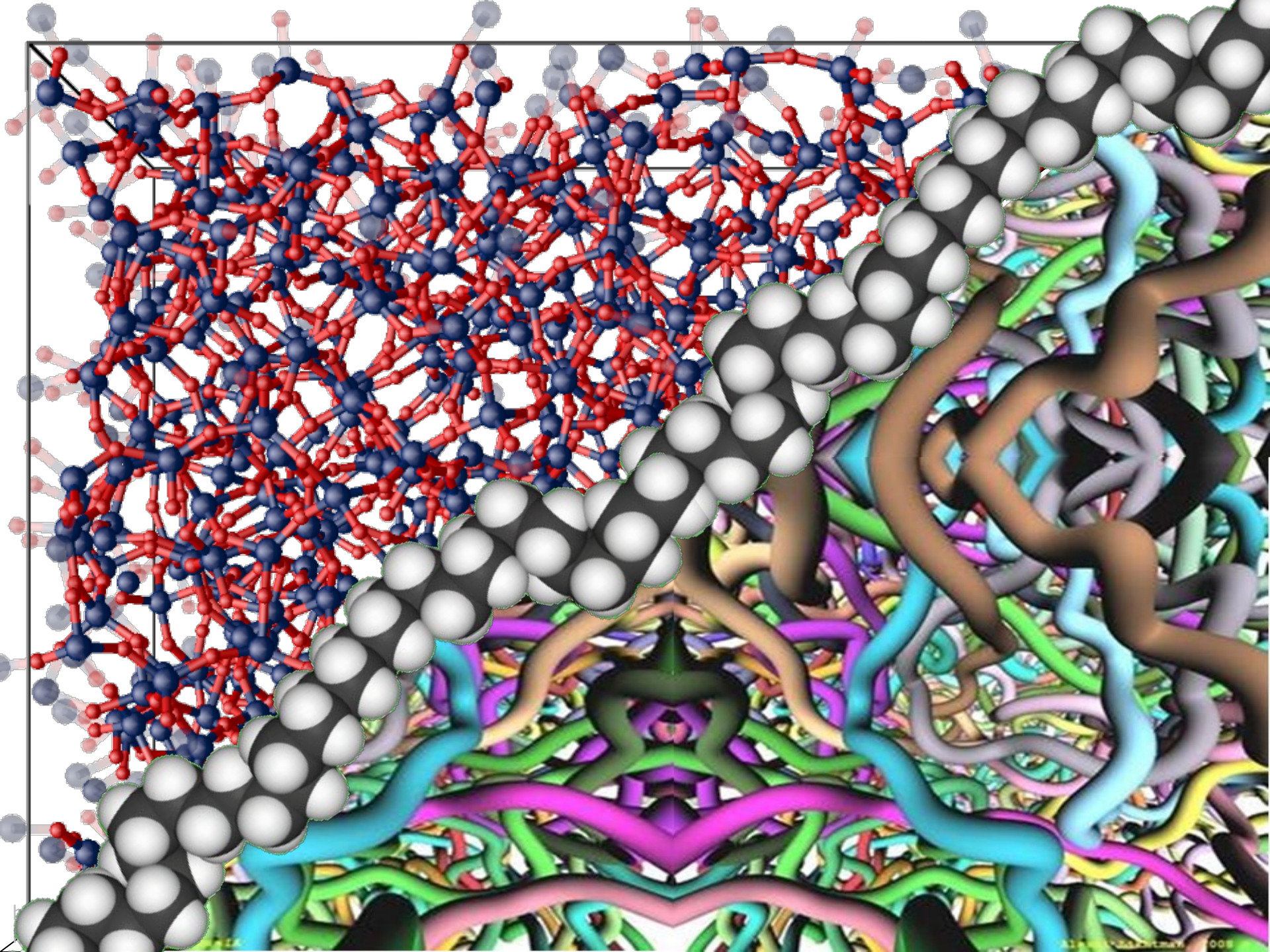


Categories of Properties

- **Mechanical Properties** – deformation of material due to applied force
- **Electrical** – reaction of material to applied electric field
- **Thermal** – reaction of material to applied heat
- **Magnetic** – response of material to applied magnetic field
- **Optical** – response of material to light radiation
- **Deteriorative** – response of material to chemical and environmental stimuli

Metals

- **Bonding:** Metallic Bonding
- **Structure:** Crystalline Lattice
- **Plusses:** Strong, Tough, Heat Resistant, Weldable
- **Minuses:** Heavy, Prone to Corrosion

Ceramics

- **Bonding:** Covalent Bonding
- **Structure:** Crystalline Lattice
- **Plusses:** High Compressive Strength, Heat Resistant
- **Minuses:** Low Impact Strength

Polymers

- **Bonding:** Covalent Bonding and Inter-Chain IMFs
- **Structure:** Amorphous and Semi-crystalline
- **Plusses:** Easy to form, recyclable

- **Minuses:** Low Heat Tolerance, Not as Strong

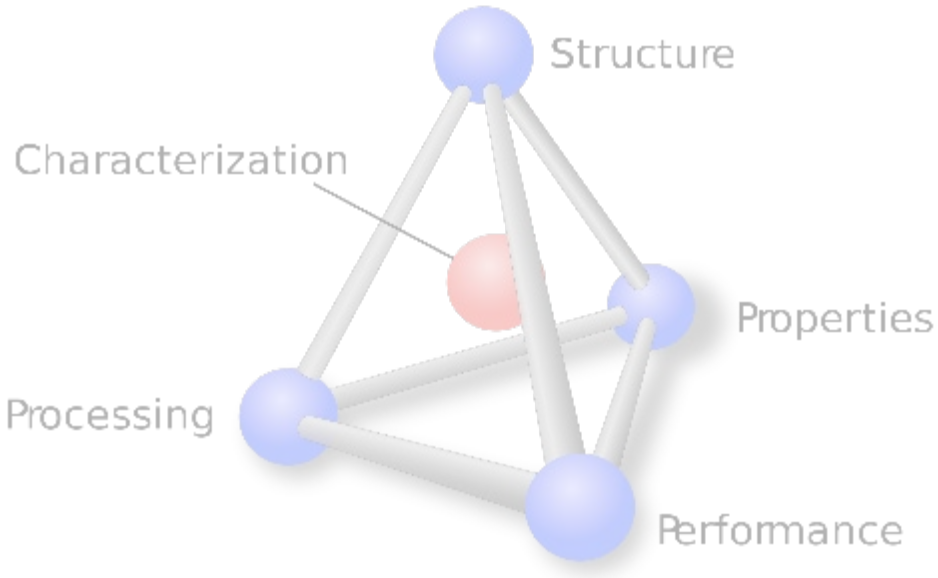
Materials and Nanoscience

- Structure

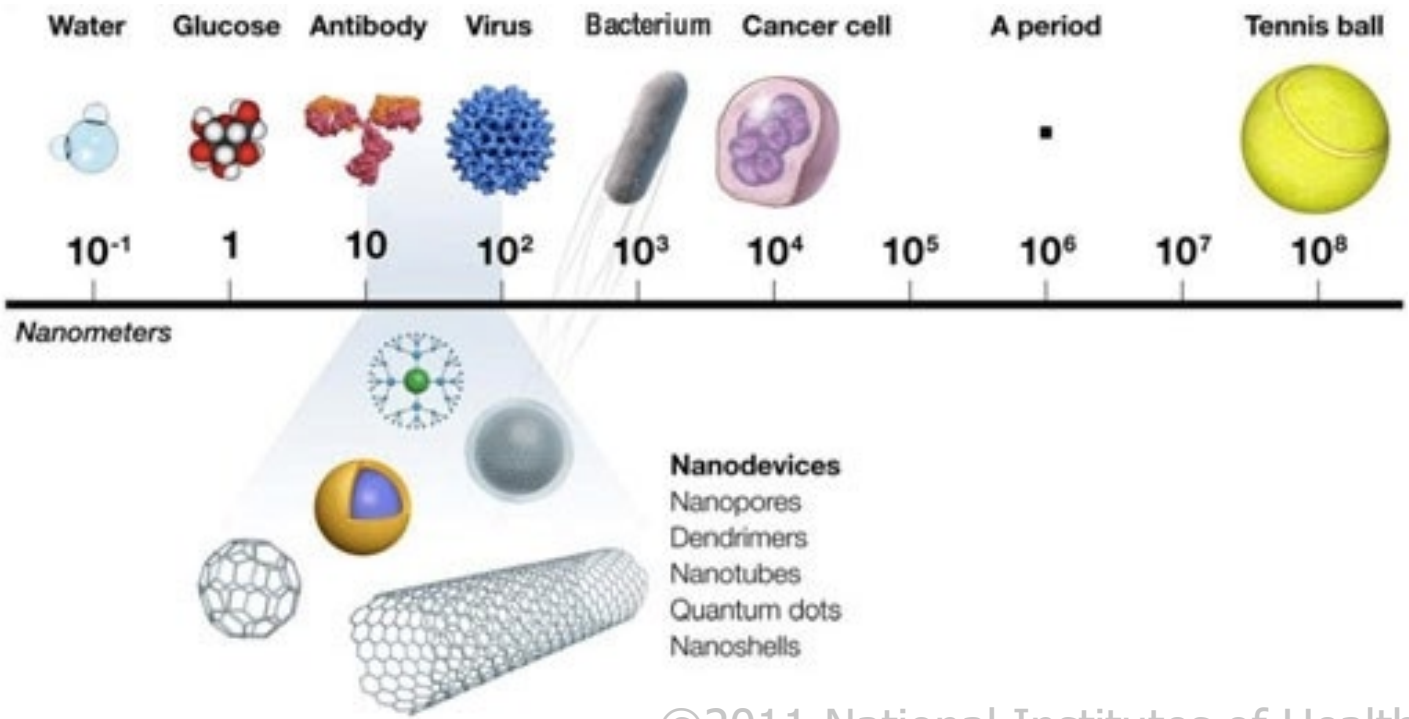
-Property-Performance-Processing-Characterization

- Size

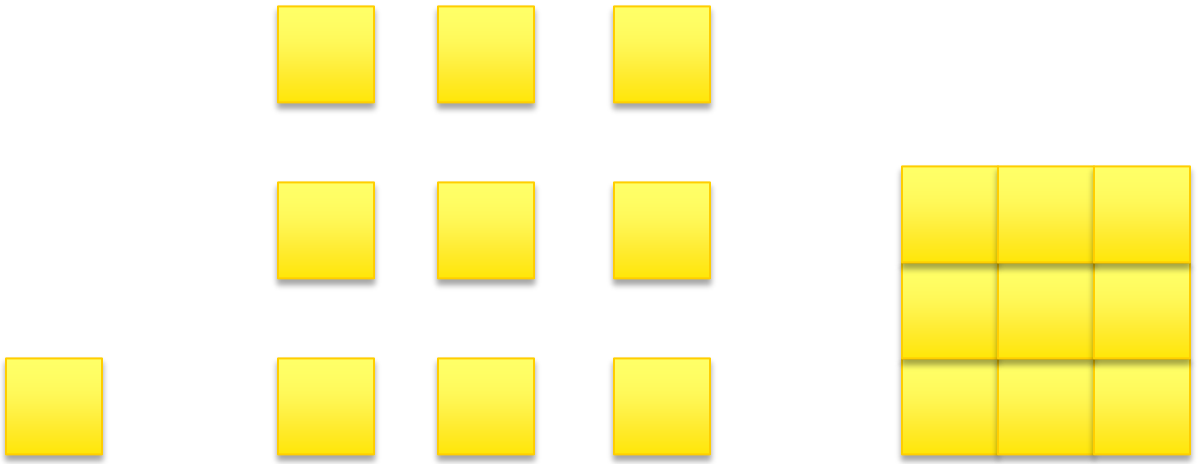
-Property-Performance-Processing-Characterization



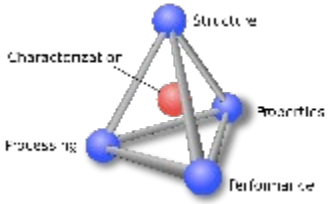
Size Range



Surface Area to Volume Ratio

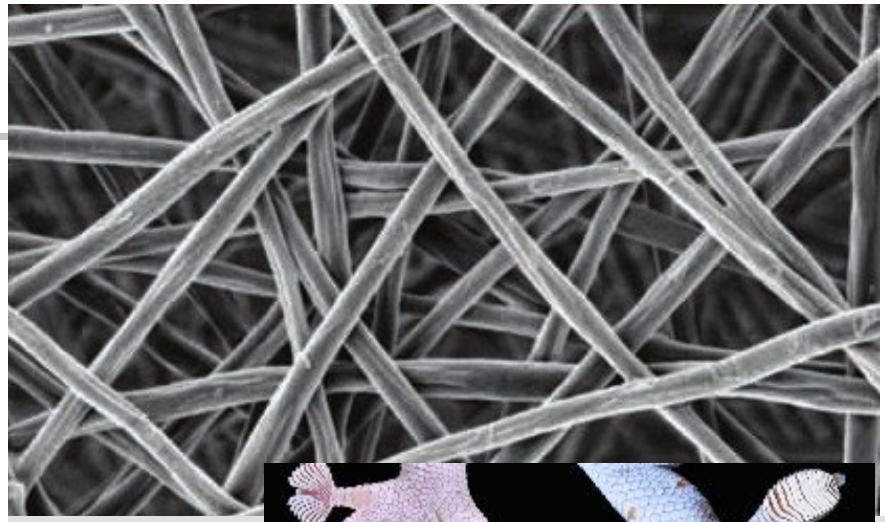


Surface Area (m^2)	.24	2.2	1.2
Volume (m^3)	.008	.072	.072
Ratio (m^{-1})	30	30	17



Surface Area

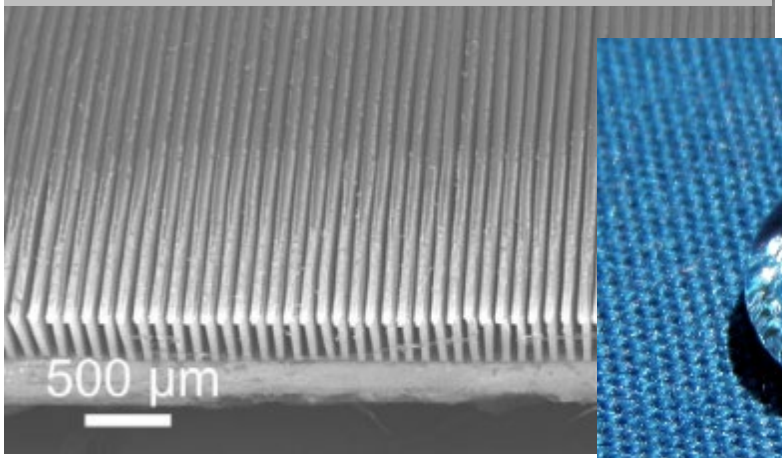
- Filtration
- Heat dissipation
- Wetting
- Adhesion

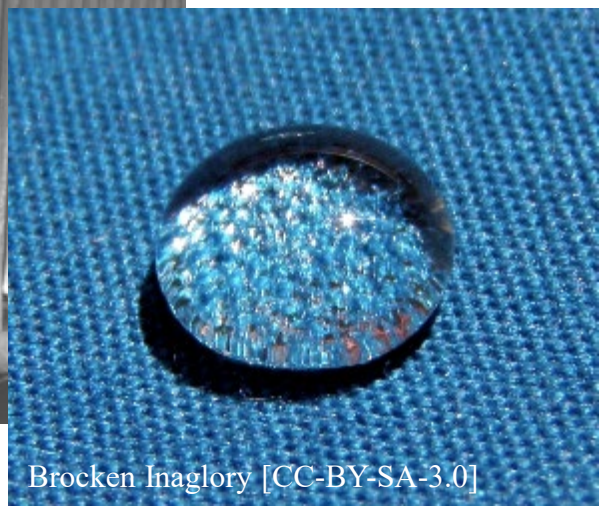


materialsviews.com

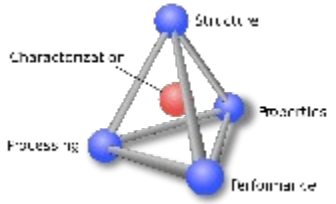
gecko feet © 2009 Kellar Autumn

CNT microfins by Dr. Liu, Chalmers U. of Tech.

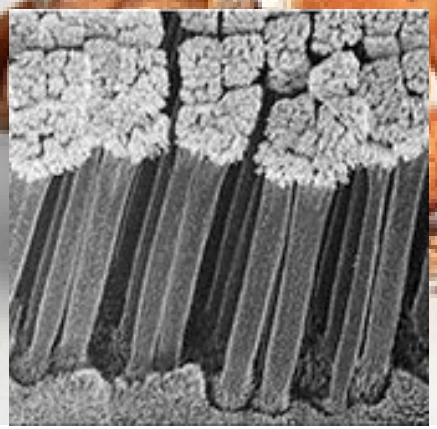


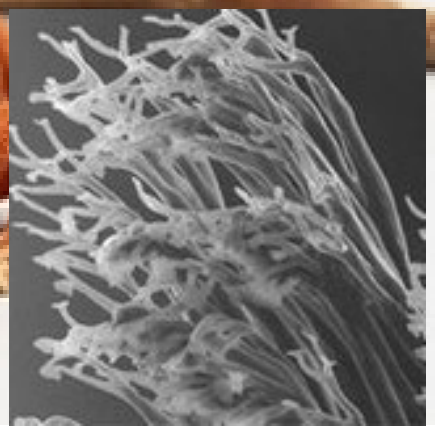


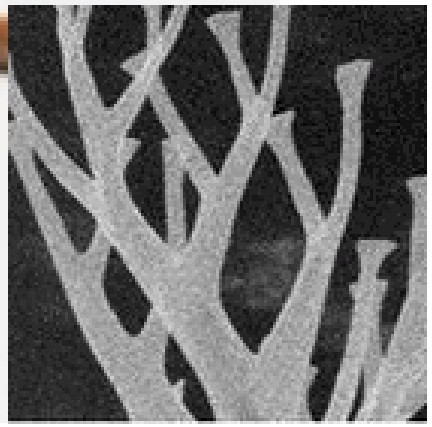
Brocken Inaglory [CC-BY-SA-3.0]



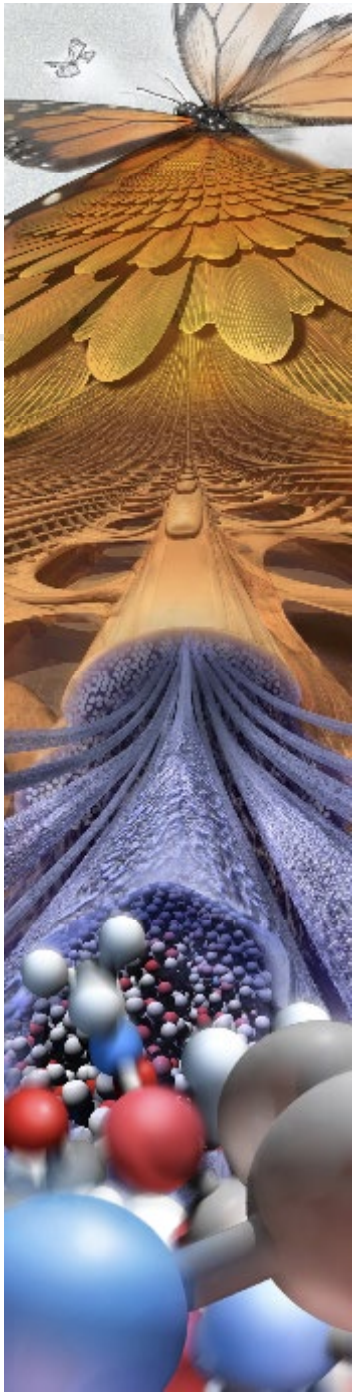
van der Waals forces



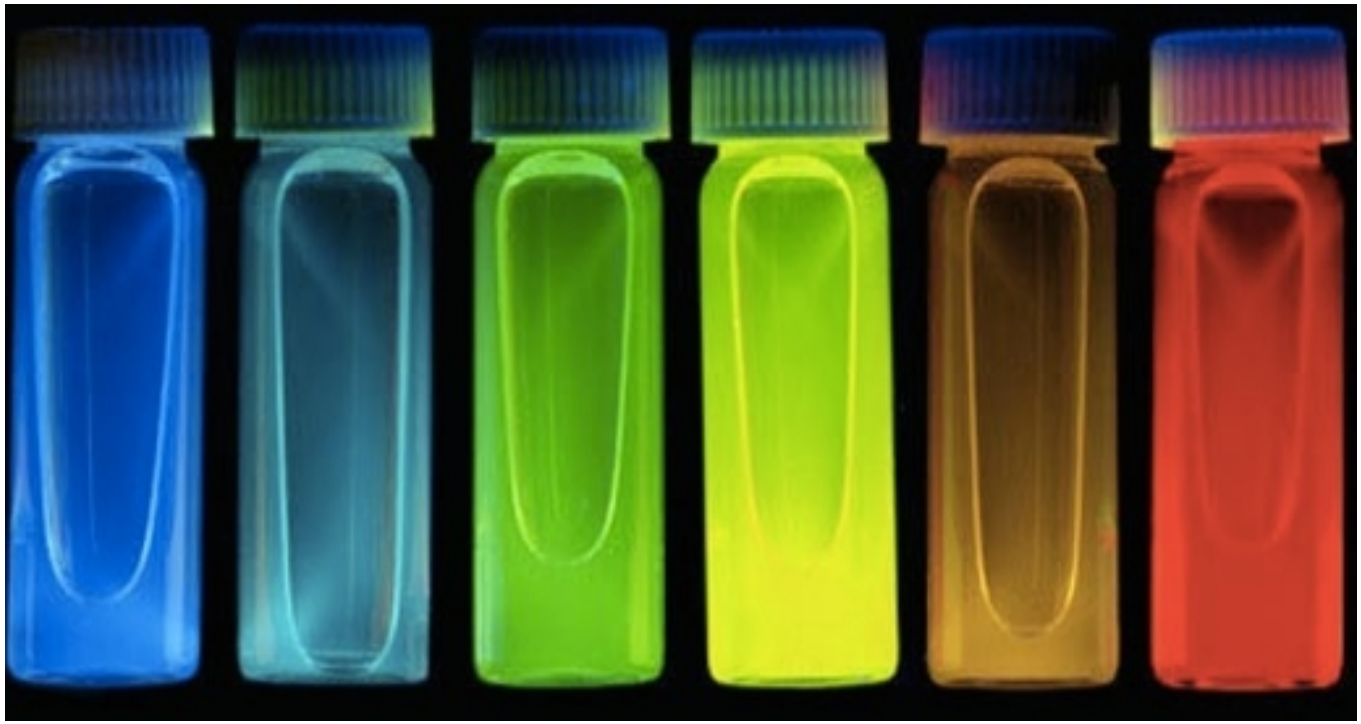




Blue Morpho Butterfly



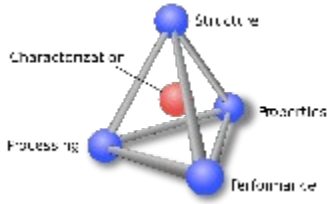
Size Matters



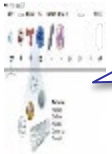
colloidal suspensions of variously-sized quantum dots in inert solvents © Felice Frankel

Medieval Stained Glass

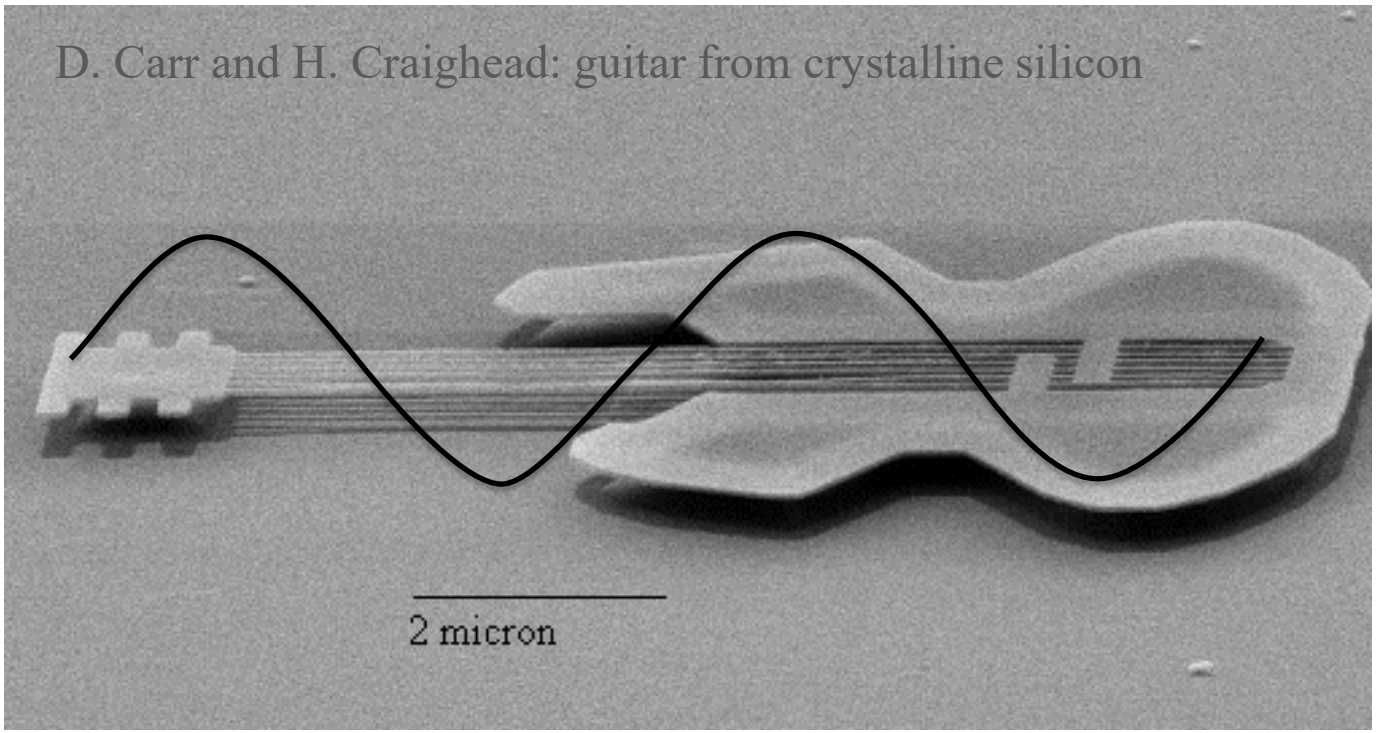
Theodosius Arrives at Ephesus (Scene from the Legend of the Seven Sleepers), ca. 1200–1205. The Cloisters Collection, 1980 (1980.263.4)



Nano Guitar



Button your vacuole, baby!

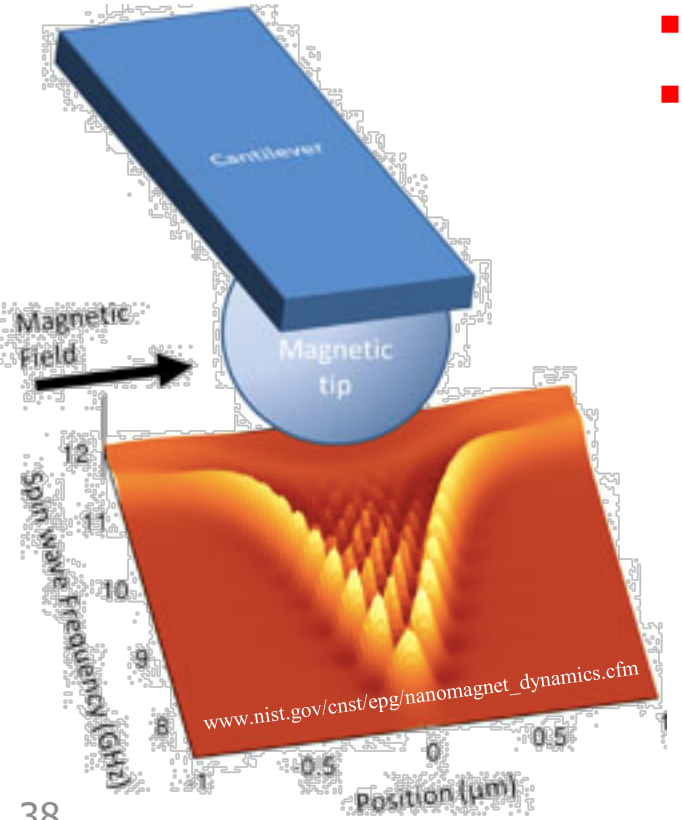


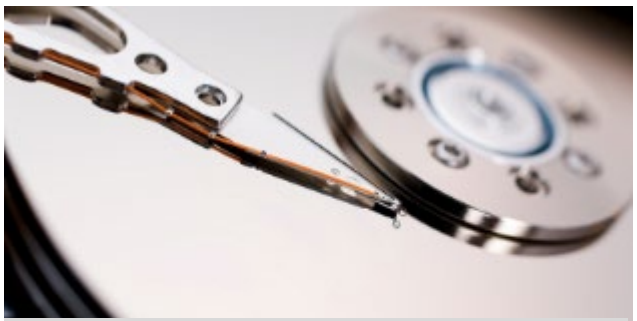
86 MHz (humans can't hear above 20 kHz)

Nanomagnet Fabrication

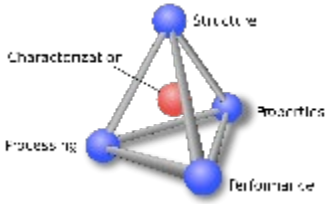
Hard Disks

- more robust than solid state drives
- current hard disks (10^{11} bytes)
- Nanomagnet disks (>10^{13} bytes)



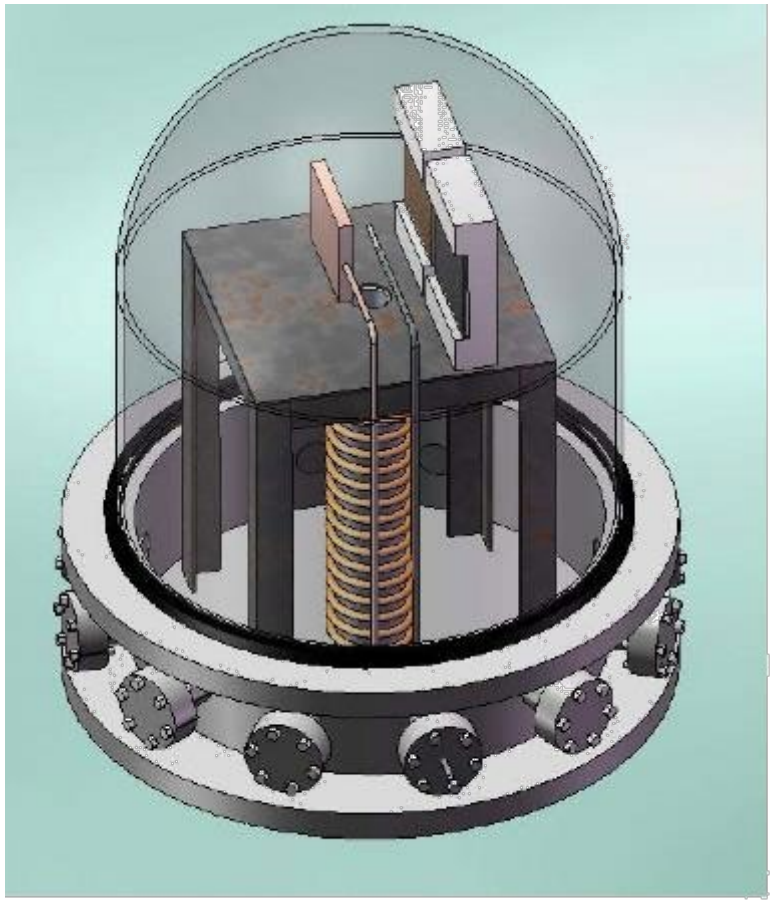


University of California - Davis. (2013, May 20). Iron-platinum alloys could be new-generation hard drives. ScienceDaily.



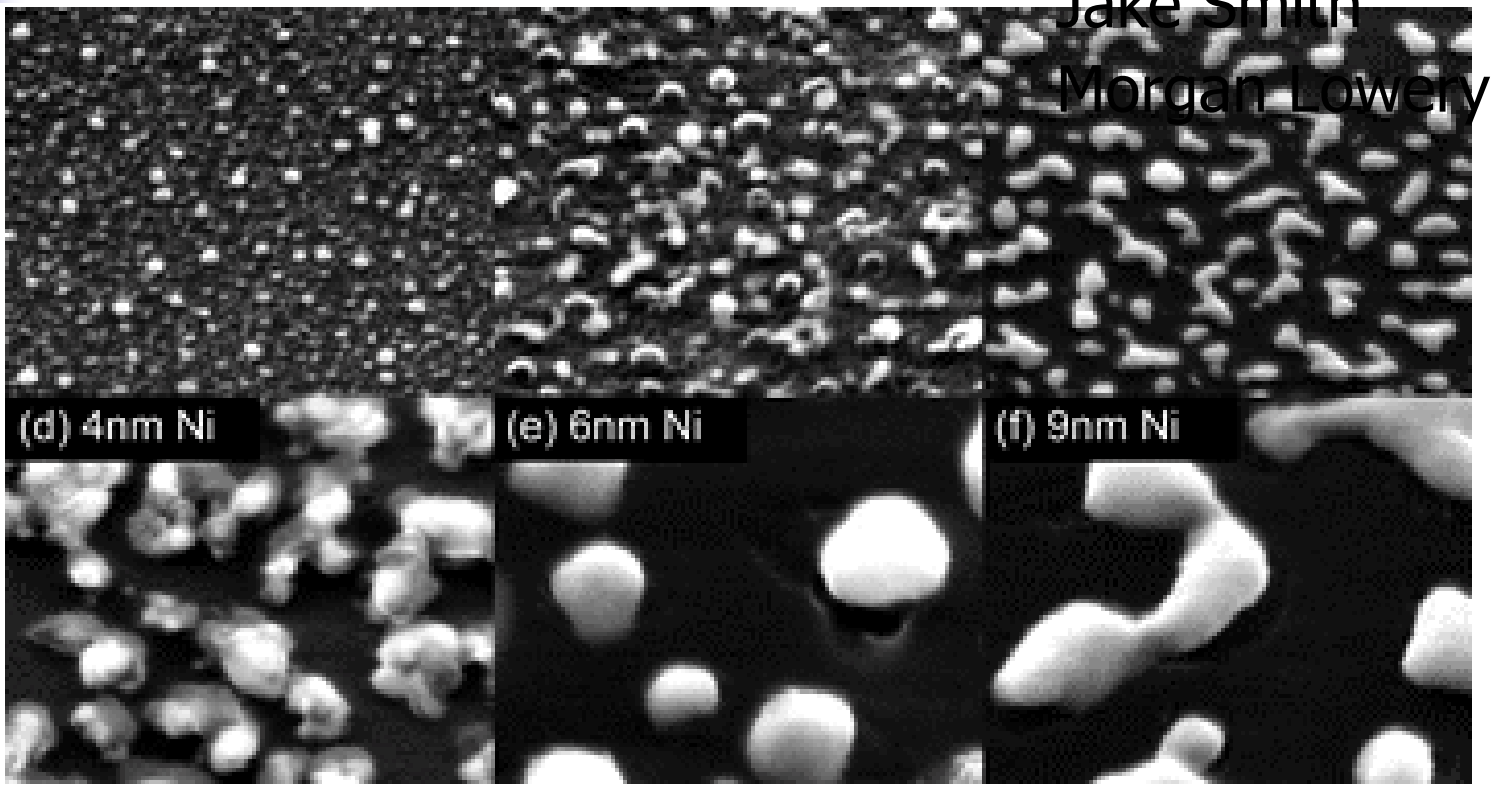
Sputter Chamber Construction

Cody Lang
Roy Lindsay
Aaron Forde
Kirk Coughlin
Ryan Kraft
Bill Hahn
Shawn Kozey
Jake Smith

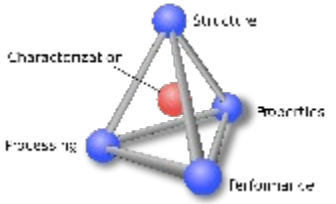


IGC

Sarah Voeller
Aaron Cochran
Jacob Ferrina
Shawn Kozey
Jake Smith
Morgan Lowery

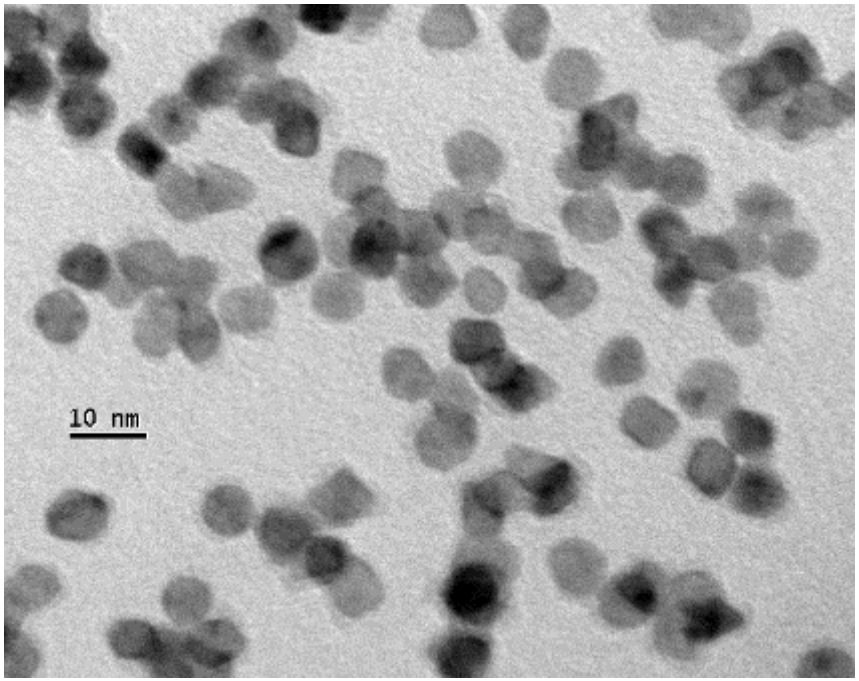


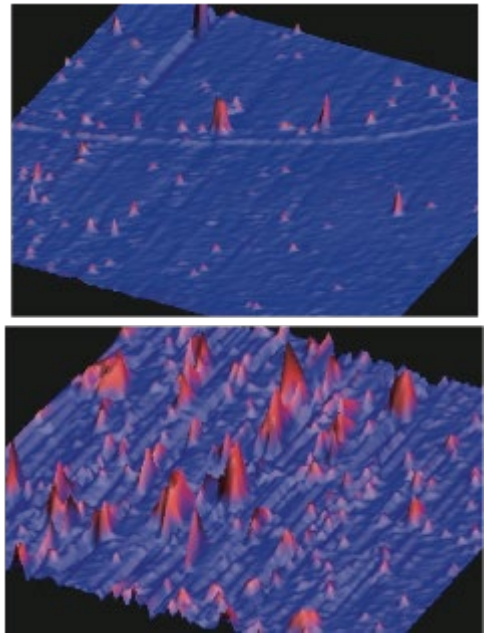
13 SEM photographs of Ni films with varying thicknesses deposited using magnetron sputtering on 50 nm of SiO2 after annealing at 750 ° C in 20 Torr of H2 for ...

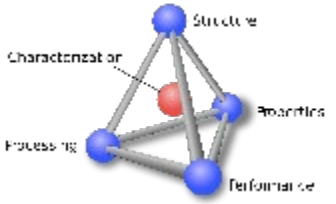


Nanomagnet Characterization

- AFM
- TEM

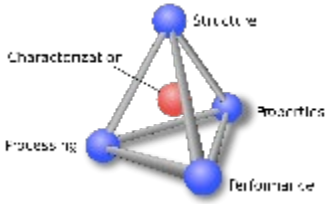






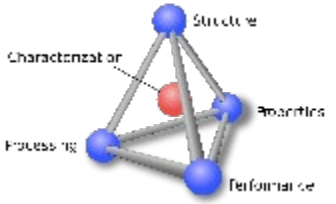
Quadrupole Mass Spec

- Matt Bouc



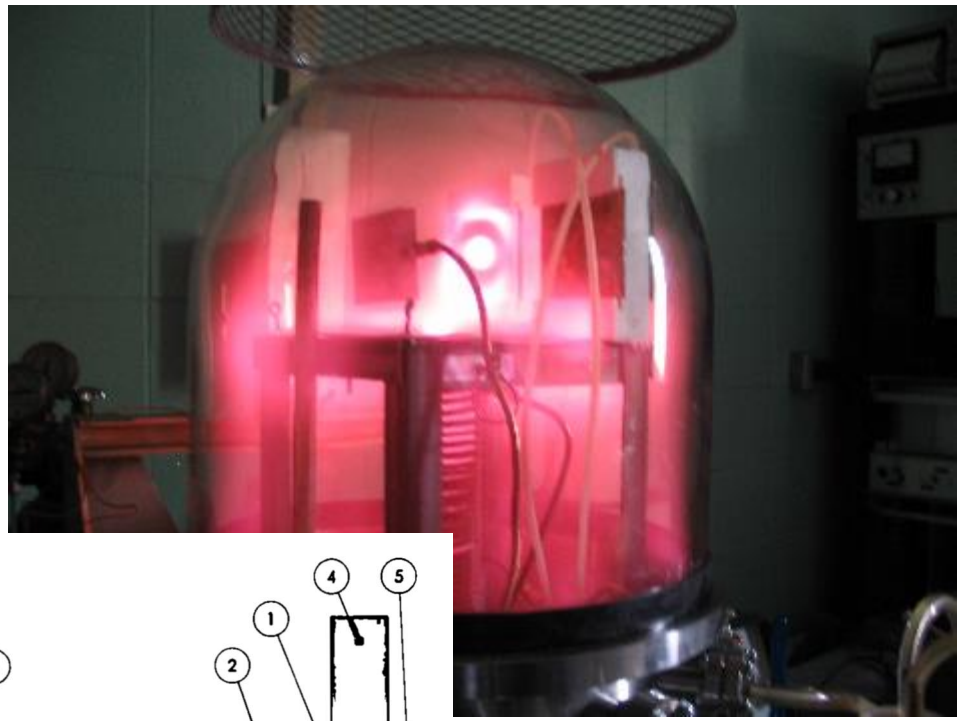
SEED Chamber Construction

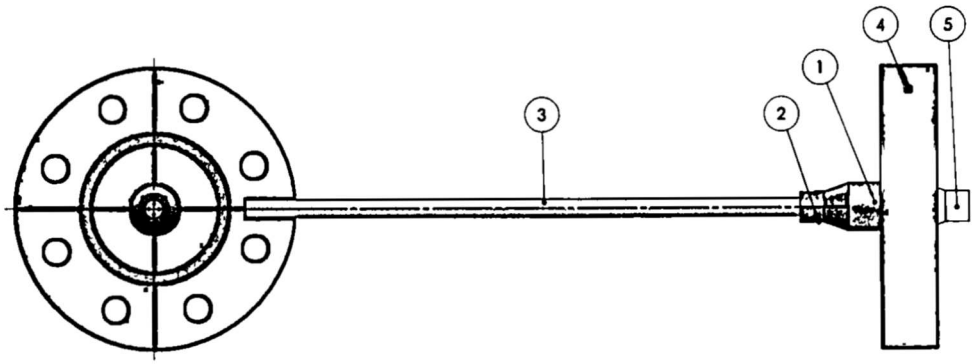
- Bill Hahn
- Joe Pagenkopf
- Matt Bouc

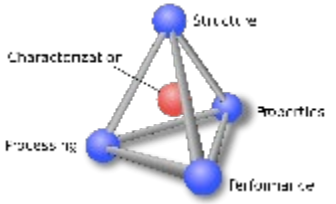


Plasma Diagnostics

- Langmuir Probe
- Emissive Probe
- Spectroscopy

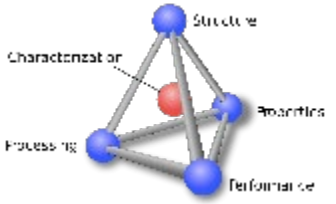






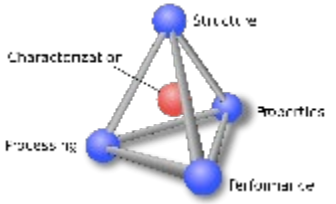
Physics of Cloud Formation

- Caleb Ryberg



Indexing Nanomagnets

- Tom Yungbauer
- Chris Buelke
- Kirk Coughlin
- Matt Bouc



Reverse Engineering in Clean Room

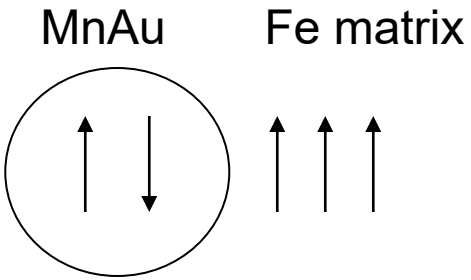
- Take apart a microchip

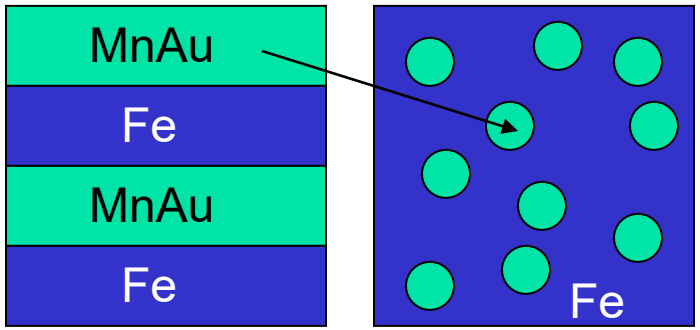
Introduction to Nano-Clusters

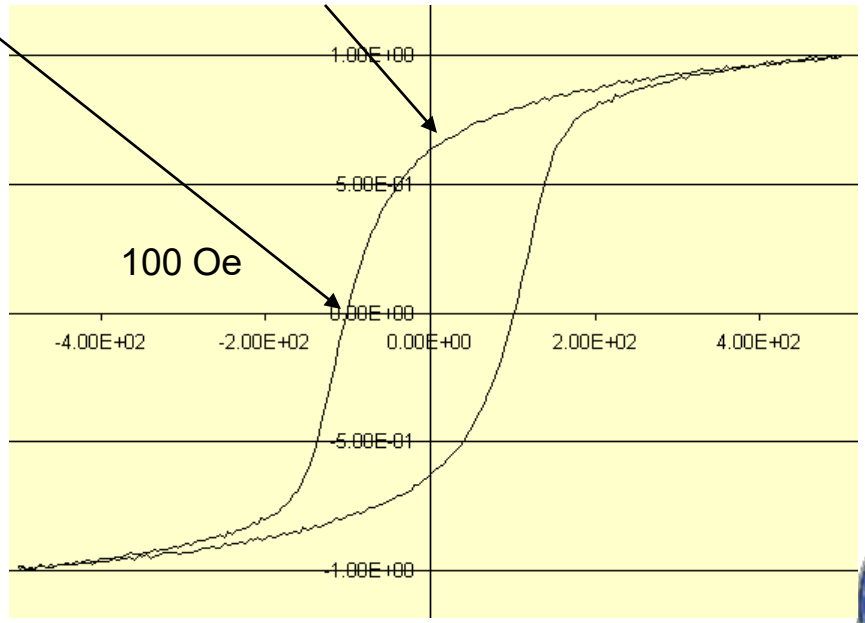
- Current data storage device
  - Hard disc
    - Thin Glass coated with magnetic material
  - Reading/Writing pads
    - Limits size of byte
- Desire for small devices/more data
  - 1950's hard disks (10^6 bytes)
  - Current hard disks (10^{11} bytes)
  - Nanomaterial hard disks ?
    - *At least* another factor of 100 increase

Nanomaterials Engineering

- Anti-Ferro magnet in Ferromagnetic Matrix
  - Cluster-matrix boundary pins the electron spin
  - High coercivity and Low magnetization

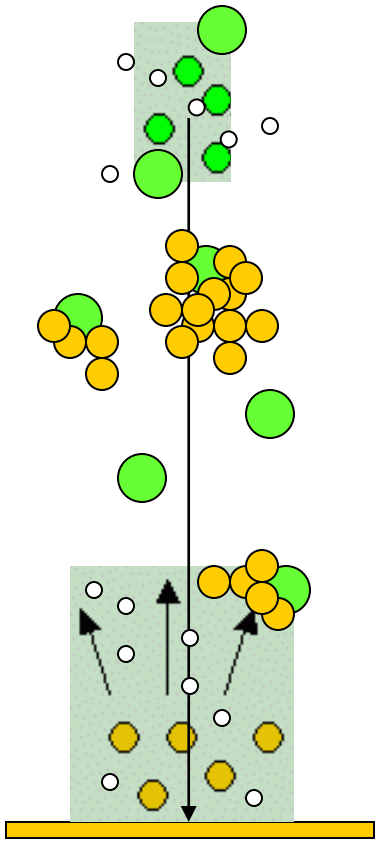






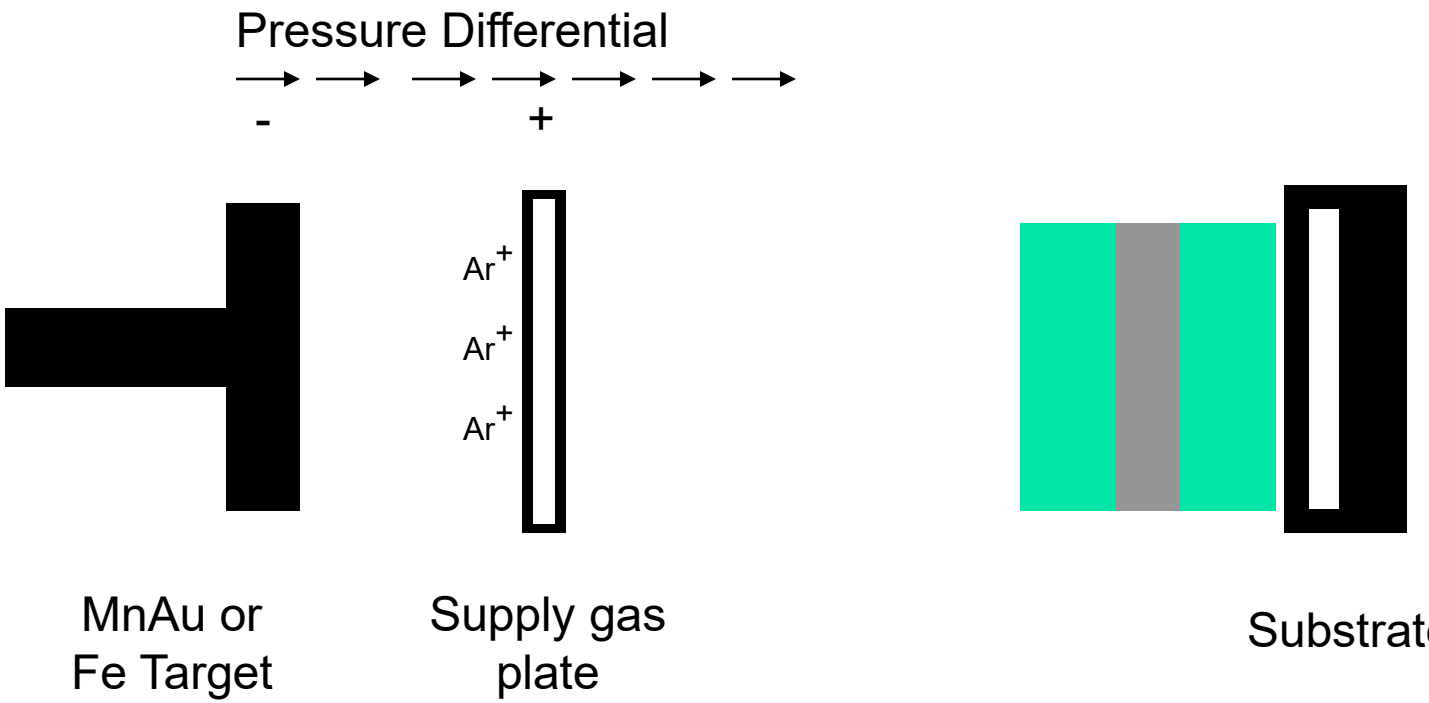
Gas Phase Aggregation

- Electron
- Inert atom
- Inert ion
- Target atom



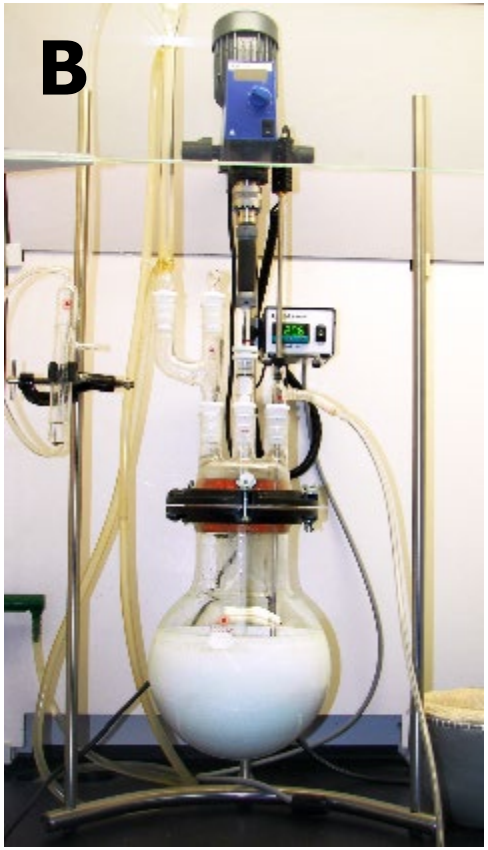
- Proto-Cluster Formation
  - Bombardment by ions
  - Target atom ejection
- Cluster Formation
  - Nucleation of target atoms
  - Anneal to change structure
    - Heating mechanism: *collisions between argon ions & clusters*
- Cluster Density
  - Secondary electron ejection
  - B field confines ejected electrons
  - More ions born!

How a Sputtering Device Works



Ray Research

Suspension Polymerization



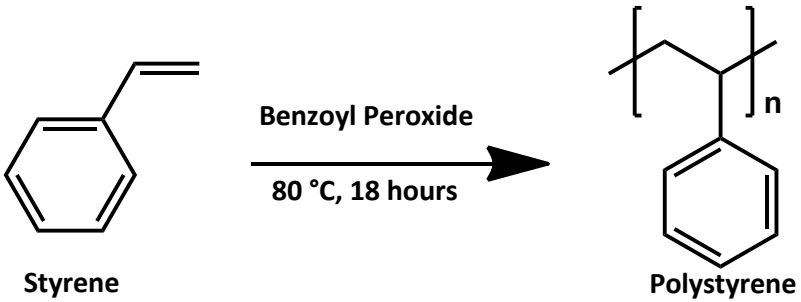


Table 1: Suspension Polymer Recipe	
Ingredients	**Amount**
Water	234 g
5% Polyvinyl Alcohol	26 g
Styrene	88 g
Hexadecane	2 g
Benzoyl Peroxide	0.4 g

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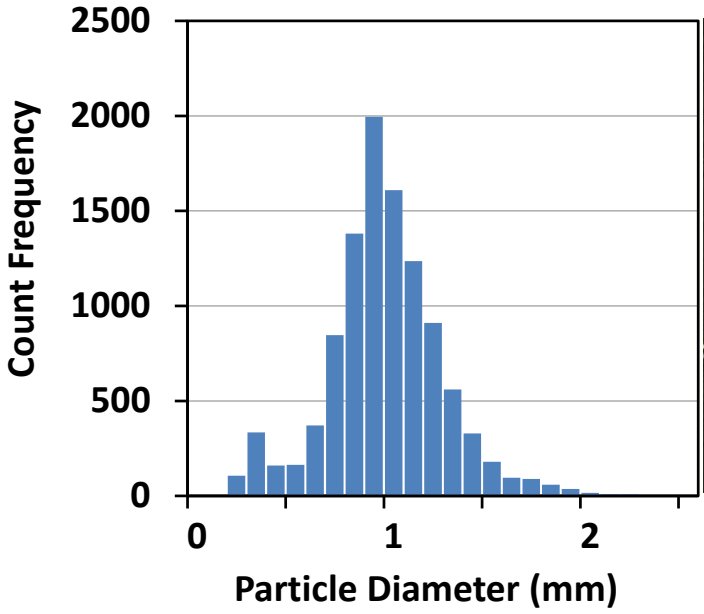
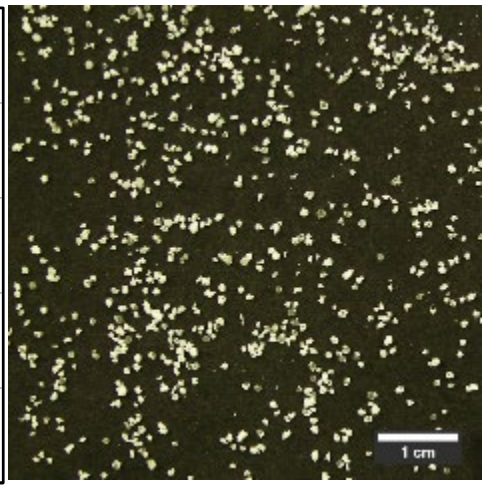
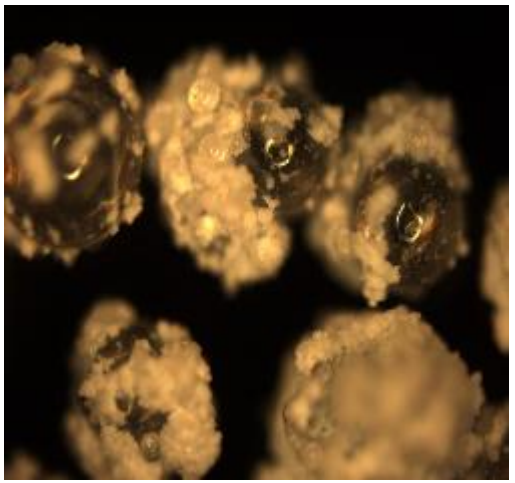
Mitchell Woellner, Ellie Raethke

Particle Size Distribution







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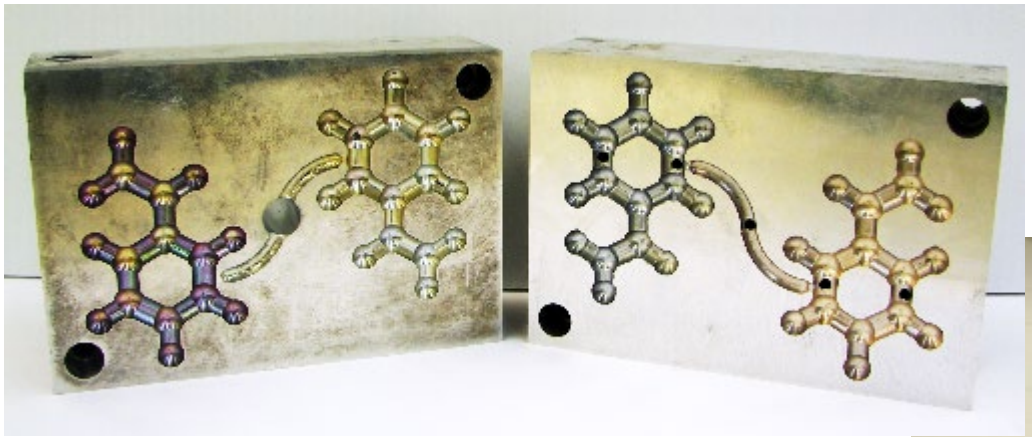
Injection Molding



Clayton Barrix
Dayton Ramirez

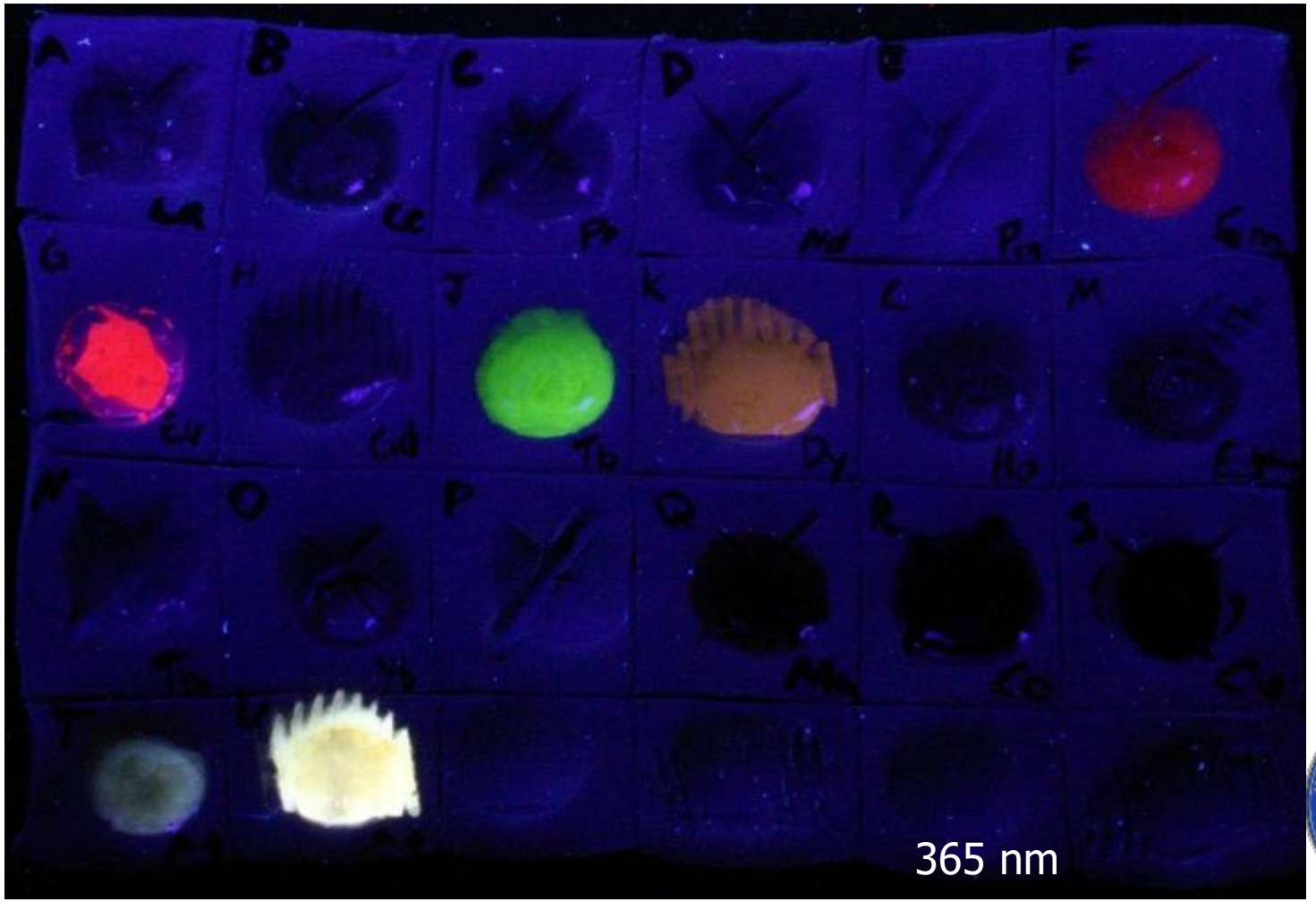
Fluorescent Ceramics

Fluorescent Ceramics

Visible
400 – 700 nm

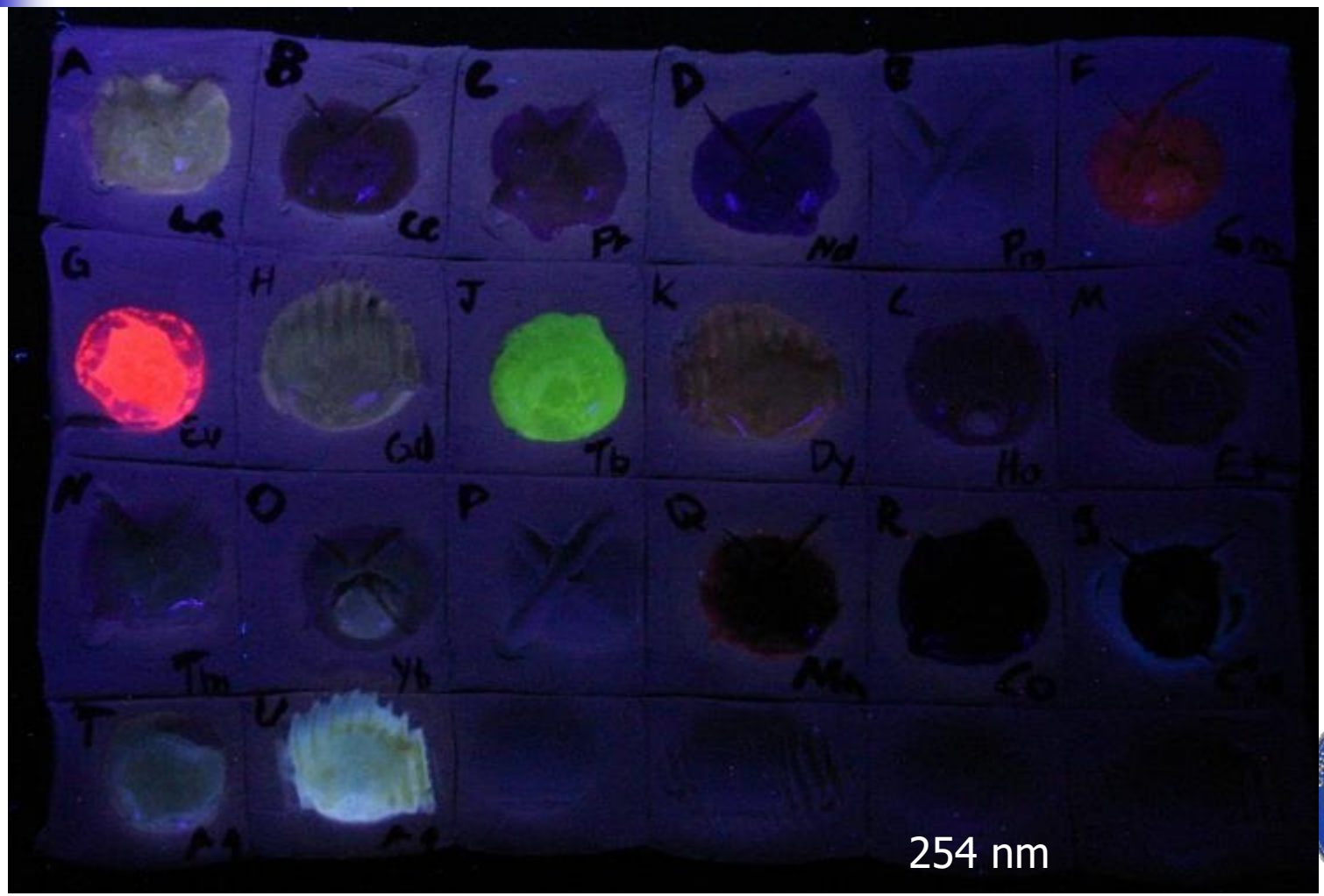
Felipe Marra-Mateus

Fluorescent Ceramics



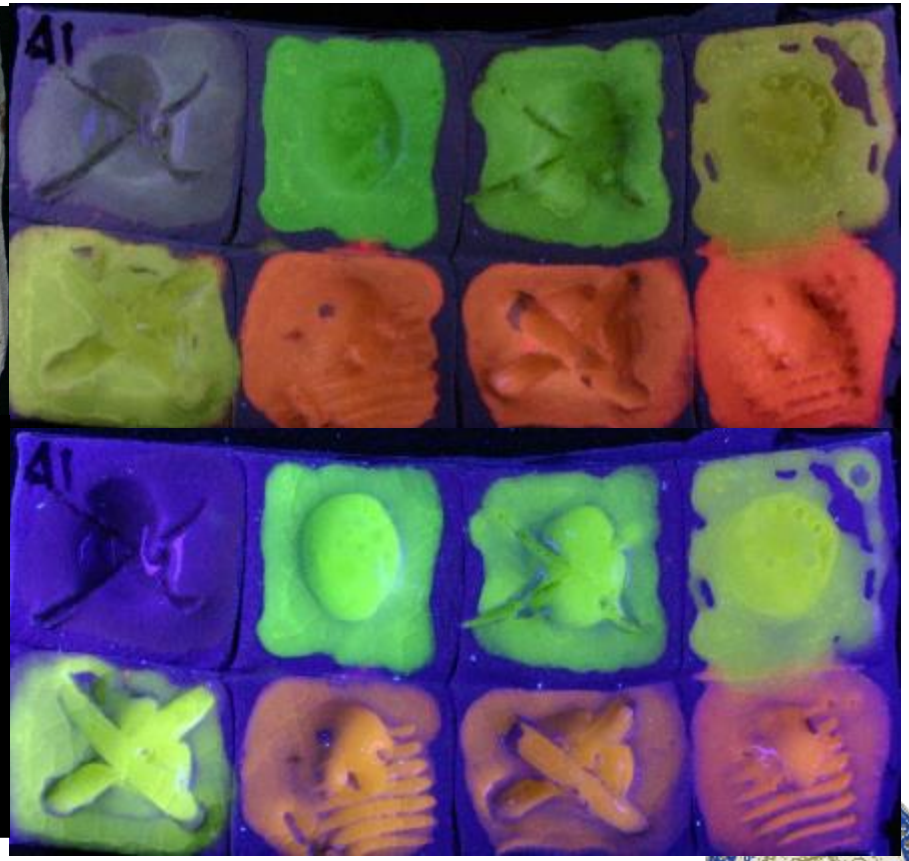
Felipe Marra-Mateus

Fluorescent Ceramics



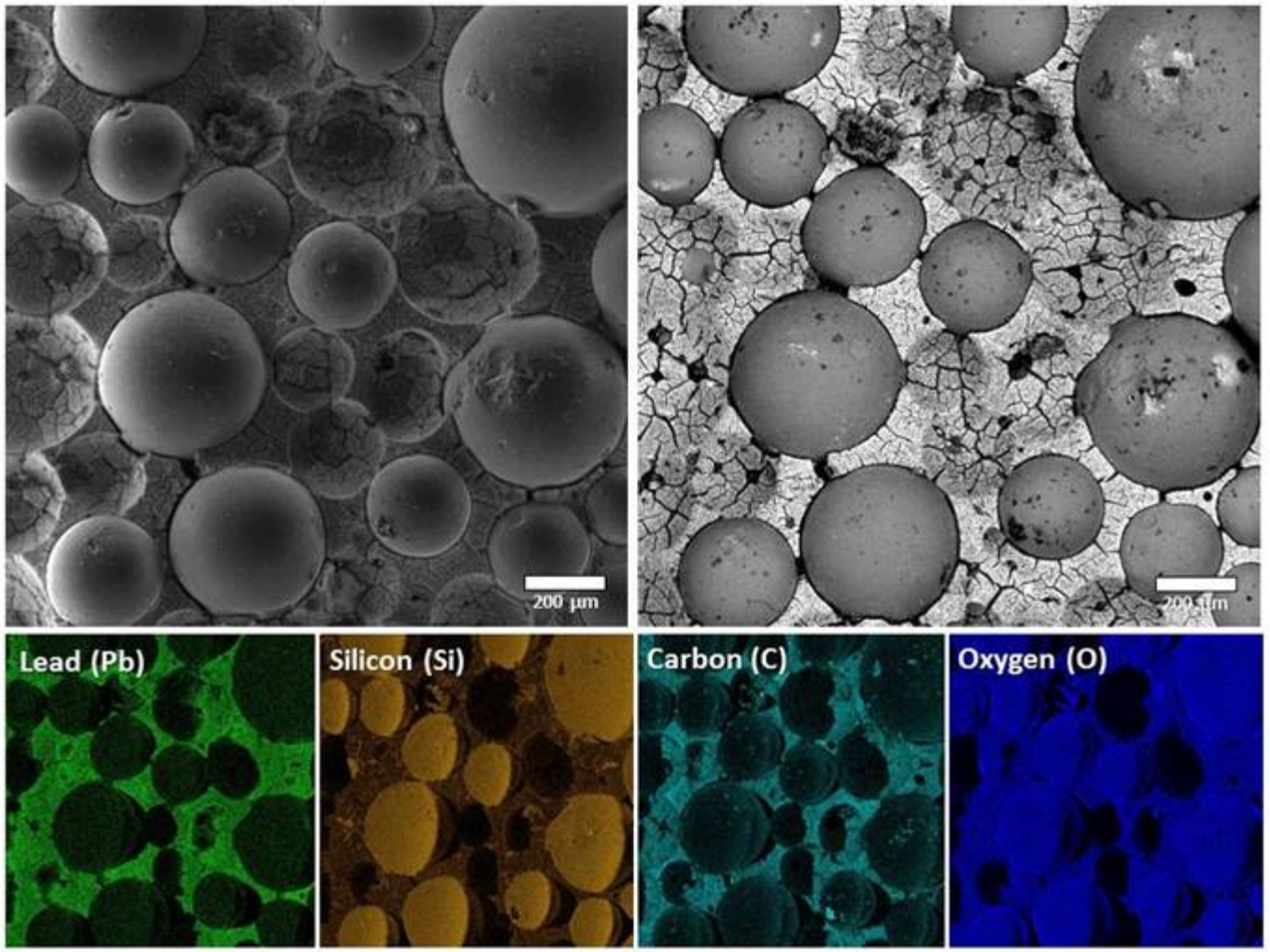
Felipe Marra-Mateus

Fluorescent Ceramics

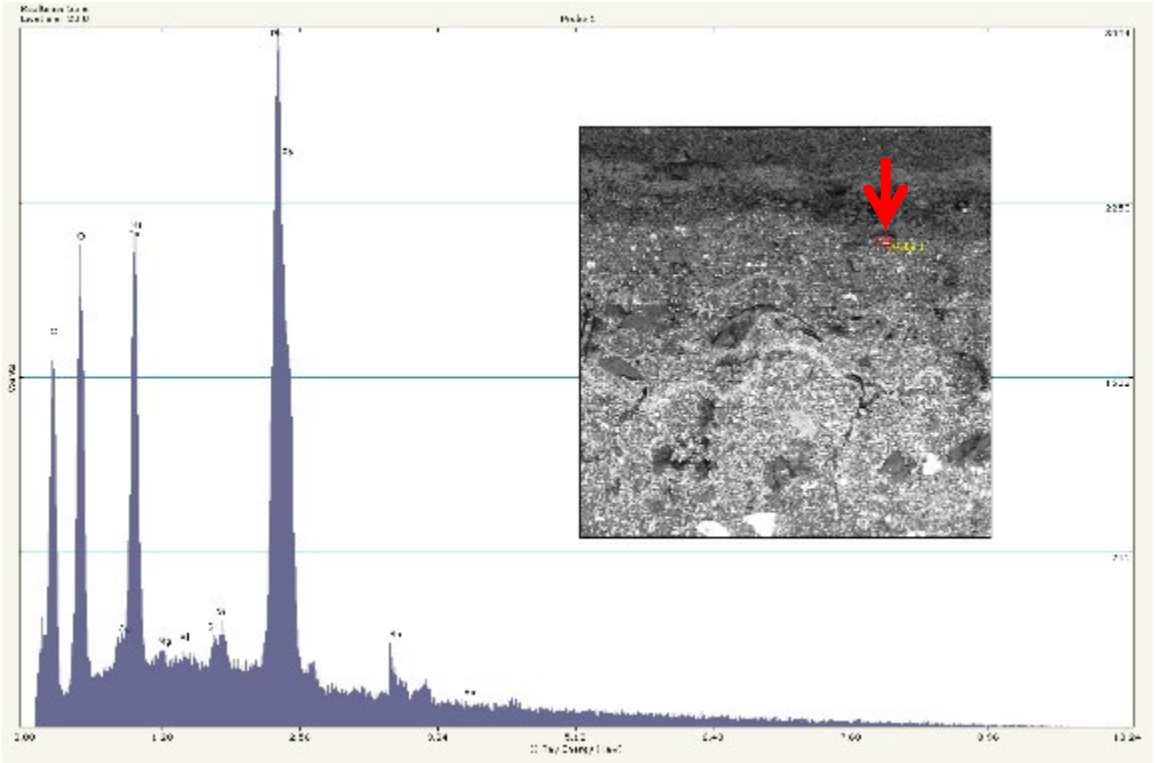


Worthington Control	**3.0% Tb 0% Eu**	**3.0% Tb 0.1% Eu**	**3.0% Tb 0.3% Eu**
3.0% Tb 0.5% Eu	**3.0% Tb 0.75% Eu**	**3.0% Tb 1.0% Eu**	**3.0% Tb 1.5% Eu**

Lead Analysis

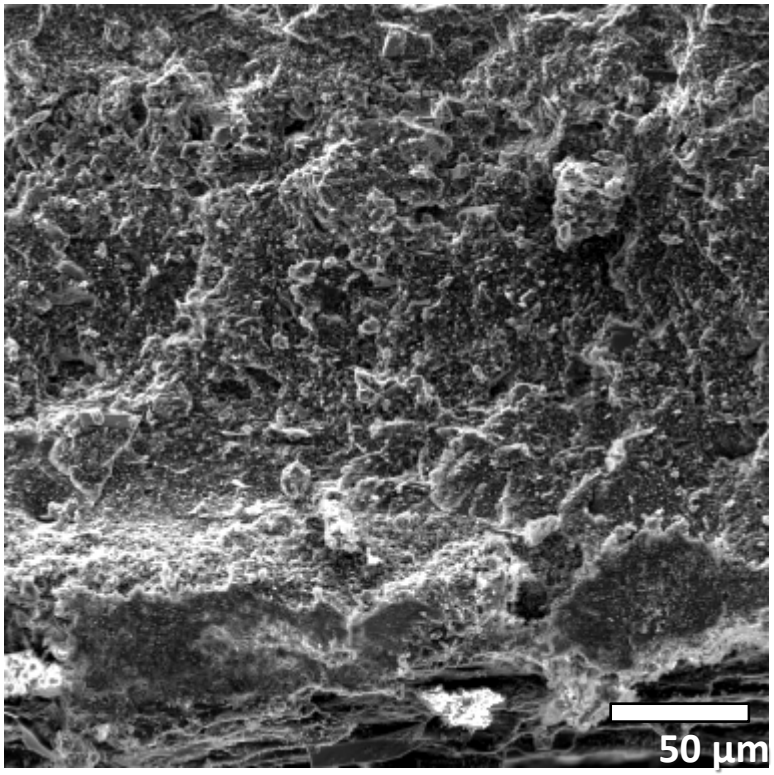


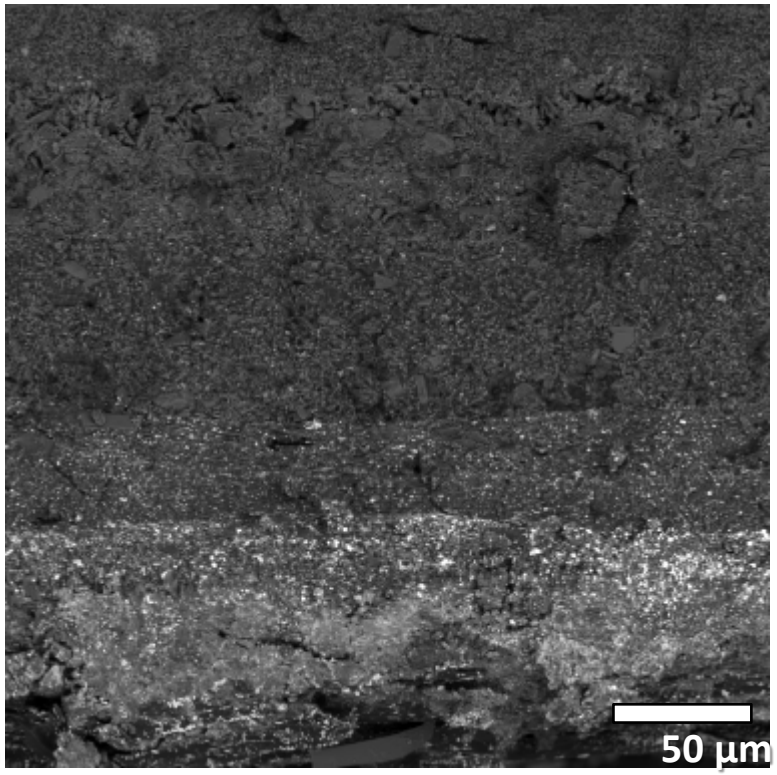
Lead Analysis



- X-Ray Energy Spectrum produced by probing the paint pigment particle marked with the red arrow with the electron beam and measuring the energies of the resulting emitted x-ray photons.

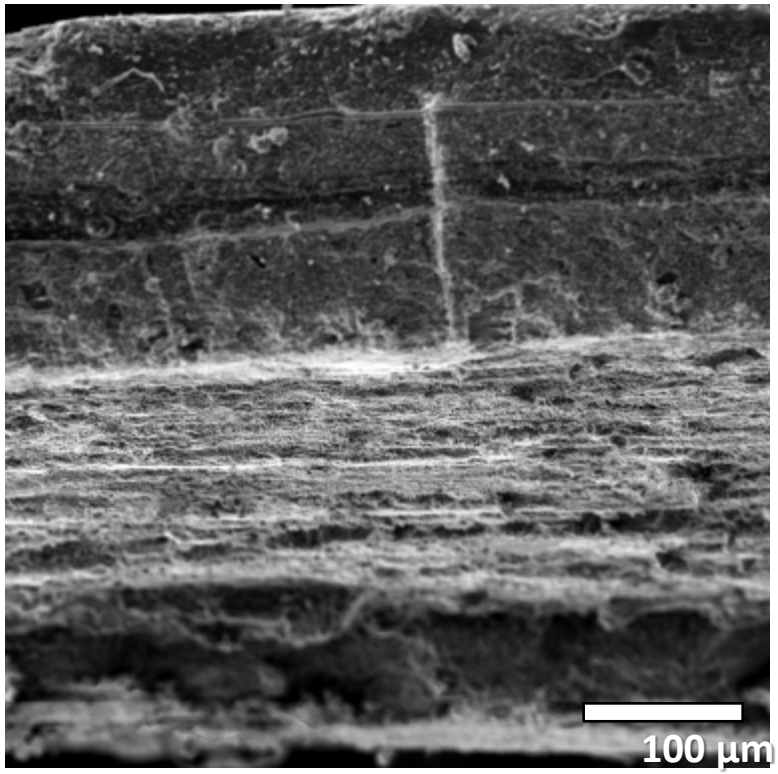
Lead Analysis

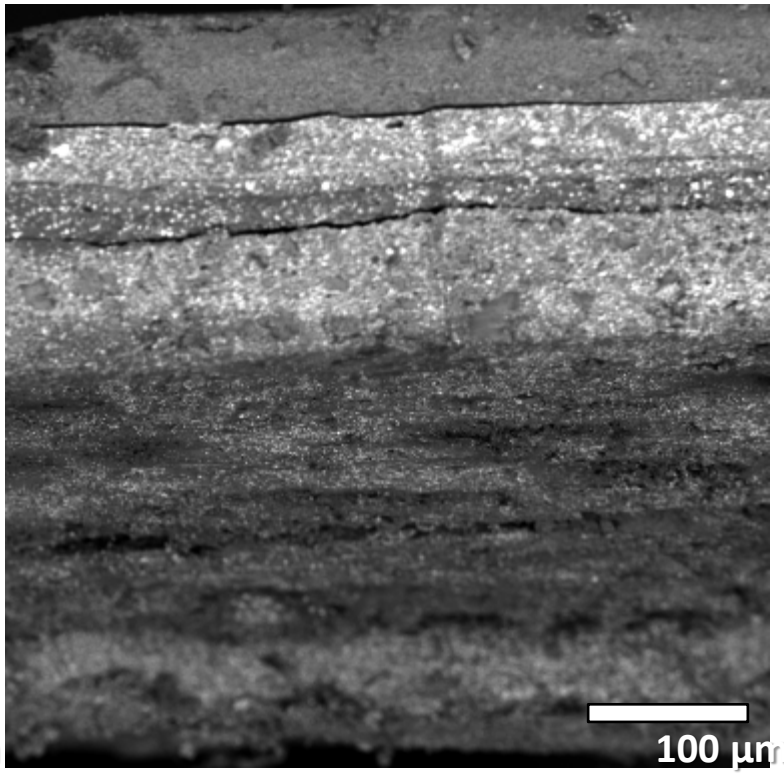




- SEM Micrographs of Sample ER130147D with both (left) secondary electron detection and (right) backscattered electron detection.

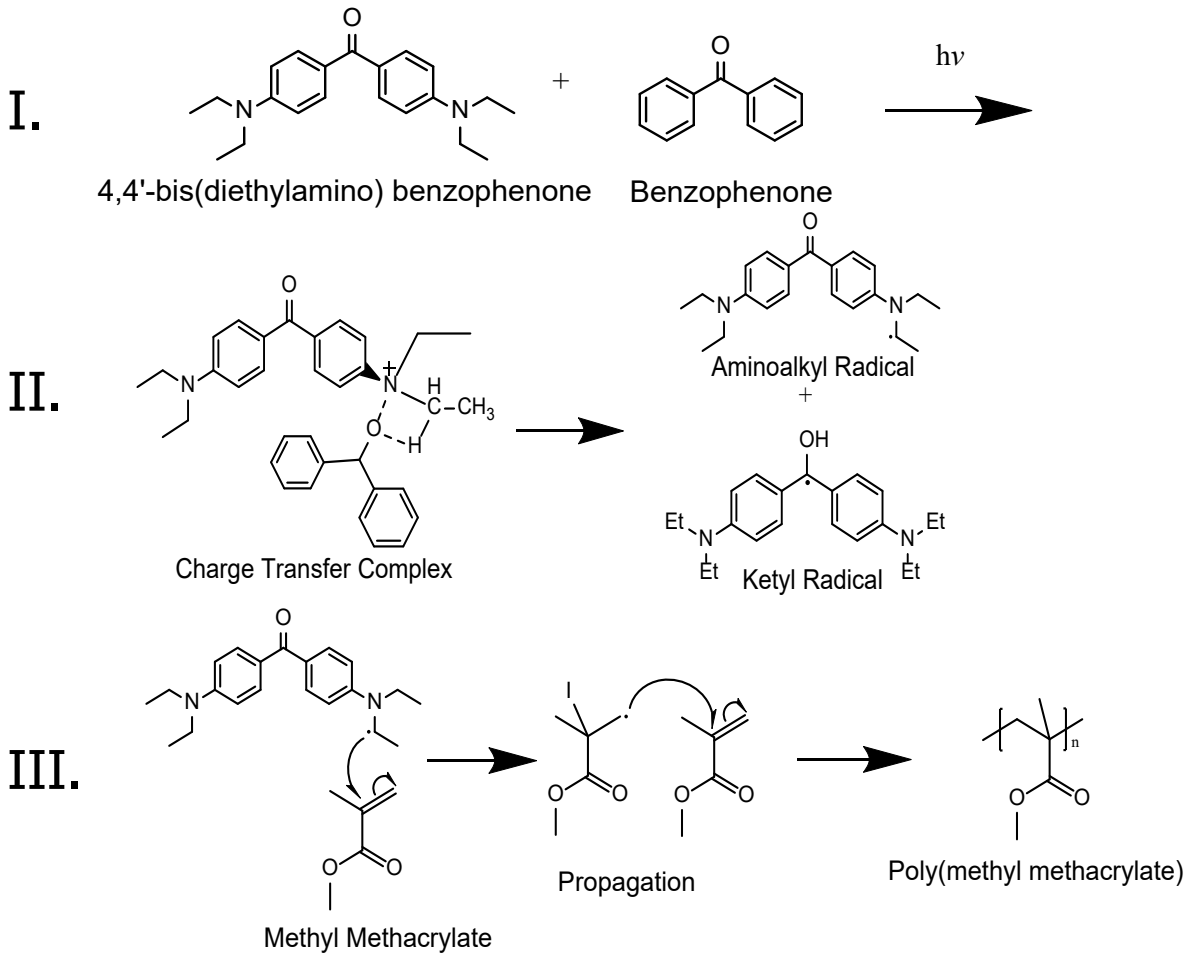
Lead Analysis



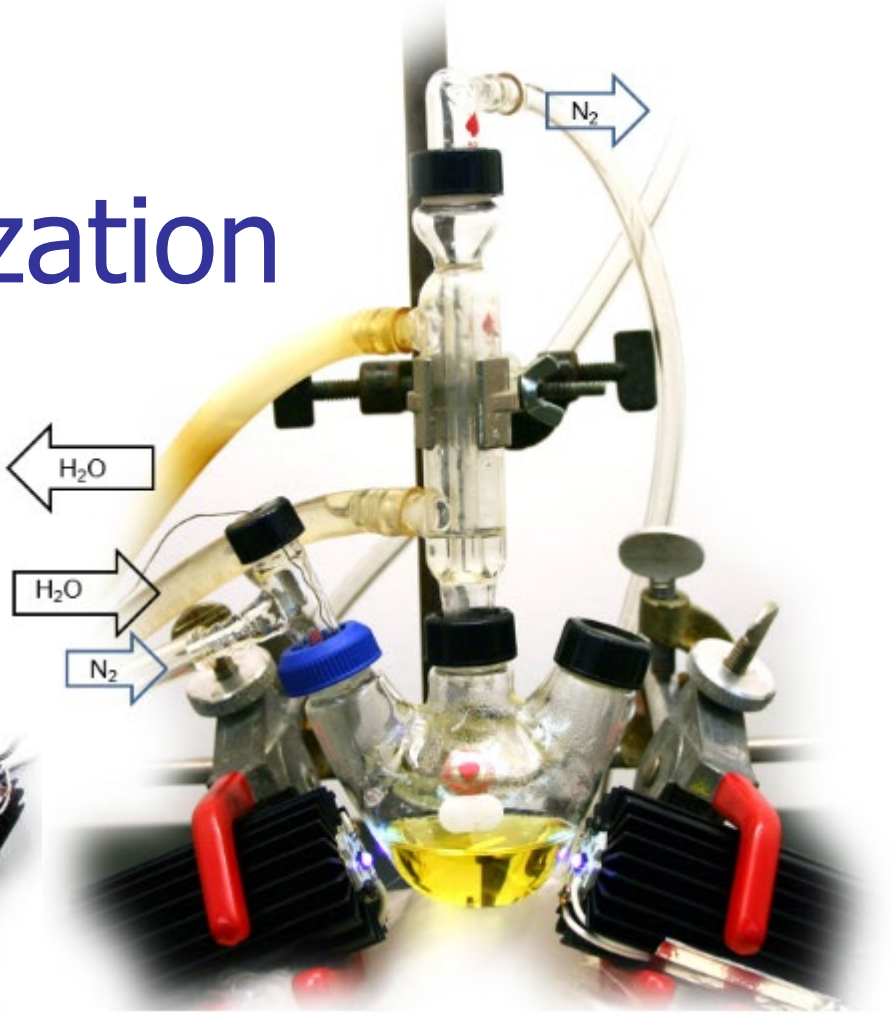


- SEM Micrographs of Sample ER130147G with both (left) secondary electron detection and (right) backscattered electron detection.

Photopolymerization

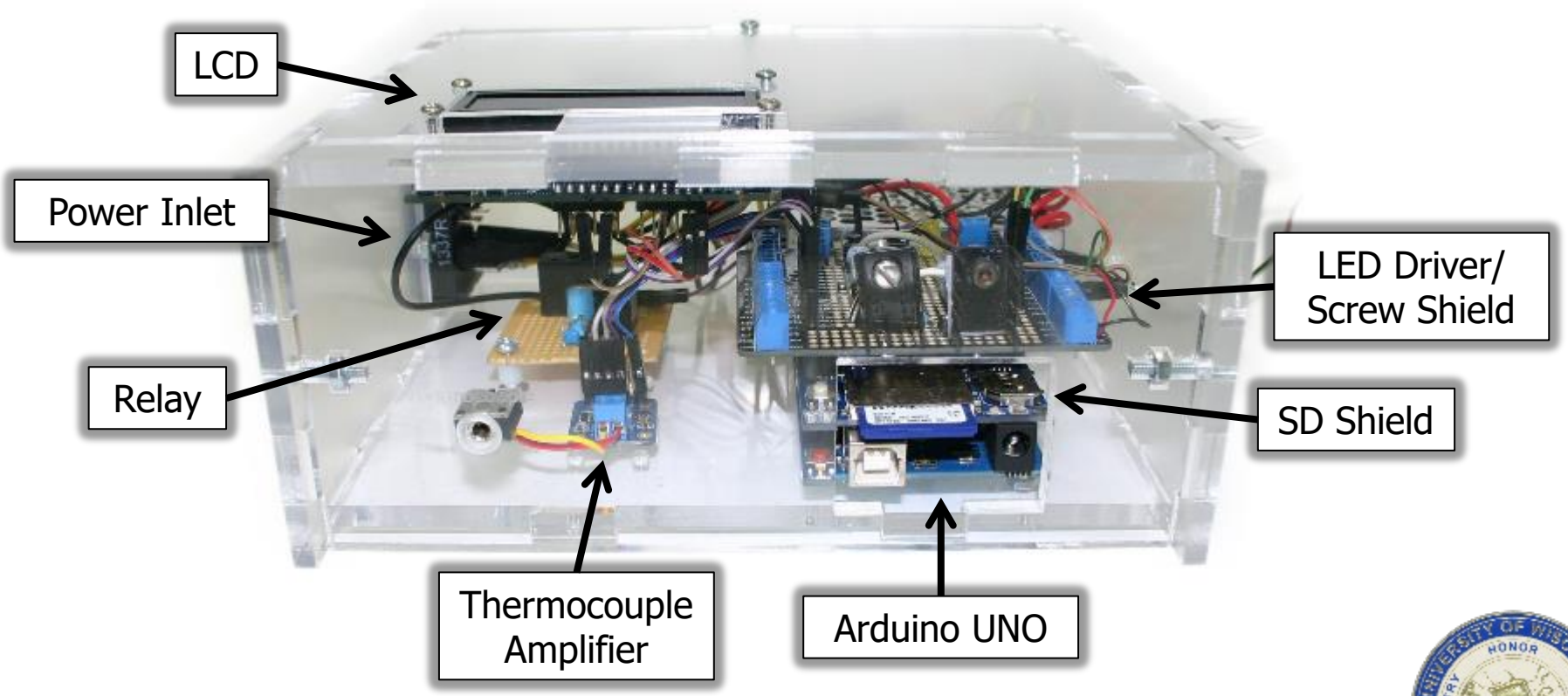


Photopolymerization

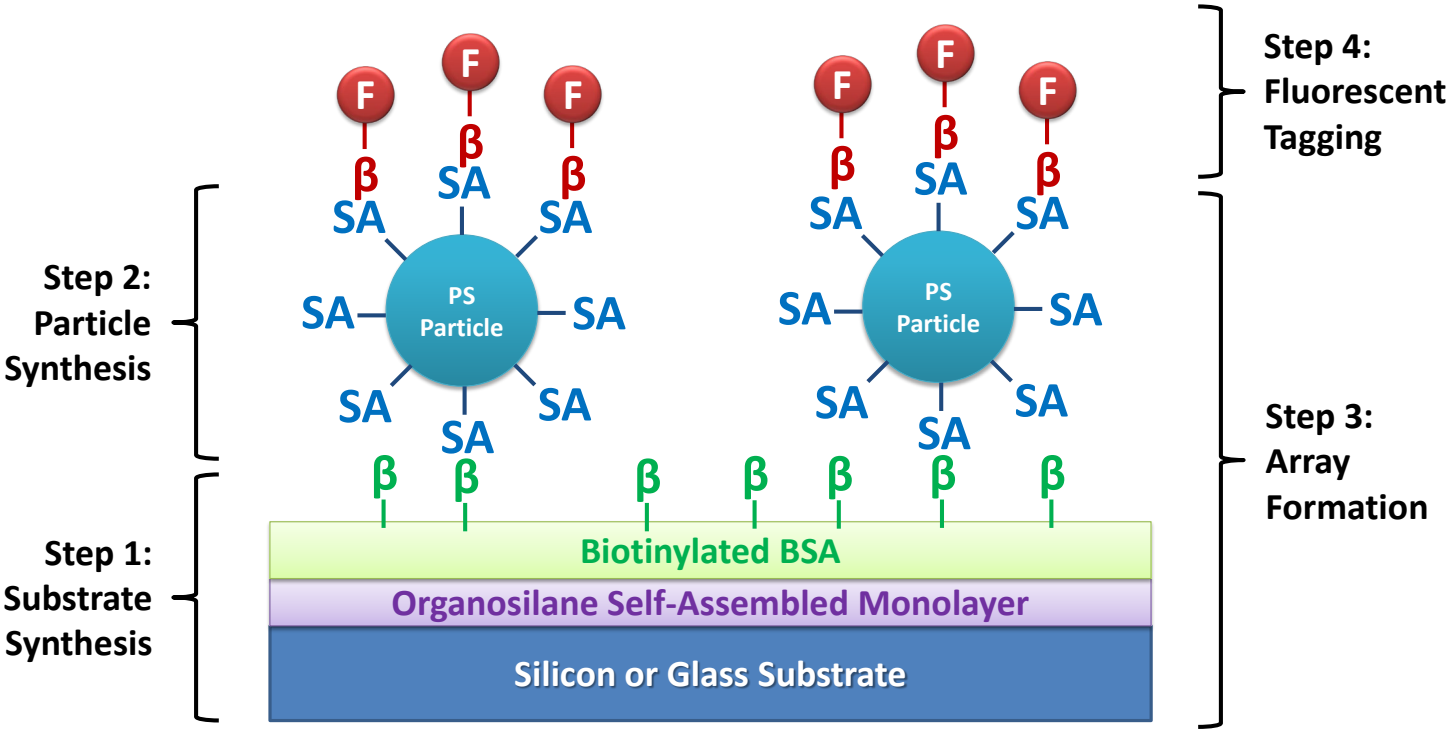


Noah Holzman

Photopolymerization



Bioassay Development



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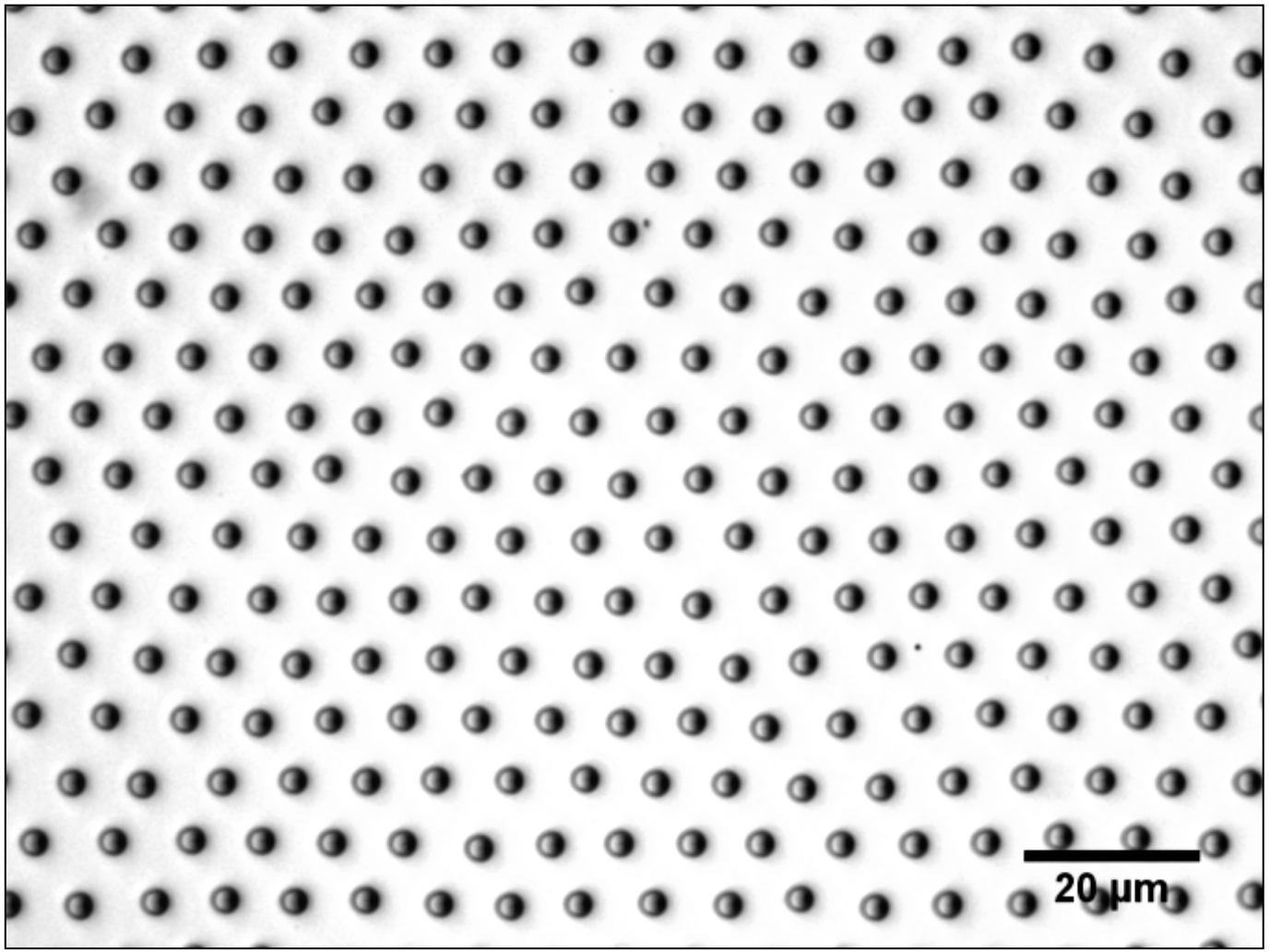
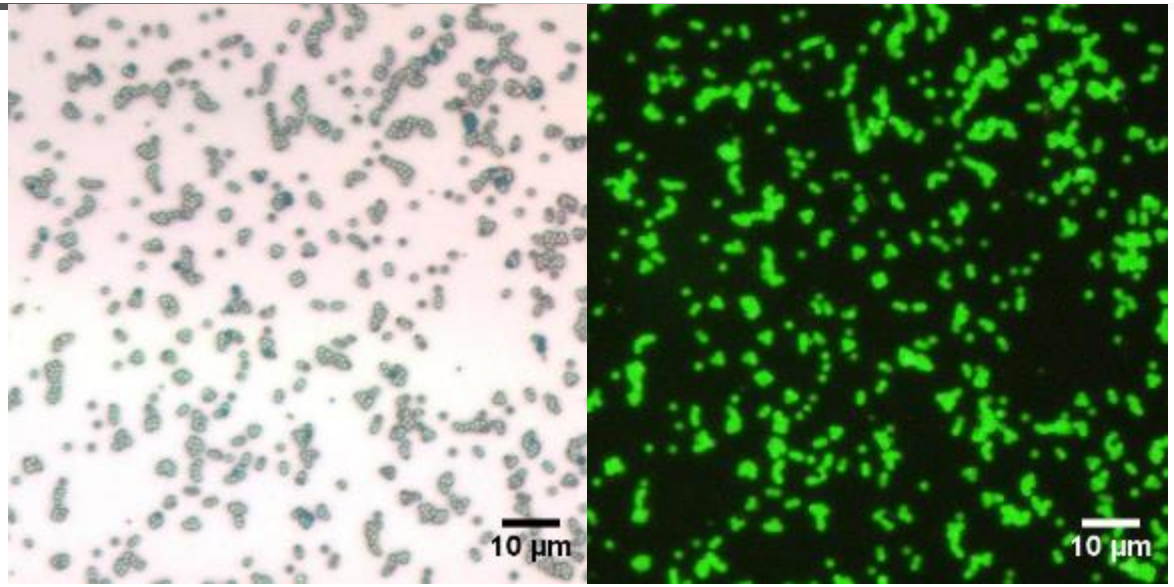
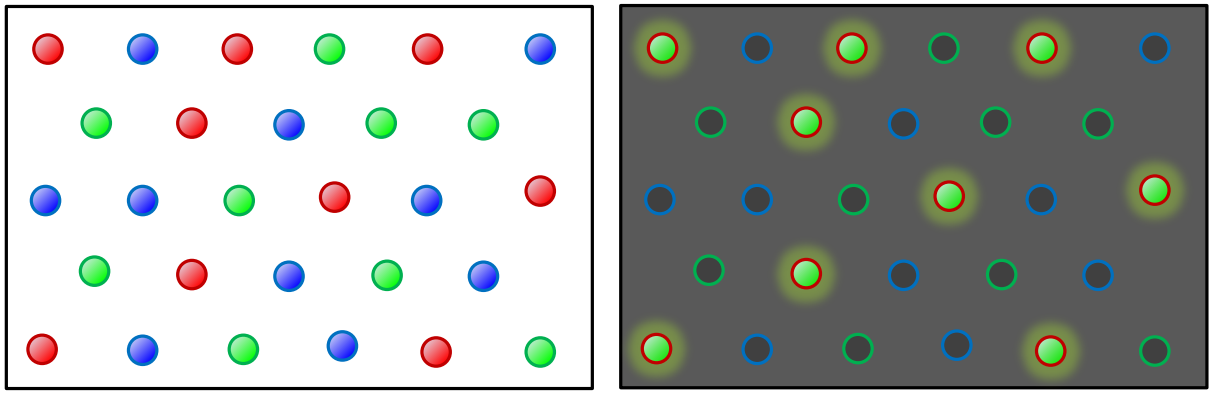
Bioassay Development



Bioassay Development





Acknowledgements

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at the Spring 2014 STEM EXPO