



Building College-University
Partnerships for Nanotechnology
Workforce Development

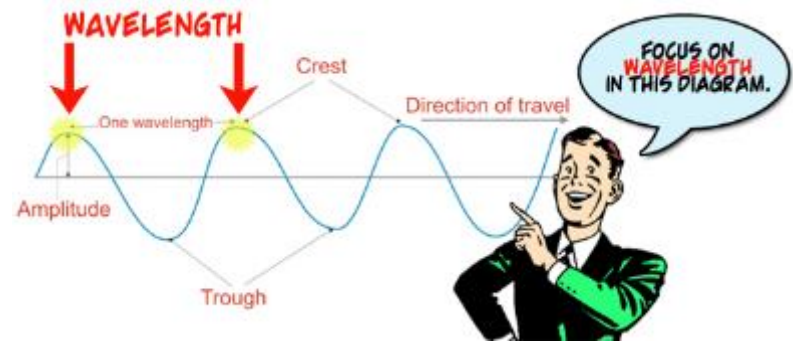
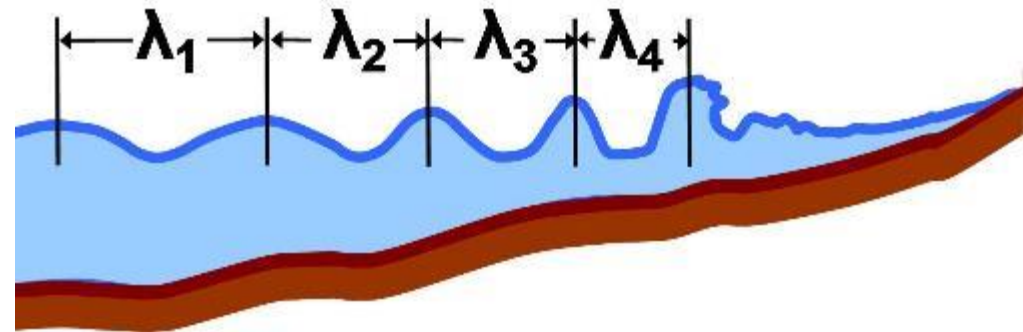
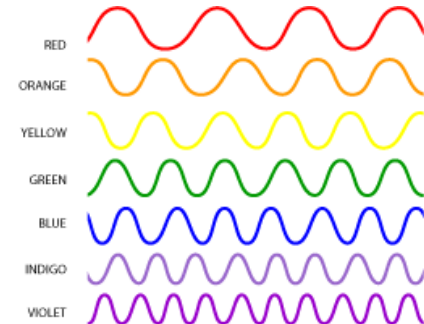
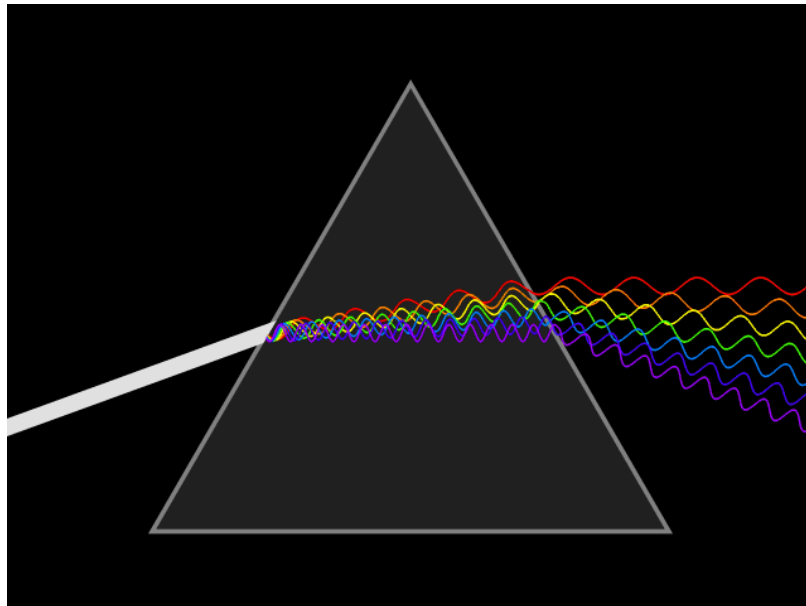
Scanning Electron Microscopy

Atilla Ozgur Cakmak, PhD



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How do we see normally?

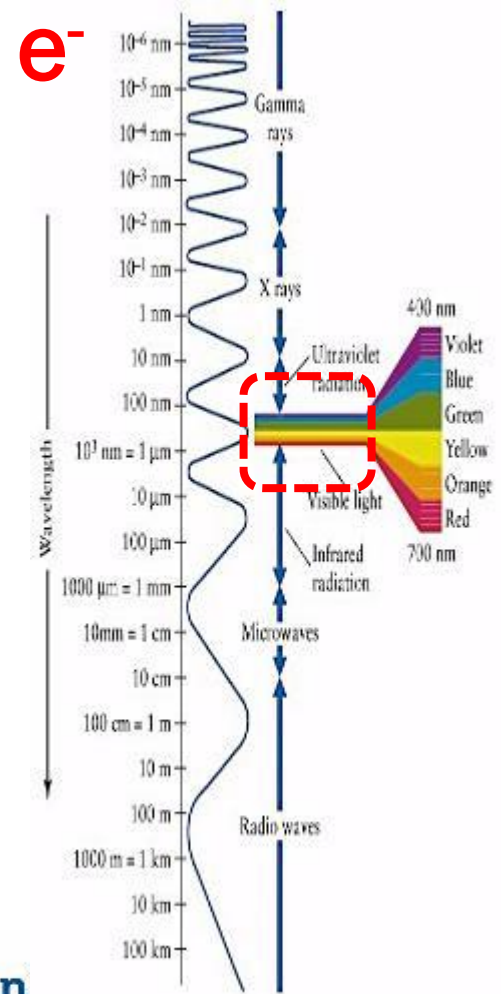
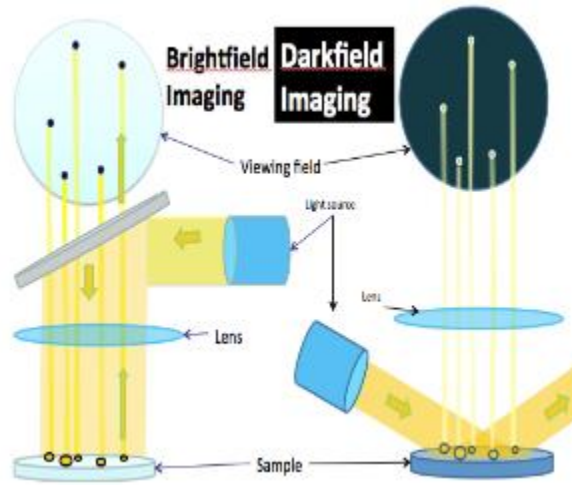


- What is light?
- Light propagates as wave packets

How do we see normally?

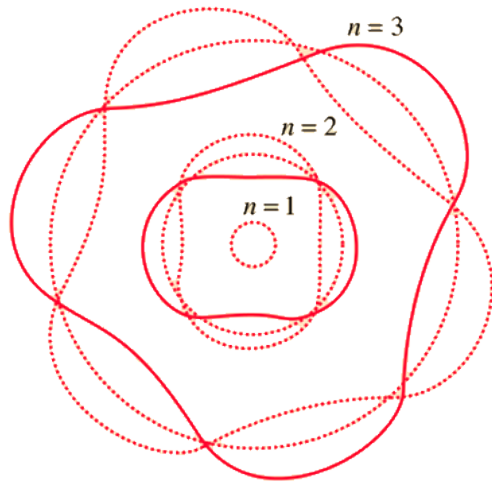


$$R \propto \lambda$$

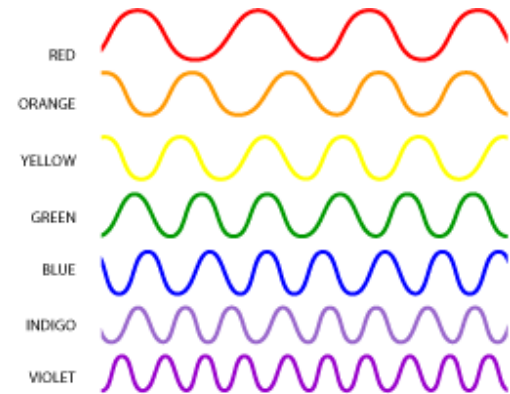


The use of electrons

$$2\pi r = n\lambda$$

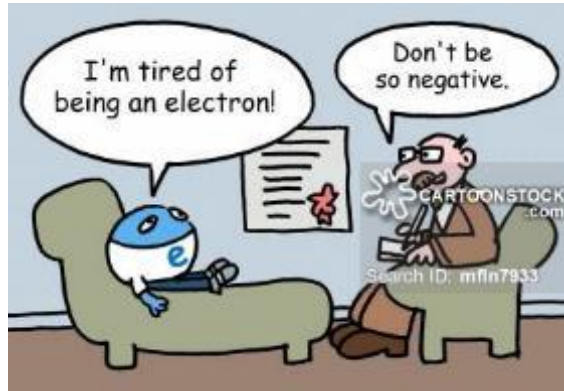


Before his Nobel-winning work in quantum theory, Niels Bohr was goalkeeper for the Danish football team Akademisk Boldklub. His mathematician brother Harald was the real sporty one, though – he played for the Danish national football team at the 1908 Olympics.



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The use of electrons



Electrons

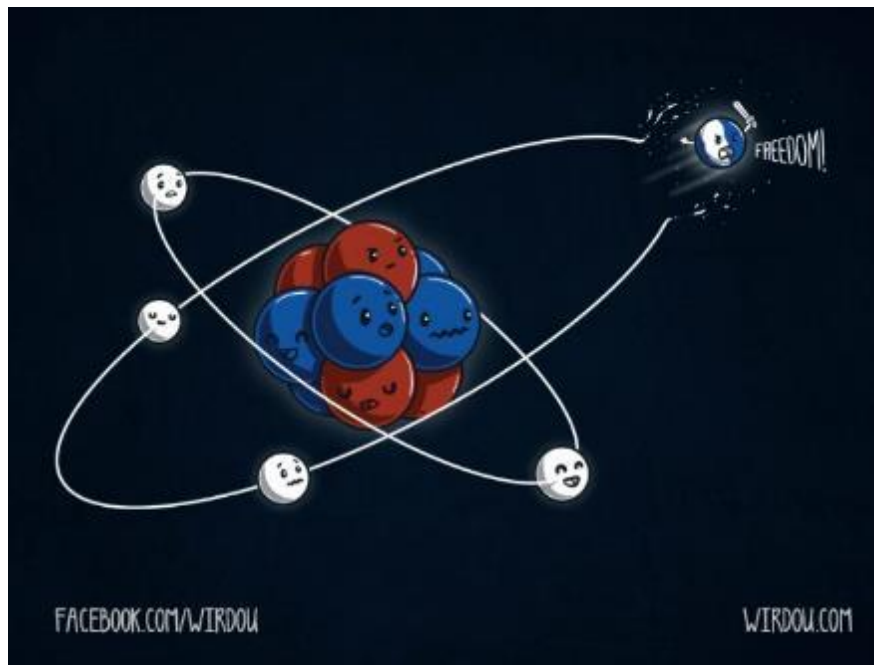
$$R \propto \lambda$$

A PHOTON CHECKS INTO A HOTEL AND IS ASKED IF HE NEEDS ANY HELP WITH HIS LUGGAGE.

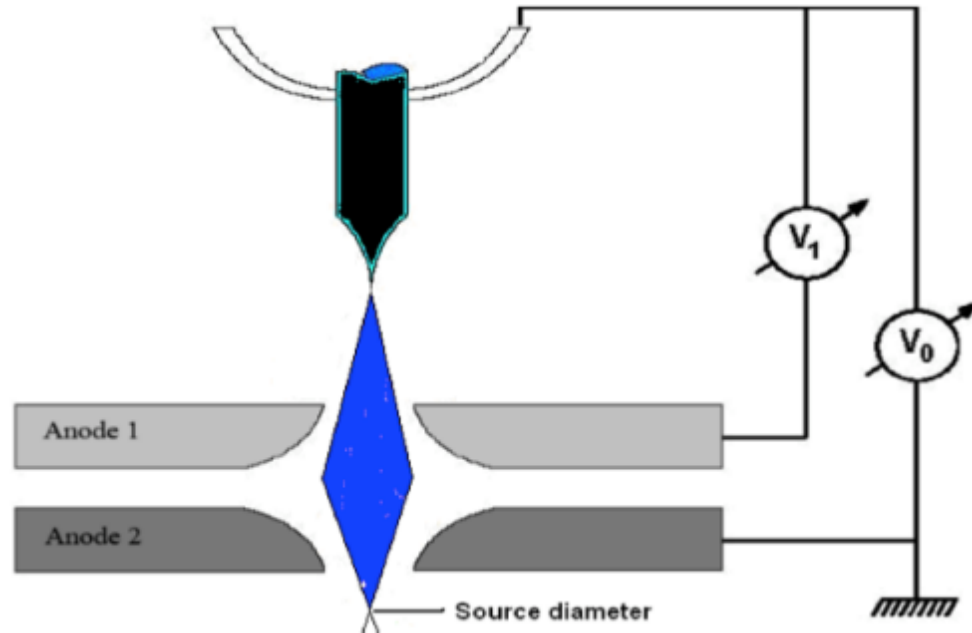
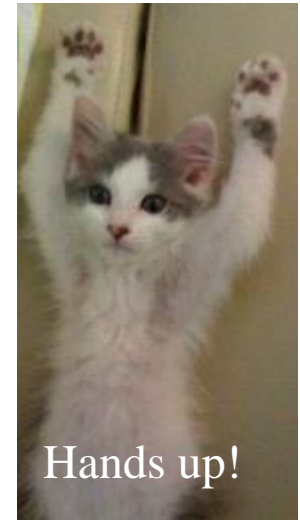
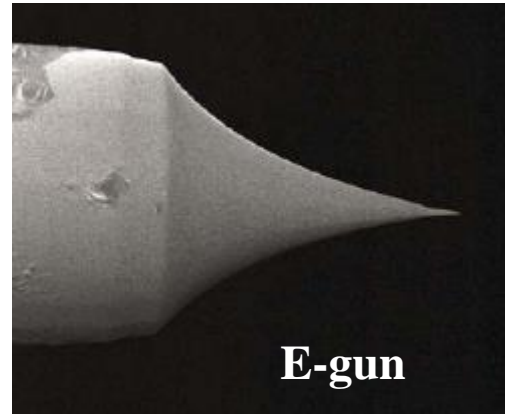


"NO, I'M TRAVELLING LIGHT."

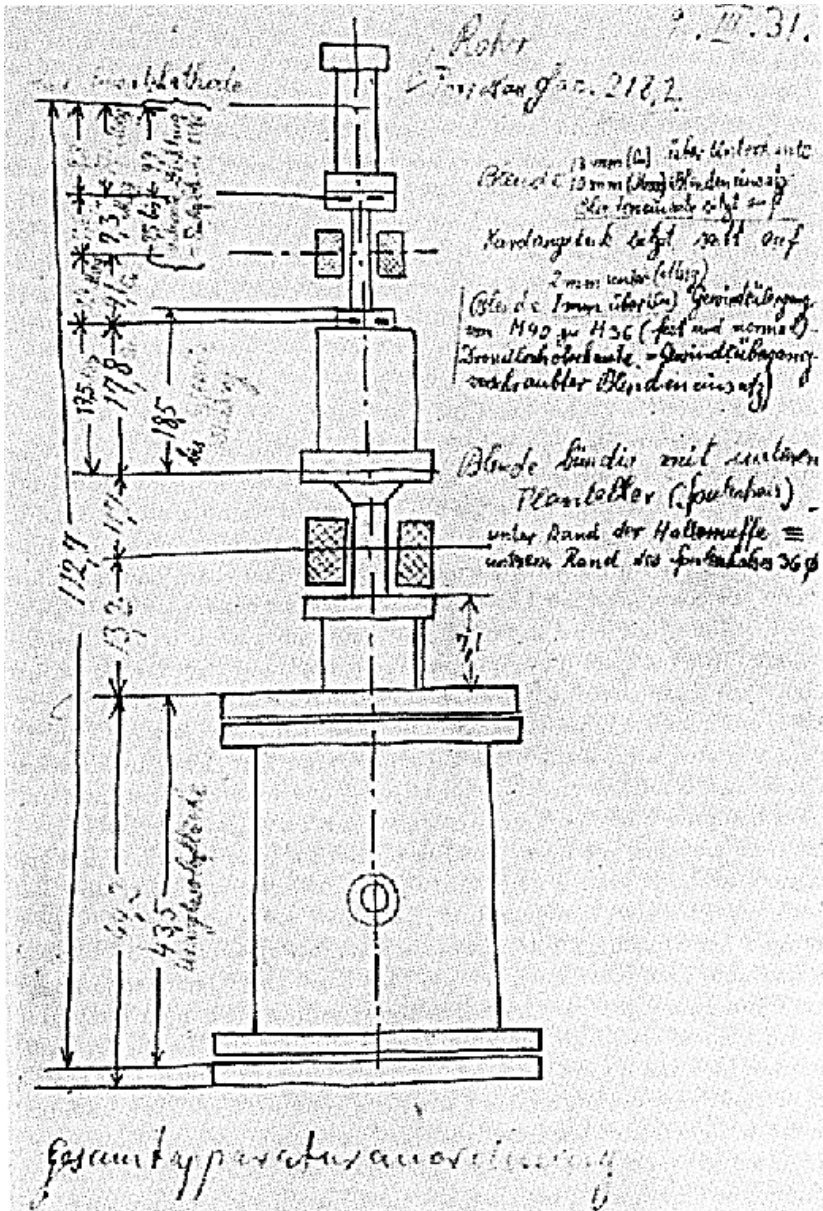
Light



The use of electrons



First Electron Microscope

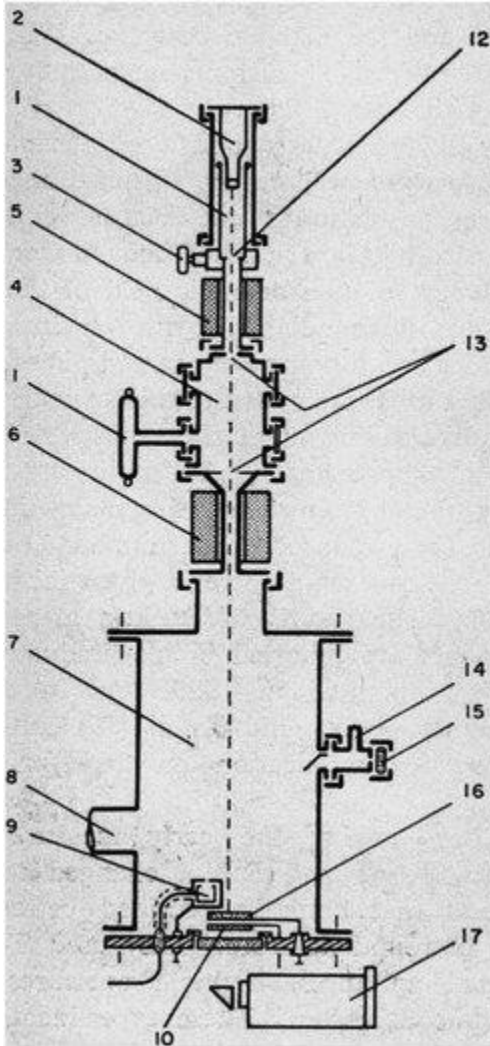


Ruska and Knoll

Ruska's sketch from his PhD work

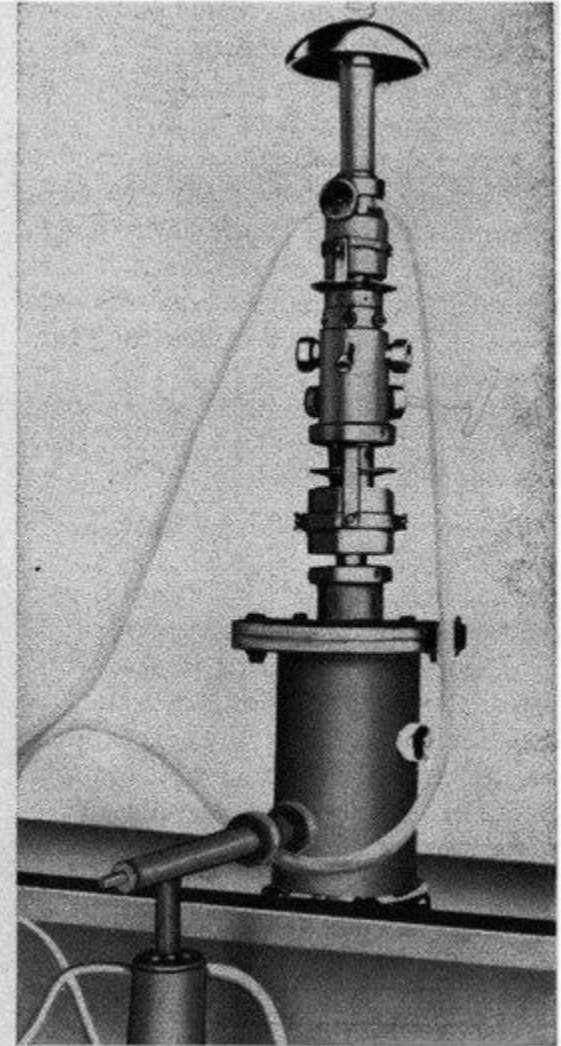


First Electron Microscope



X16 Mag-1931
X400 Mag-1932

1. GAS DISCHARGE TUBE
2. CATHODE
3. AIR-INLET NEEDLE VALVE
4. CHAMBER FOR ELECTROSTATIC LENS (IF USED)
5. OBJECTIVE MAGNETIC LENS
6. PROJECTION LENS
7. HIGH VACUUM CHAMBER
8. VACUUM PUMP OUTLET
9. FARADAY CAGE FOR BEAM CURRENT MEASUREMENTS
10. FLUORESCENT SCREEN OR GLASS PLATE
11. GAS DISCHARGE TUBE FOR VACUUM TESTING
12. ANODE APERTURE
13. LIMITING APERTURES
14. OUTLET FOR VACUUM GAUGE
15. OBSERVATION WINDOW
16. REMOVABLE FLUORESCENT SCREEN FOR OBSERVATION
17. CAMERA

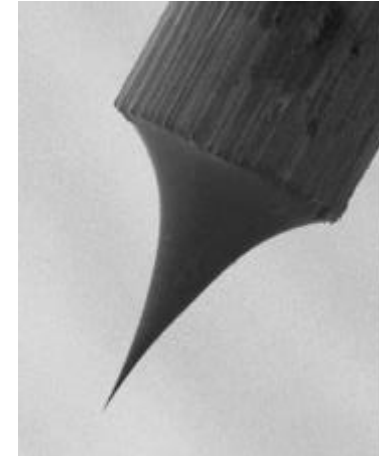
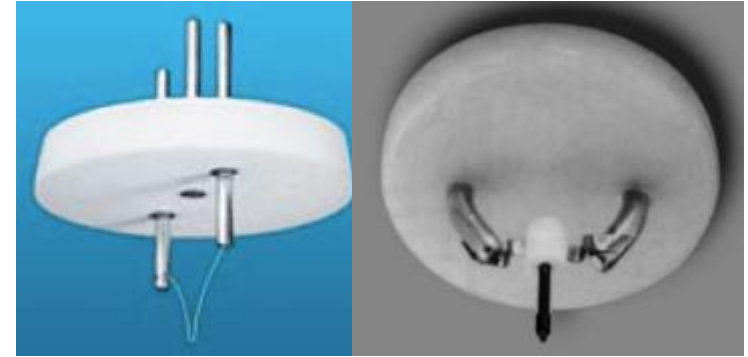
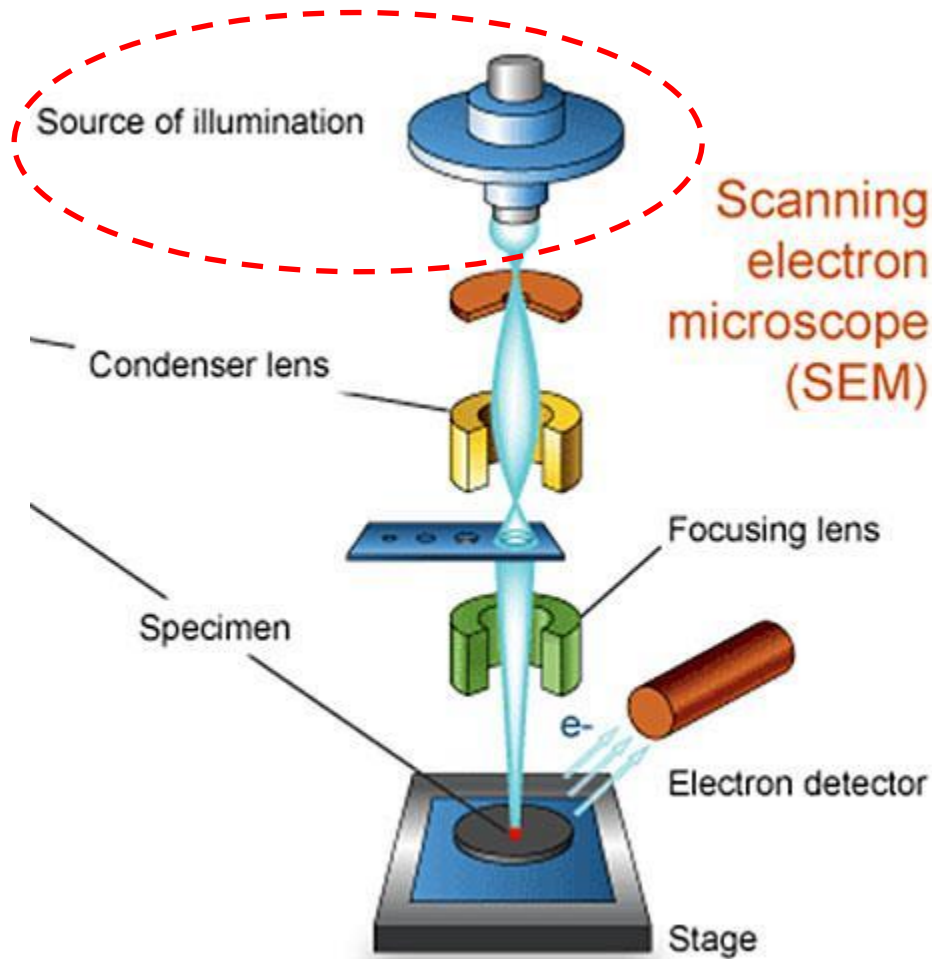


Can read more about it as supplementary material

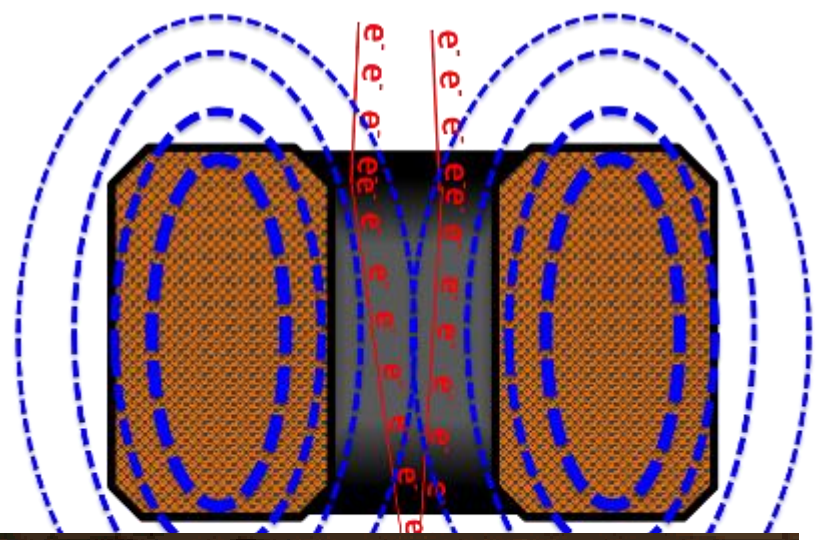
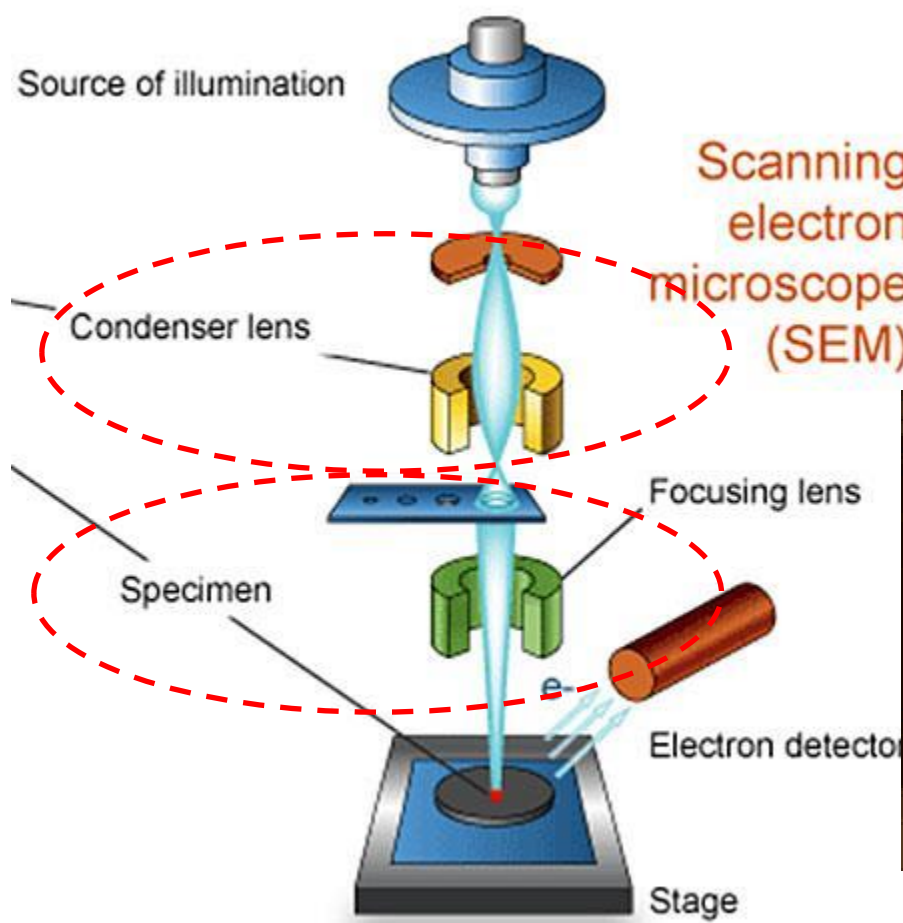


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Building an SEM-1 Source of Illumination



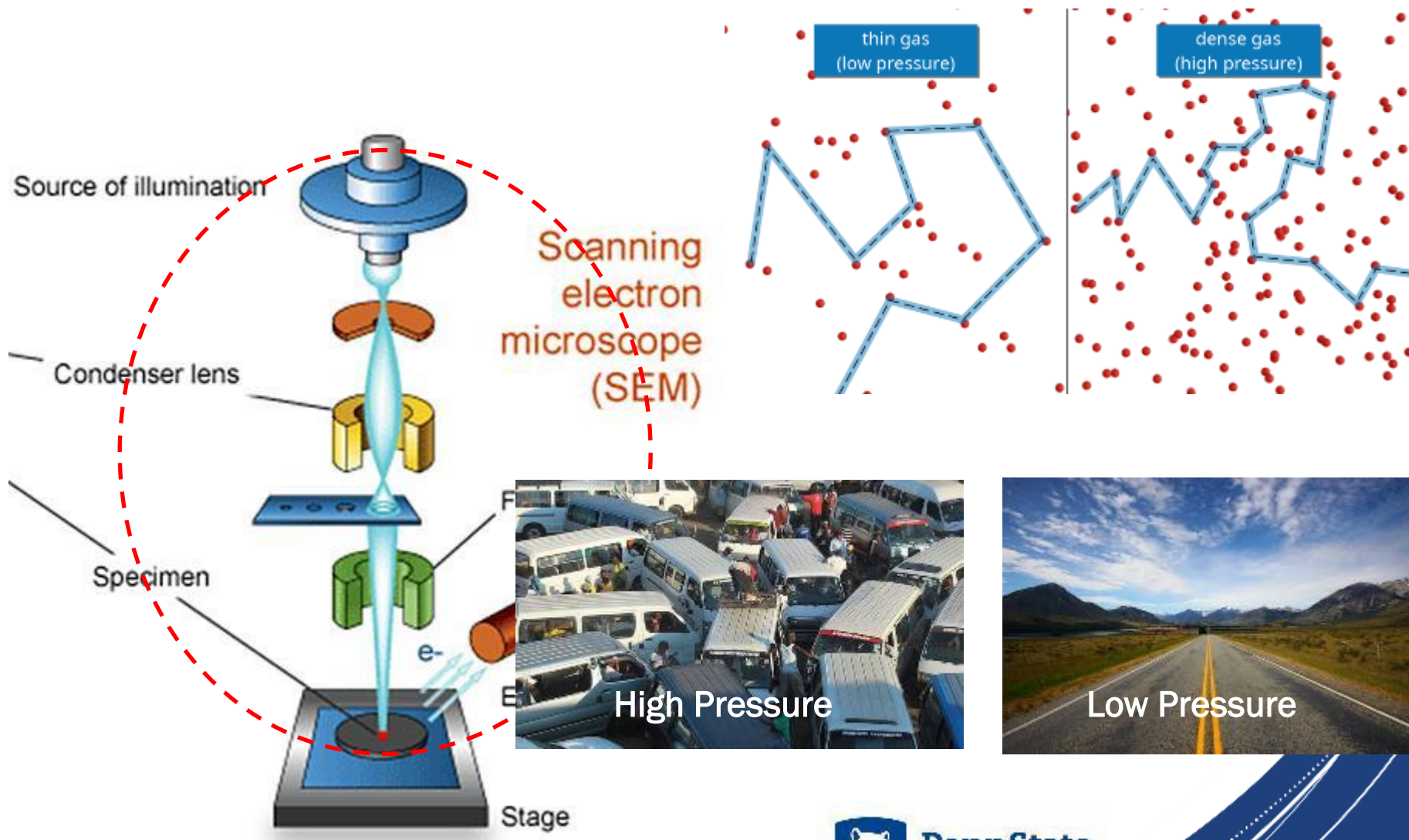
Building an SEM-2 Beamguide



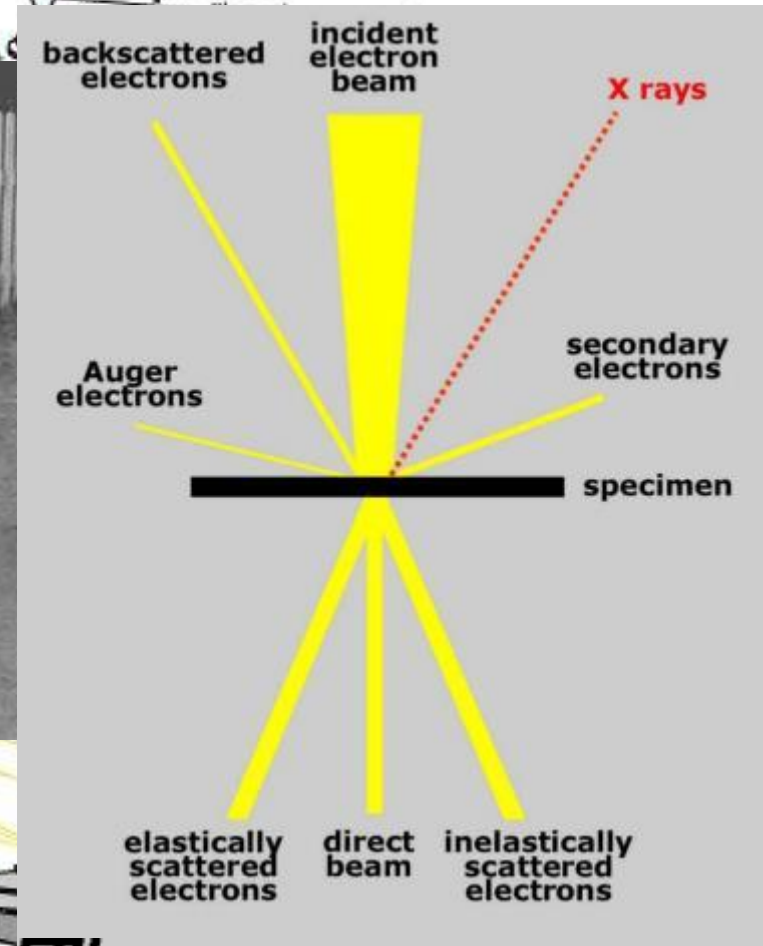
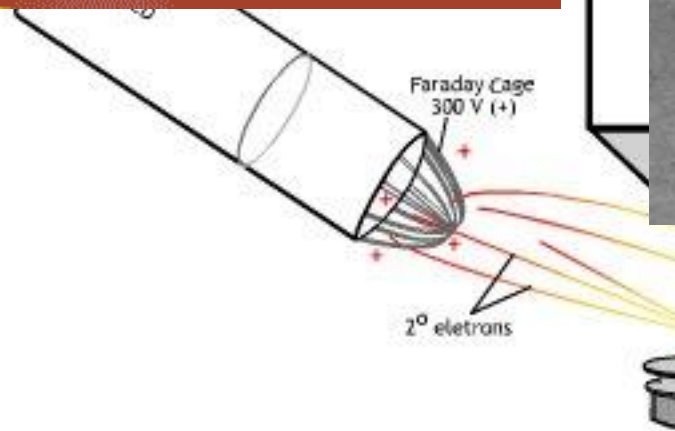
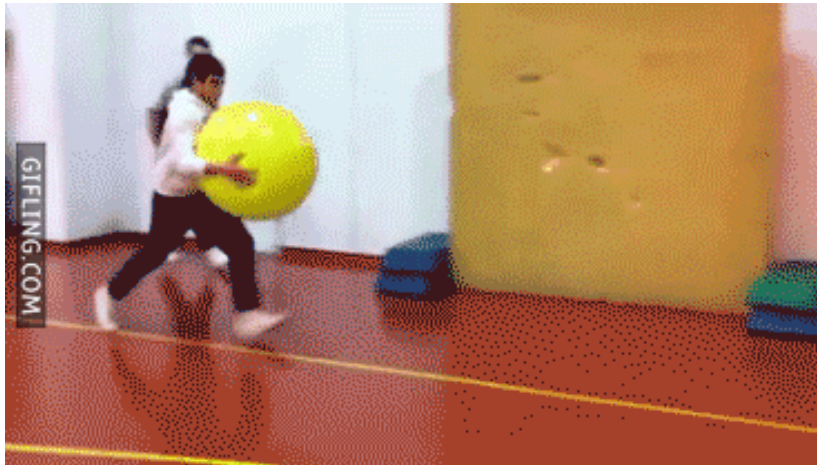
Building an SEM-3 Vacuum



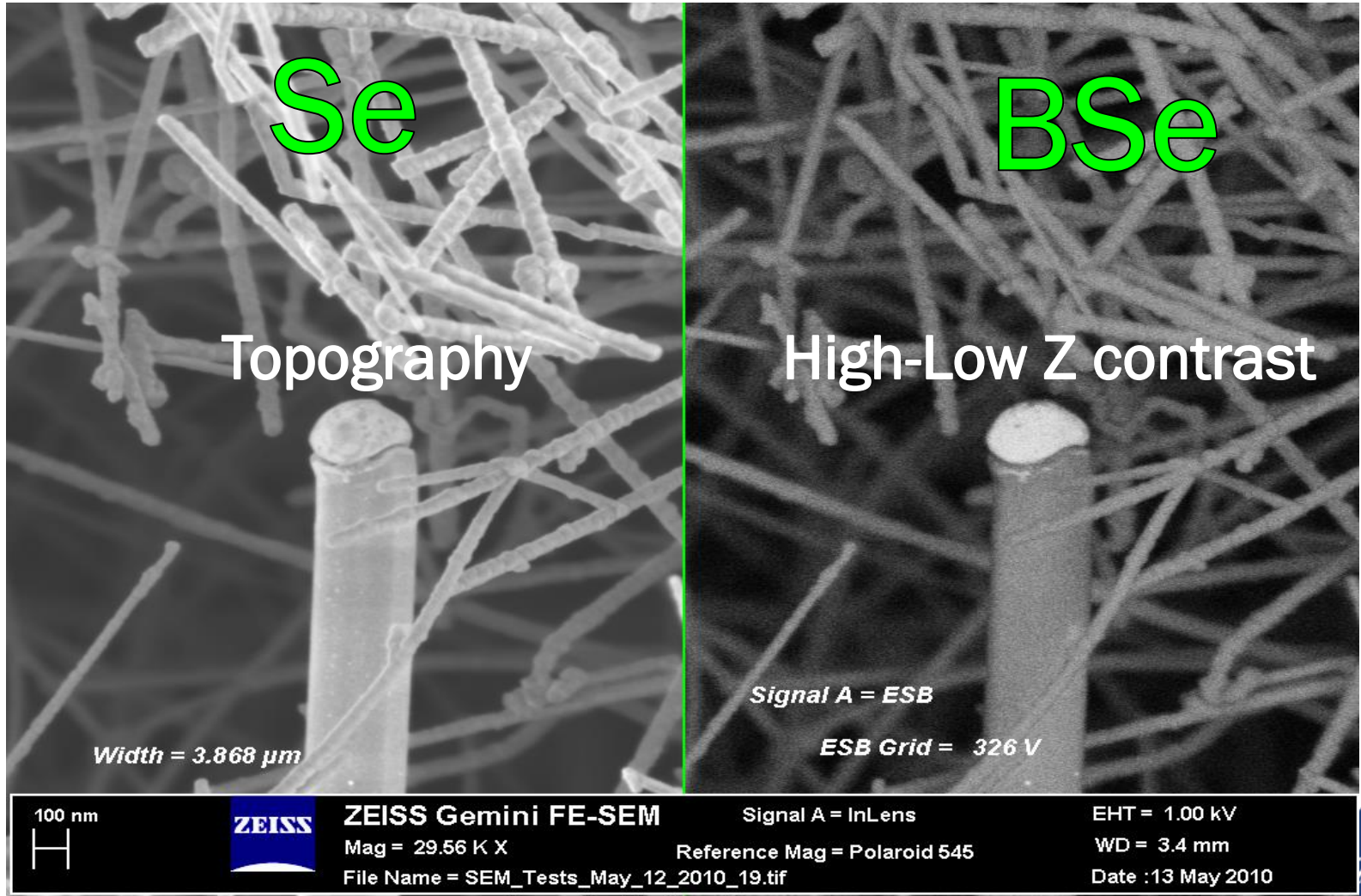
Building an SEM-3 Vacuum



Building an SEM-4 Detection



Building an SEM-4 Detection



100 nm



ZEISS Gemini FE-SEM

Mag = 29.56 K X

File Name = SEM_Tests_May_12_2010_19.tif

Signal A = InLens

Reference Mag = Polaroid 545

EHT = 1.00 kV

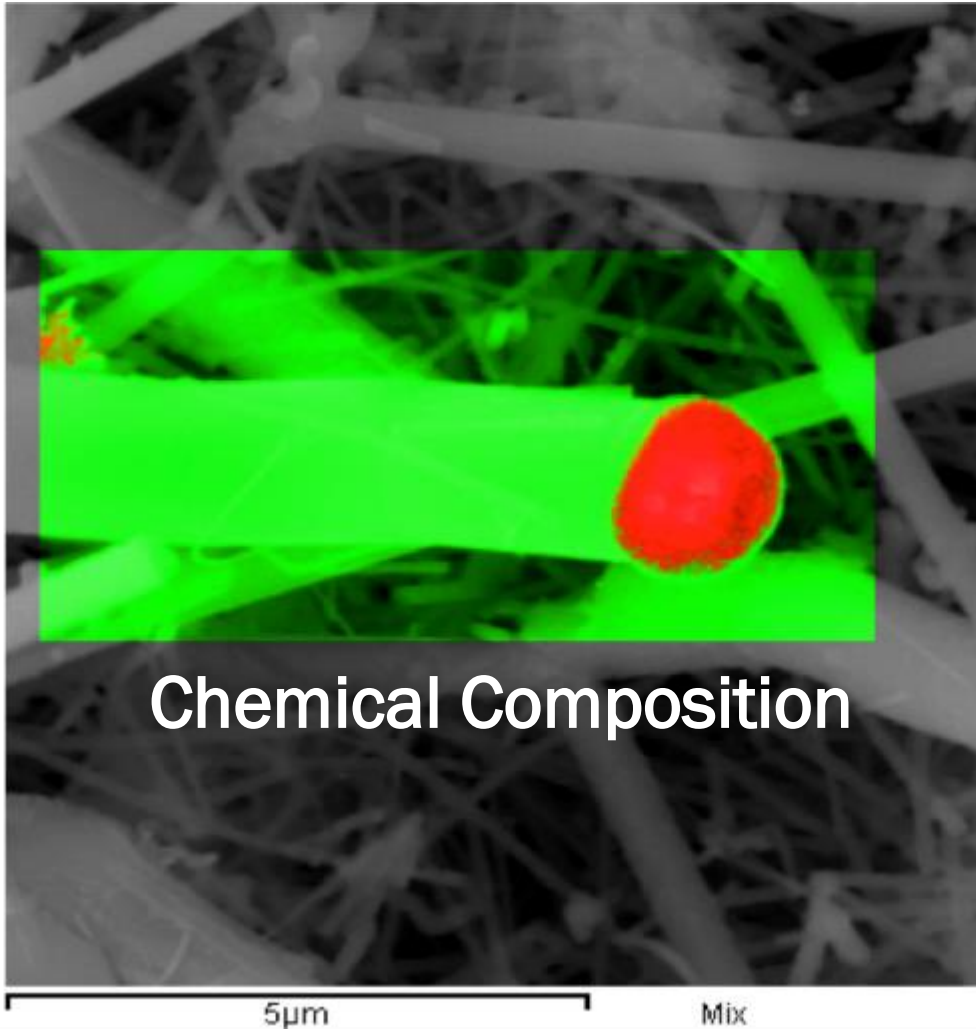
WD = 3.4 mm

Date :13 May 2010



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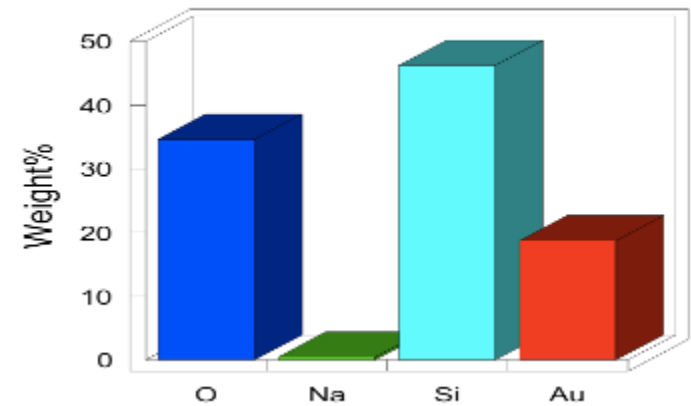
Building an SEM-4 Detection



Chemical Composition



Quantitative results

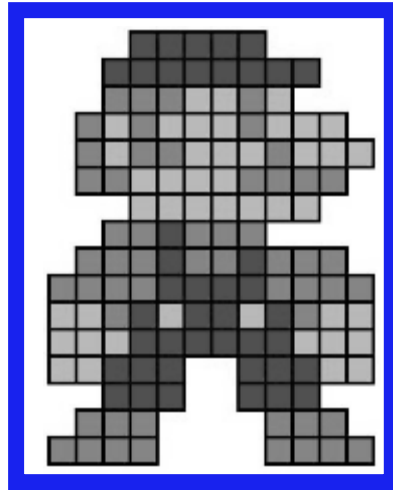
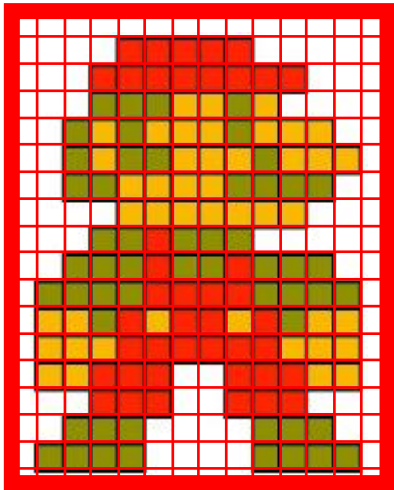


Building an SEM-5 Scanning

Larger raster areas = Low mag.

Raster on Sample

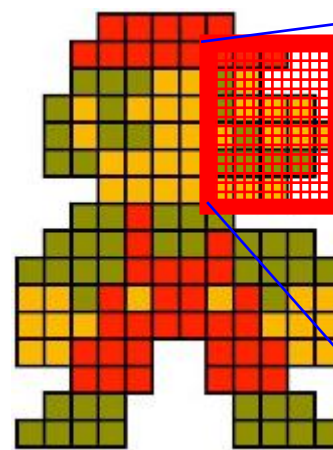
Pixels on screen image



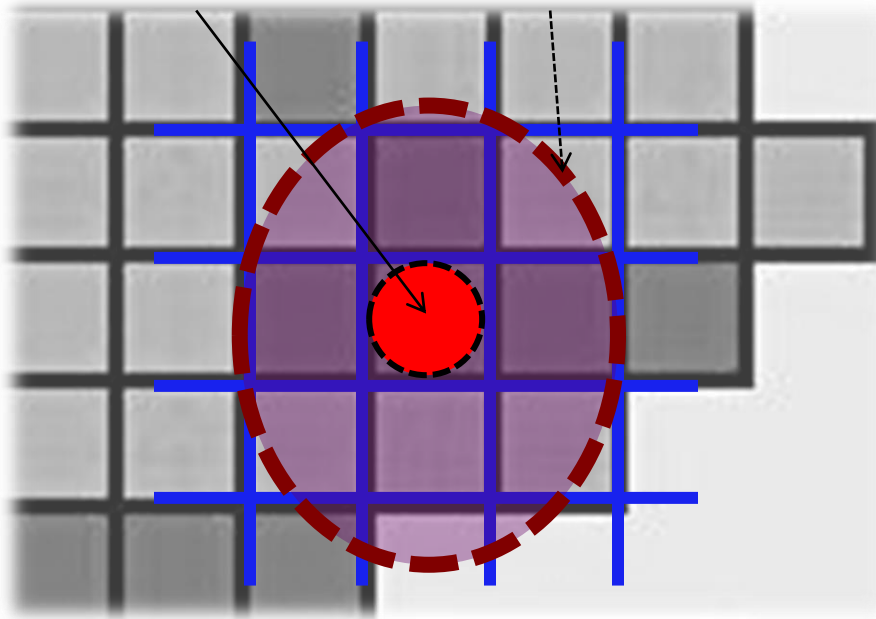
Smaller raster areas = Higher mag.

Raster on Sample

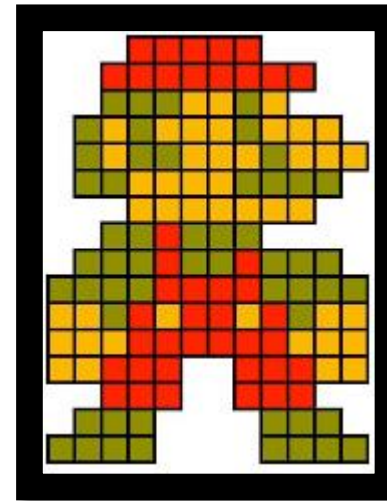
Pixels on screen image



Building an SEM-5 Scanning

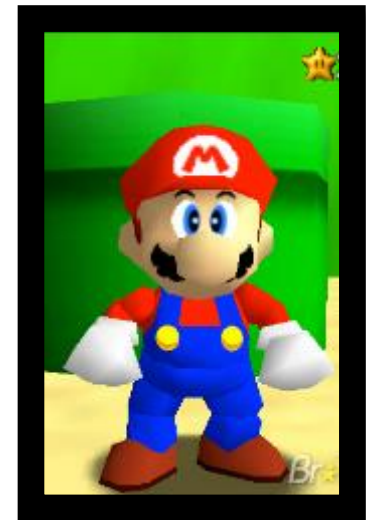


8-bit



Large spot size

64-bit



Small spot size

Building an SEM-5 Scanning

X, Y Coordinate	Time (μSec.)
1, 10	0:01
2, 10	0:38
3, 10	1:15
4, 10	1:52
5, 10	2:29
6, 10	3:06
7, 10	3:43
8, 10	4:20
9, 10	4:57
10, 10	5:04
11, 10	5:11
12, 10	5:18

Time	Signal Intensity
0:01	█░░░░░░░
0:38	█░░░░░░░
1:15	███░░░░░
1:52	█████████░
2:29	█░░░░░░░
3:06	█████████░
3:43	█████████░
4:20	█░░░░░░░
4:57	█████████░
5:04	███░░░░░
5:11	█░░░░░░░
5:18	█░░░░░░░

It's me,
Mario



Guessing Game-1

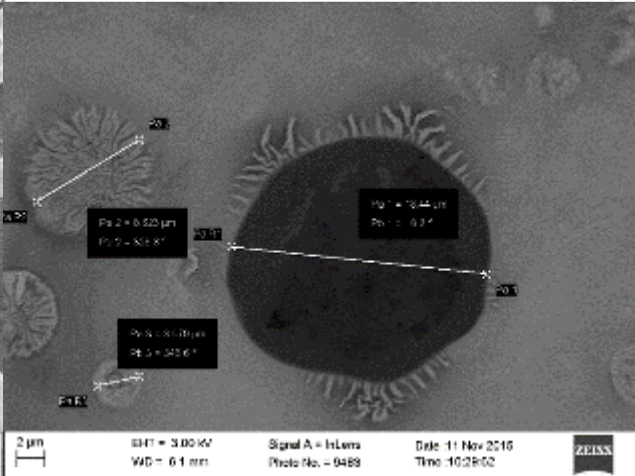
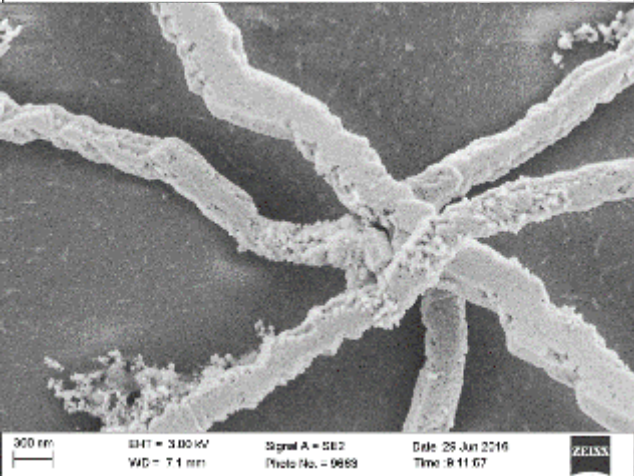
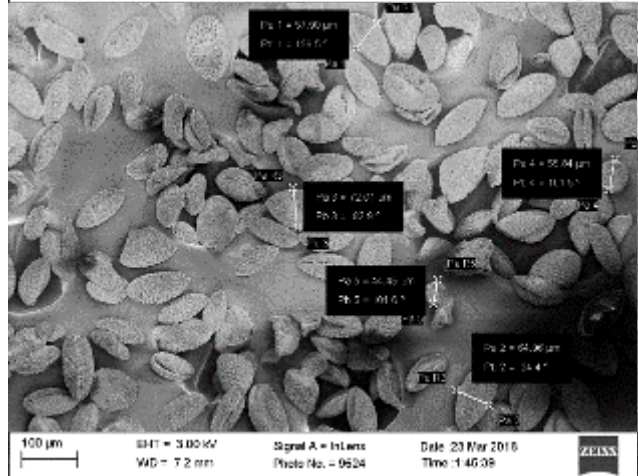
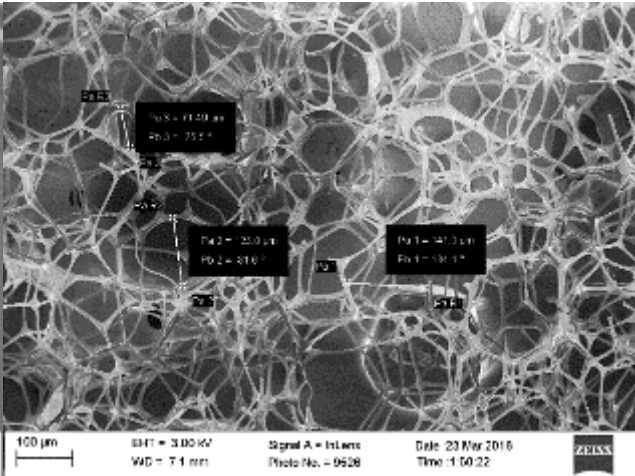
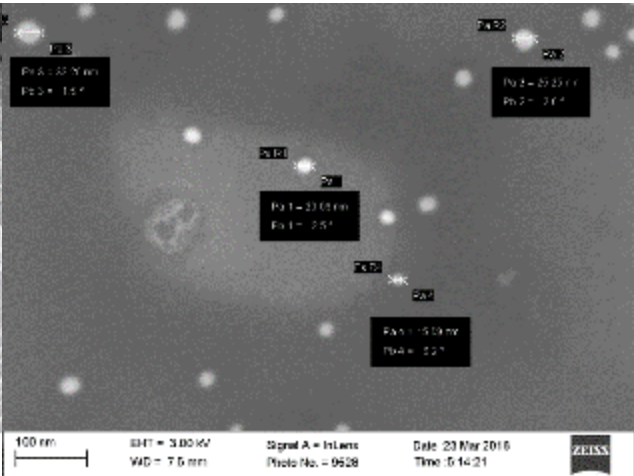
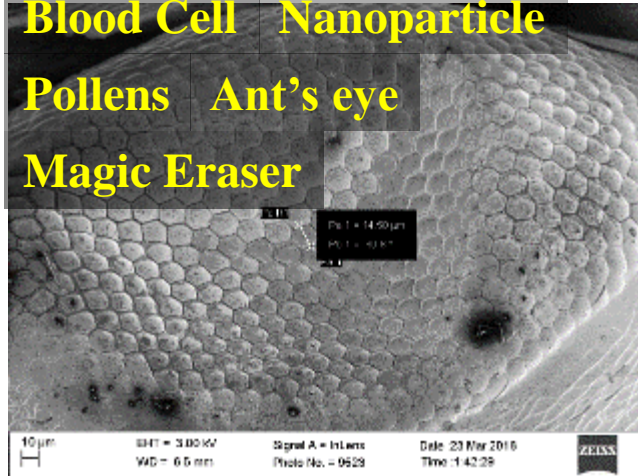
Can you guess what they are?

Nanowire

Blood Cell Nanoparticle

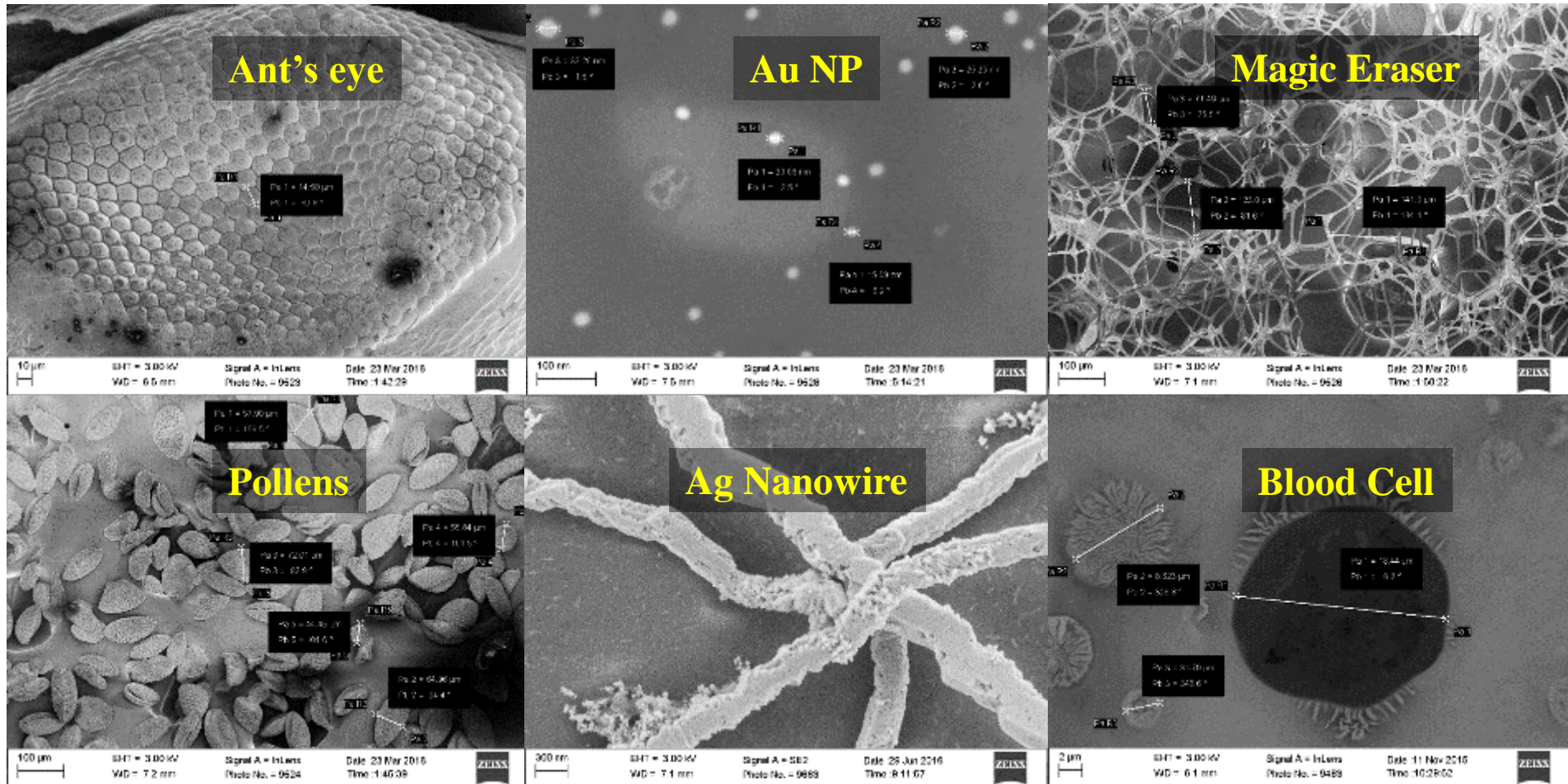
Pollens Ant's eye

Magic Eraser

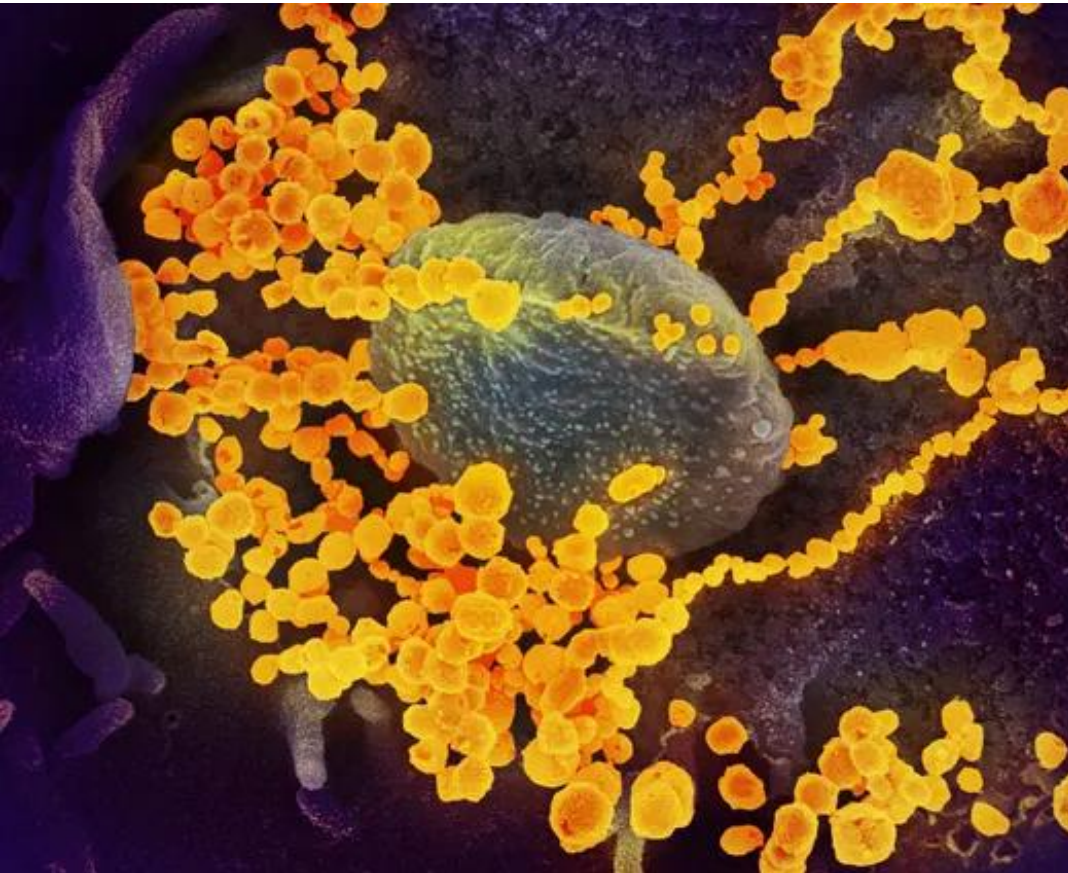


Guessing Game-2

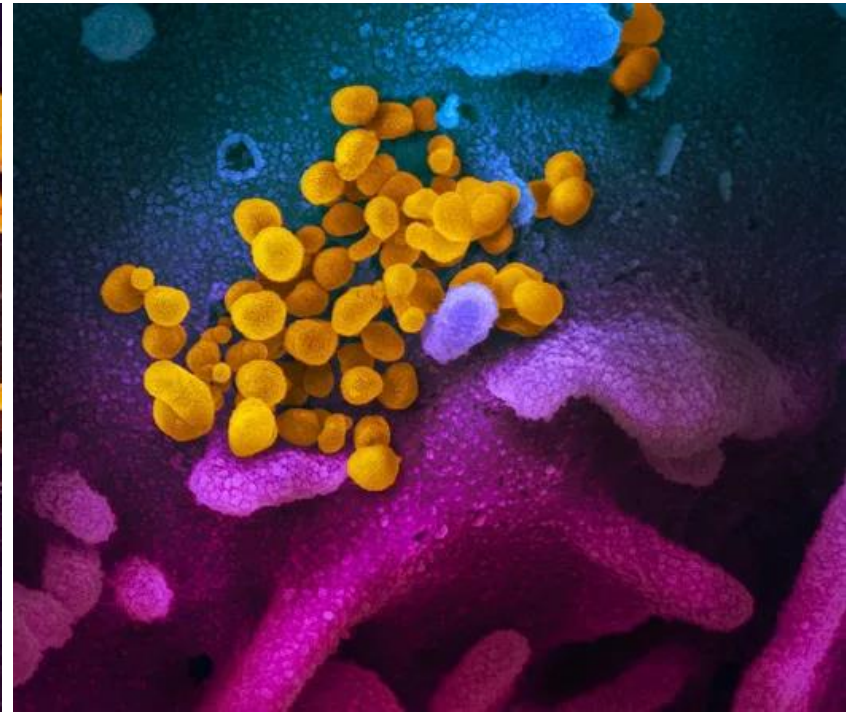
Can you guess what they are?



SARS-Cov-2



Scanning Electron Microscope image of SARS-CoV-2 (gold) emerging from the surface of cells cultured in lab by National Institute of Allergy and Infectious Diseases-
<https://www.flickr.com/photos/niaid/49557785797>, CC BY 2.0



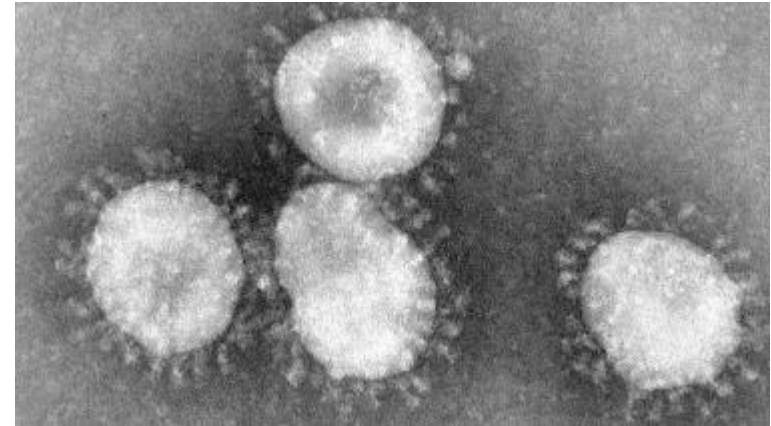
Novel Coronavirus SARS-CoV-2, also known as Covid 19, scanning electron microscope image by NIAID / CC BY
<https://creativecommons.org/licenses/by/2.0>

SARS-Cov-2

The New York Times

Overlooked No More: June Almeida, Scientist Who Identified the First Coronavirus

In 1966, she used a powerful electron microscope to capture an image of a mysterious pathogen — the first coronavirus known to cause human disease.



One of the first micrographs belonging to coronaviruses –
Getty Images

June Almeida (née Hart) an internationally renowned virologist who developed **innovative methods for the identification of viruses under an electron microscope.**

Born in Scotland in 1930.

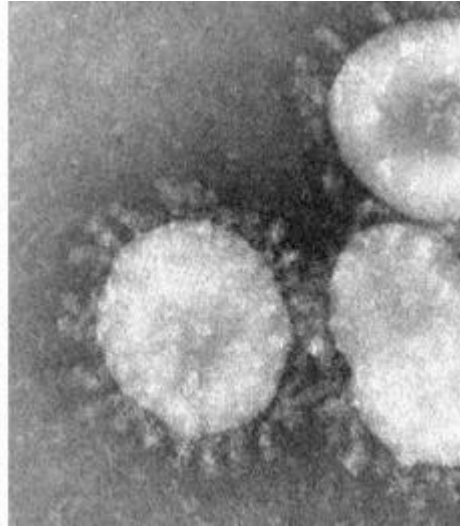
Father bus driver, lost brother to diphtheria

Did not have the funds to go to college

Left secondary school and worked as a technician

June Almeida in 1963 as she is gaining a reputation for extending the range of the electron microscope to new limits. - Getty Images

SARS-Cov-2



Moves to Canada in 1954 for an open position as a technician at the Ontario Cancer Institute.
 Masters the technique called negative staining to heighten the contrast of EM images.
 Turns out to be revolutionary for virology. Publishes her work in Science in 1963.
 Obtains Doctor of Science degree in 1964.
 Recruited back to the UK in 1964, works on hepatitis B, common cold, HIV...
 Identifies Coronaviruses in 1966!
 Collects a sample from a schoolboy in Surrey (sample B814).

SARS-Cov-2


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Article | [Open Access](#) | Published: 30 September 2020

Ultrastructural analysis of SARS-CoV-2 interactions with the host cell via high resolution scanning electron microscopy

[Lucio Ayres Caldas](#) , Fabiana Avila Carneiro, Luiza Mendonça Higa, Fábio Luiz Monteiro, Gustavo Peixoto da Silva, Luciana Jesus da Costa, Edison Luiz Durigon, Amilcar Tanuri & Wanderley de Souza

Scientific Reports **10**, Article number: 16099 (2020) | [Cite this article](#)

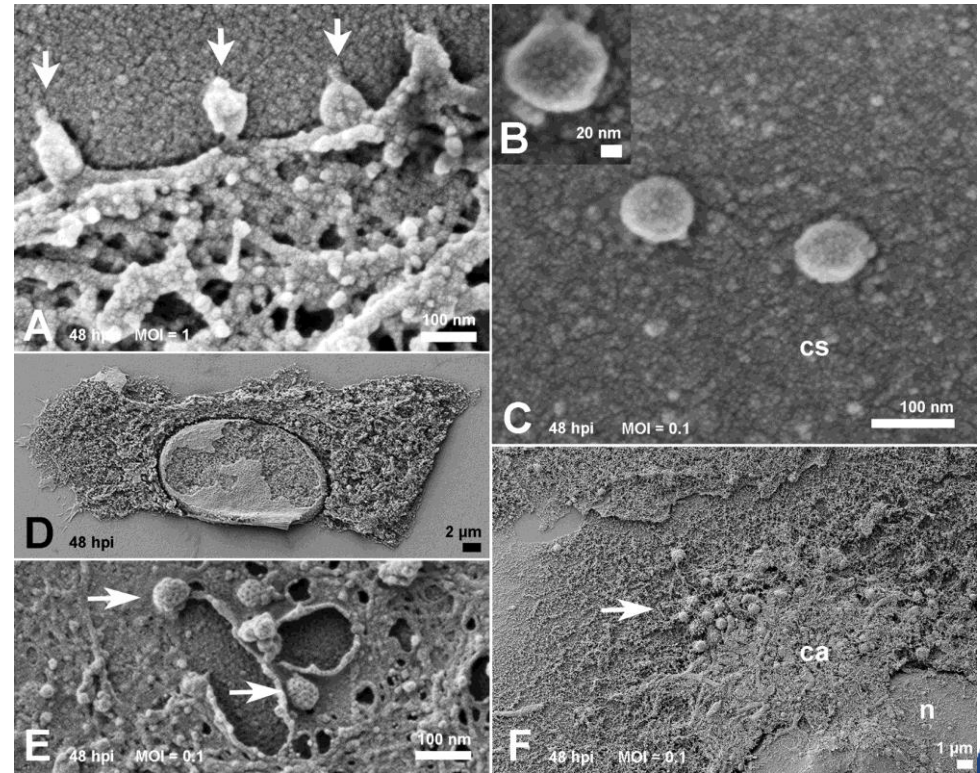
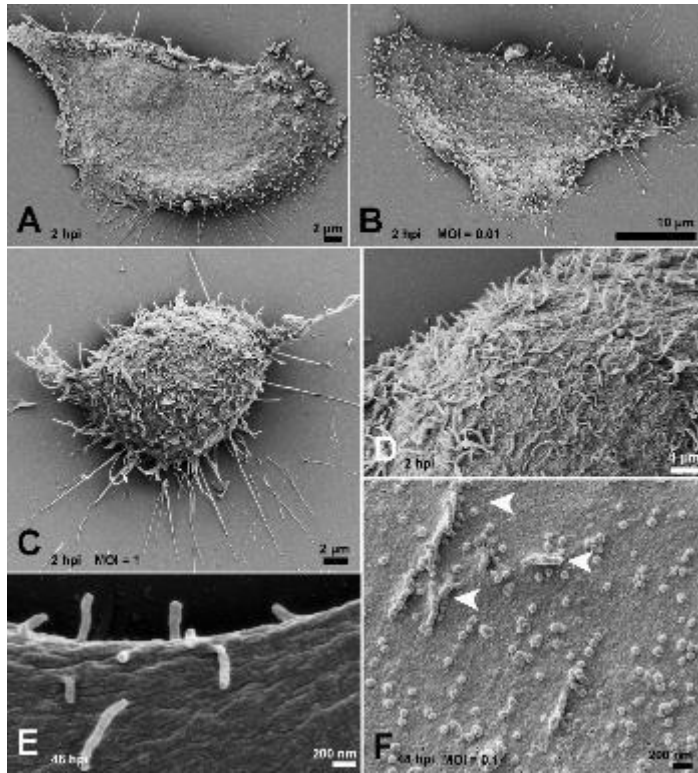
13k Accesses | **4** Citations | **54** Altmetric | [Metrics](#)

Can read more about it as supplementary material



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SARS-Cov-2

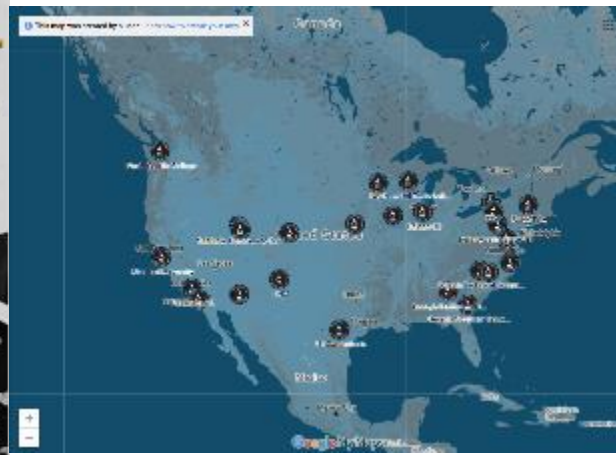


Changes in 2hrs to 48hrs

Remotely Accessible Instruments for Nanotechnology (RAIN)



*Remotely Accessible Instruments
for Nanotechnology (RAIN)*

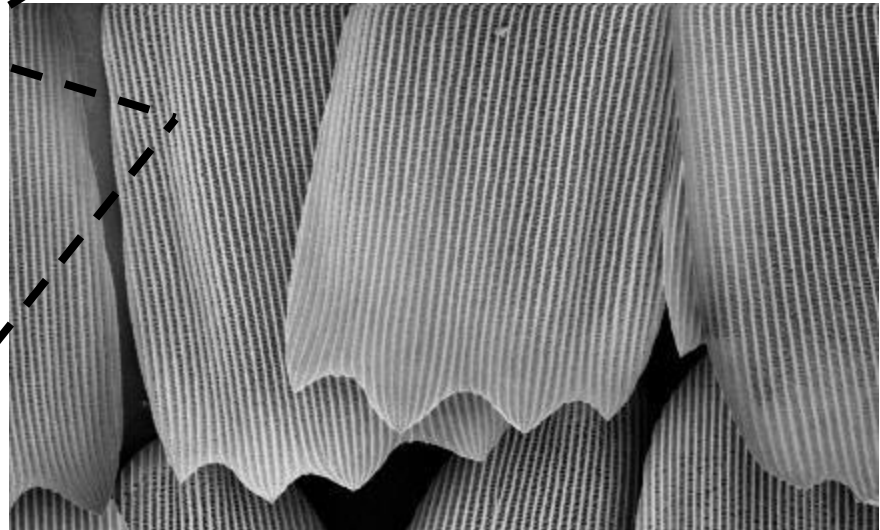
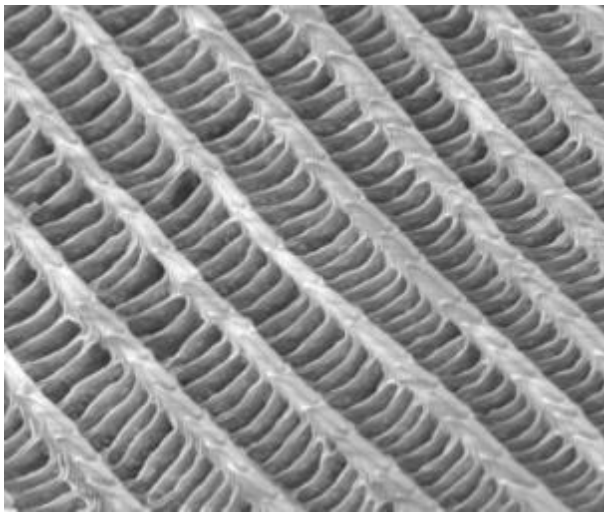
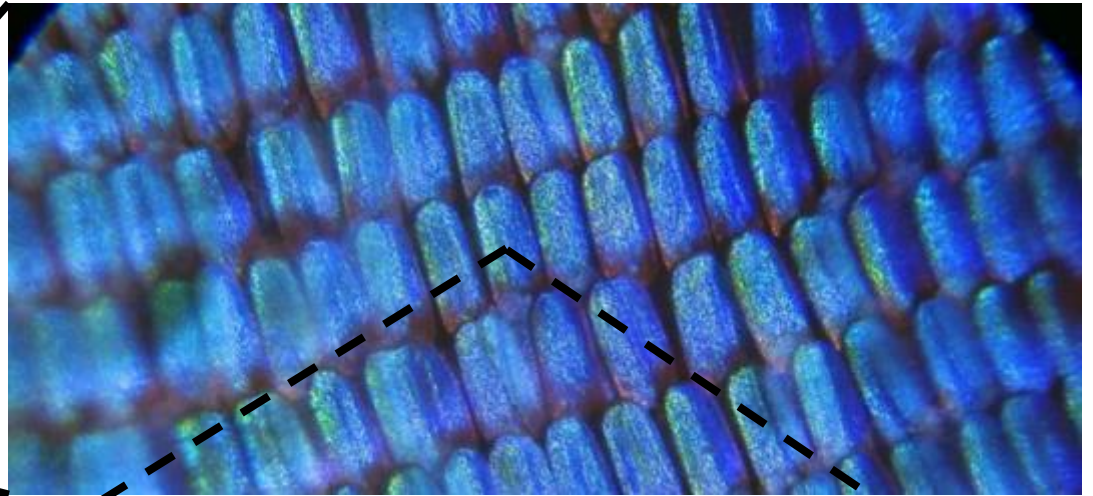
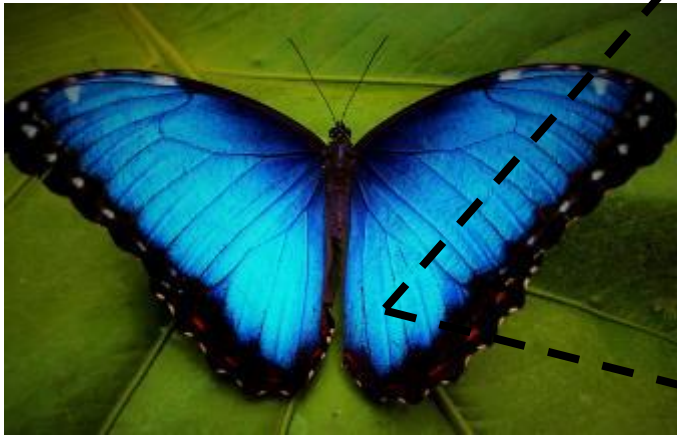


[Remote Access | Nano4me.org](http://Nano4me.org)

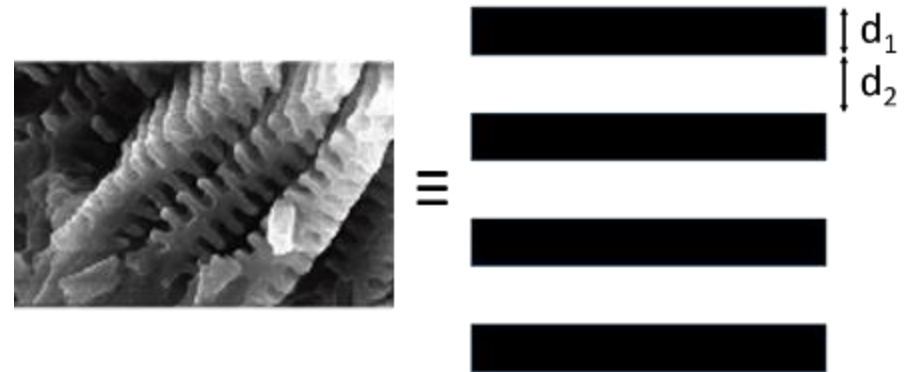
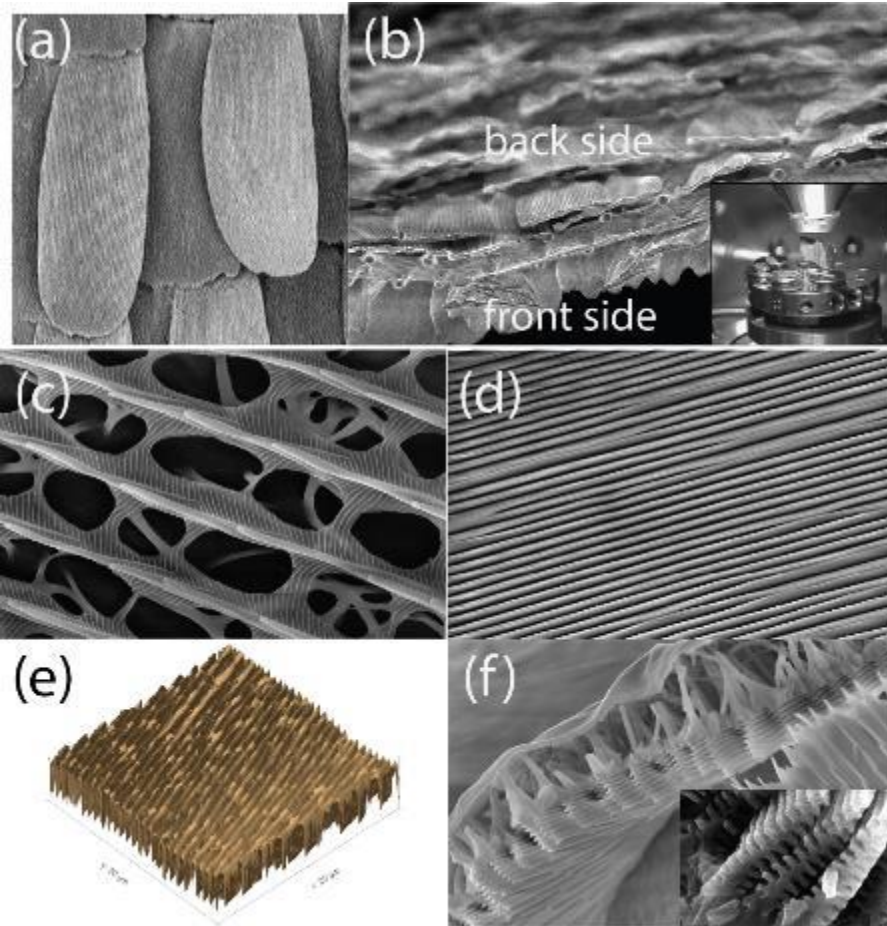


SEM Imaging Starts...

Sample-1 Blue Morpho Butterfly

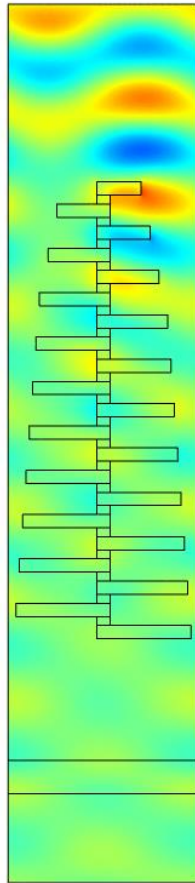


Sample-1 Blue Morpho Butterfly

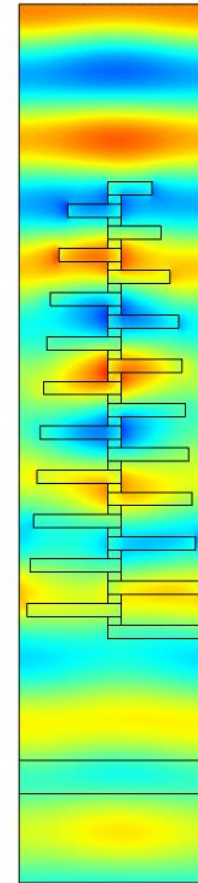


Naturally occurring Photonic Crystal

Sample-1 Blue Morpho Butterfly



Blue Light incoming



Red Light Incoming



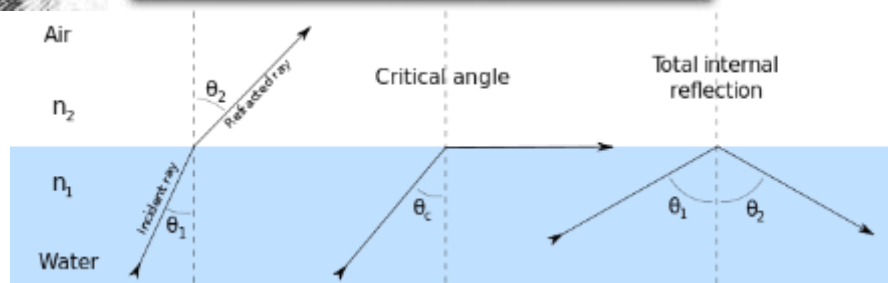
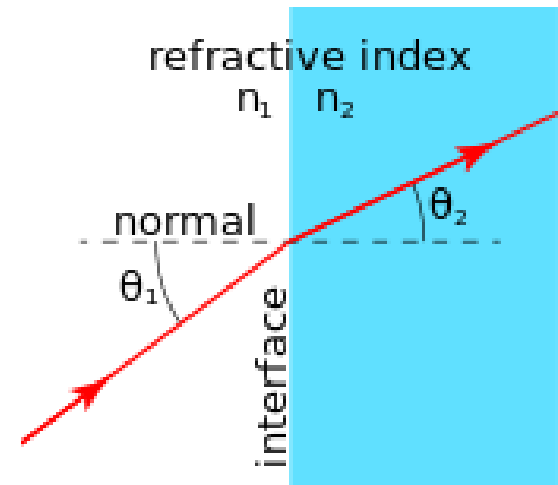
Sample-1 Blue Morpho Butterfly



Willebrord Snellius

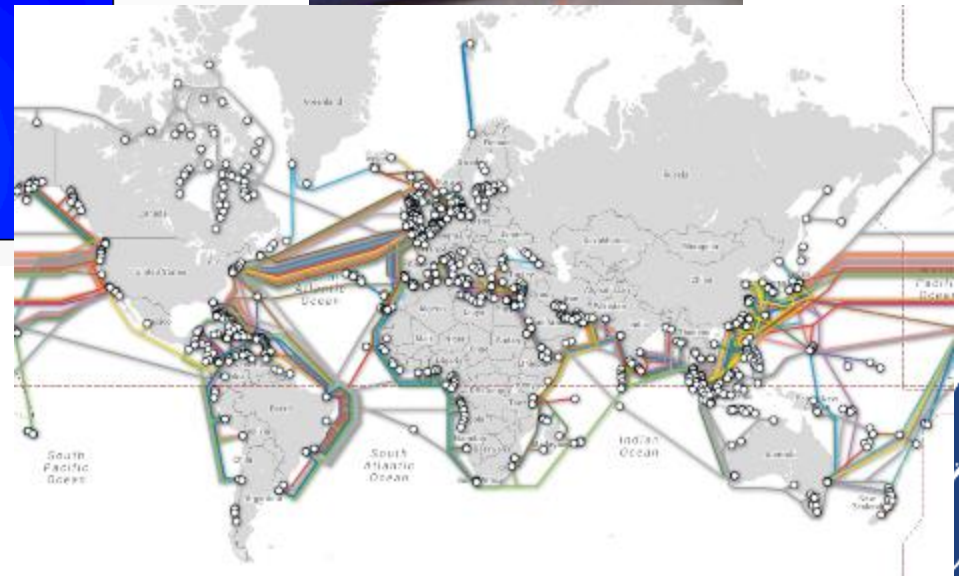
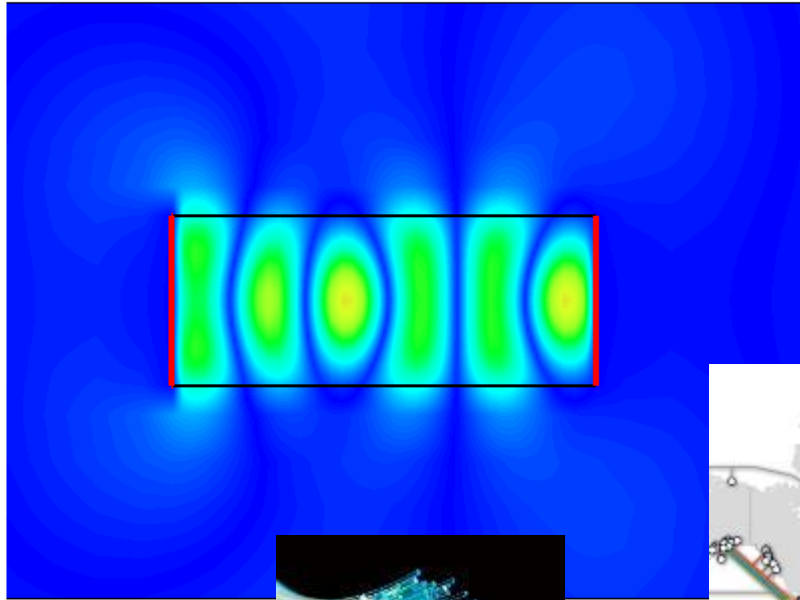


$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

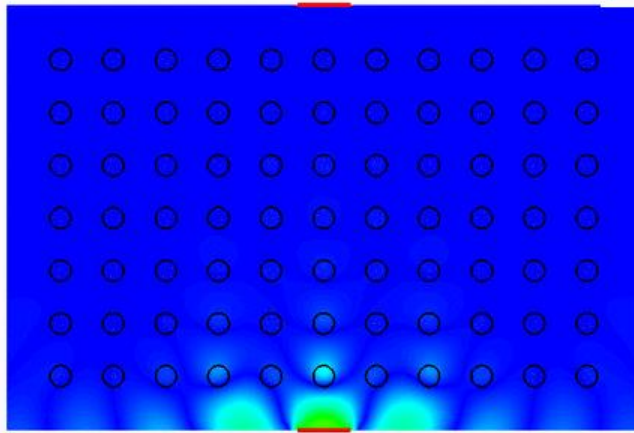


Sample-1 Blue Morpho Butterfly

Remember Snell different refractive index



Sample-1 Blue Morpho Butterfly

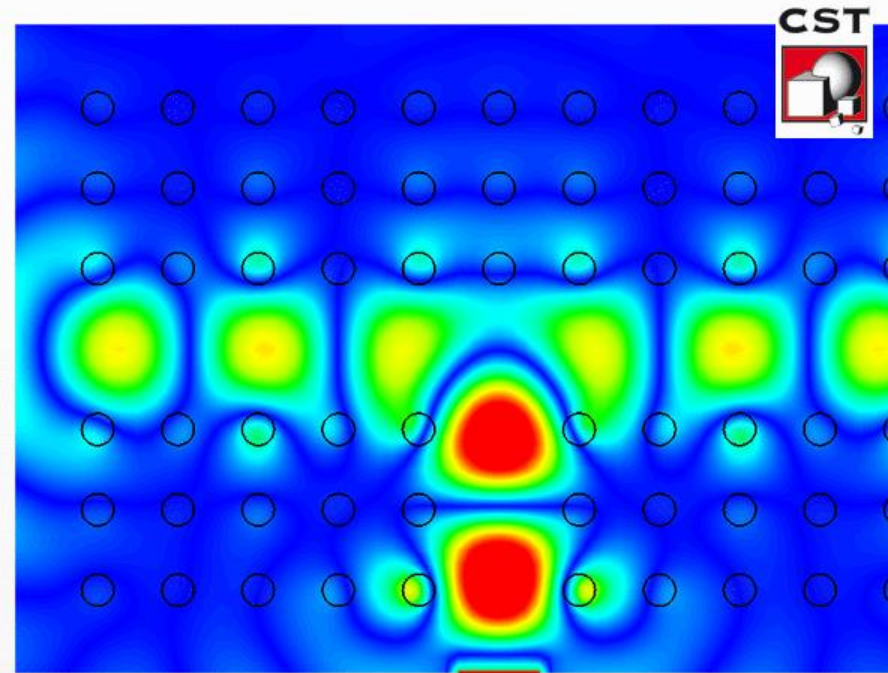
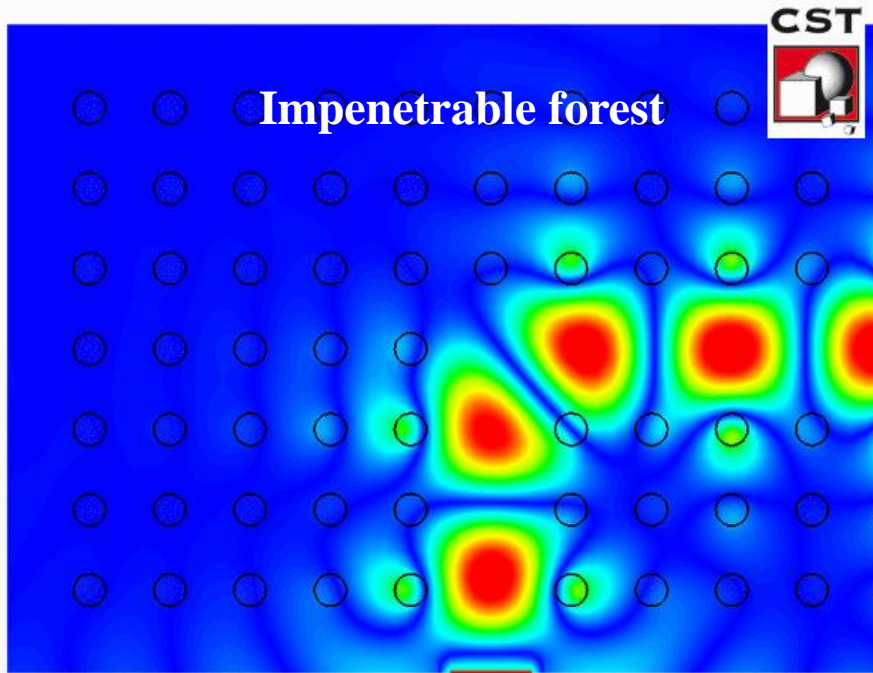


Direction
of Light

Let us say: Blue color



Sample-1 Blue Morpho Butterfly

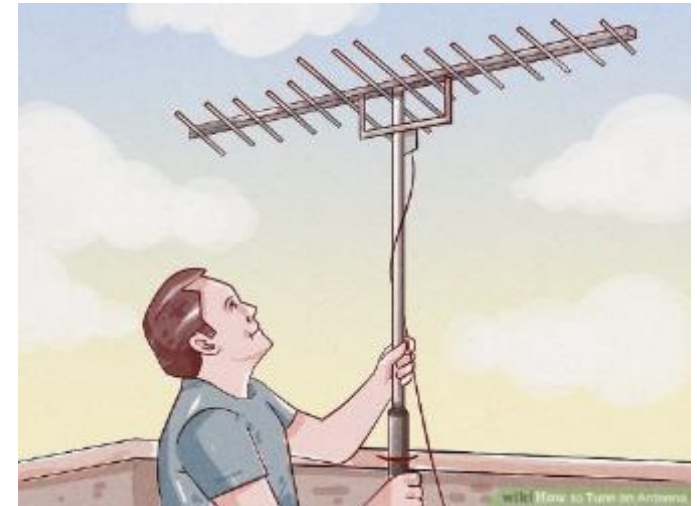
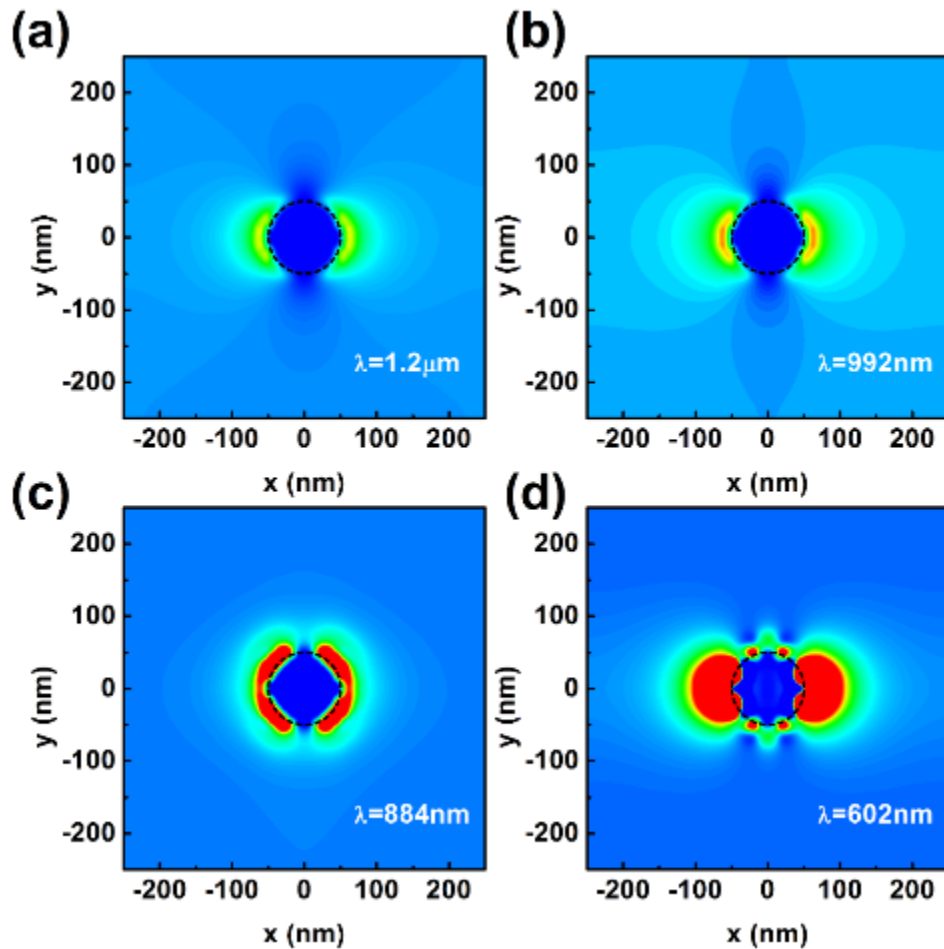


Direction of
Light



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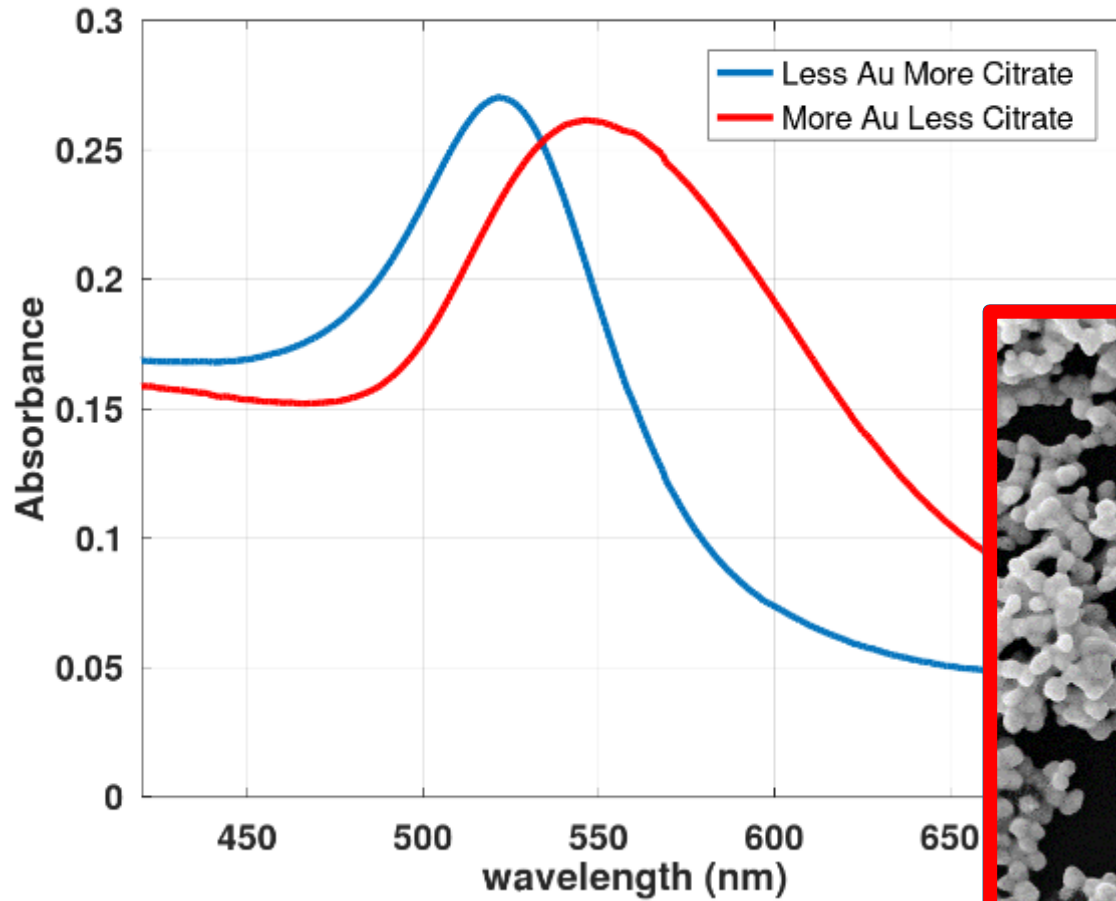
Sample-2 Gold Nanoparticles



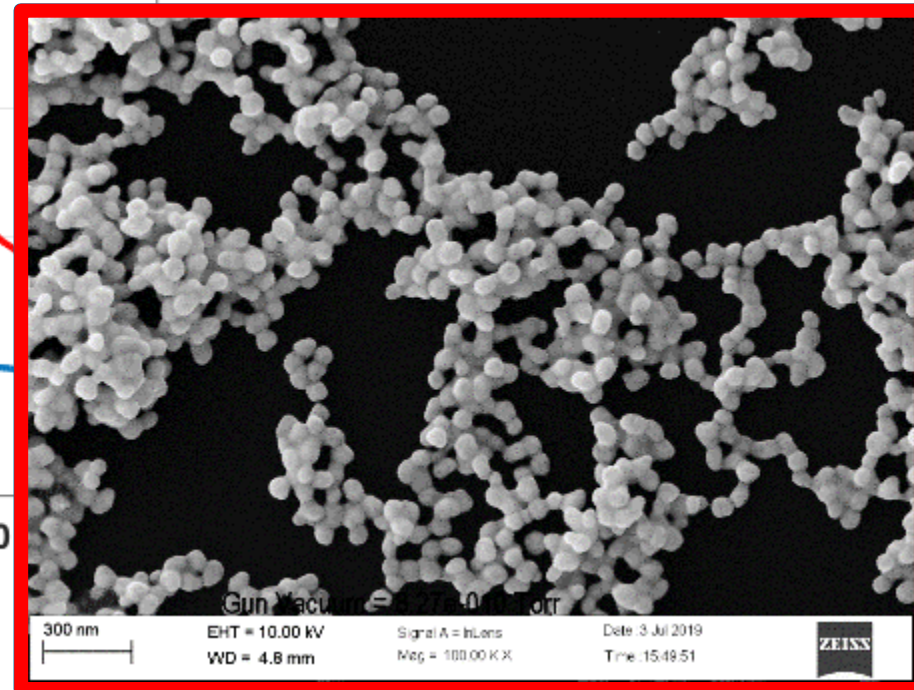
Nanoantennas!



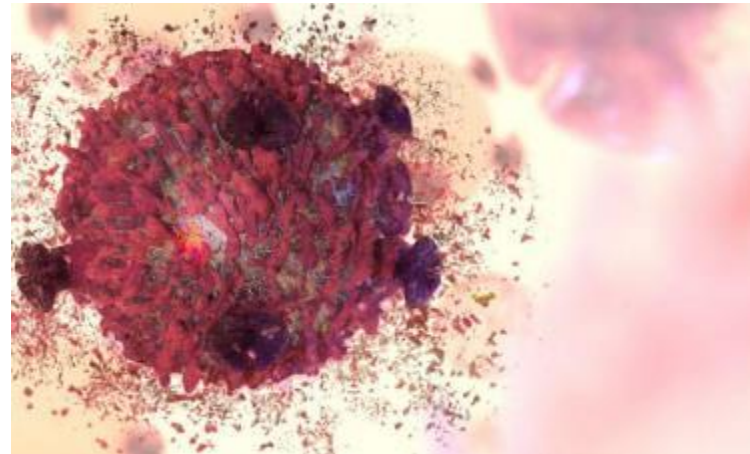
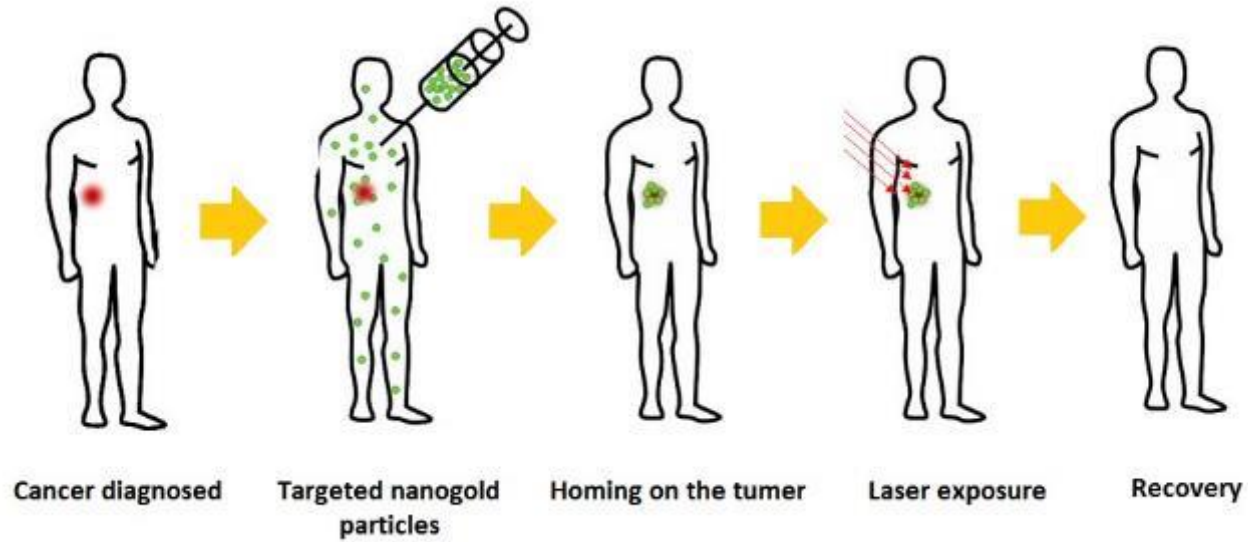
Sample-2 Gold Nanoparticles



Electron Microscope data



Sample-2 Gold Nanoparticles



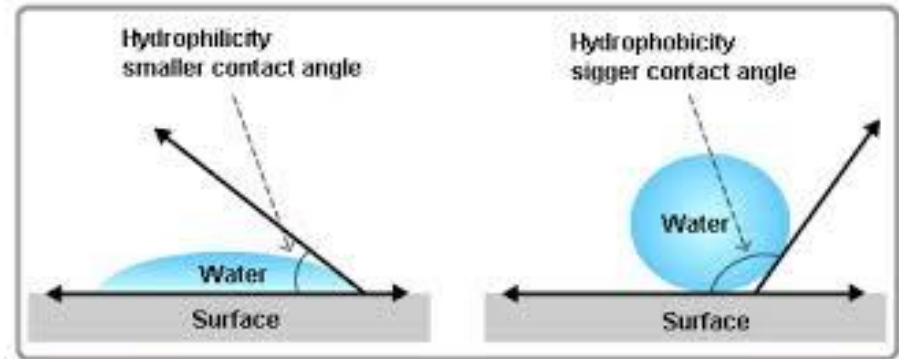
Sample-3&4 Lotus Leaf and C-Nanowires

- What do we call things that absorb water?

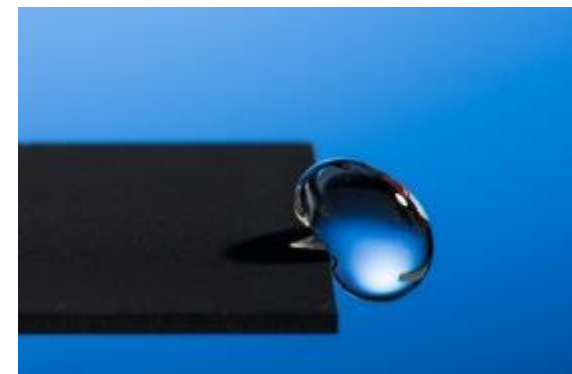
Hydrophilic

- What do we call things that repel water?

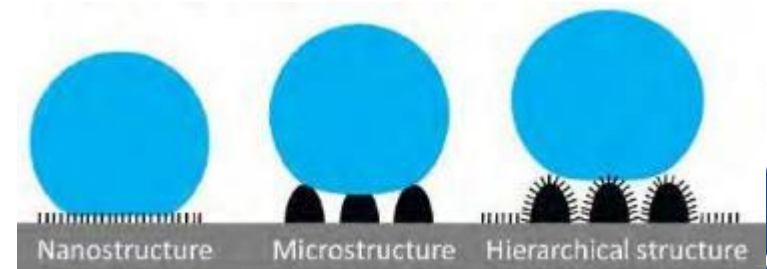
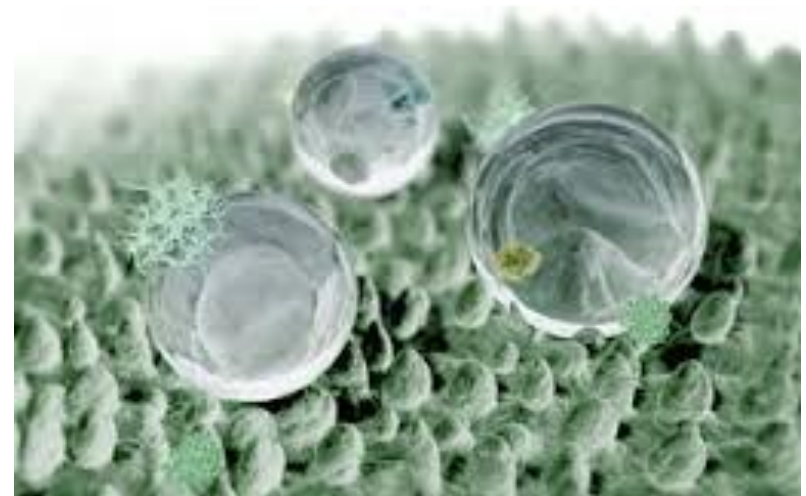
Hydrophobic



ARC-FLASH光觸媒親水性與疏水性示意圖 ©ARC-FLASH光觸媒2004



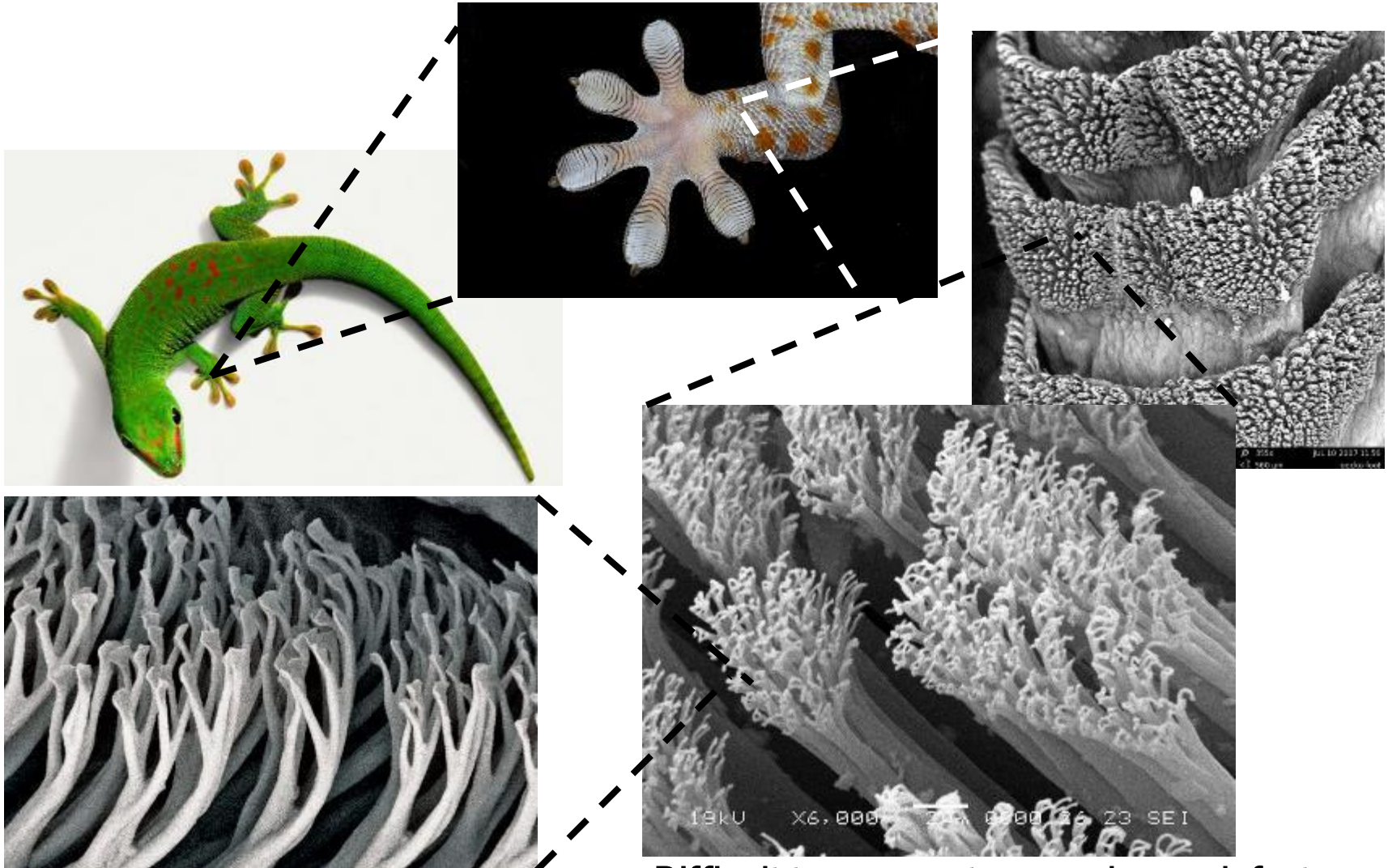
Sample-3&4 Lotus Leaf and C-Nanowires



Sample-3&4 Lotus Leaf and C-Nanowires



Sample-5 Gecko Hand



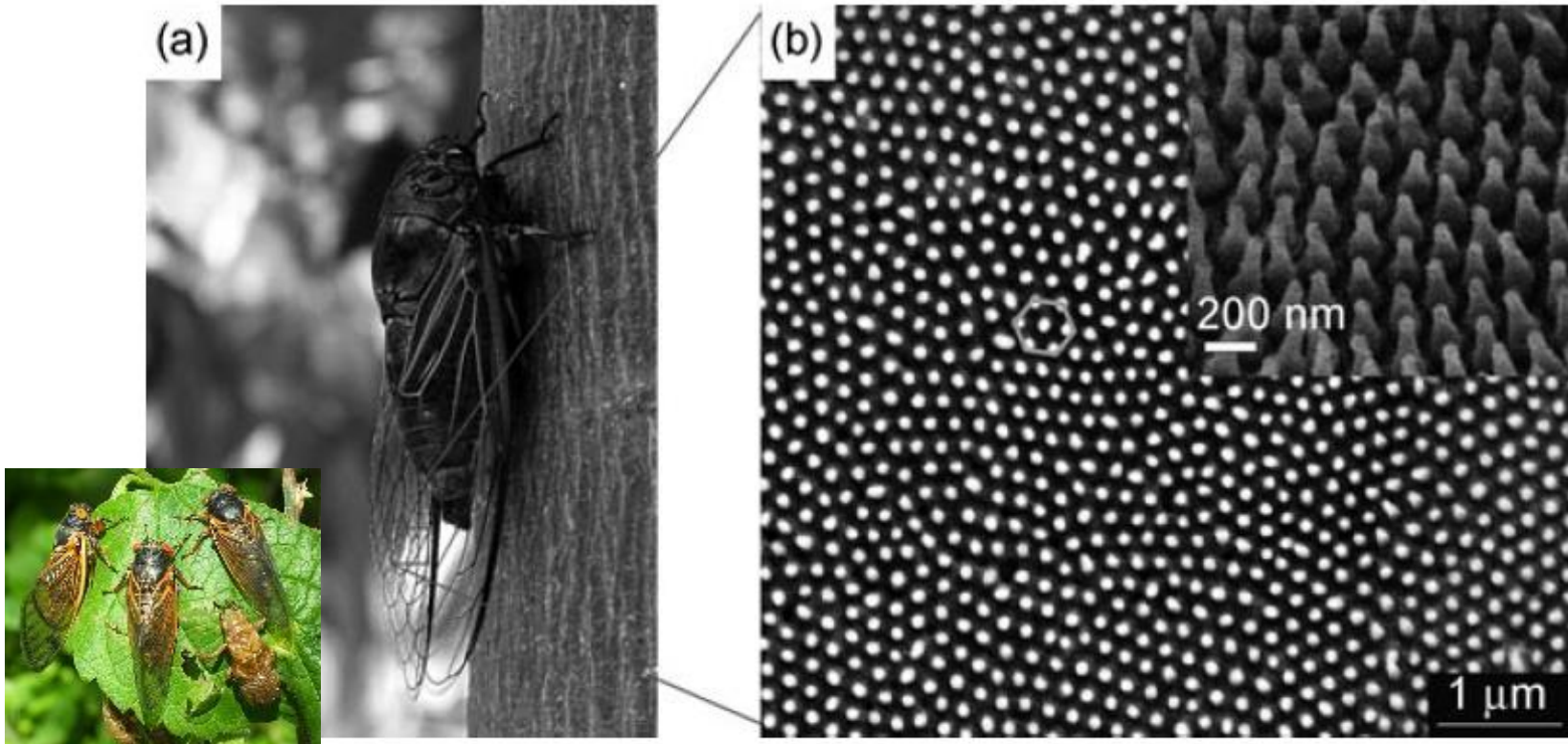
Difficult to propagate a crack or a defect

Sample-5 Gecko Hand



Sample-6 Cicada wing

Cicada Wings: a mold from Nature



The cicada wings consist of ordered hexagonal close-packed arrays of pillars with a spacing of about 190nm. The height of the pillars is about 400nm and the diameters at the pillar top and bottom are about 80nm and 150nm, respectively.

Sample-6 Cicada wing

Nano-imprinting?

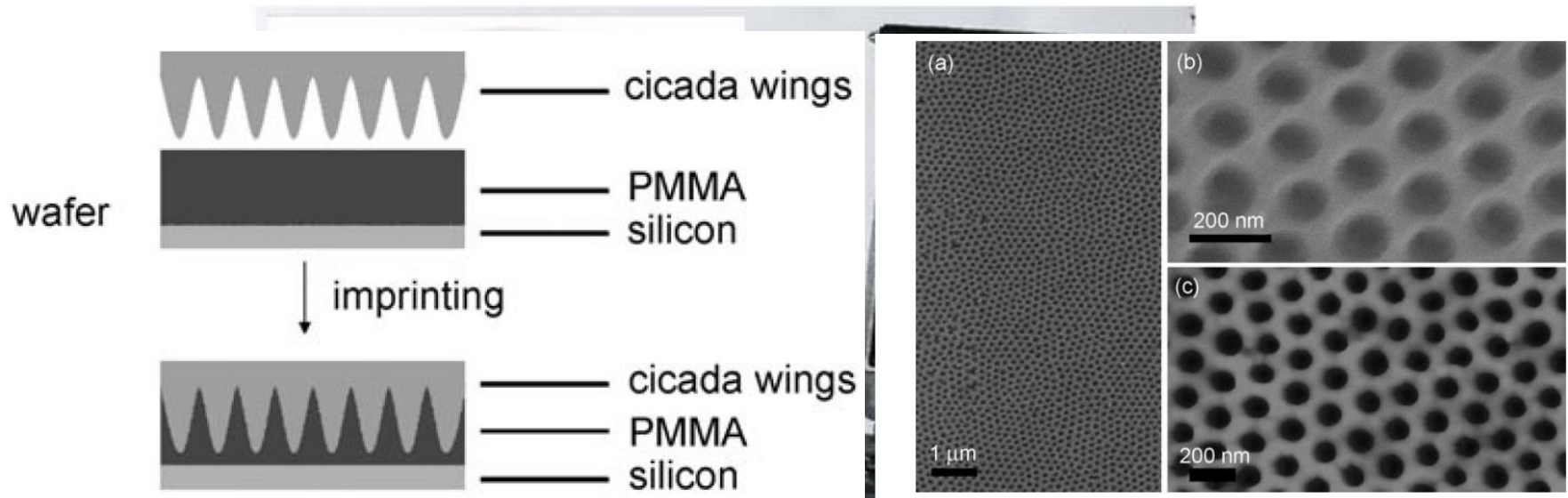


Figure 3. Results after imprinting using cicada wings as the stamp. (a) and (b) are SEM images of patterned PMMA with different scales. (c) is an AFM image of the patterned PMMA surface.





Building College-University
Partnerships for Nanotechnology
Workforce Development

Thank you, any questions?

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Please do not forget to use the office hours for any questions and discussions



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