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# Nanotechnology Characterization

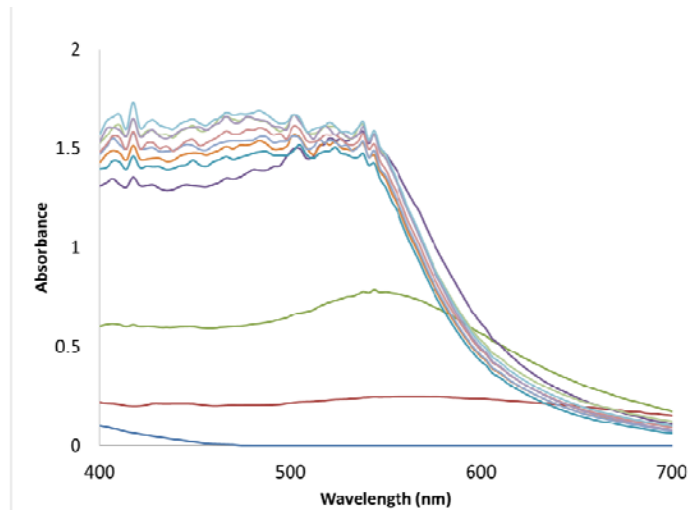
**SHINE:** Seattle's **H**ub for Industry-driven **N**anotechnology **E**ducation  
North Seattle College



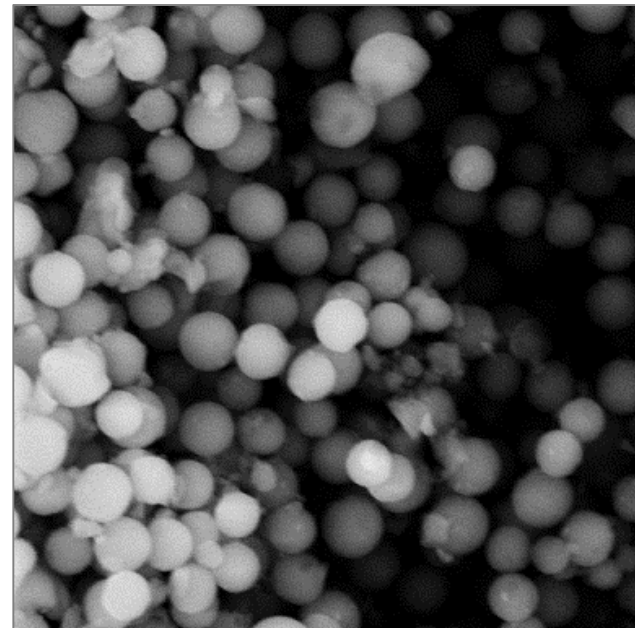
# Characterization Techniques

## Two types of nanomaterial characterization:

- Spectroscopic methods
  - i.e. UV-VIS, DLS
- Imaging methods
  - i.e. TEM, SEM, AFM



Source: NSC students

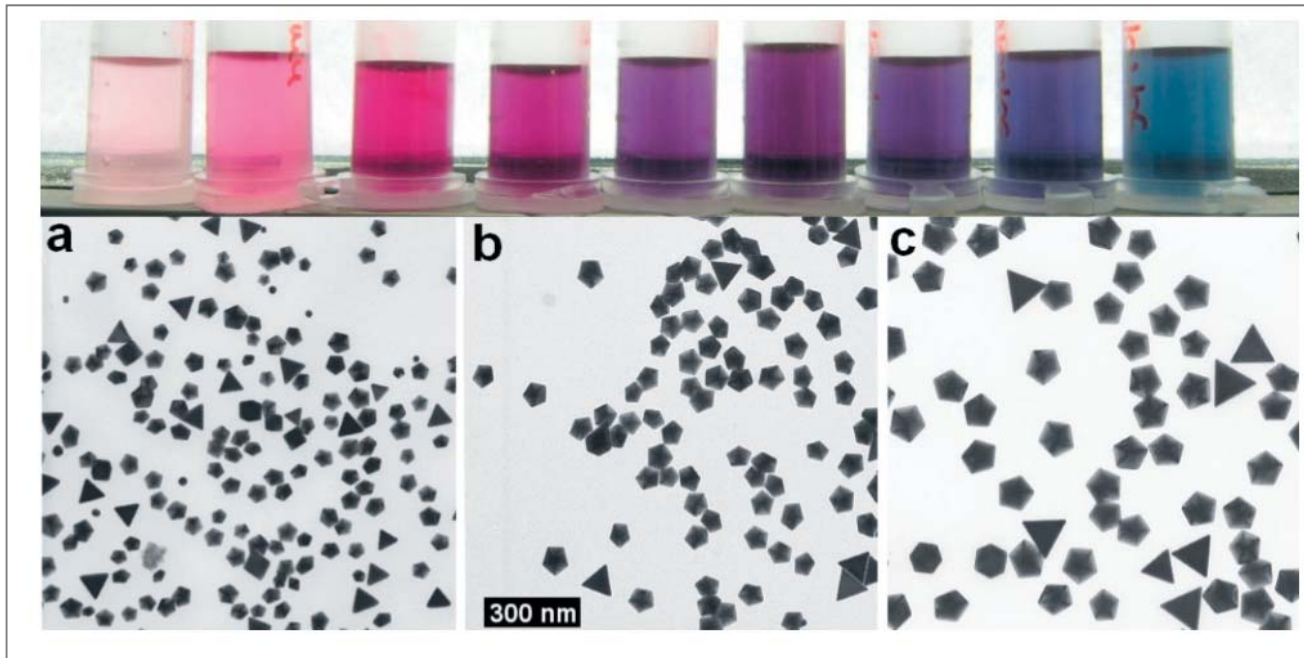


Source: NSC students



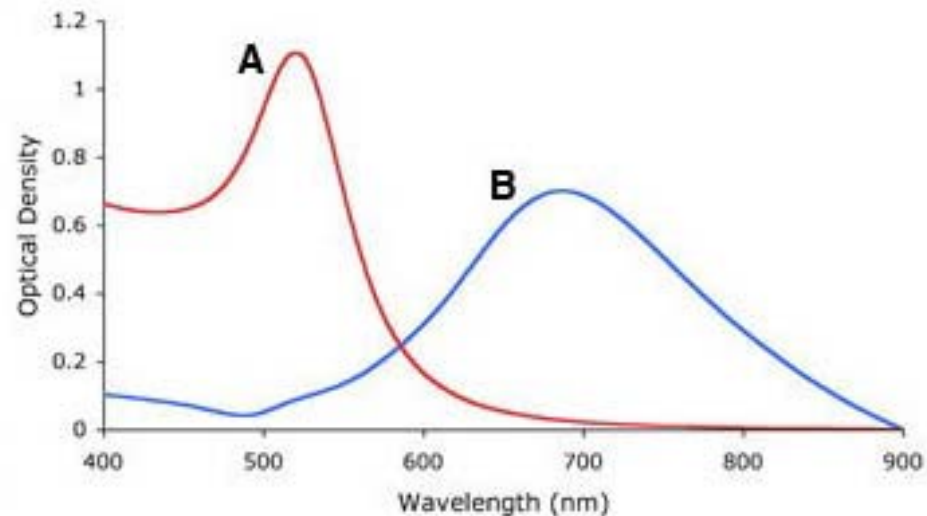
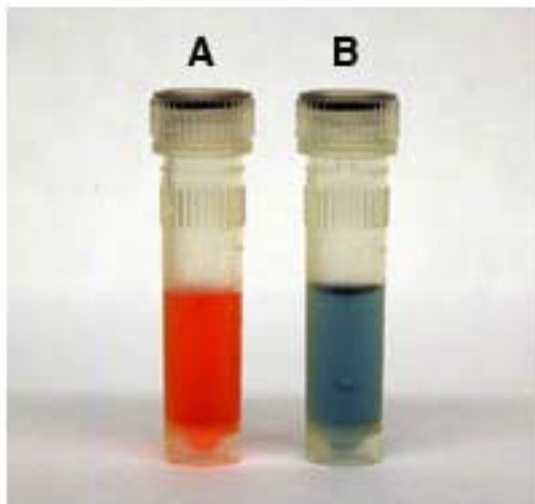
# 0-D Nanoparticles

Color of a nanoparticle solution is dependent on nanoparticle size.



# UV-Vis Absorption

Gives quantitative measure of color.  
What wavelengths are absorbed?  
What wavelengths are transmitted?



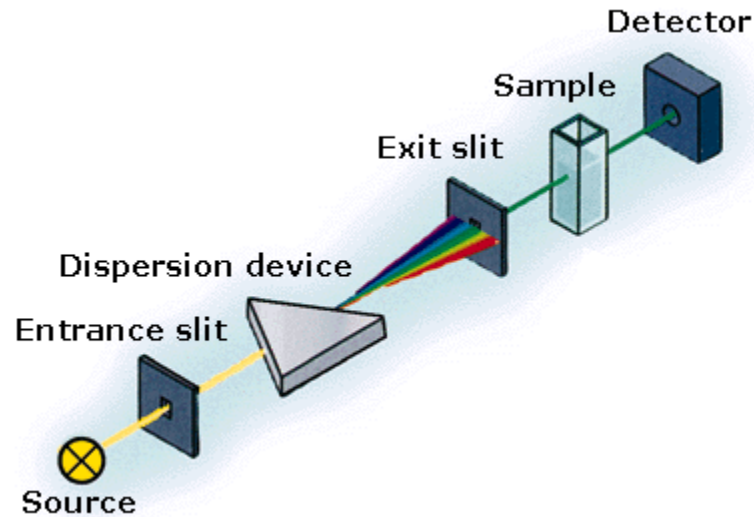
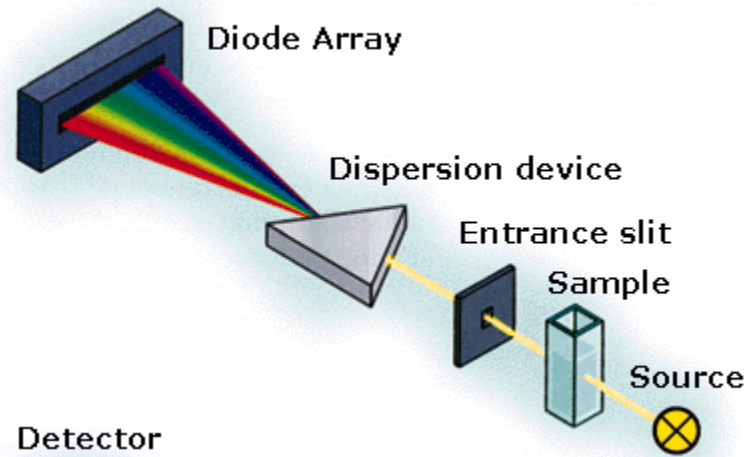
Source: Cytodiagnosics



# UV-Vis Spectrometer

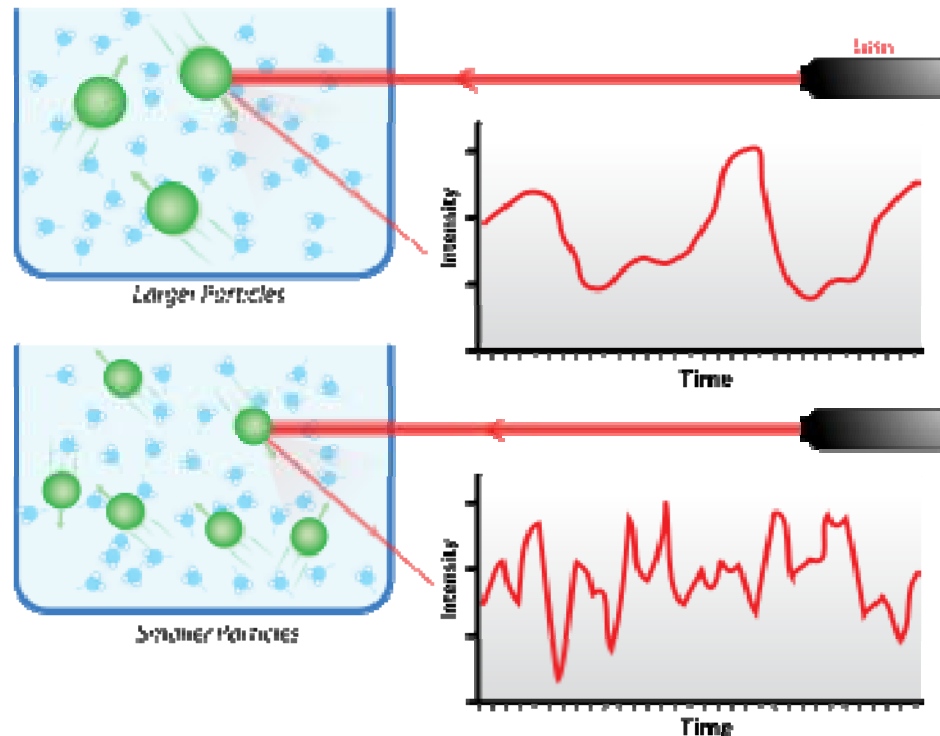


Source: Vernier



# Dynamic Light Scattering (DLS)

DLS measures the Brownian motion of the nanoparticles and correlates this to particle size



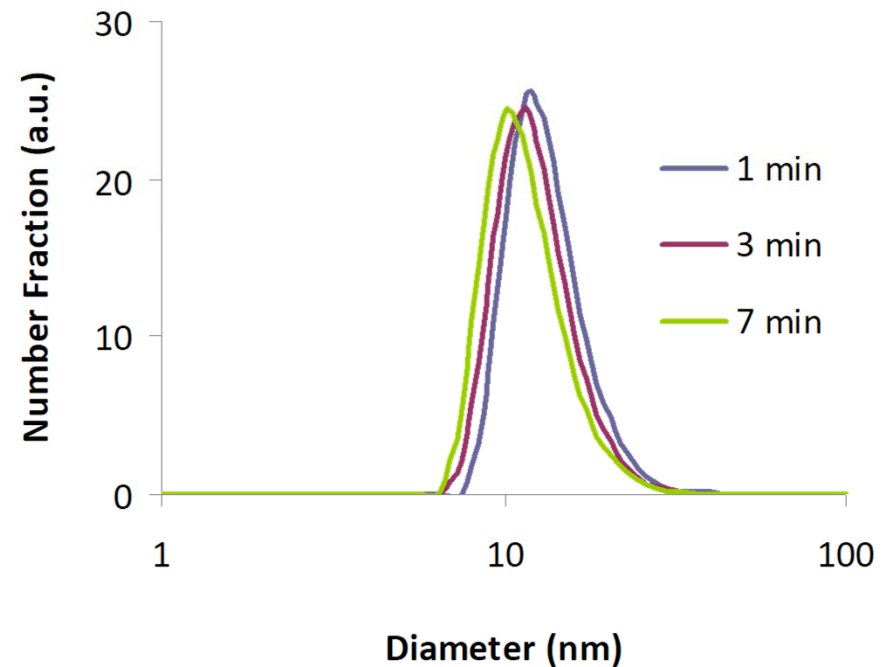
# Dynamic Light Scattering (DLS)

## DLS instrument



Source: [www.Malvern.com](http://www.Malvern.com)

## Number fraction of Au nano-particles vs. particle size as measured by DLS



Source: NSC Students



# Imaging Methods

Light (Optical) Microscopy

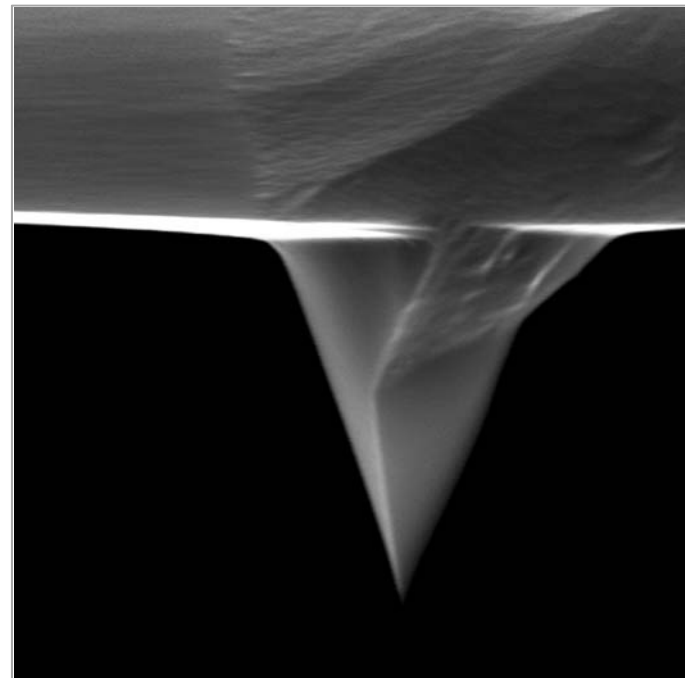
Electron Microscopy

- TEM
- SEM

Scanning Probe Microscopy

- STM
- AFM
- Profilometry

SEM micrograph



Source: NSC Students



# Resolution Limit

## Light microscopes

- 500 X to 1500 X magnification
- Resolution of  $\sim 0.2 \mu\text{m}$
- Limits reached by early 1930's



## Resolution dependent on:

- wavelength of illumination ( $\lambda$ )
- Numerical Aperture (NA) of lens system

$$d = \frac{0.612\lambda}{NA}$$



# Electron Microscopes

Wavelength of the electron dependent on:

- Electron mass ( $m$ )
- Electron charge ( $q$ )
- Potential difference to accelerate electrons ( $V$ )

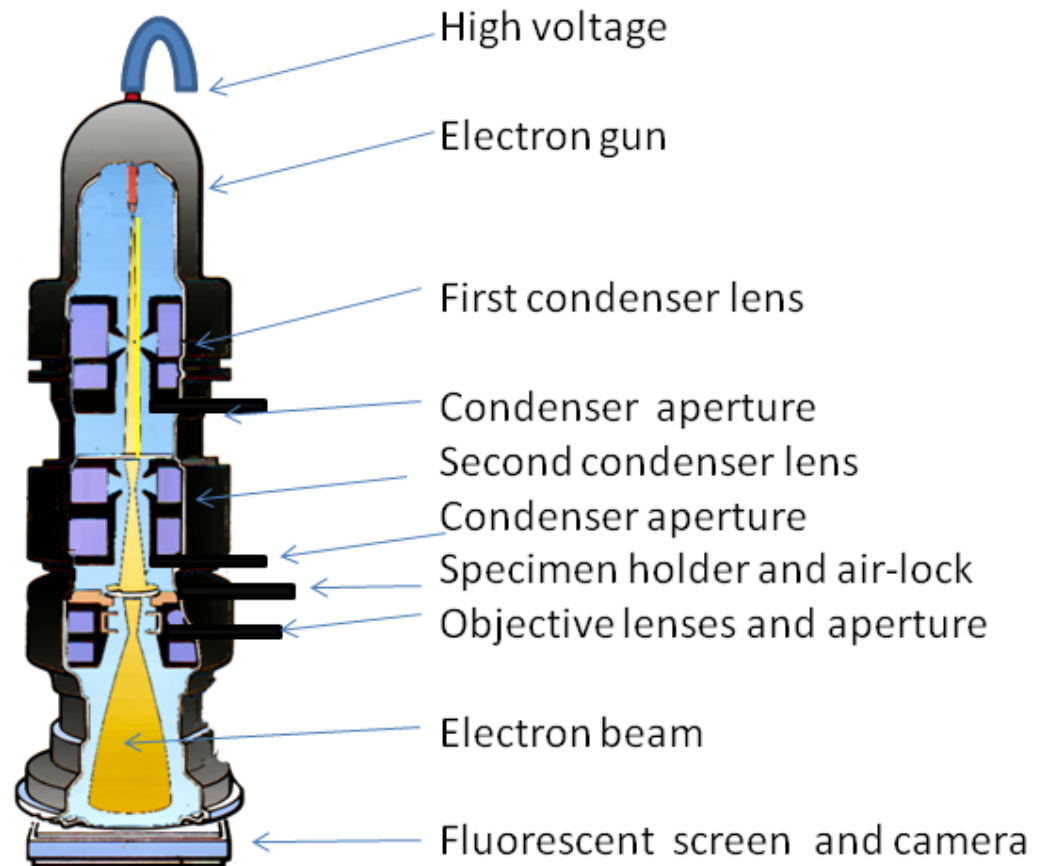
$$\lambda = \frac{h}{\sqrt{2mqV}}$$



# Transmission Electron Microscope

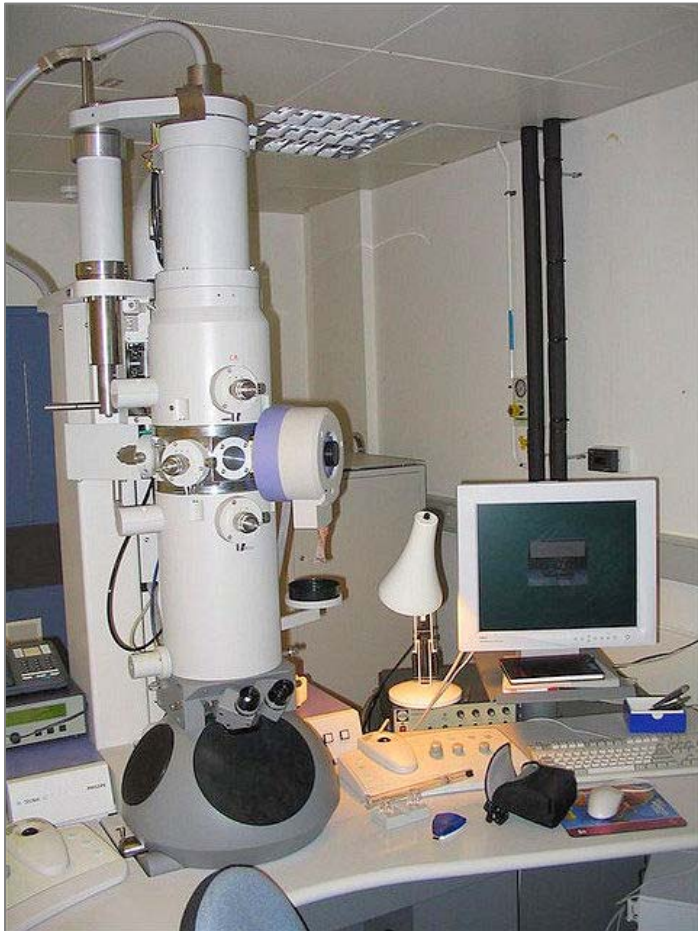
## Transmission Electron Microscope (TEM)

1. e-beam strikes sample and is transmitted through the sample
2. Scattering occurs
3. Un-scattered electrons pass through sample and are detected

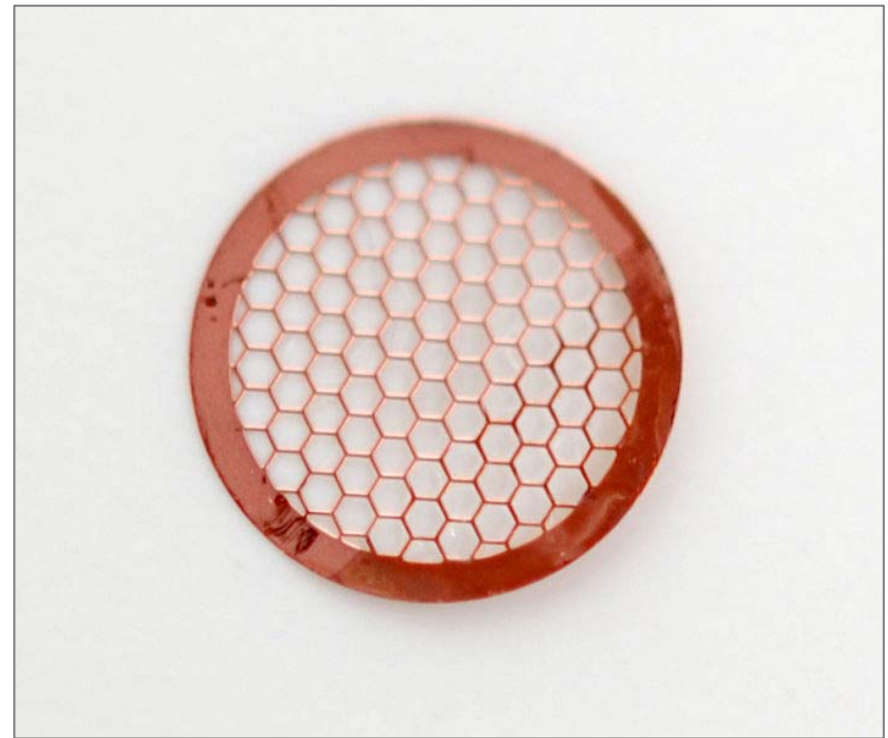


# Transmission Electron Microscope

TEM

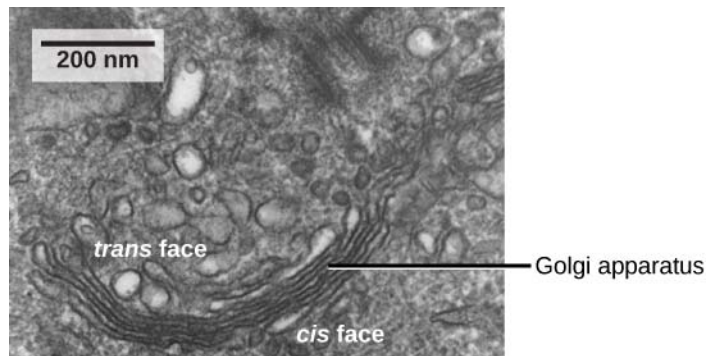


Copper Grid Sample Holder

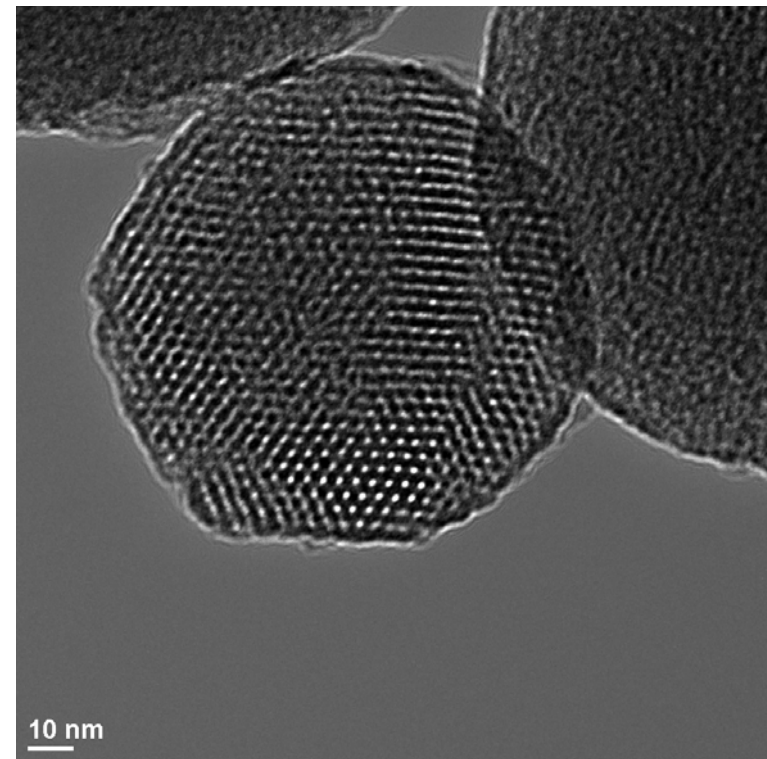


# TEM Images

Organic Material



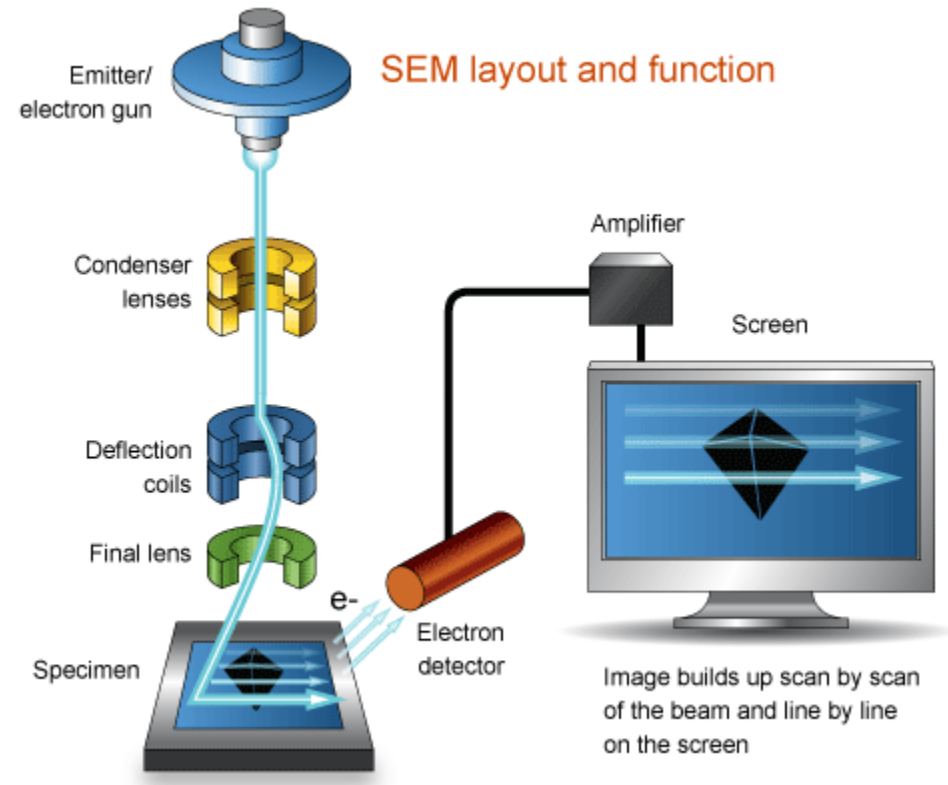
Inorganic Material



# Scanning Electron Microscope

## Scanning Electron Microscope (SEM)

1. e- beam strikes sample and electron penetrate surface
2. Interactions occur between electrons and sample
3. Electrons and photons emitted from sample
4. Emitted e- or photons detected



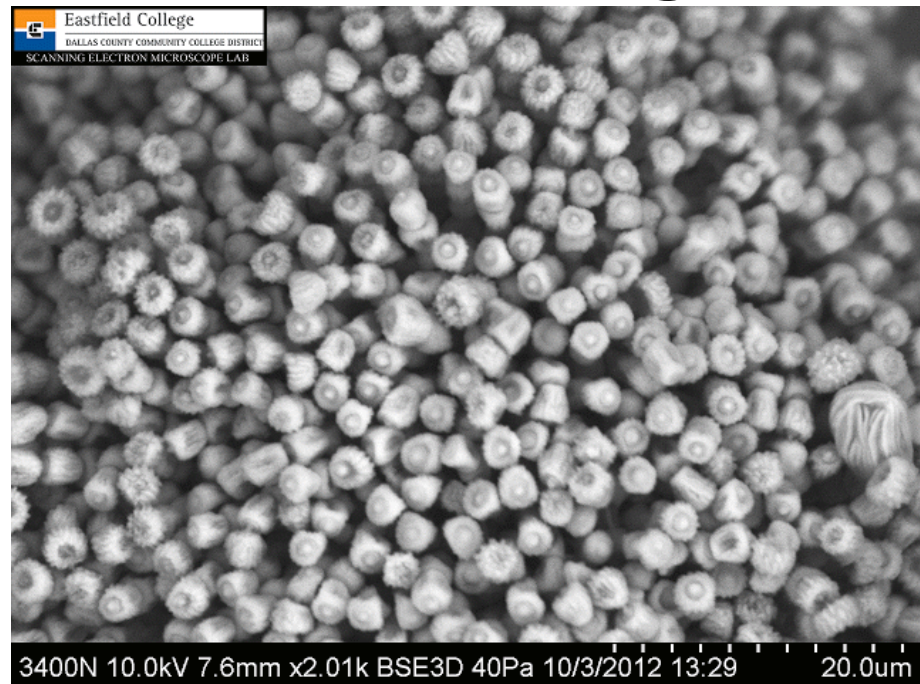
# Scanning Electron Microscope (SEM)

## SEM



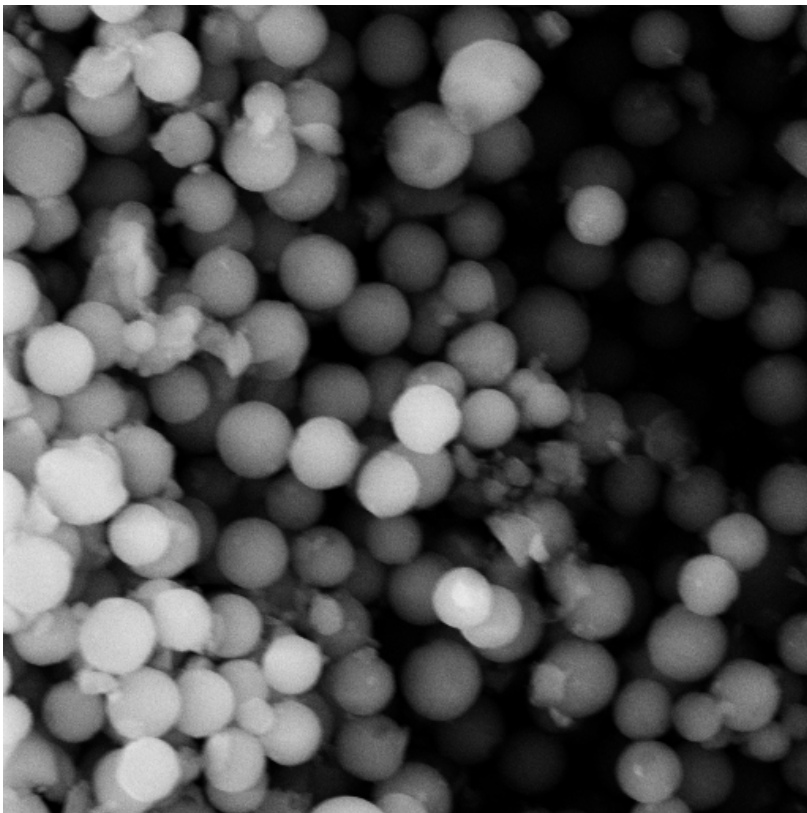
Aspex Explorer located at NSC

## Conidia of *Aspergillus*



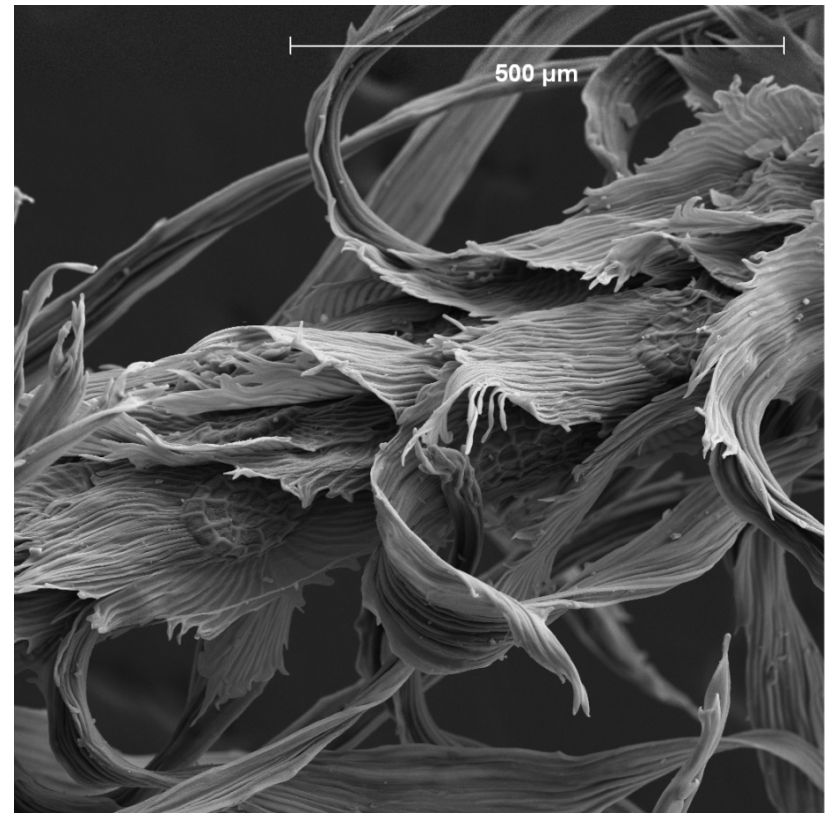
# Scanning Electron Microscope (SEM)

**SiO<sub>2</sub> spheres**



Source: NSC Students

**A succulent plant**

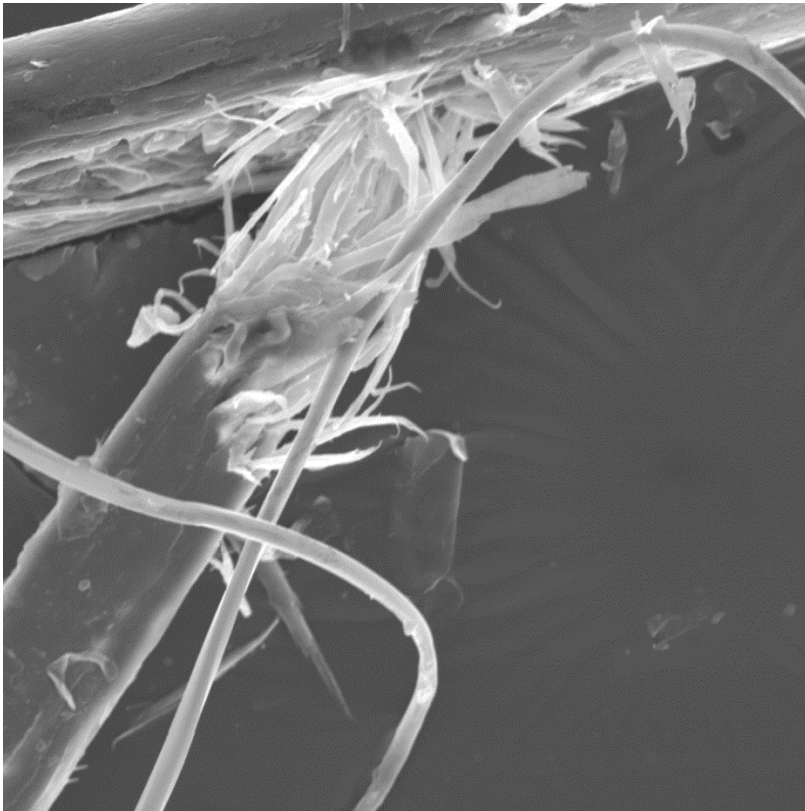


Source: NSC students



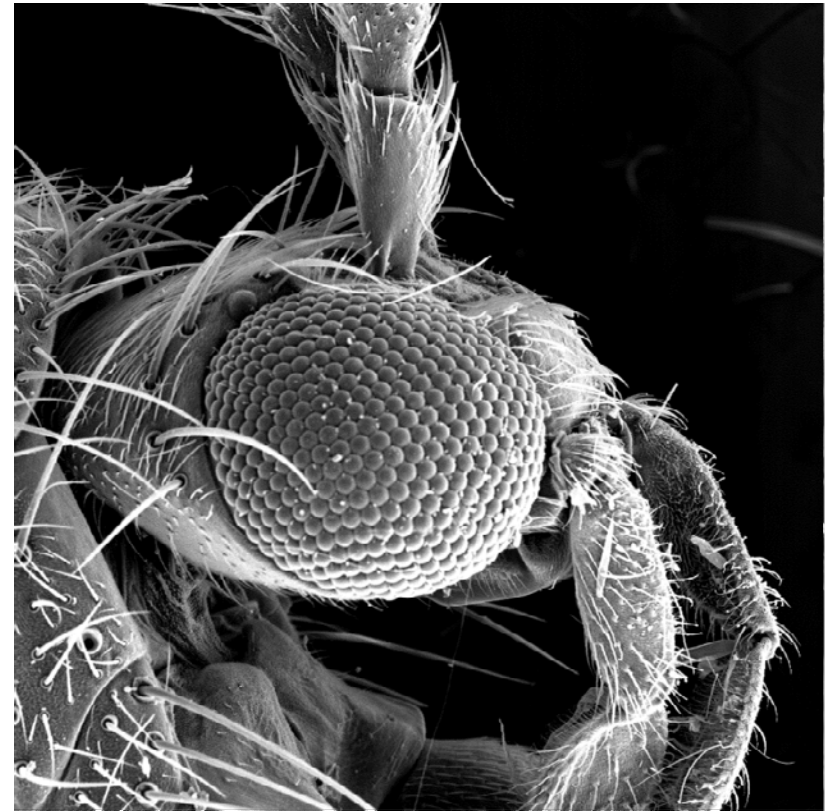
# Scanning Electron Microscope (SEM)

A hair “split end”



Source: NSC Students

A “bug” eye



Source: NSC students



# Scanning Probe Microscopy

Measure feedback from atomically defined tip

Many types of feedback (dependent on tip)

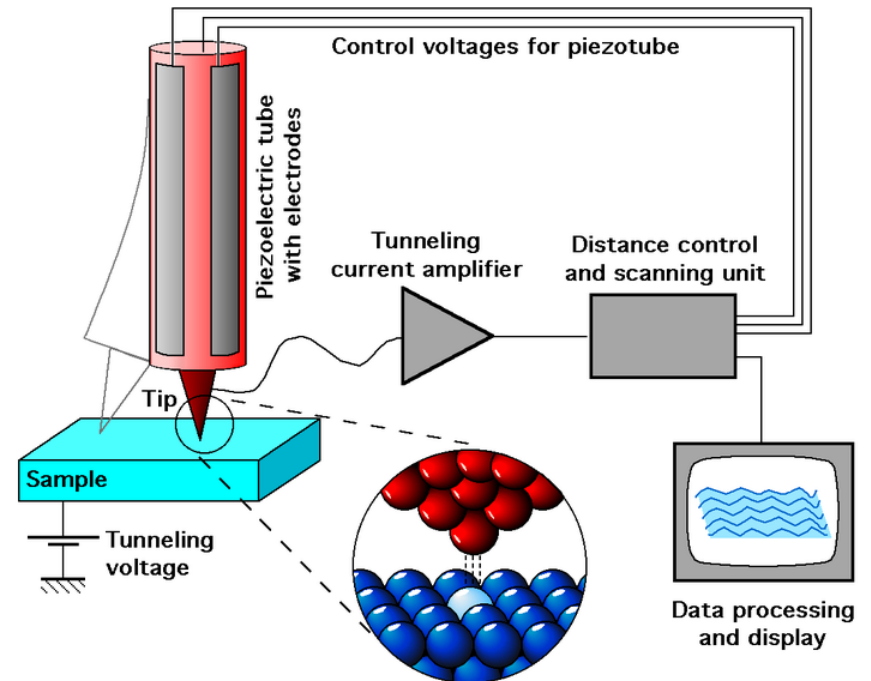
AFM – Forces between sample and tip

STM – Tunneling current between sample and tip



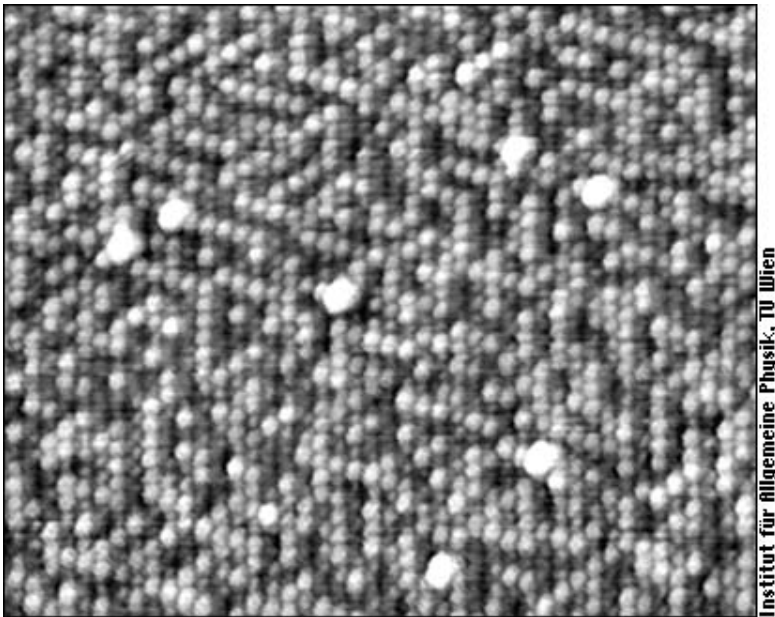
# Scanning Tunneling Microscope

- Tip scans just above surface of stage
- Electrons have a small probability of escaping material to tip creating tunneling current
- Tunneling current is depends on distance between tip and sample

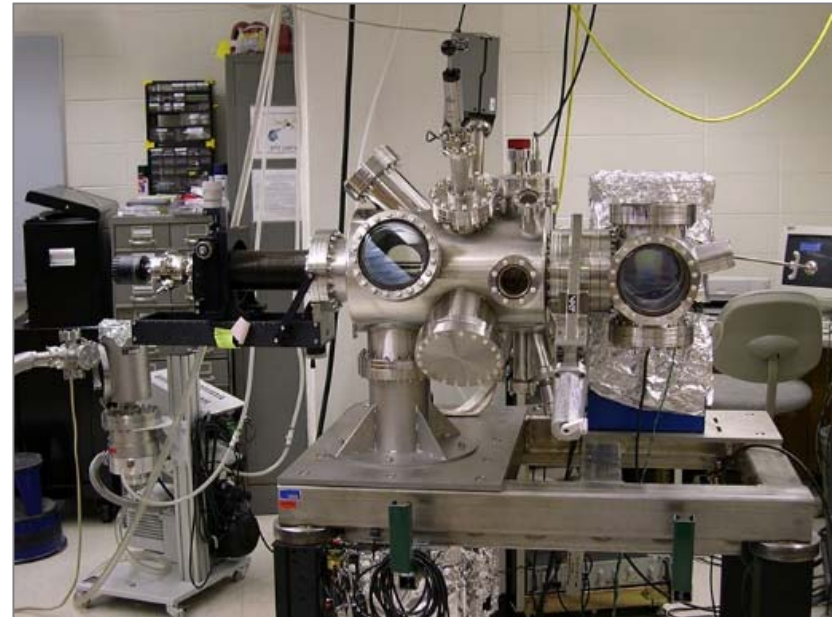


# STM Images

- “See” individual atoms
- Must have high vacuum , low temp (4 K)



Pt and Ni atoms on an alloy surface

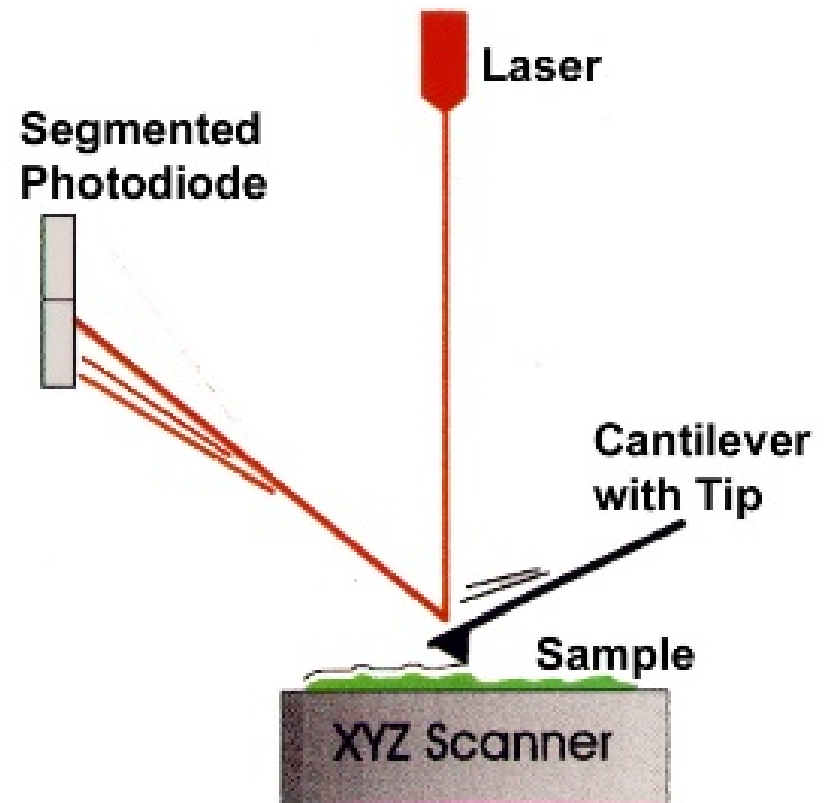


STM at University of Wisconsin – Eau Claire



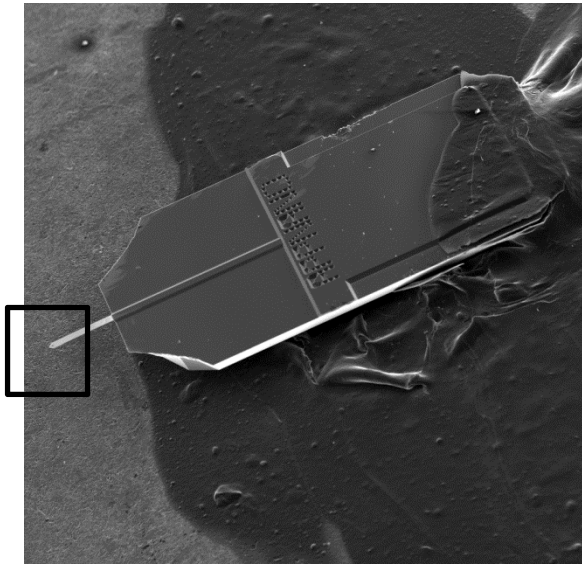
# Atomic Force Microscope (AFM)

1. Tip scans across surface
2. Laser reflects off of cantilever to a photodetector
3. Feedback loop changes tip to sample distance
4. Height changes recorded

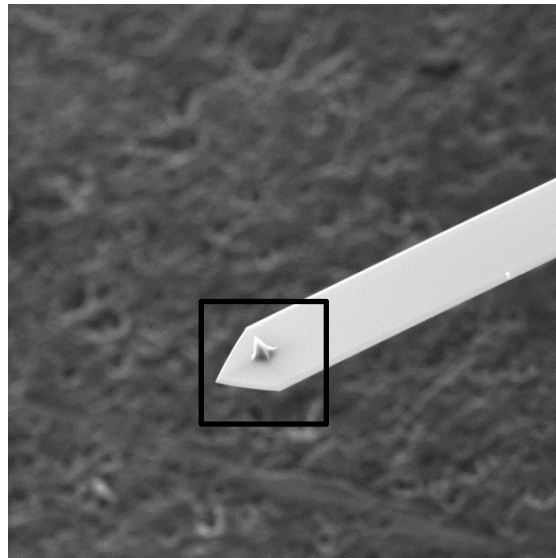


# Atomic Force Microscopy (AFM)

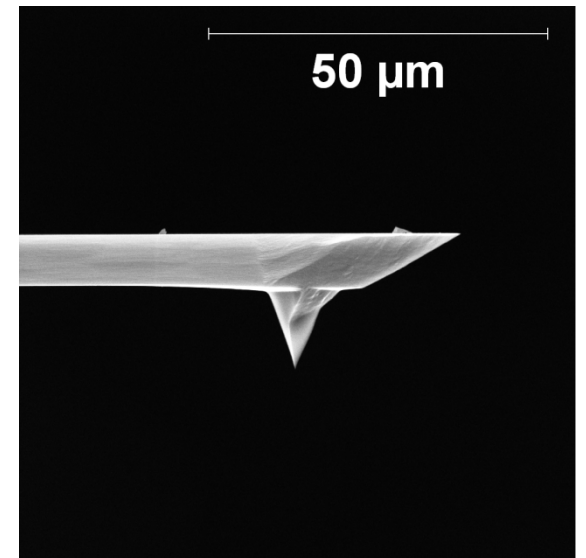
## AFM Cantilevers and tips



Source: NSC Students



Source: NSC Students



Source: NSC Students

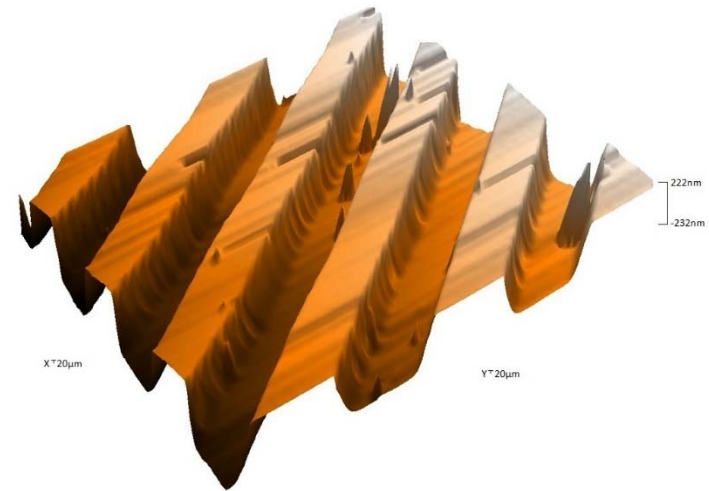


# Atomic Force Microscopy (AFM)

## Nanosurf EasyScan 2

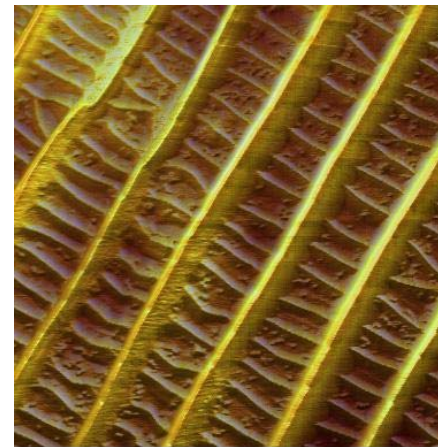


Source: SHINE



Source: NSC Students

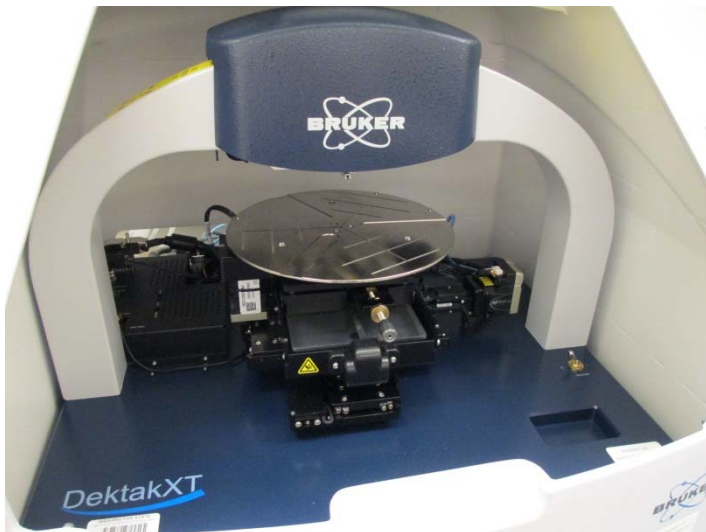
## Butterfly Wing



# Profilometry

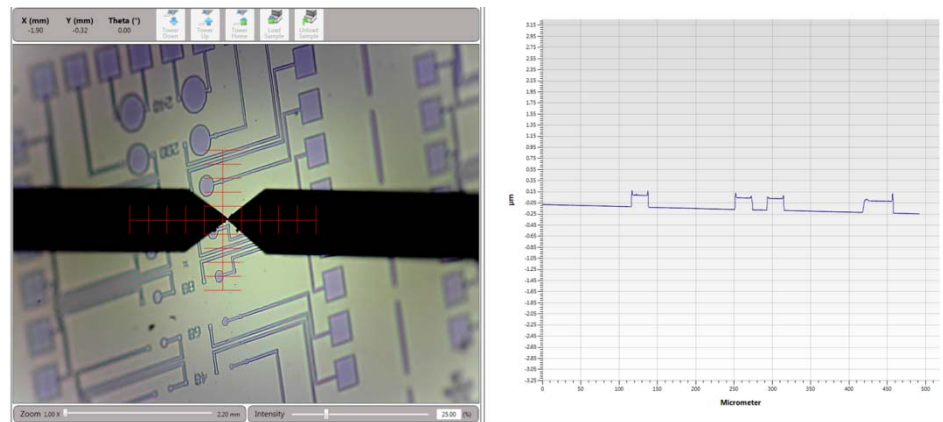
0.5 nm resolution in the Z-direction

Bruker Dektak XT profilometer



Source: NSC students

Typical profilometer scan

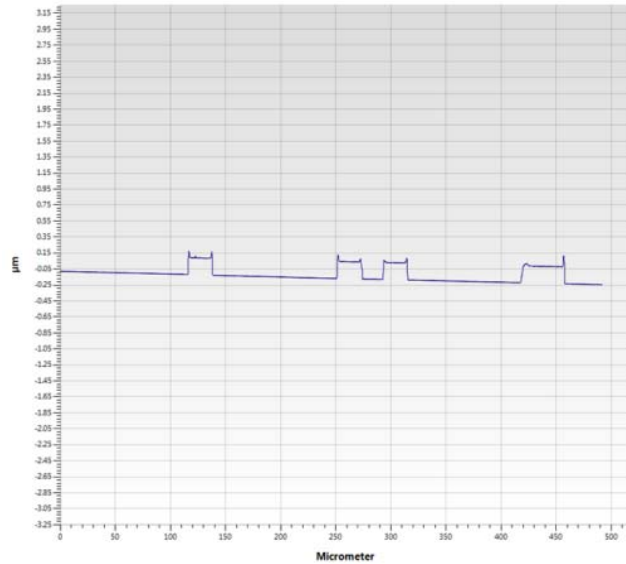


Source: NSC students



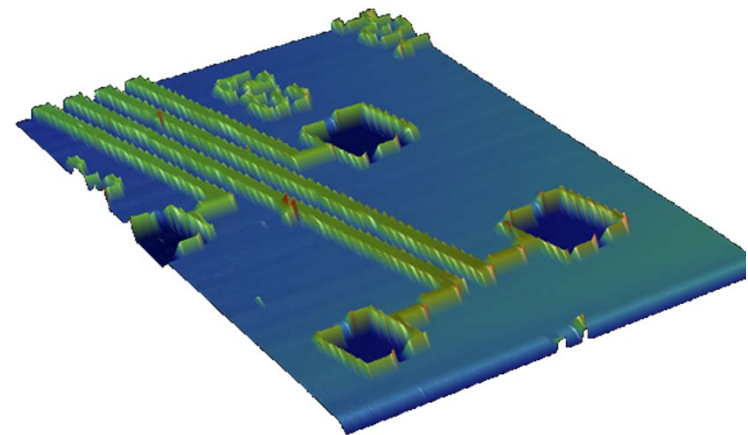
# 3-D Profilometry

2-D profilometer scan



Source: NSC students

3-D profilometer scan



Source: NSC students



# Image References

Slide 3	<i>Adv. Mater.</i> 2006., 18, 2529 - 2534
Slide 4	<i>Gold nanoparticle shape dependent LSPR. Cytodiagnosics. [Online Image]. 8 May 2016. &lt;<a href="http://www.cytodiagnosics.com/store/pc/Introduction-to-Gold-Nanoparticle-Characterization-d3.htm">http://www.cytodiagnosics.com/store/pc/Introduction-to-Gold-Nanoparticle-Characterization-d3.htm</a>&gt;</i>
Slide 5	<i>SpectraVis Plus Spectrophotometer. Vernier. [Online Image]. 8 May 2016. &lt;<a href="http://www.vernier.com/products/sensors/spectrometers/visible-range/svis-pl/">http://www.vernier.com/products/sensors/spectrometers/visible-range/svis-pl/</a>&gt;</i> <i>Spectrometer Diagrams. Adapted from Hewlett-Packard's "Fundamentals of Modern UV-Visible Spectroscopy" publication number 12-5965-512E, 1996. [Online Image]. 8 May 2016 &lt;<a href="http://www.the-scientist.com/?articles.view/articleNo/18797/title/Across-the-Spectrum--Instrumentation-for-UV-Vis-Spectrophotometry/">http://www.the-scientist.com/?articles.view/articleNo/18797/title/Across-the-Spectrum--Instrumentation-for-UV-Vis-Spectrophotometry/</a>&gt;</i>
Slide 6	<i>Dynamic Light Scattering. Jones, Mike. [Online Image]. 21 June 2016. &lt;<a href="https://commons.wikimedia.org/wiki/File:DLS.svg">https://commons.wikimedia.org/wiki/File:DLS.svg</a>&gt;</i>



# Image References

<b>Slide 6</b>	<p>Intensity Fluctuations and Brownian Motion. AZO Materials. [Online Image] 10 May 2016. &lt;<a href="http://www.azom.com/article.aspx?ArticleID=12255">http://www.azom.com/article.aspx?ArticleID=12255</a>&gt;</p> <p>Weighted Distributions. Yilun LiAndrew R. Barron, Dynamic Light Scattering. OpenStax CNX. May 7, 2014 <a href="http://cnx.org/contents/3fc98dad-934d-45e6-a19f-c0a1cf440d43@1.">http://cnx.org/contents/3fc98dad-934d-45e6-a19f-c0a1cf440d43@1.</a>&gt;</p>
<b>Slide 7</b>	<p>Microscope. [Online Image] 10 May 2016. &lt;<a href="http://mssmith.wicomico.wikispaces.net/Tools+Scientists+Use">http://mssmith.wicomico.wikispaces.net/Tools+Scientists+Use</a>&gt;</p>
<b>Slide 11</b>	<p>Transmission Electron Microscope. Wikimedia Commons. [Online Image]. 10 May 2016 &lt;<a href="https://commons.wikimedia.org/wiki/File:Electron_Microscope.png">https://commons.wikimedia.org/wiki/File:Electron_Microscope.png</a>&gt;</p>



# Image References

<b>Slide 12</b>	<p>TEM. Boundless. "Electron Microscopy." Boundless Microbiology. Boundless, 13 Apr. 2016. Retrieved 10 May. 2016 from &lt;<a href="https://www.boundless.com/microbiology/textbooks/boundless-microbiology-textbook/microscopy-3/other-types-of-microscopy-30/electron-microscopy-249-1065/">https://www.boundless.com/microbiology/textbooks/boundless-microbiology-textbook/microscopy-3/other-types-of-microscopy-30/electron-microscopy-249-1065/</a>&gt;</p> <p>3 mm copper grid. Lilly_M. Wikimedia Commons. [Online Image]. 17 May 2016. &lt;<a href="https://commons.wikimedia.org/wiki/File:3_mm_copper_grid_electron_microscopy_for_sample-04.jpg">https://commons.wikimedia.org/wiki/File:3_mm_copper_grid_electron_microscopy_for_sample-04.jpg</a>&gt;</p>
<b>Slide 13</b>	<p>Golgi Apparatus. [Online Image]. 17 May 2016. &lt;<a href="https://courses.candelalearning.com/biology11xmaster/chapter/eukaryotic-cells/">https://courses.candelalearning.com/biology11xmaster/chapter/eukaryotic-cells/</a>&gt;</p> <p>Mesoporous silica nanoparticle. [Online Image]. 21 May 2016. &lt;<a href="https://en.wikipedia.org/wiki/File:Mesoporous_silica_closeup.jpg">https://en.wikipedia.org/wiki/File:Mesoporous_silica_closeup.jpg</a>&gt;</p>
<b>Slide 14</b>	<p>SEM Image. MyScope. [Online Image]. 21 May 2016. &lt;<a href="http://li155-94.members.linode.com/myscope/sem/practice/principles/layout.php">http://li155-94.members.linode.com/myscope/sem/practice/principles/layout.php</a>&gt;</p>



# Image References

Slide 15	Conidium. Gans, Murray. [Online Image]. 21 May 2016. < <a href="http://murry-gans.blogspot.com/2013_04_01_archive.html">http://murry-gans.blogspot.com/2013_04_01_archive.html</a> >
Slide 19	Scanning Tunneling Microscope. [Online Image]. 22 May 2016. < <a href="https://en.wikipedia.org/wiki/Scanning_tunneling_microscope#/media/File:ScanningTunnelingMicroscope_schematic.png">https://en.wikipedia.org/wiki/Scanning_tunneling_microscope#/media/File:ScanningTunnelingMicroscope_schematic.png</a> >
Slide 20	Pt and Ni. Richmond, Michael. [Online Image]. 22 May 2016. < <a href="http://spiff.rit.edu/classes/phys314/lectures/stm/stm.html">http://spiff.rit.edu/classes/phys314/lectures/stm/stm.html</a> > STM. [Online Image]. 22 May 2016. < <a href="http://www.uwec.edu/Matsci/center/instrumentation/">http://www.uwec.edu/Matsci/center/instrumentation/</a> >
Slide 21	AFM. Hansma, Helen. [Online Image]. 22 May 2016. < <a href="http://web.physics.ucsb.edu/~hhansma/biomolecules.htm">http://web.physics.ucsb.edu/~hhansma/biomolecules.htm</a> >



# Image References

Slide 22

Butterfly Wing. NanoSurf. [*Online Image*]. 22 May 2016.  
<<https://www.nanosurf.com/en/application/70-butterfly-wings-a-fragile-biological-nanostructure>>

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