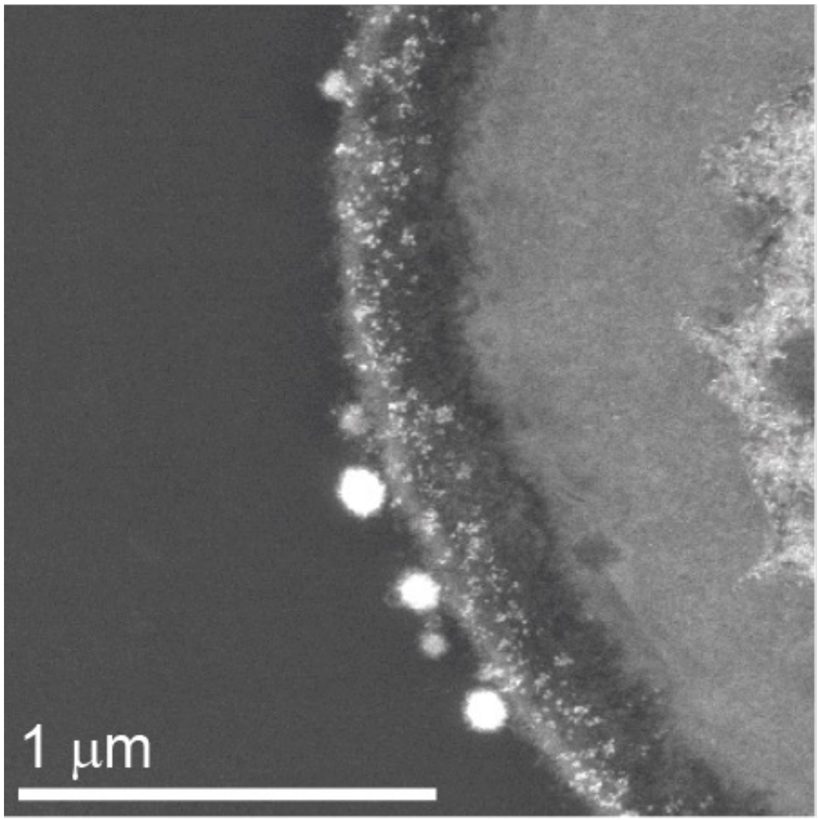
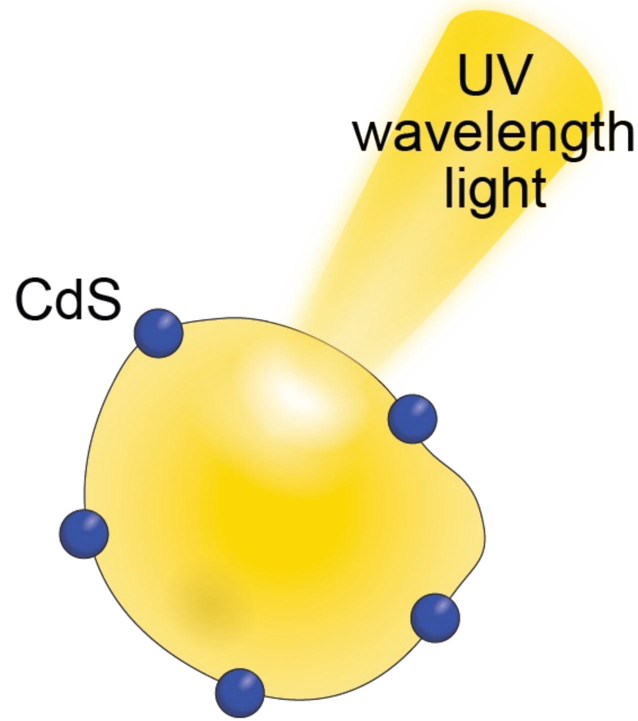
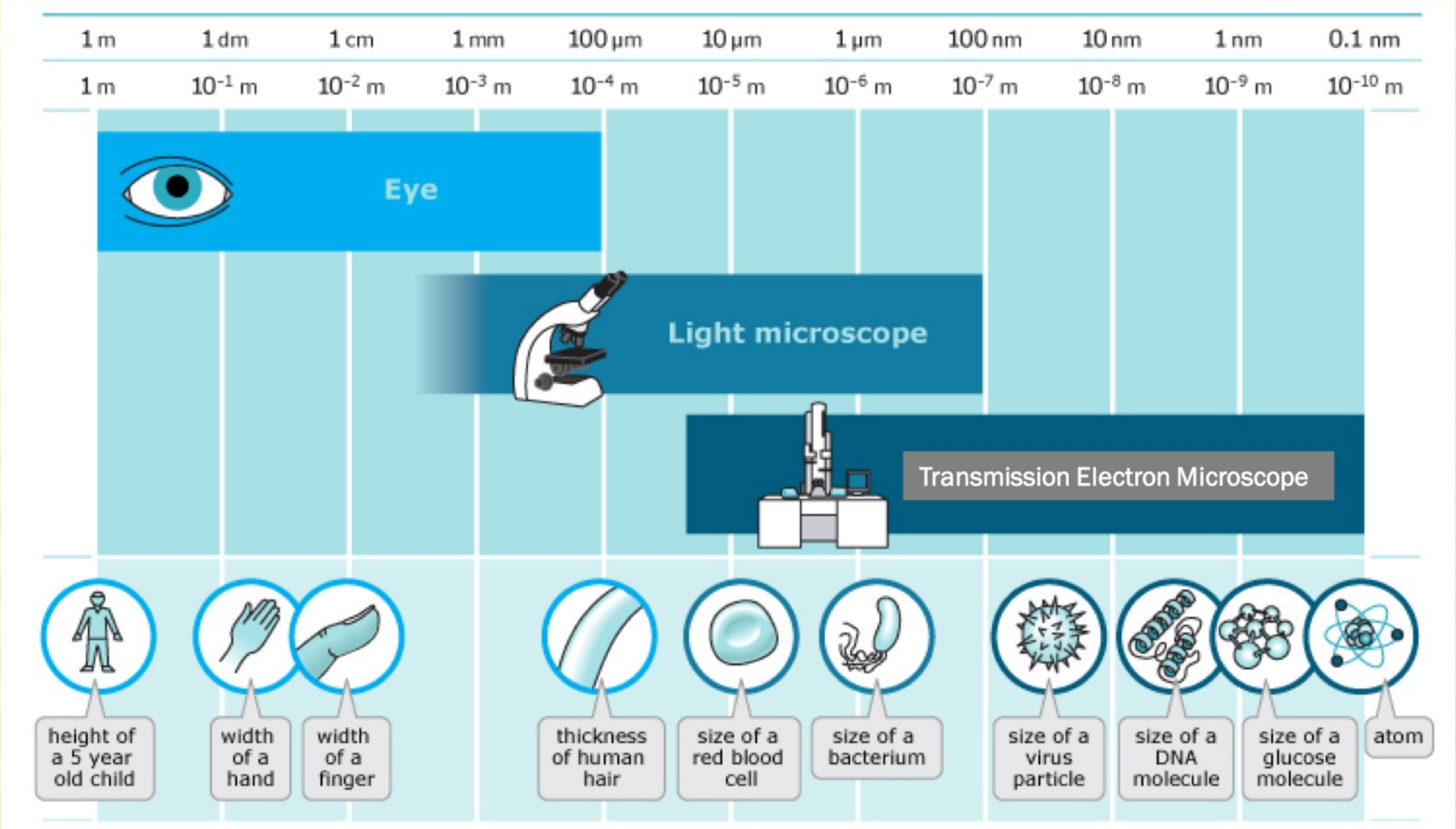
Yeast Nanoparticles Clean- up
Is seeing believing?   20.109





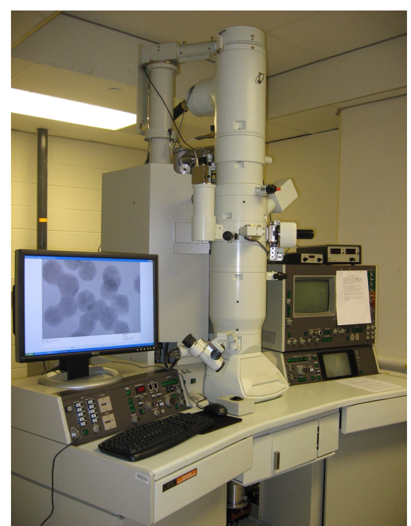
Resolving Power of Microscopes

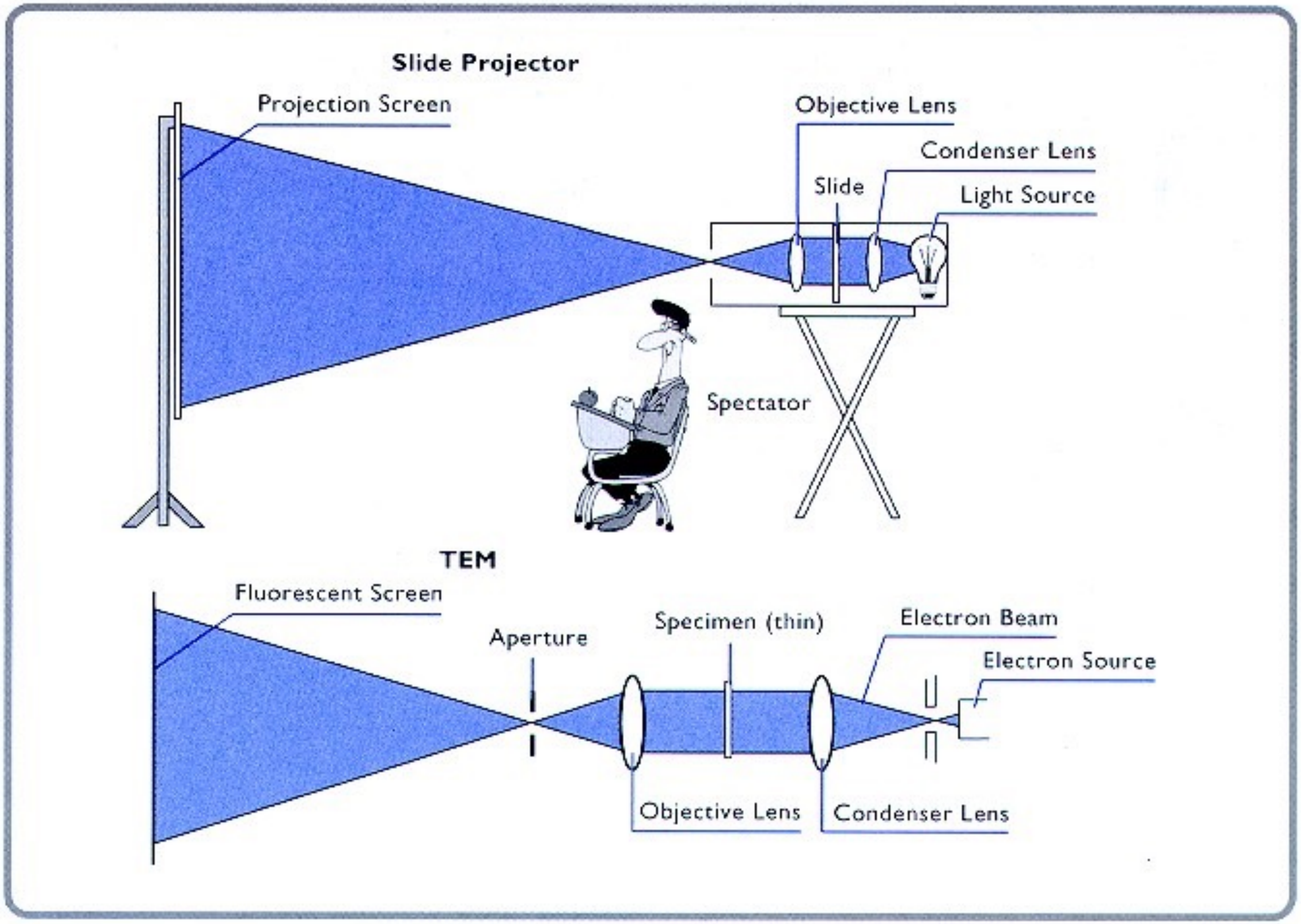


What' s TEM

- An electron-optical microscope that uses electromagnetic lenses to focus and direct an electron beam.
- Bright field imaging is from electrons interacting with electron dense materials to cast a shadow on a screen or camera.
- High voltages between 10KV and 1MV. The higher the voltage is, the shorter the wavelength of electrons, giving the better resolution. **200KV.** ultimate point-to-point resolution of 0.19 nm



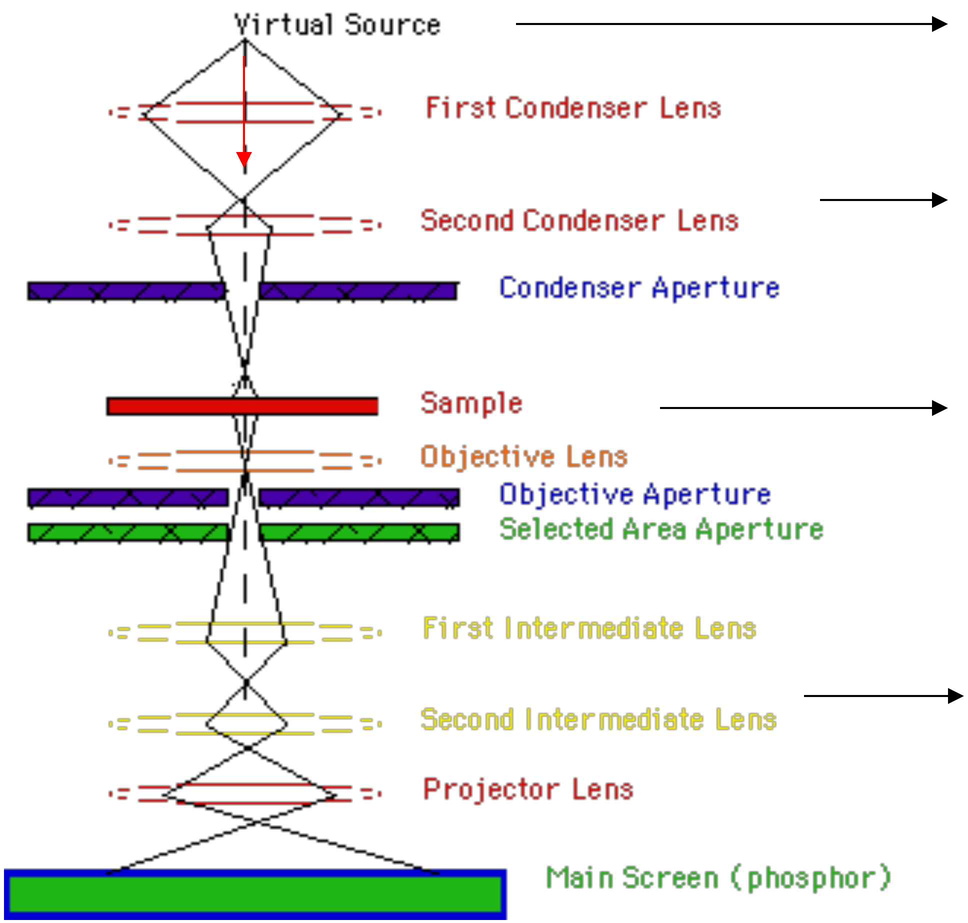


http://labs.mete.metu.edu.tr/tem/TEMtext/TEMtext.html

What' s TEM

Electron beam path



Source is a beam of high velocity electrons

Lanthanum hexaboride cathode or tungsten

Electron beam focused by condenser lens onto specimen

If a sample is thin enough, electron beam can pass through it

Transmission/scattering beam is focused by objective lens/intermediate/projection lens. Final image/electron diffraction pattern forms on a screen for viewing

Yong Zhang (CMSE TEM facility)

Why We Need TEM

The main use of the TEM is to examine the microstructure structure, composition, and properties of specimens in ways that cannot be examined using other equipment or techniques.

Morphology (Bright Field Image, Dark Field , HRTEM)

- The size, shape, morphology, and distribution of the particles as well as their relationship to each other on the scale of atomic diameters.

- Contrast comes from electrons interacting with electron dense atoms in the sample, the scattered electrons cause a shadow to be cast on the camera or screen.

- Crystalline samples scatter more electrons than noncrystalline samples, so amorphous samples have less contrast than crystalline samples

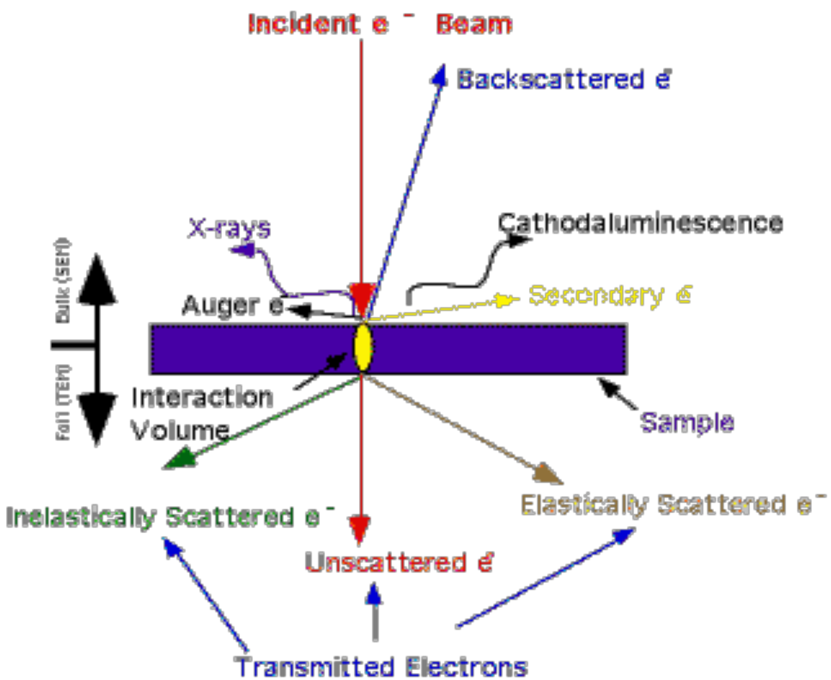
Why We Need TEM

- **Crystallographic Information (Electron Diffraction, HRTEM)**
  - For crystalline samples, crystal structure, degree of ordering, and detection of atomic-scale defects in areas a few nanometers in diameter can be determined

- **Compositional Information (Energy dispersive spectroscopy (EDX), Electron energy loss spectroscopy (EELS)**The elements and compounds the sample is composed of and their relative ratios, in areas a few nanometers in diameter

What's TEM

Different equipment in TEM is then used to collect scattered electrons produced by the specimen-electron interaction, giving different types of information

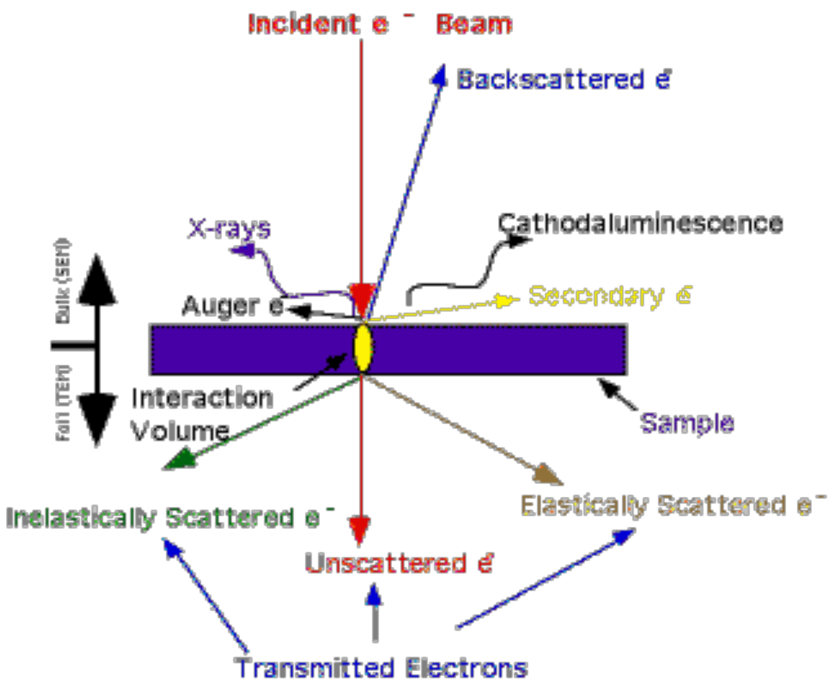


} Compositional Information

} Morphology & Crystallographic Information

Yong Zhang (CMSE TEM facility)

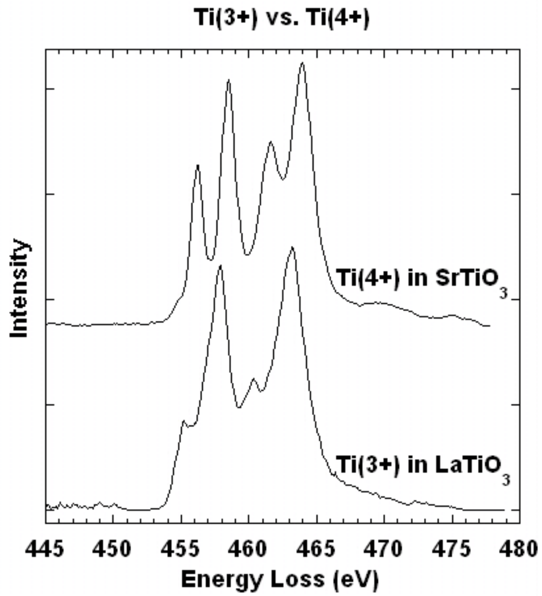
Elemental mapping and information



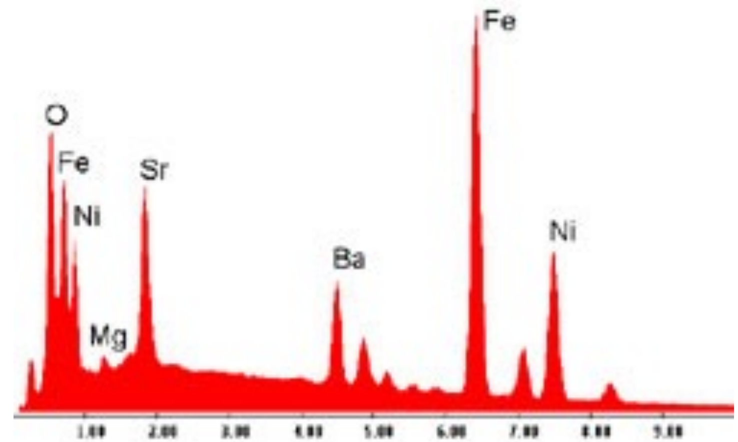
- Elemental mapping can be done by two methods, STEM and EELS
- STEM involves rastering an electron beam through a sample and determining the elemental composition of each spot by either X-ray analysis or EELS (element specific)

Elemental Analysis

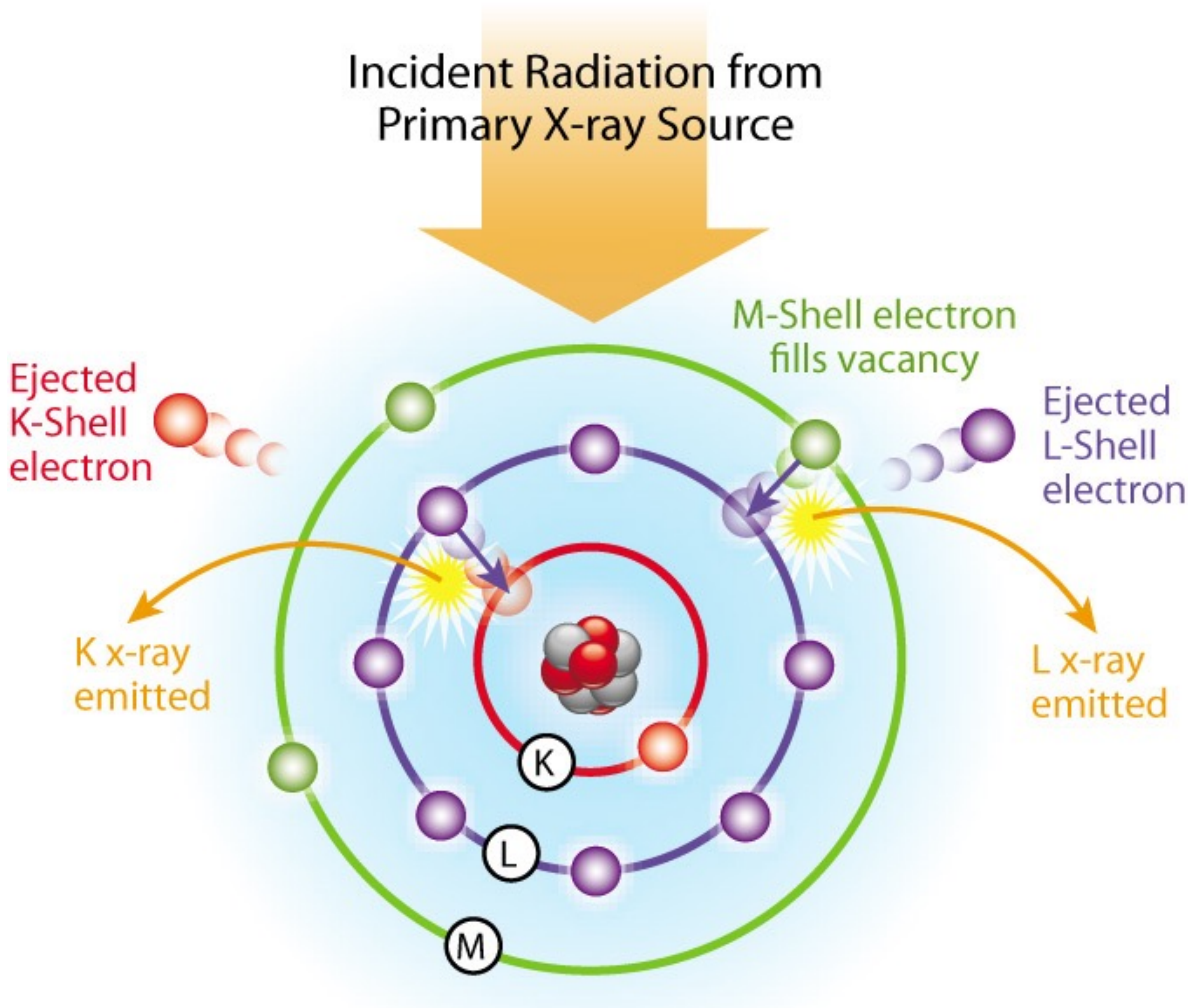
- The e^- beam has the energy to remove core electrons
- This causes for a measurable loss of energy in the electron beam (EELS)
- And also for the emission of X-rays (EDX)
- Both techniques are element specific and can be combined to show images that isolate where each element is present in the sample



EELS of Titanium particles shows a difference between Ti^{3+} and Ti^{4+}



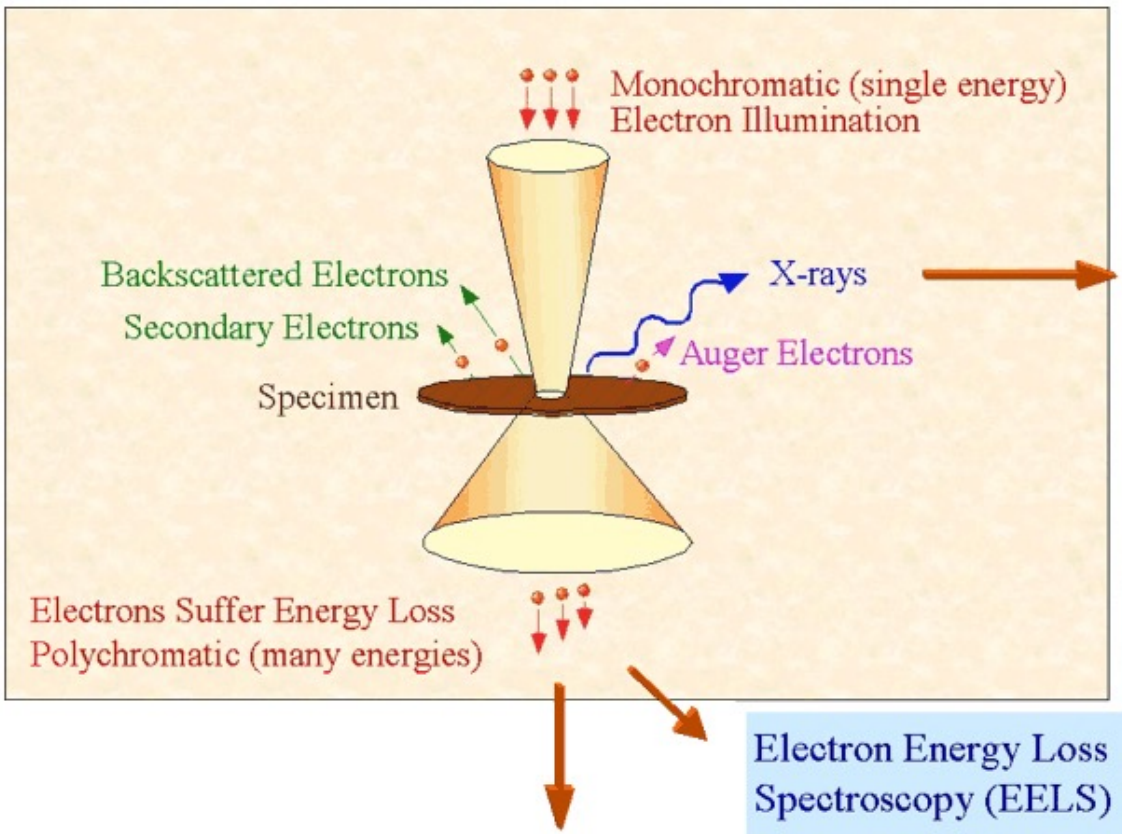
EDX of $BaSrO_x$ shows all the elements present in the sample


Incident Radiation from
Primary X-ray Source
M-Shell electron
fills vacancy
Ejected
K-Shell
electron
Ejected
L-Shell
electron
K x-ray
emitted
L x-ray
emitted
K
L
M

Energy Dispersive X-ray Spectroscopy (EDXS)

Different elements emit different characteristic X-rays when excited by an electron beam.

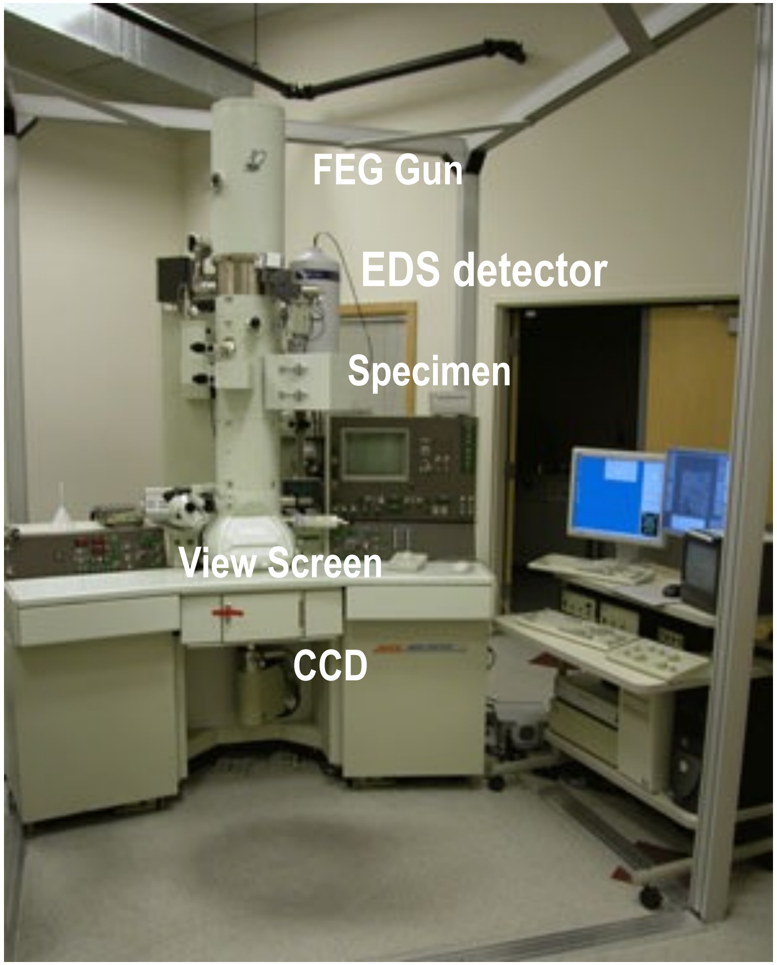
These X-rays can be used to identify the elements present, quantify their relative or absolute concentration, and map their distribution.



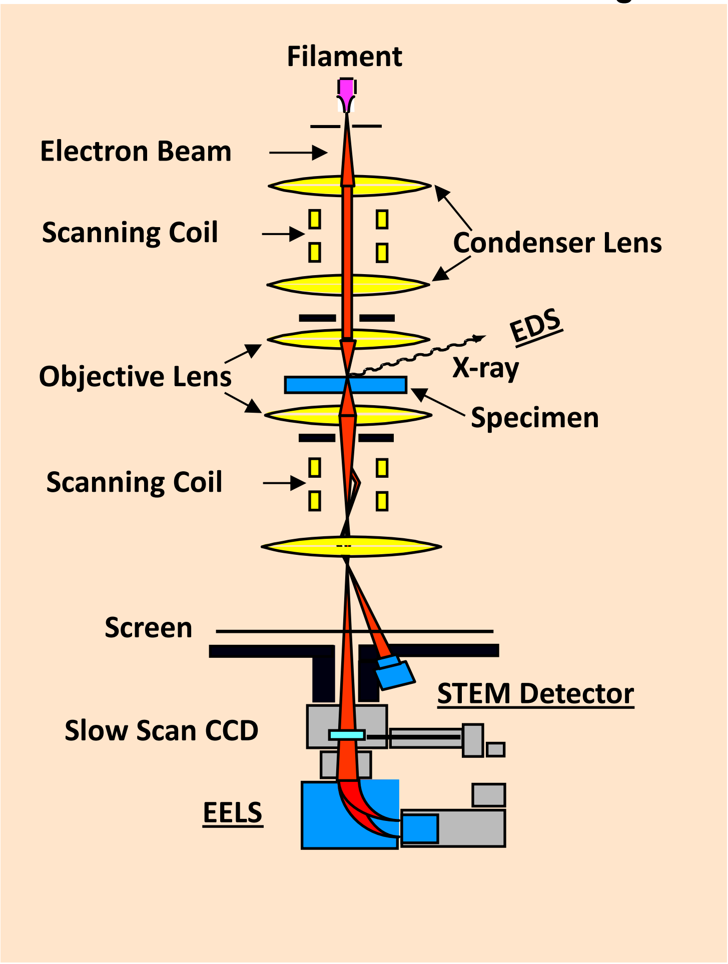
Different elements cause incident electrons to lose different amounts of energy. EELS can be used to identify the elements present, quantify their relative or absolute concentration.

JEOL 2010 Field Emission Gun(FEG) TEM

2010FEG TEM Photo



2010FEG TEM Schematic Diagram



2010FEG TEM Characteristics

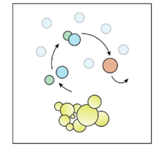
1. Point Resolution : less than 0.2nm

2. Brightness : 2-order higher brightness than with the LaB6 electron gun,(JEOL 2010 TEM)
3-order higher with tungsten thermionic gun(JEOL 200CX TEM)

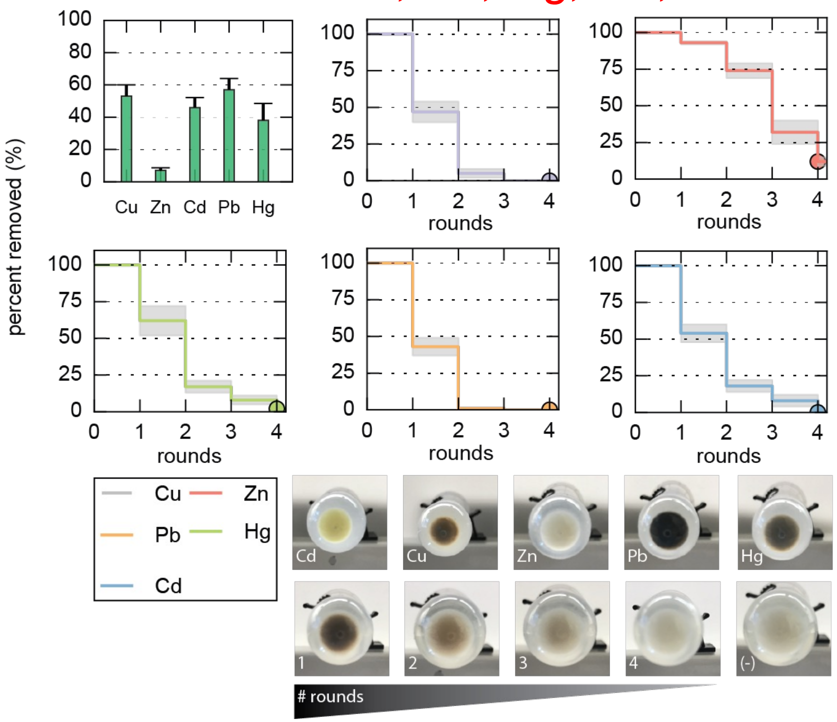
3. Nanoanalysis : Atomic arrangement, Grain Size, Crystal Orientation, Defects,
Chemical analysis - elements, composition

Alberta Canada Oil Sands

Bio-precipitation of heavy metals

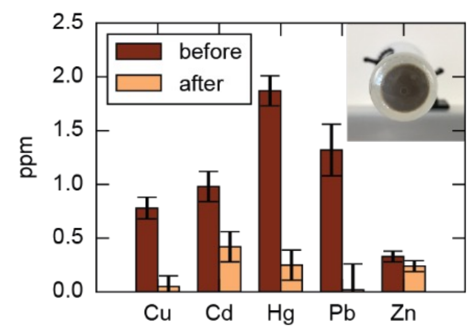


Metabolic engineering for heavy metal precipitation, *we can clean to EPA standards for Cu, Pb, Hg, Cd, Zn*

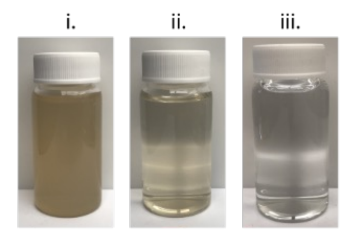


Nat Sustain **3,** 303–311 (2020)

Real world example:
Canadian Athabasca Oil Sands

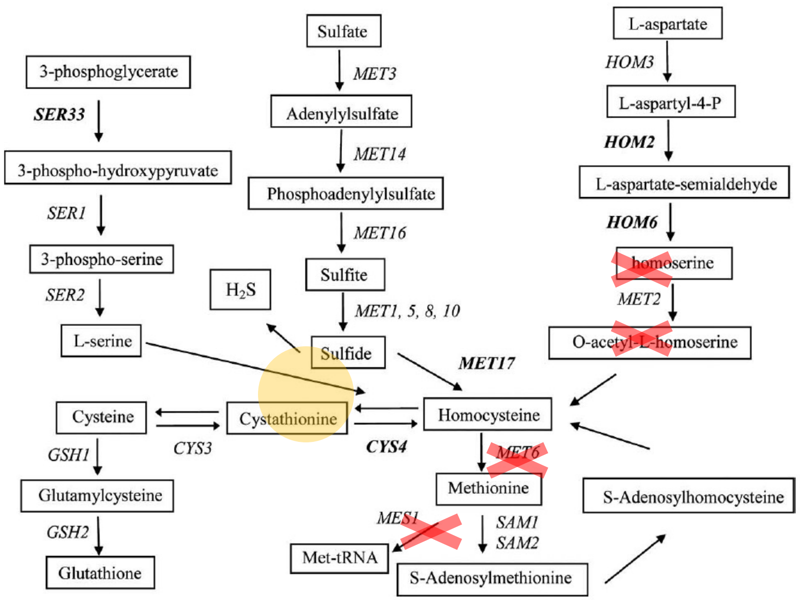


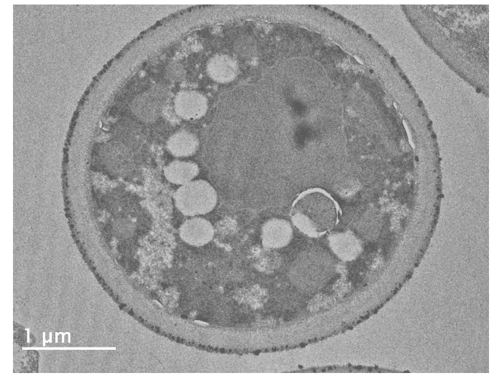
Before---middle--after

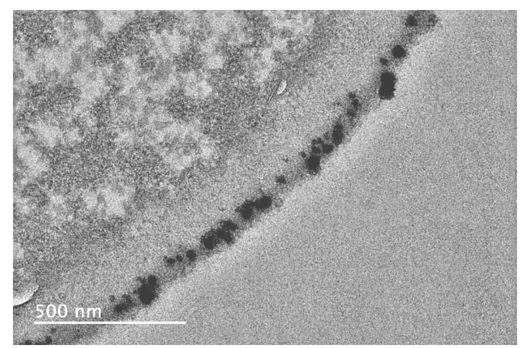


Engineering H_2S Production Mechanism

Engineering H_2S strains

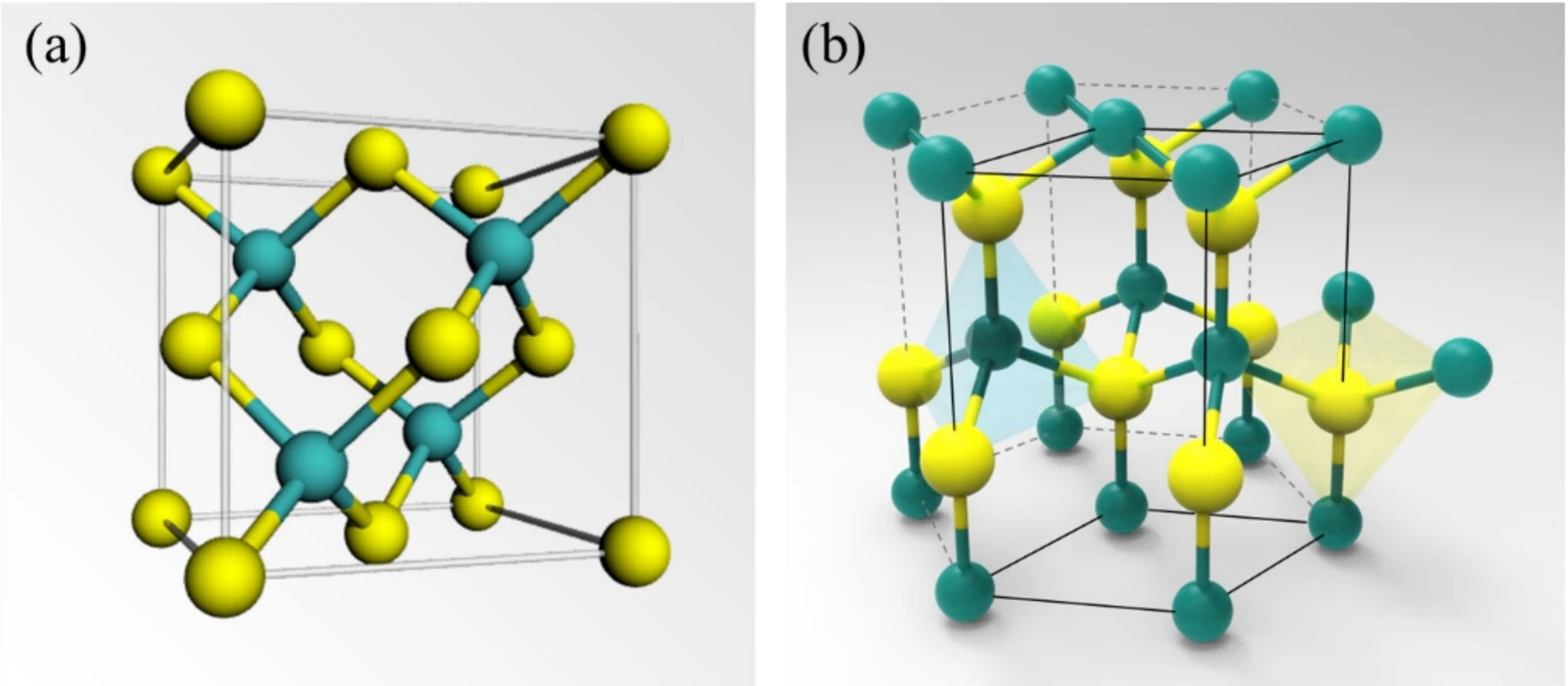






Shalmalee Pandit

Crystal lattices

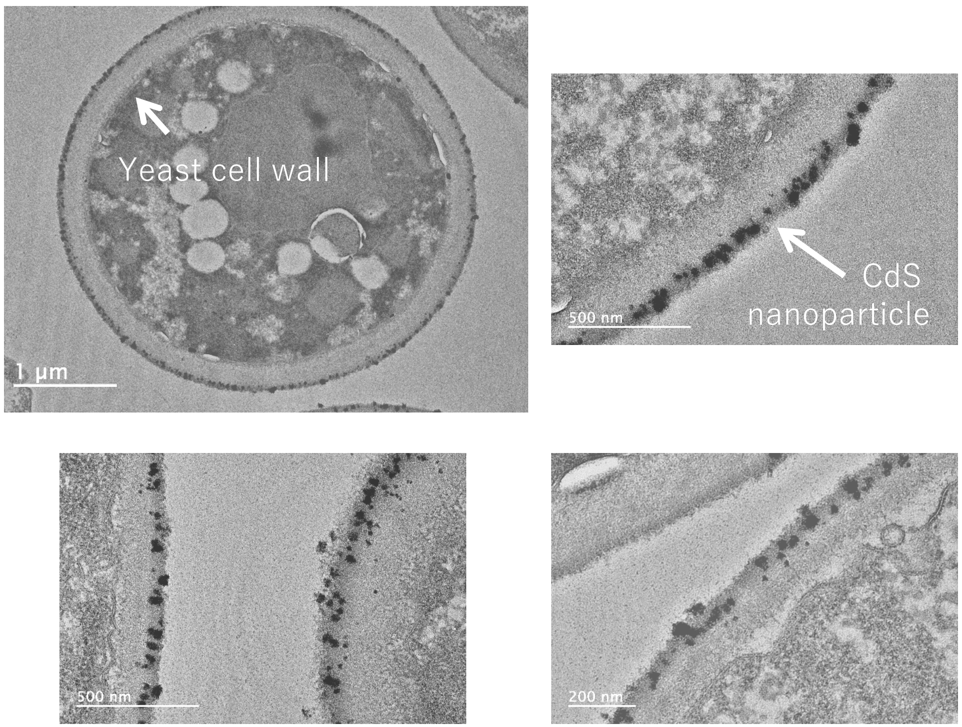


(**a**) cubic zinc blende and (**b**) hexagonal wurtzite structures

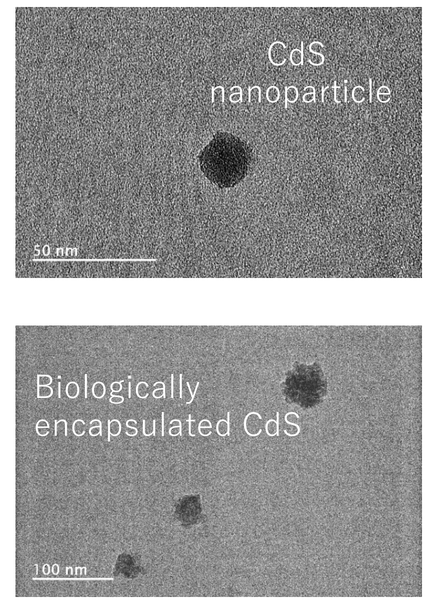
J. Korean Ceram. Soc. **58**, 631–644 (2021)

Taking a closer look: quantum dot synthesized

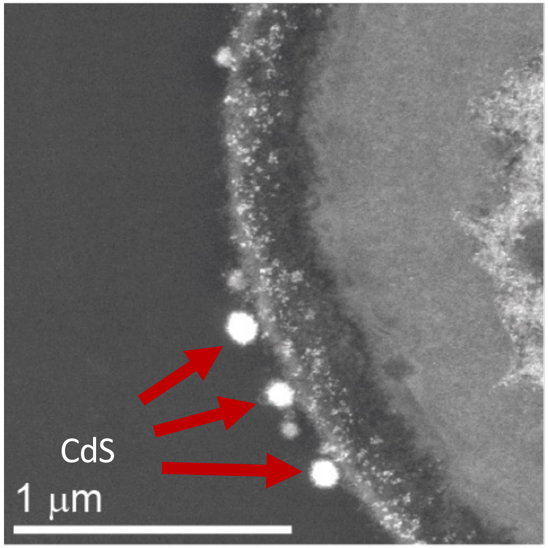
CdS precipitation



Purified CdS
from yeast



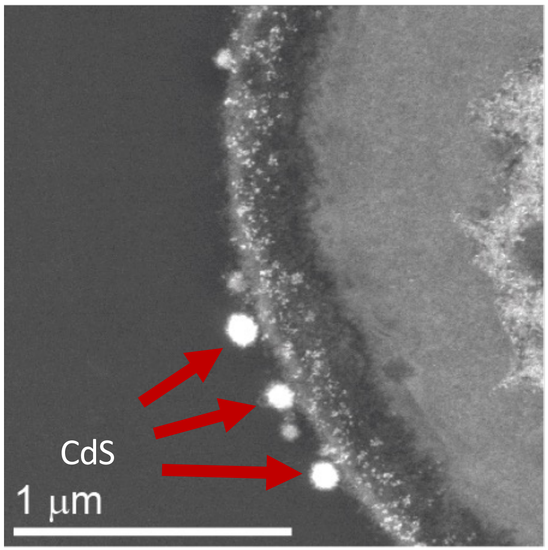
Localization of nanoparticles in yeast cell wall



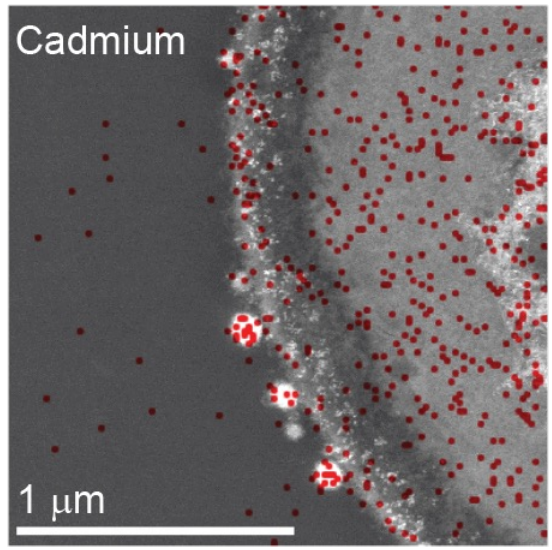
TEM image of ΔMet17 displaying CdS nanoparticles on the cell surface

Transmission electron microscopy: like an atomic scale x-ray: electrons pass through the sample to form an image

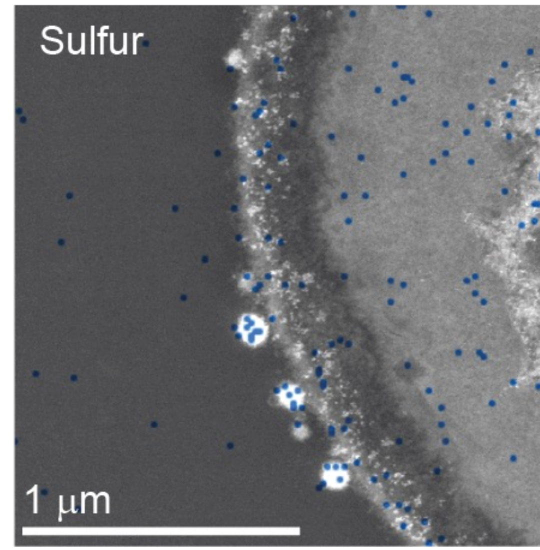
Localization of nanoparticles in yeast cell wall



TEM image of ΔMet17 displaying CdS nanoparticles on the cell surface



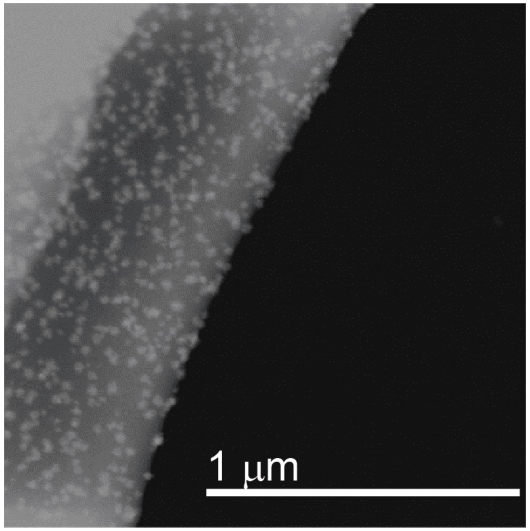
Elemental analysis of cadmium.



Elemental analysis of sulfur.

Transmission electron microscopy: like an atomic scale x-ray: electrons pass through the sample to form an image

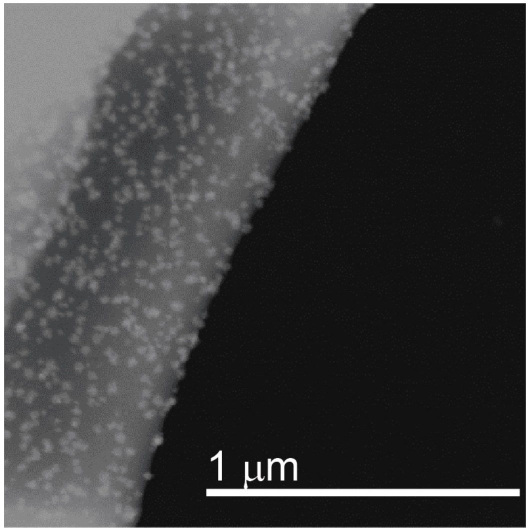
Localization of nanoparticles in yeast cell wall



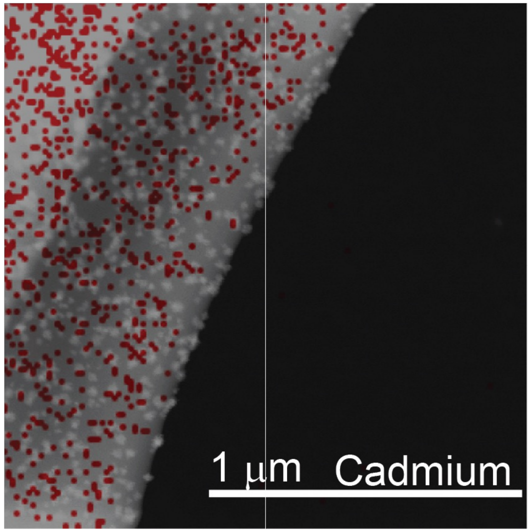
TEM image of unsliced ΔMet17 displaying CdS nanoparticles on the cell surface

Transmission electron microscopy: like an atomic scale x-ray: electrons pass through the sample to form an image

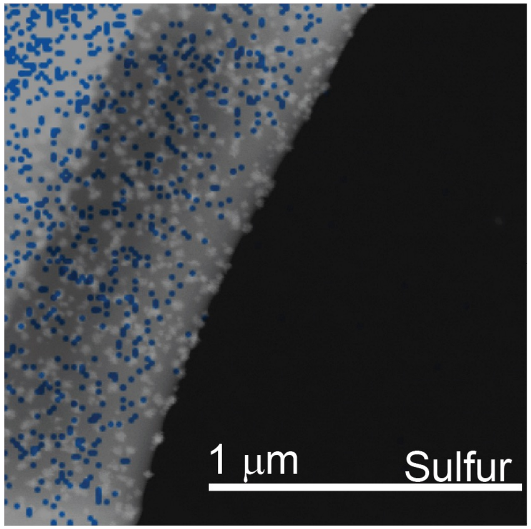
Localization of nanoparticles in yeast cell wall



TEM image of unsliced ΔMet17 displaying CdS nanoparticles on the cell surface



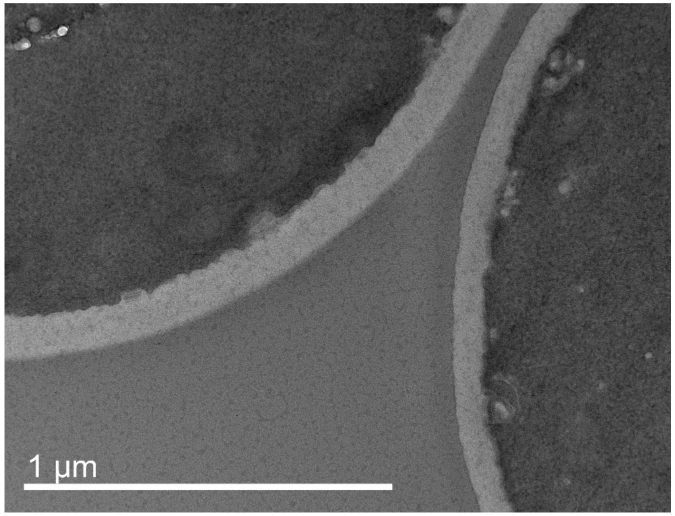
Elemental analysis of cadmium.



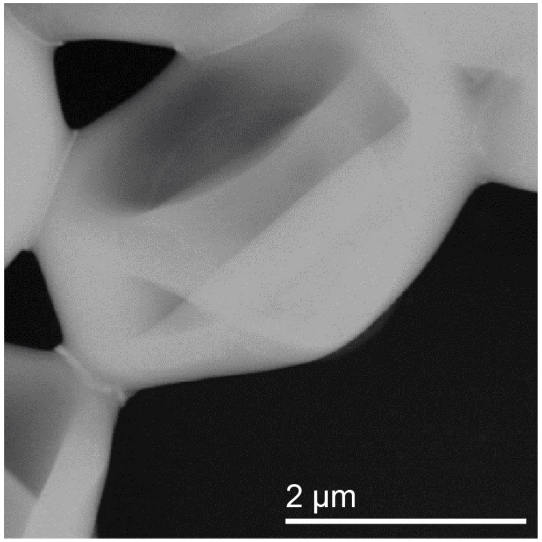
Elemental analysis of sulfur.

Transmission electron microscopy: like an atomic scale x-ray: electrons pass through the sample to form an image

Images of wild-type yeast treated with Cd^{2+} display no formation of CdS nanoparticles

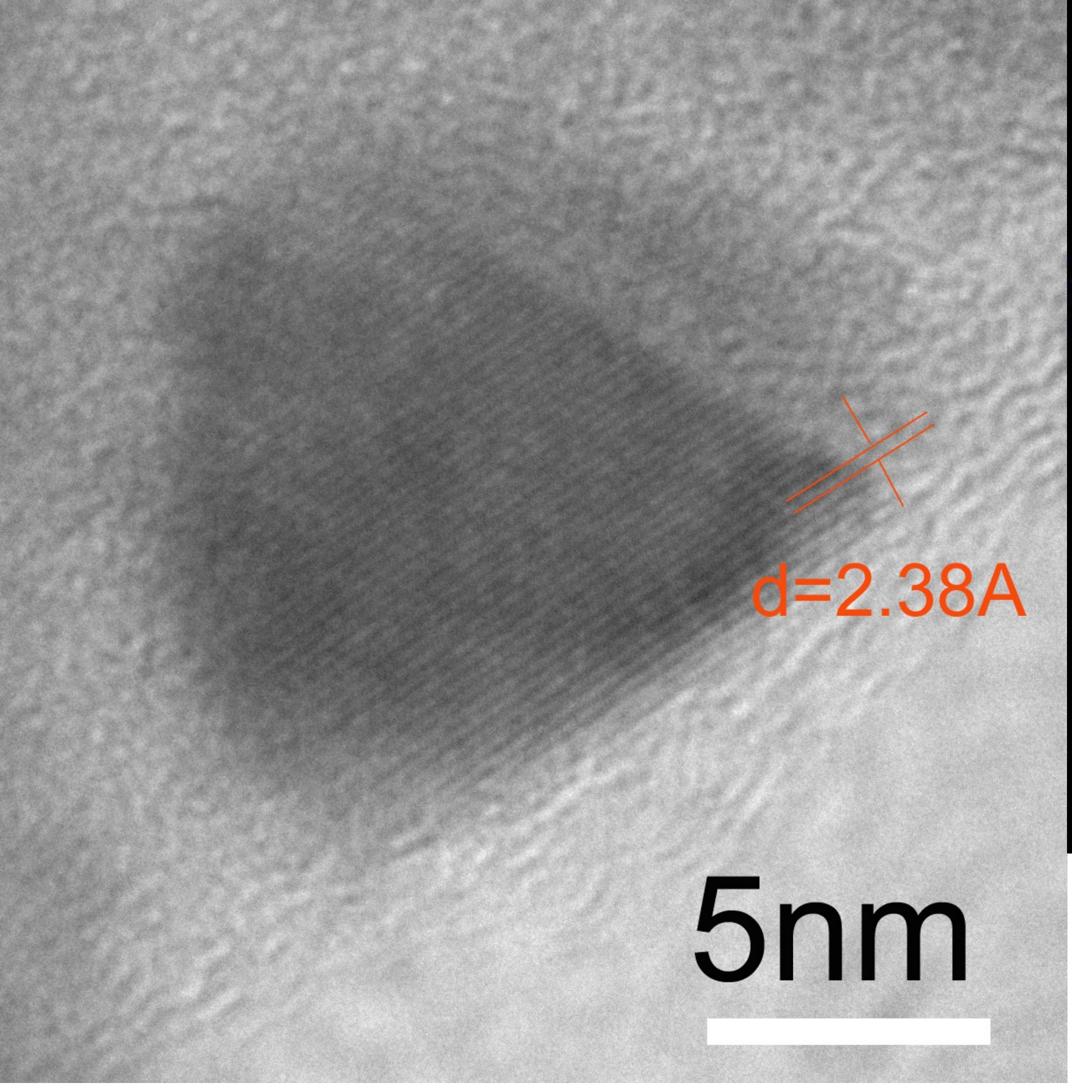


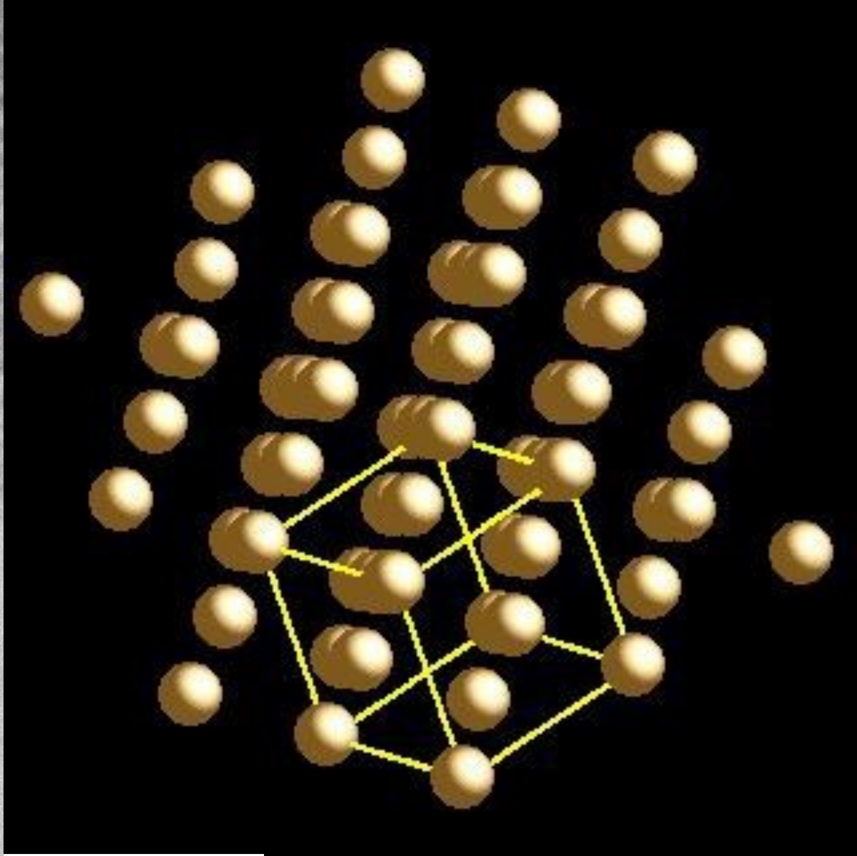
TEM image of a sliced W303α sample treated with Cd^{2+}

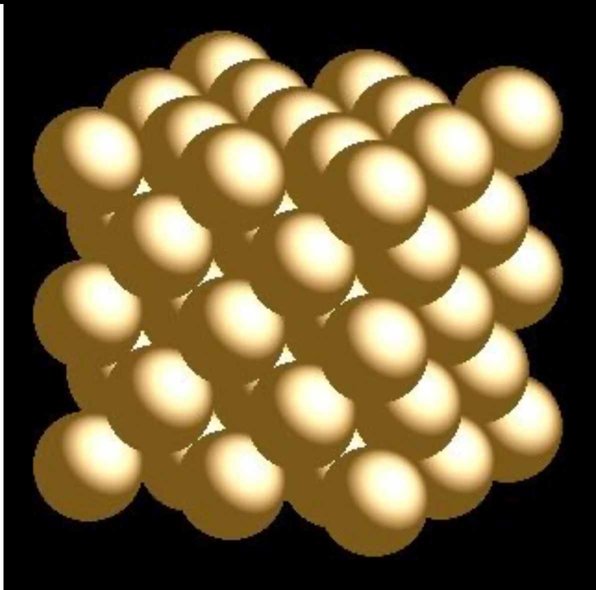


TEM image of an unsliced W303α sample treated with Cd^{2+}

Transmission electron microscopy: like an atomic scale x-ray: electrons pass through the sample to form an image







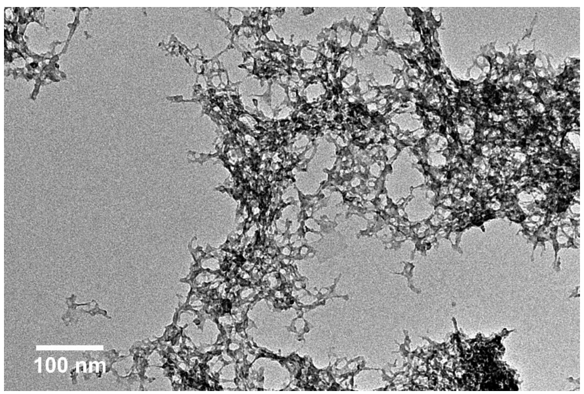
lattice distance is about 2.38A, very close to the gold (111) plane’s distance 2.36A

Bio-INC

Month 2 Milestone : Demonstrate the ability to use a bioengineering approach to change the identity of specific REE incorporated within the structure of a biosynthesized inorganic nanoparticle for ≥ 2 different REEs. **Biological synthesis of sodium rare-earth fluorides nanoparticles; Bio-$NaREEF_4$ ($NaYF_4$:Yb,Er)**

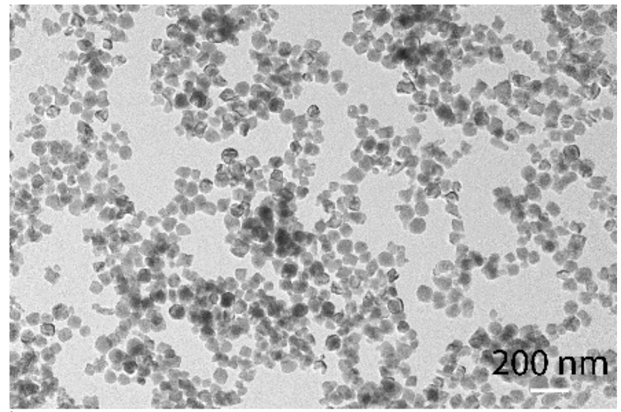
(**a**)

Aqueous solution synthesis Bio-REE hydroxide precursors

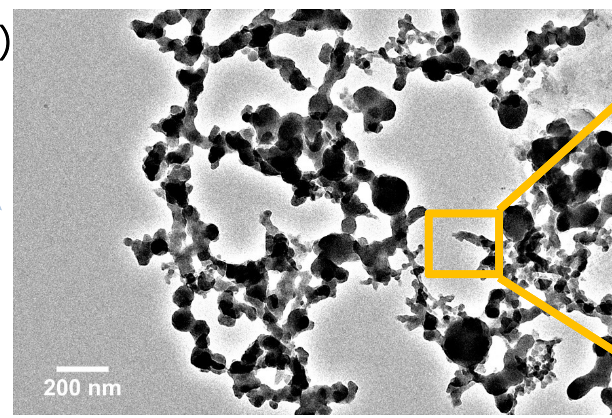


add sodium trifluoro acetate, Heat in organic solvents

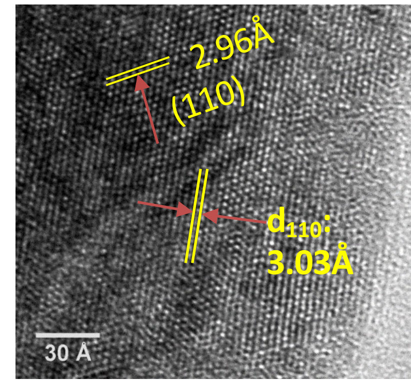
(**b**)



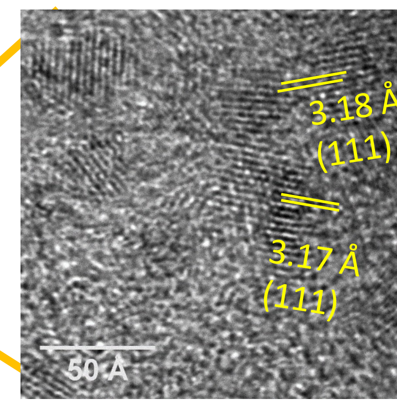
(**c**)



(**d**)



(**e**)



M13 phage template aqueous solution synthesized of Bio-YYbEr(OH)x as the precursors for synthesis of $NaYF_4$:Yb, Er NPs. Initially [Y]:[Yb]:[Er] = 78: 20:2, using REE nitrite or chloride salts as the starting materials.

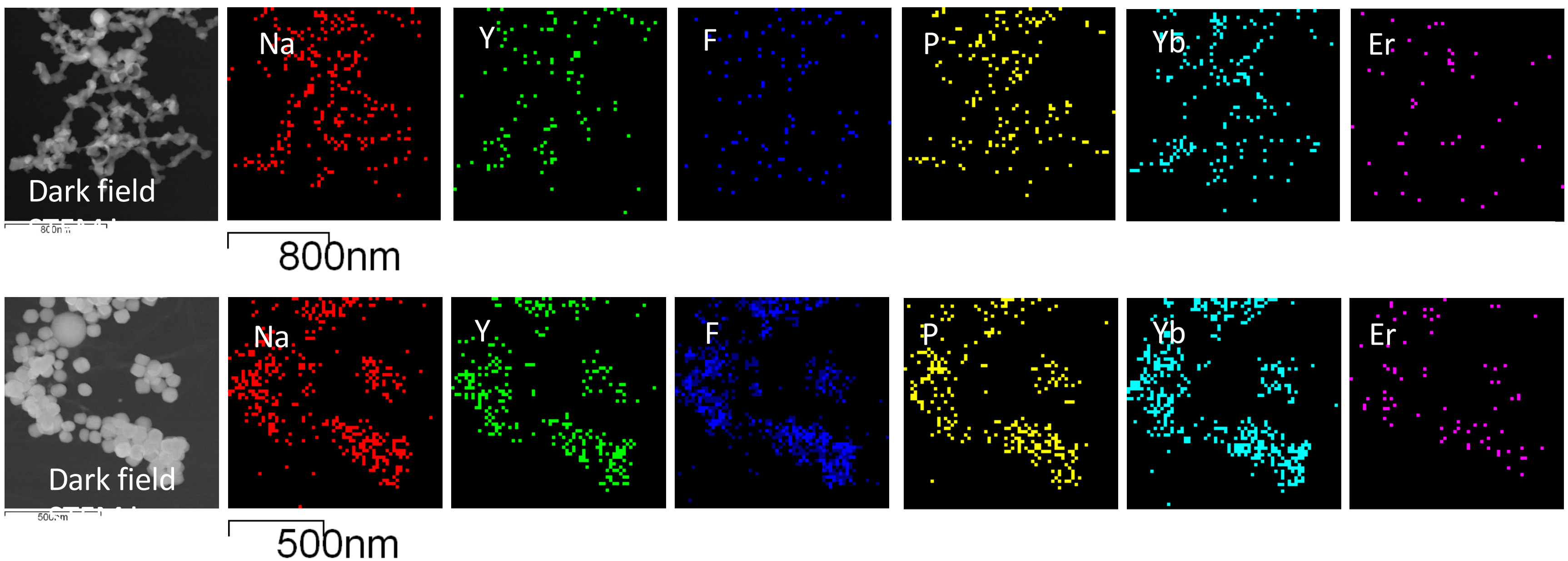
Biological synthesis of sodium rare-earth fluorides nanoparticles;

Bio-INC

STEM-EDX elemental mapping of Bio-$NaYF_4$:Yb,Er samples showing all the elements of Na, Y, F, Yb, Er are overcoat on the biotemplates (P from DNA).

#01-1

#09-2



ICP (Inductively Coupled Plasma) Spectroscopy

❖ ICP is an analytical technique used to measure and identify elements within a sample matrix based on the ionization of the elements within the sample.

- Inductively coupled plasma mass spectrometry (ICP-MS)

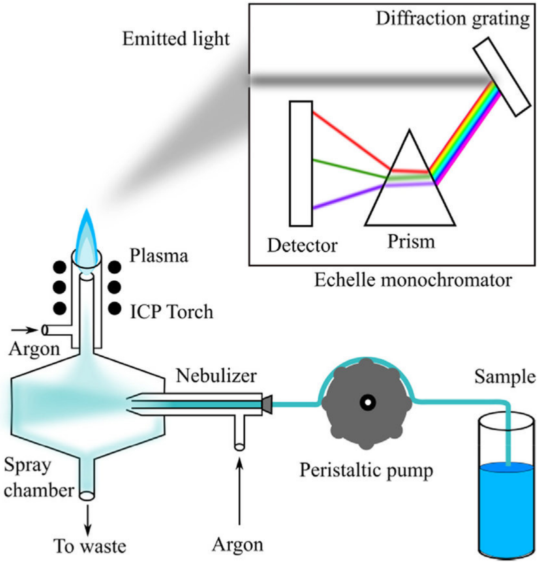
This technique uses an argon plasma to convert a sample into ions. The ions are then measured using a mass spectrometer. ICP-MS can measure elements at trace levels in biological fluids.

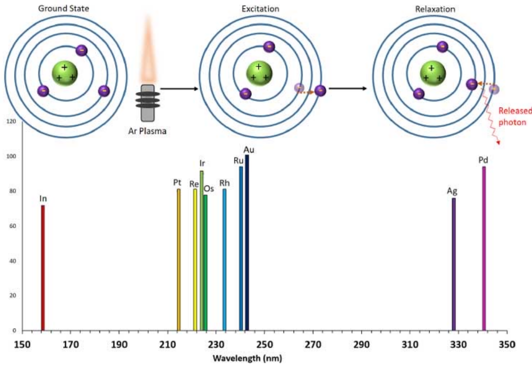
- Inductively coupled plasma - optical emission spectrometry (ICP-OES)

This technique uses plasma and a optical spectrometer to determine the composition of elements in samples. ICP-OES has been commercially available since 1974

❖ ICP analysis requires the use of liquified sample solutions, so solid samples and biological samples must be digested prior to analysis. Once the sample is liquid, the ICP uses argon (Ar) carrier gas to aerosolize the sample sending only the smallest droplets through the chamber and into the argon plasma torch.

❖ The Ar plasma causes the sample to desolvate and ionize.

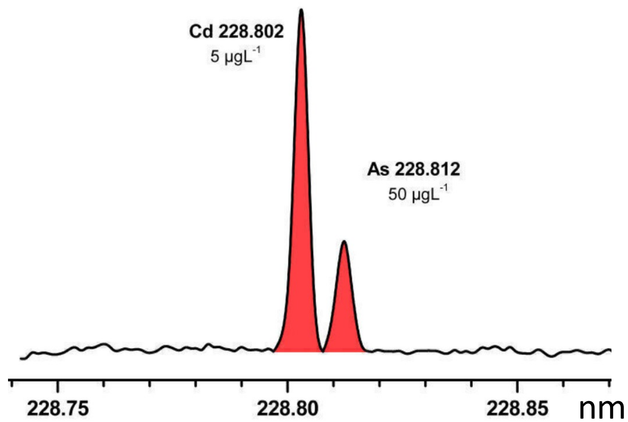




Sample preparation - how to deliver samples for ICP test

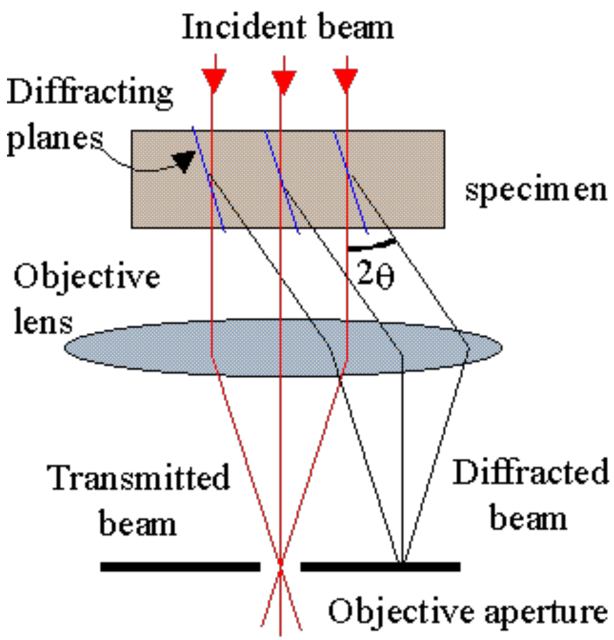
- Samples should be delivered in 12 – 15 ml tubes (at least 5ml solution).
- Samples should be acidified (preferably with 1-5 % HNO_3in order to keep metals in solution)
- Solid material should be destructed, preferably with nitric acid only (concentration HNO_3below 10%, ideally 1%), or if necessary with HNO_3/H_2OThis step can be performed as a closed destruction in a microwave-oven.
- HCl can cause precipitates and the sulfur in sulfuric acid interferes in the analysis.
- The torches present at the GI are not resistant to HF.
- For the ICP samples should not contain any organic solvents.
- Indicate as far a possible what concentration level may be expected in the samples

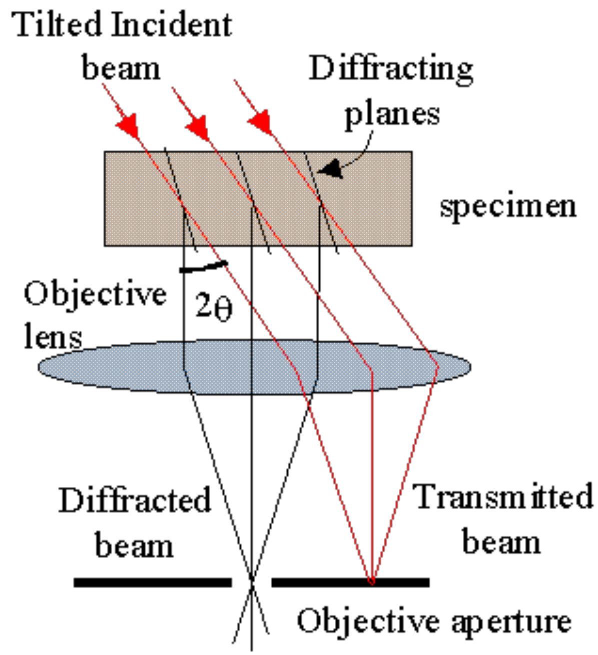
AGILENT 5100 ICP-OES SPECTROMETER



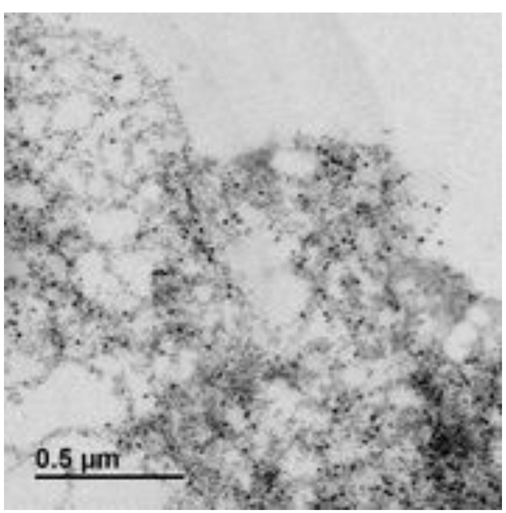
High-Resolution ICP-OES spectrum of Cd and As

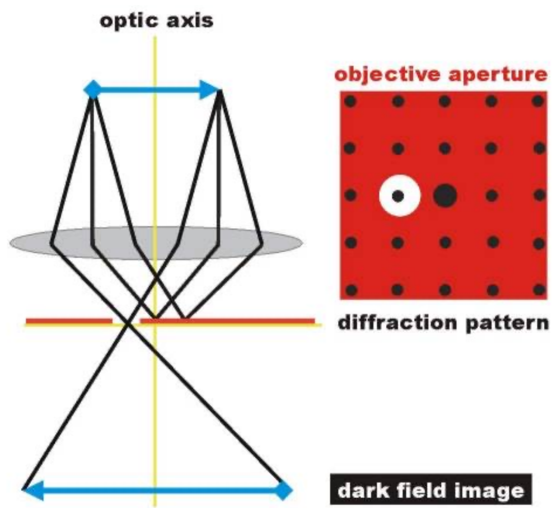
Dark Field





Bright Field Imaging





On-axis Dark Field