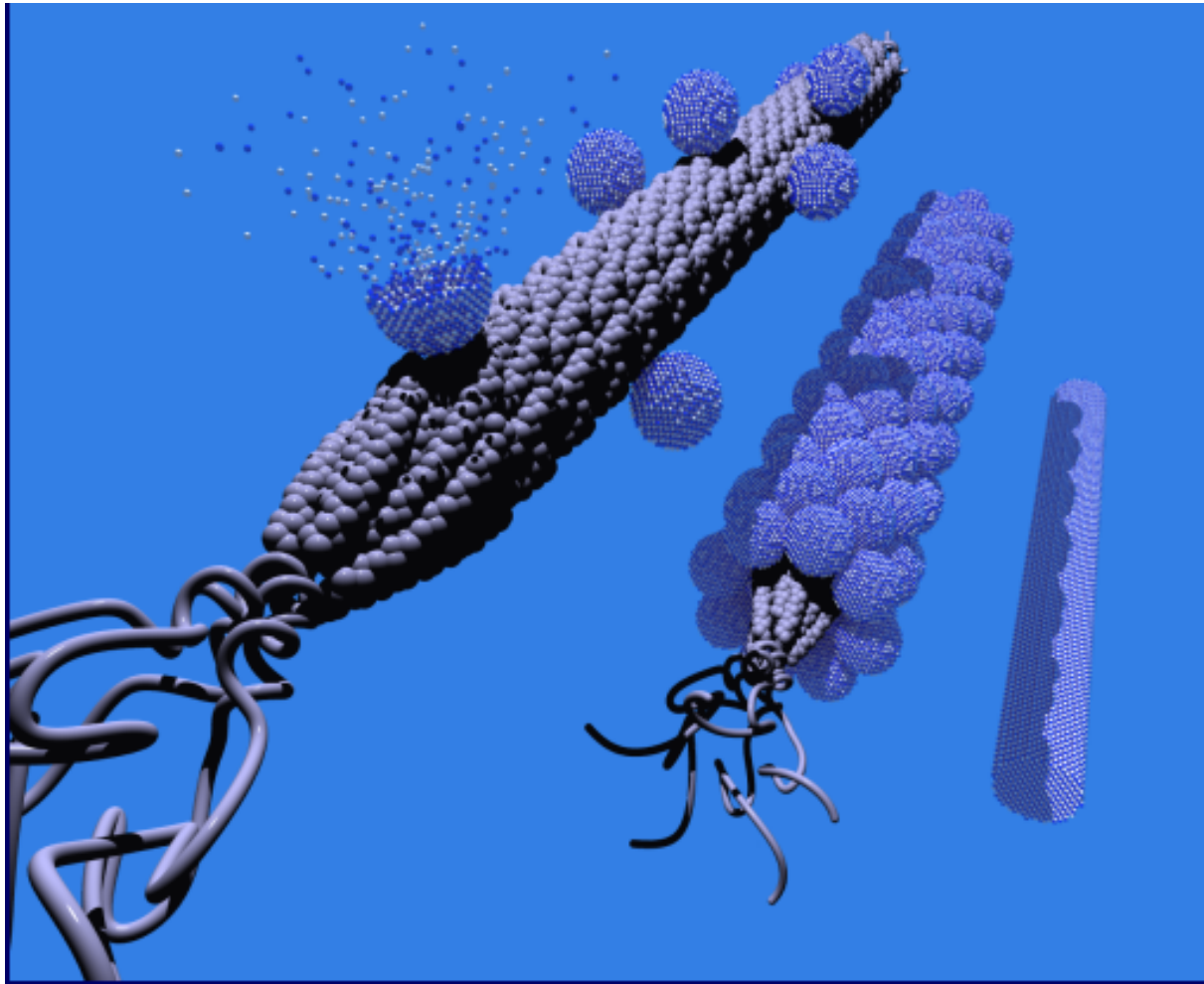
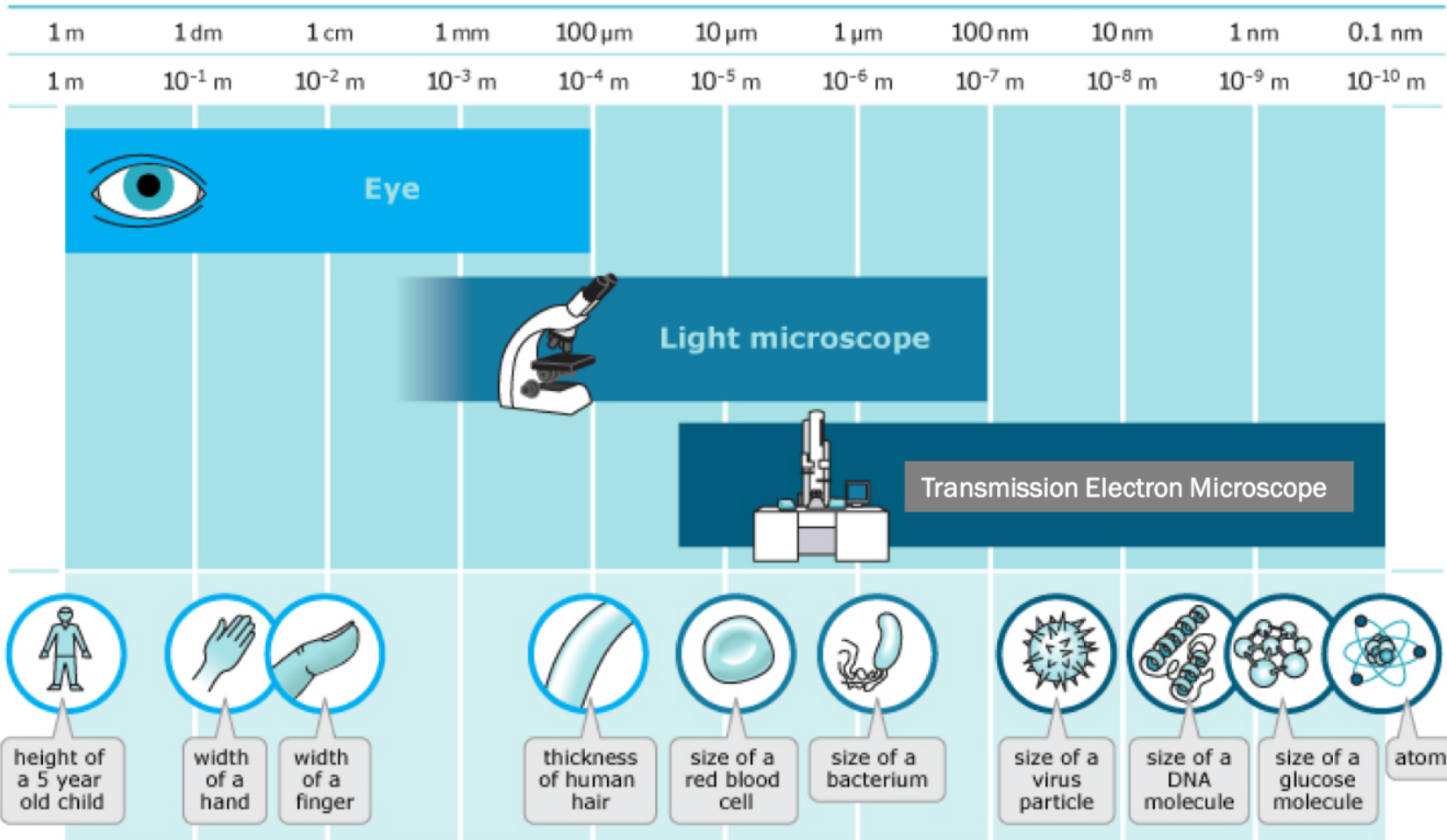


Virus Nanowires and Nanoparticles



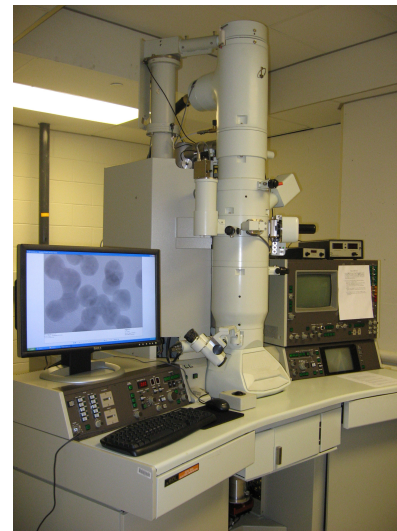
Science, 303, p213, 2004

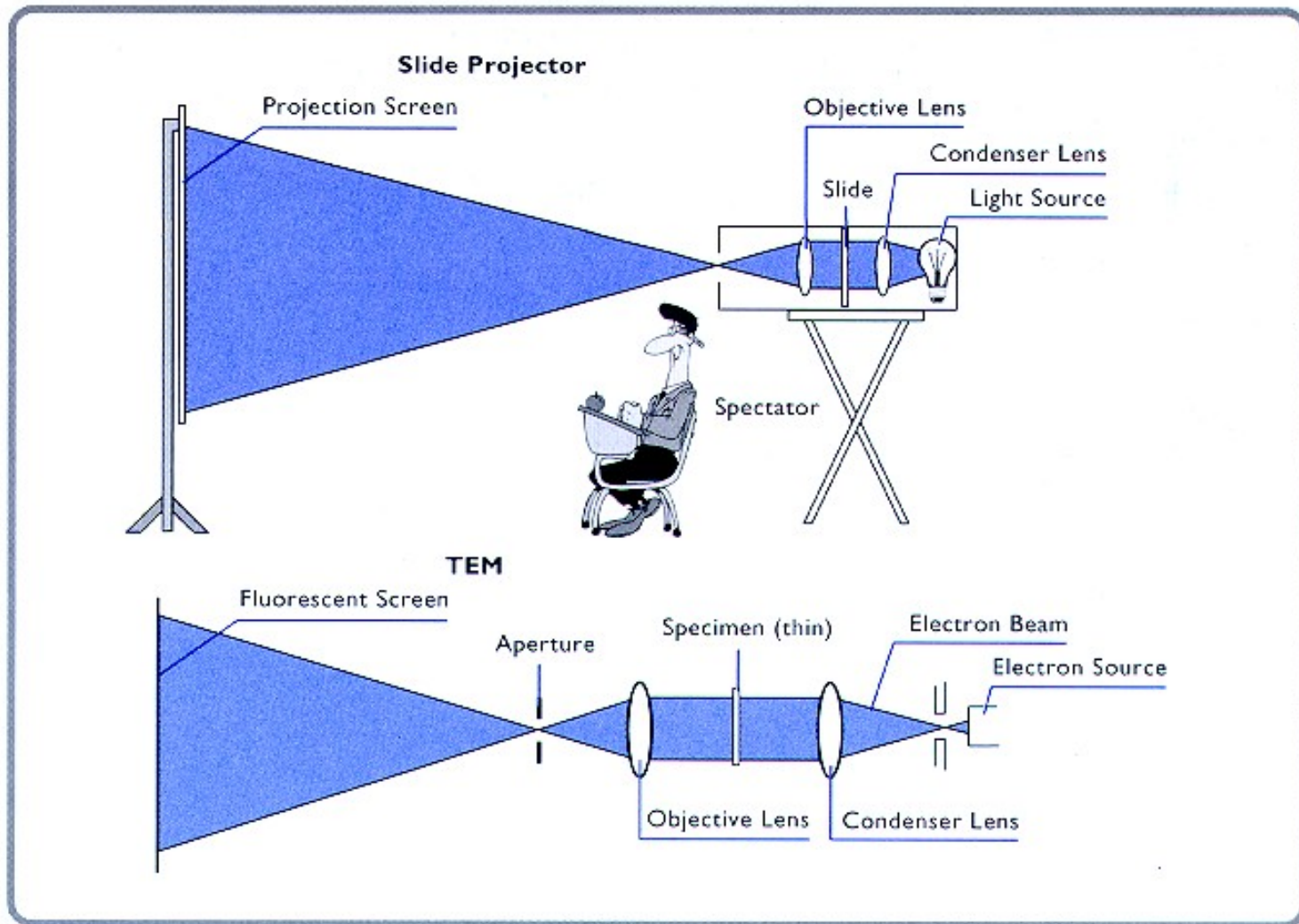
Resolving Power of Microscopes



What's TEM

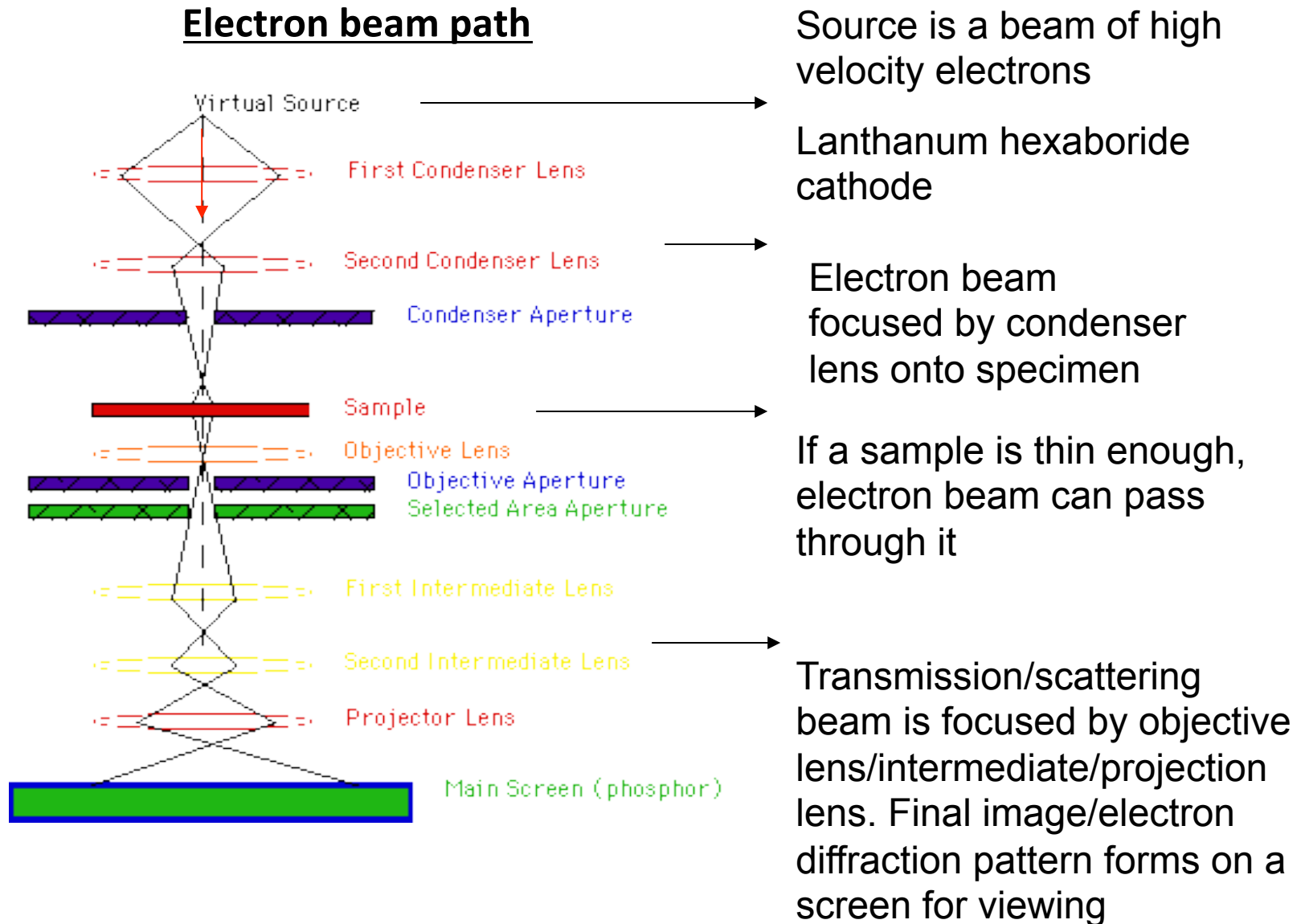
- An electron-optical microscope that uses electromagnetic lenses to focus and direct an electron beam.
- Bright field imaging is from electrons interacting with electron dense materials to cast a shadow on a screen or camera.
- High voltages between 10KV and 1MV. The higher the voltage is, the shorter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



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)

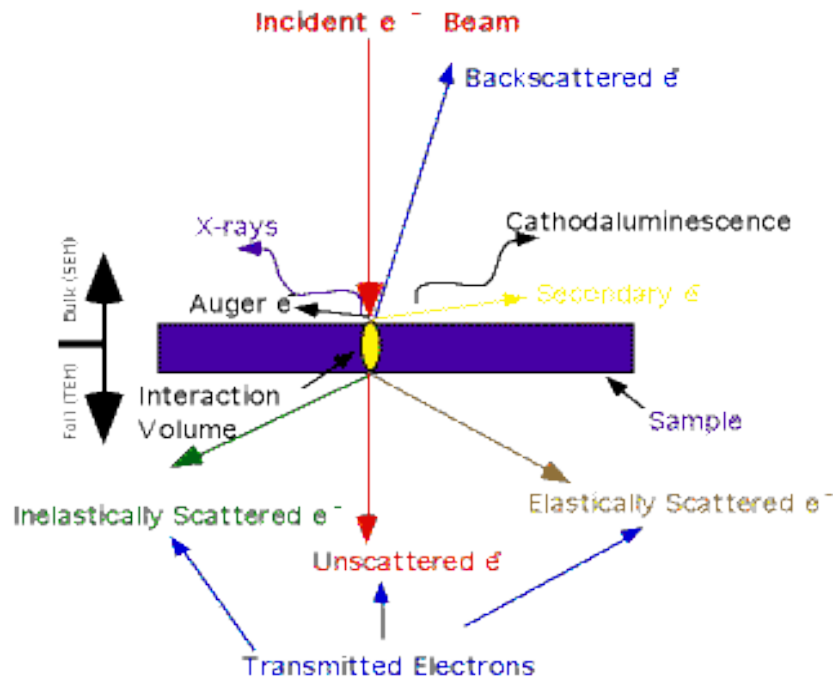
- The size, shape, morphology, and distribution of the particles as well as their relationship to each other on the scale of atomic diameters.
- Contrast comes from electrons interacting with electron dense atoms in the sample, the scattered electrons cause a shadow to be cast on the camera or screen.
- 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), Scanning TEM (STEM))**
 - The elements and compounds the sample is composed of and their relative ratios, in areas a few nanometers in diameter

What's TEM

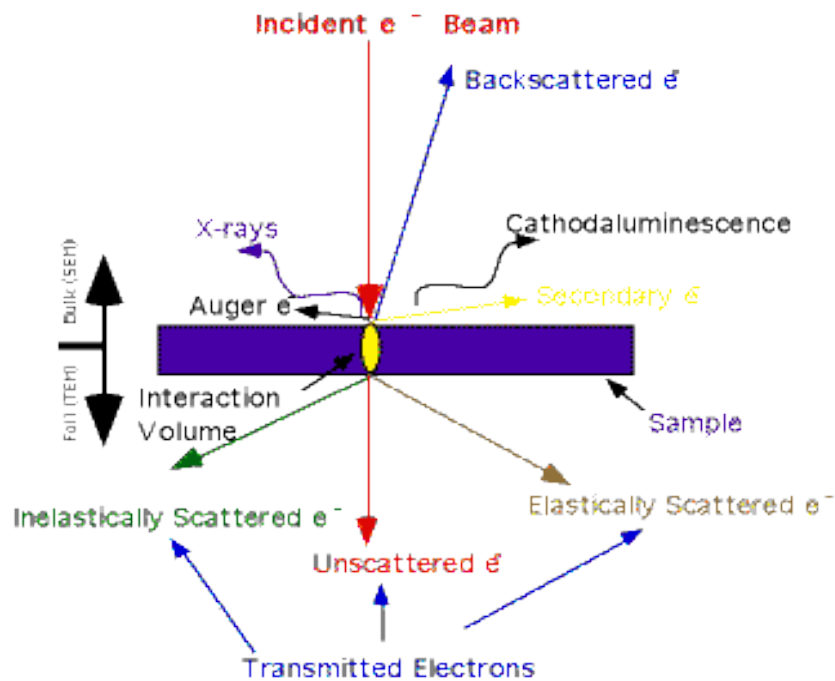
Different equipment in TEM is then used to collect scattered electrons produced by the specimen-electron interaction, giving different types of information



} Compositional Information

} Morphology & Crystallographic Information

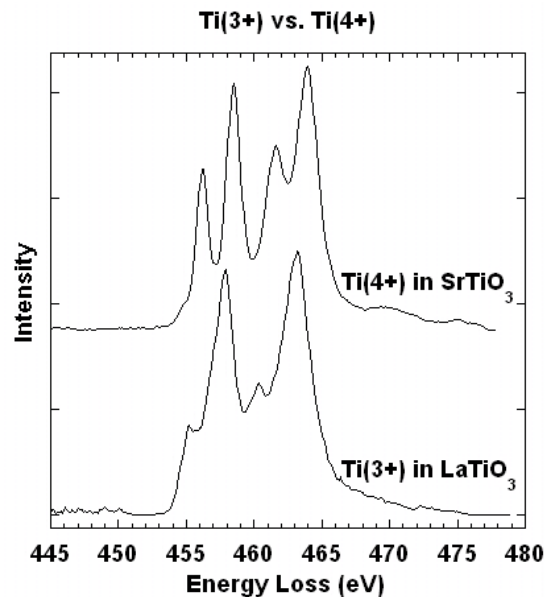
Elemental mapping and information



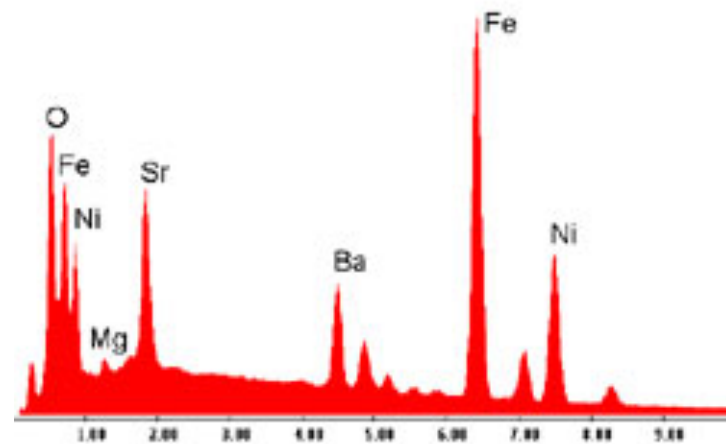
- Elemental mapping can be done by two methods, STEM and EELS
- STEM involves rastering an electron beam through a sample and determining the elemental composition of each spot by either X-ray analysis or EELS (element specific)

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

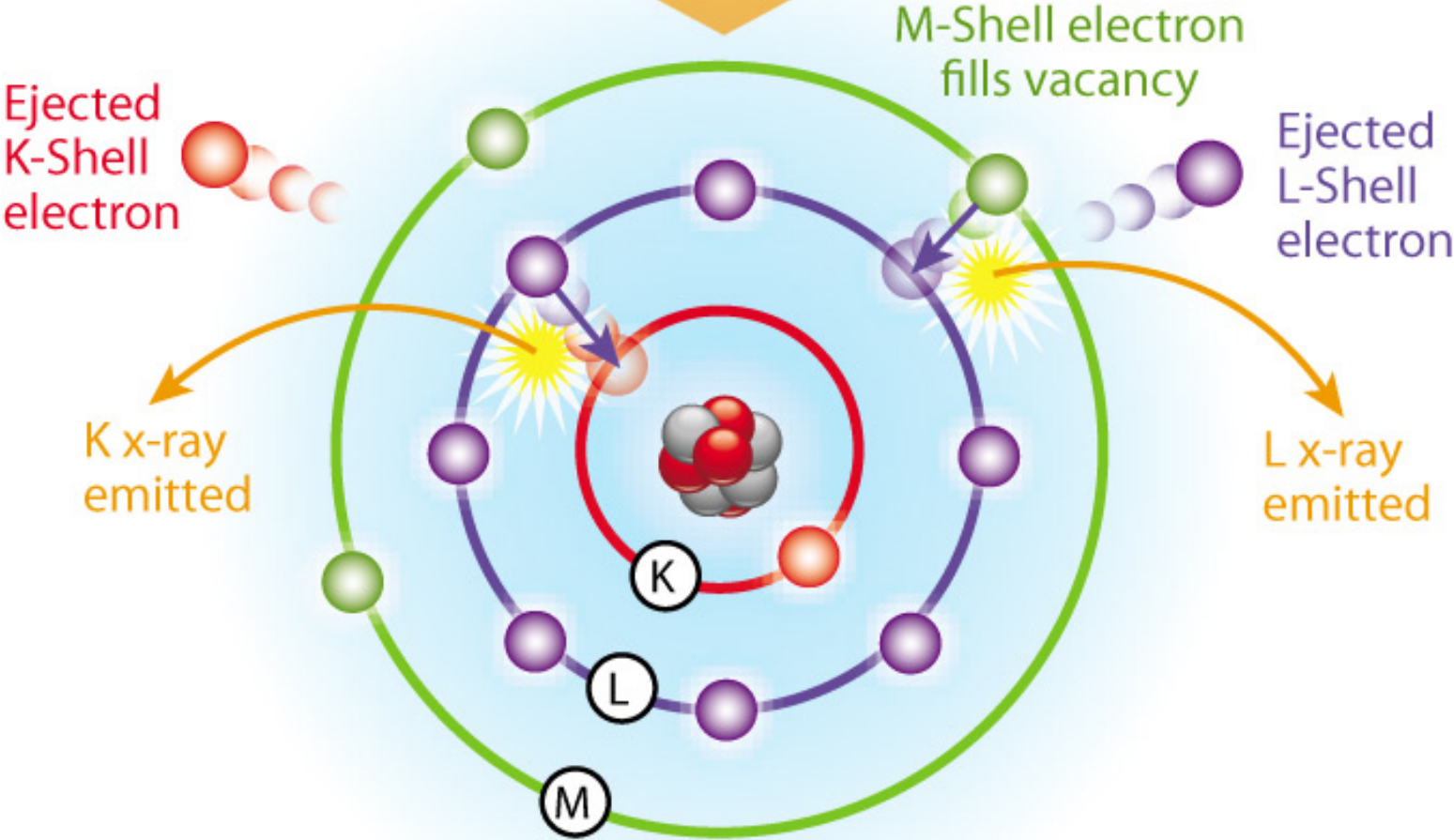


EELS of Titanium particles shows a difference between Ti^{3+} and Ti^{4+}

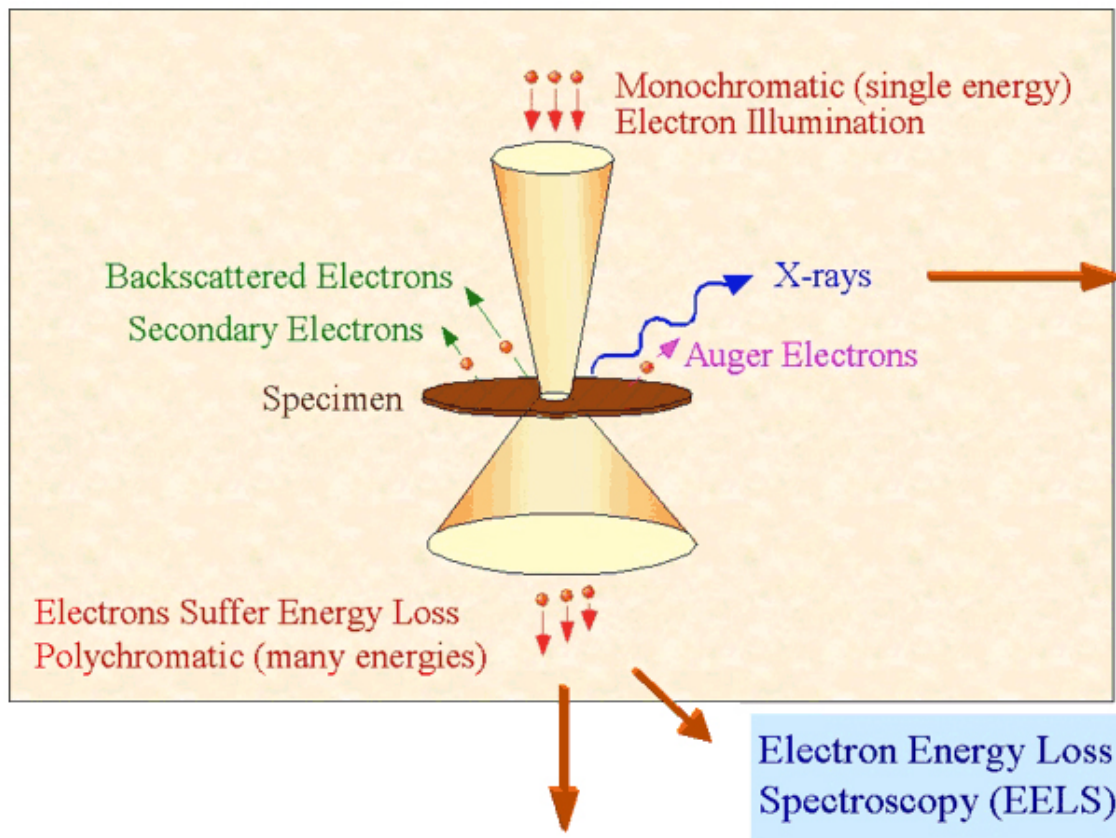


EDX of BaSrO_x shows all the elements present in the sample

Incident Radiation from
Primary X-ray Source



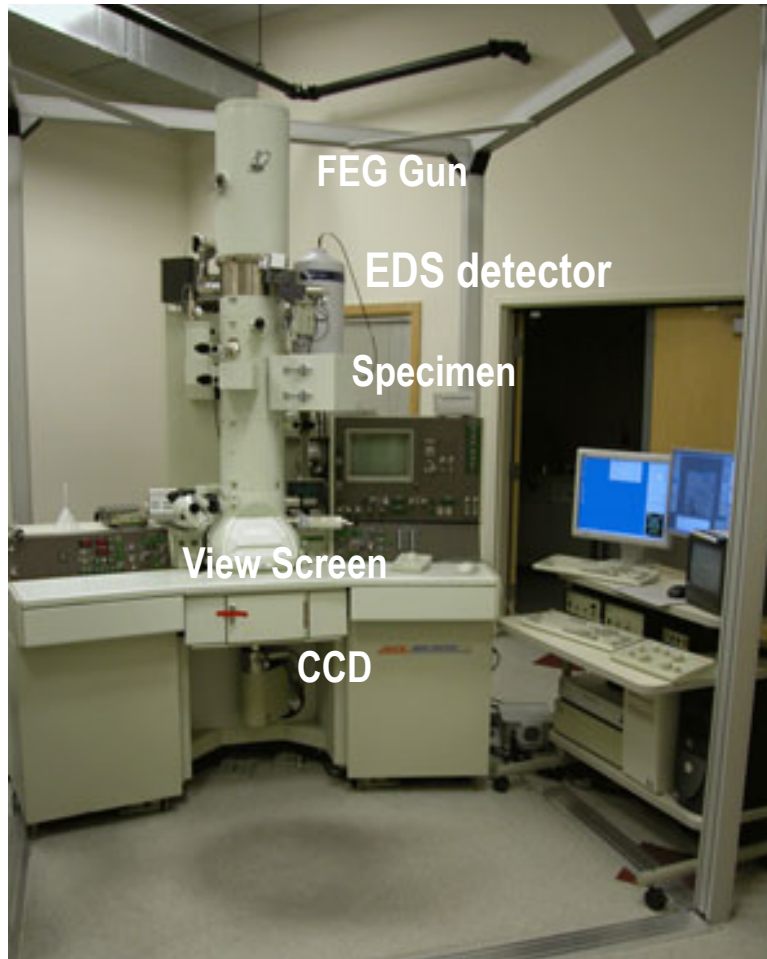
Energy Dispersive X-ray Spectroscopy (EDXS)
Different elements emit different characteristic X-rays when excited by an electron beam. These X-rays can be used to identify the elements present, quantify their relative or absolute concentration, and map their distribution.



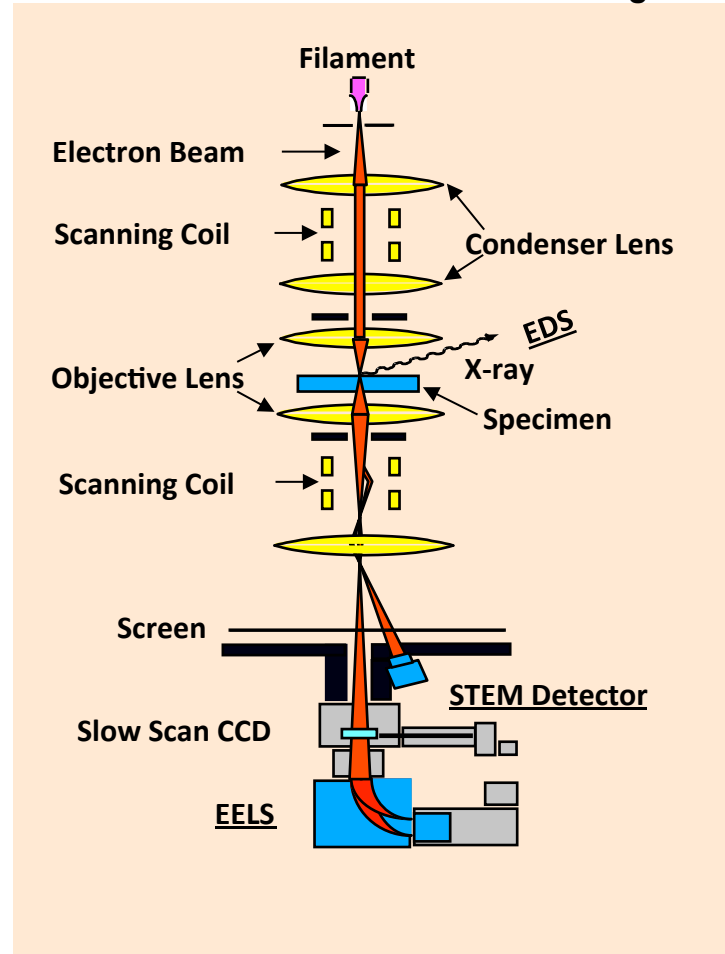
Different elements cause incident electrons to lose different amounts of energy. EELS can be used to identify the elements present, quantify their relative or absolute concentration, and map their distribution. Since the absorption of energy from incident electrons is dependent on the bonding of the elements present, EELS can also probe the structure of the material.

JEOL 2010 Field Emission Gun(FEG) TEM

2010FEG TEM Photo



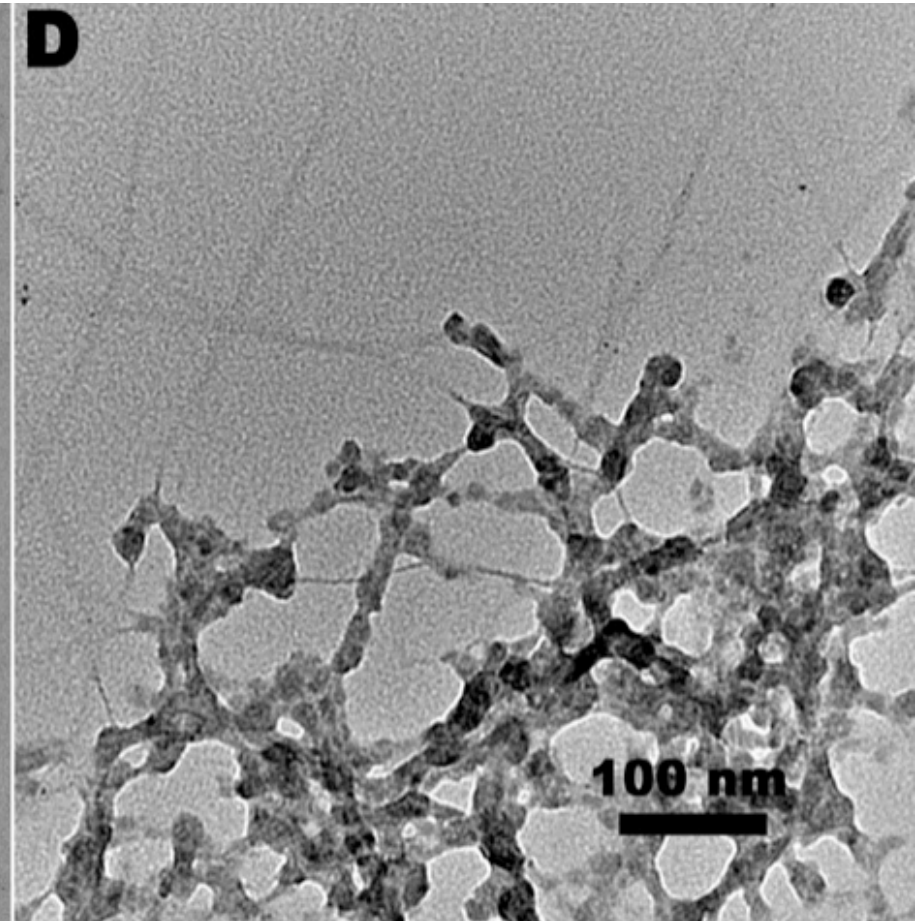
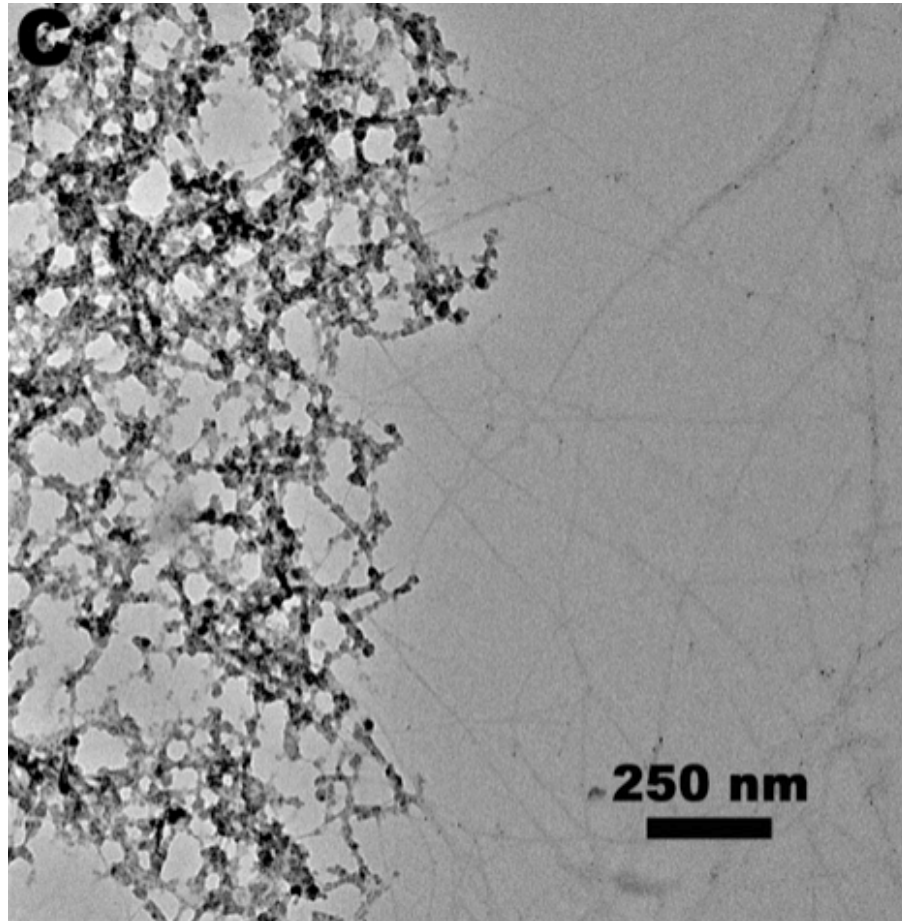
2010FEG TEM Schematic Diagram

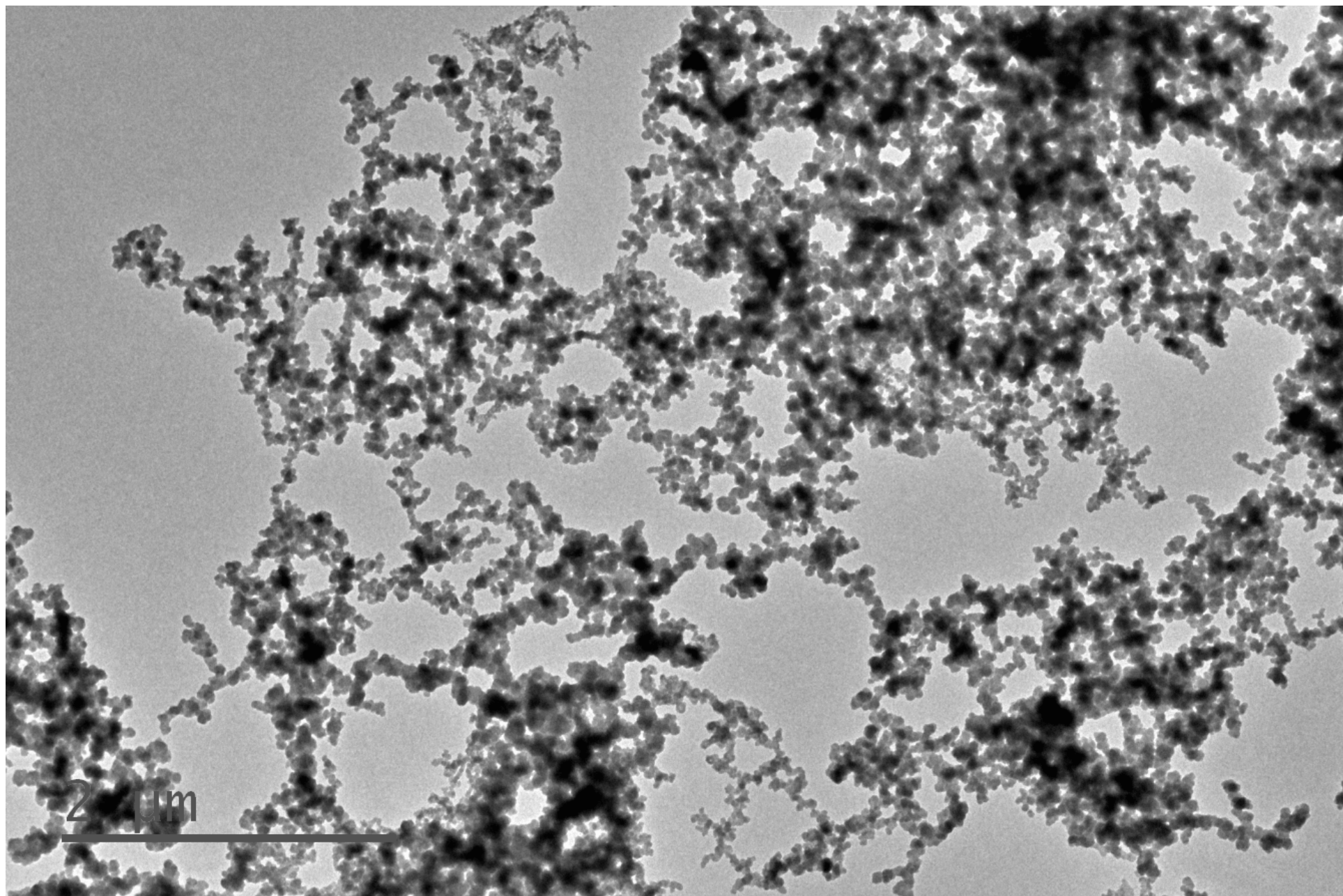


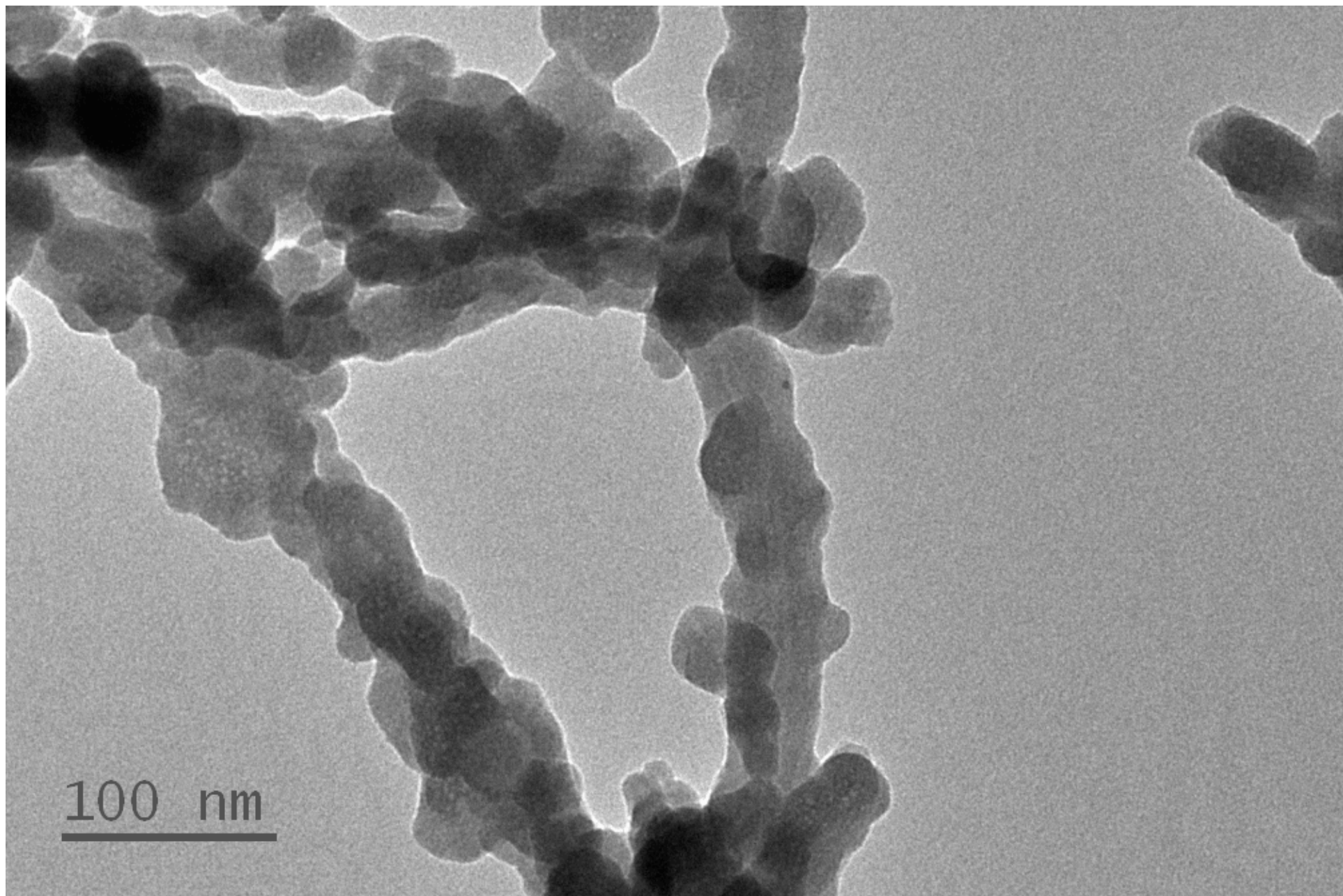
2010FEG TEM Characteristics

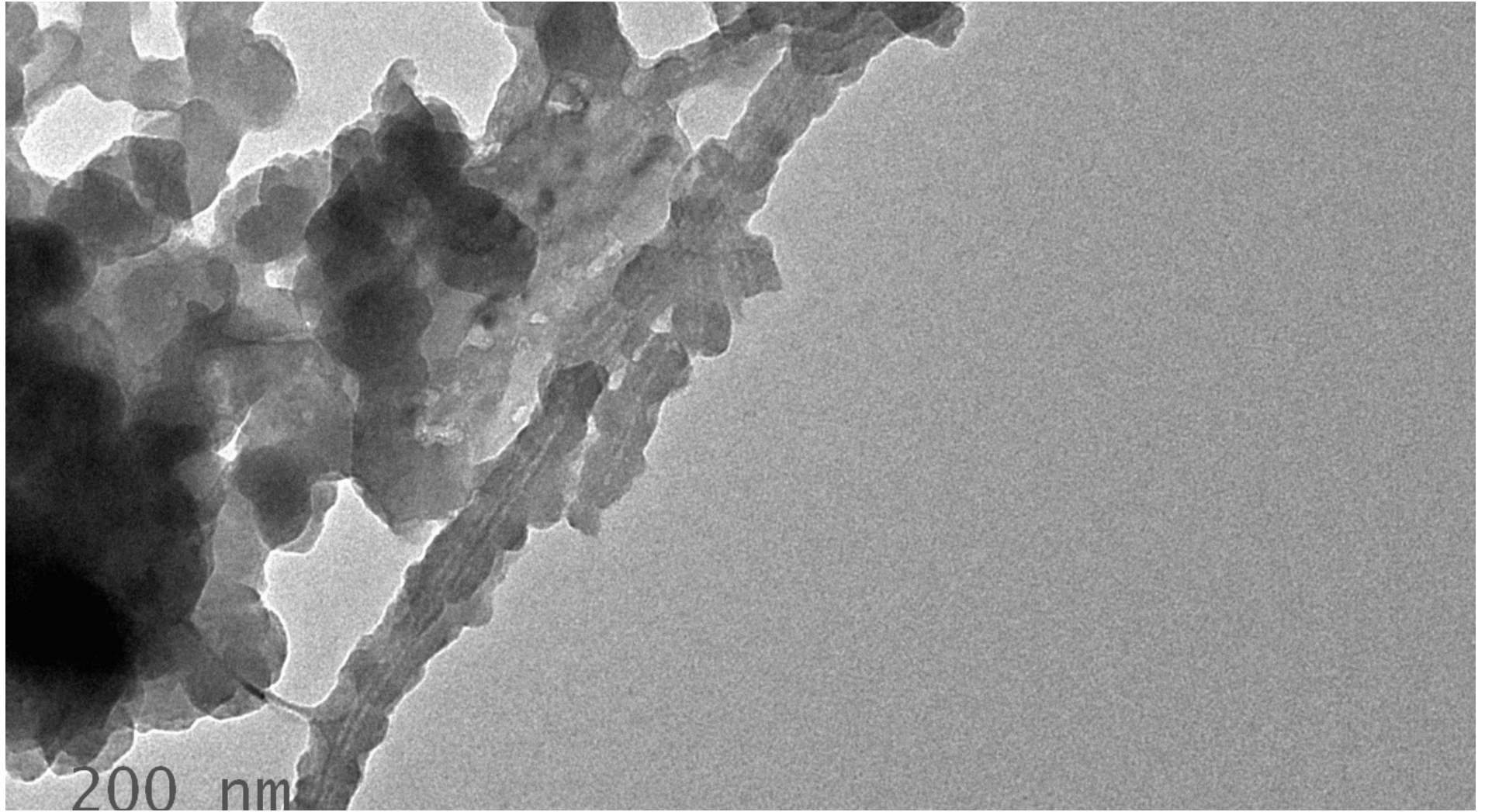
1. **Point Resolution** : less than 0.2nm
2. **Brightness** : 2-order higher brightness than with the LaB6 electron gun,(JEOL 2010 TEM)
3-order higher with tungsten thermionic gun(JEOL 200CX TEM)
3. **Nanoanalysis** : Atomic arrangement, Grain Size, Crystal Orientation, Defects,
Chemical analysis - elements, composition

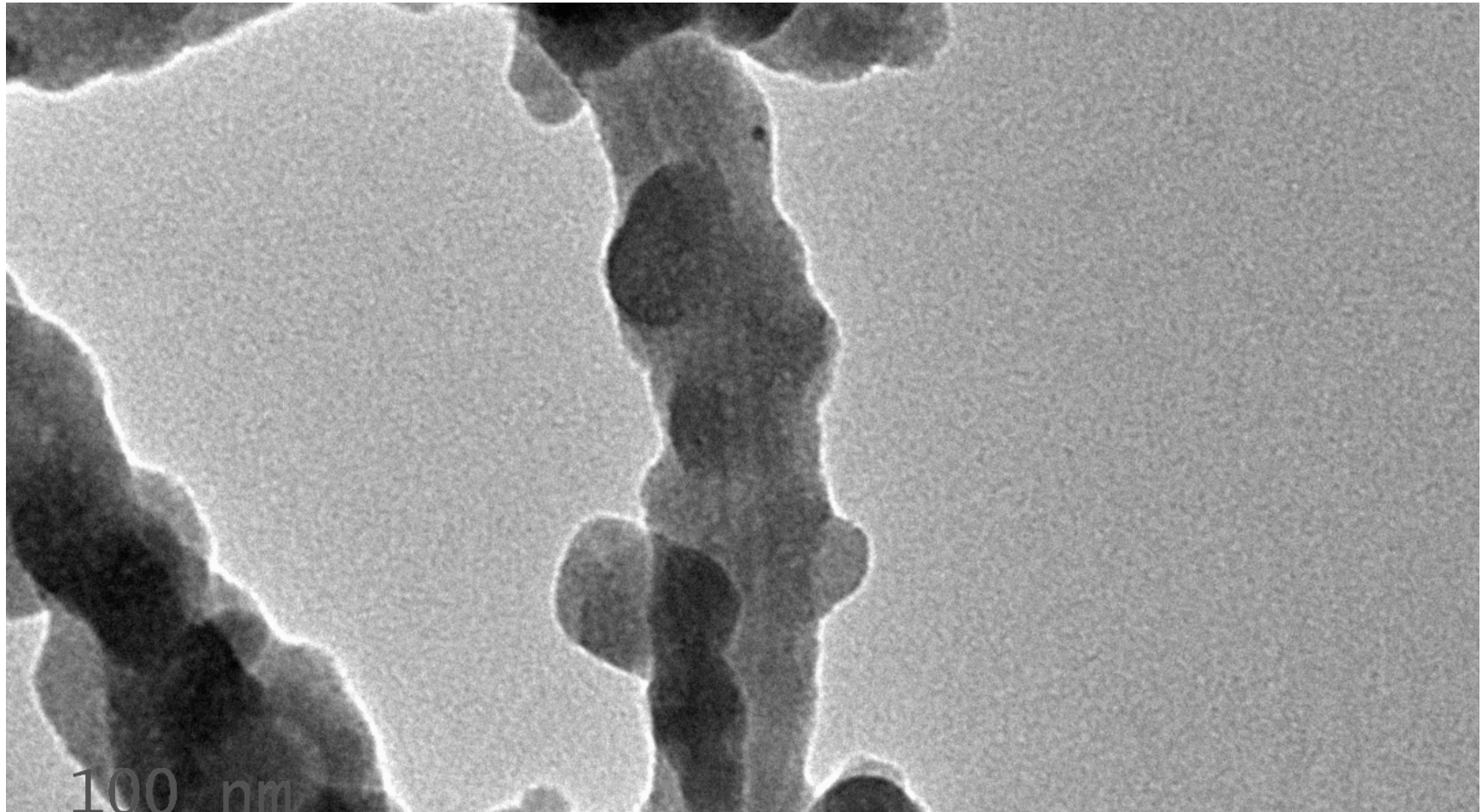
FePO₄ Nanowires



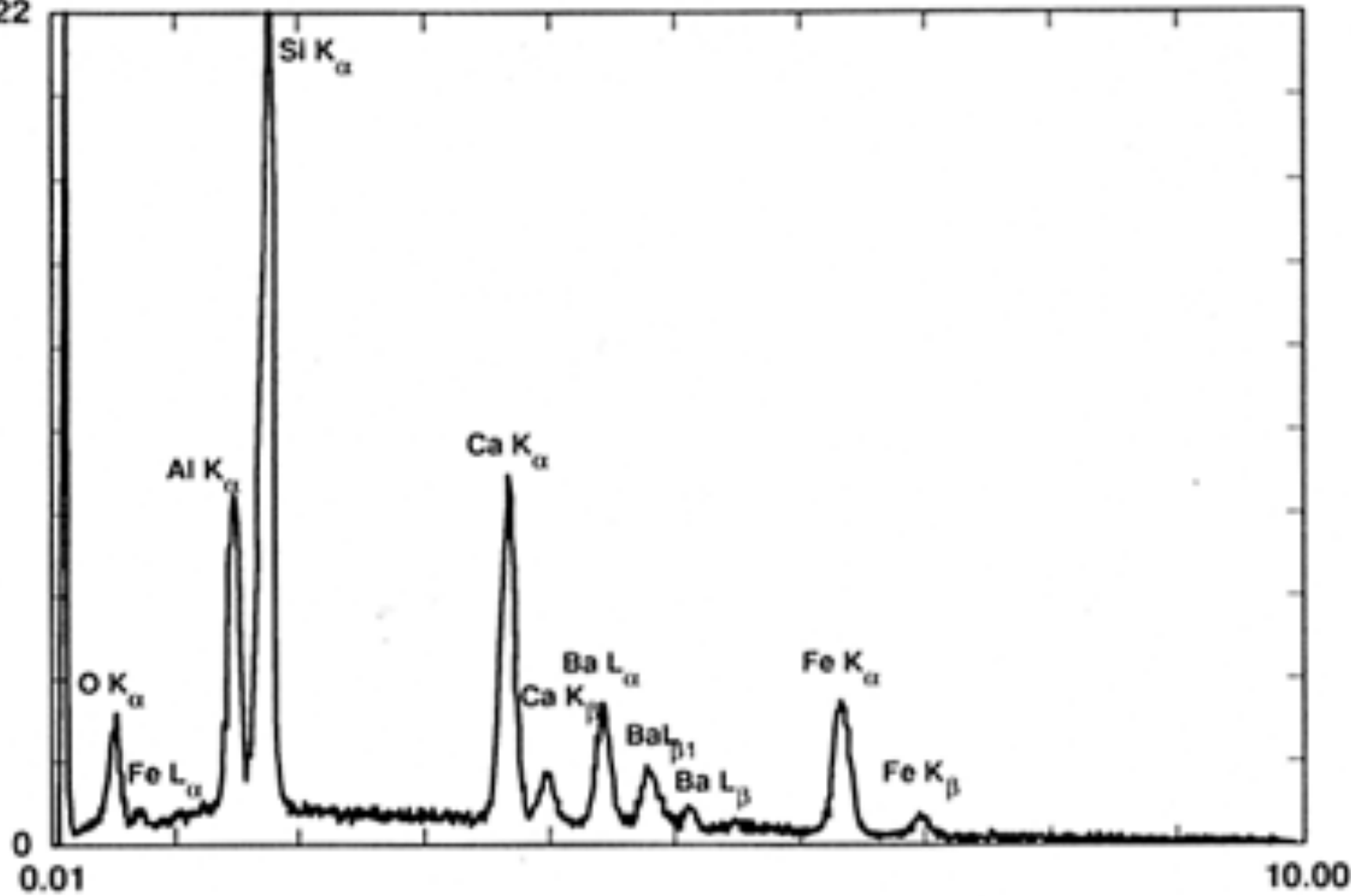




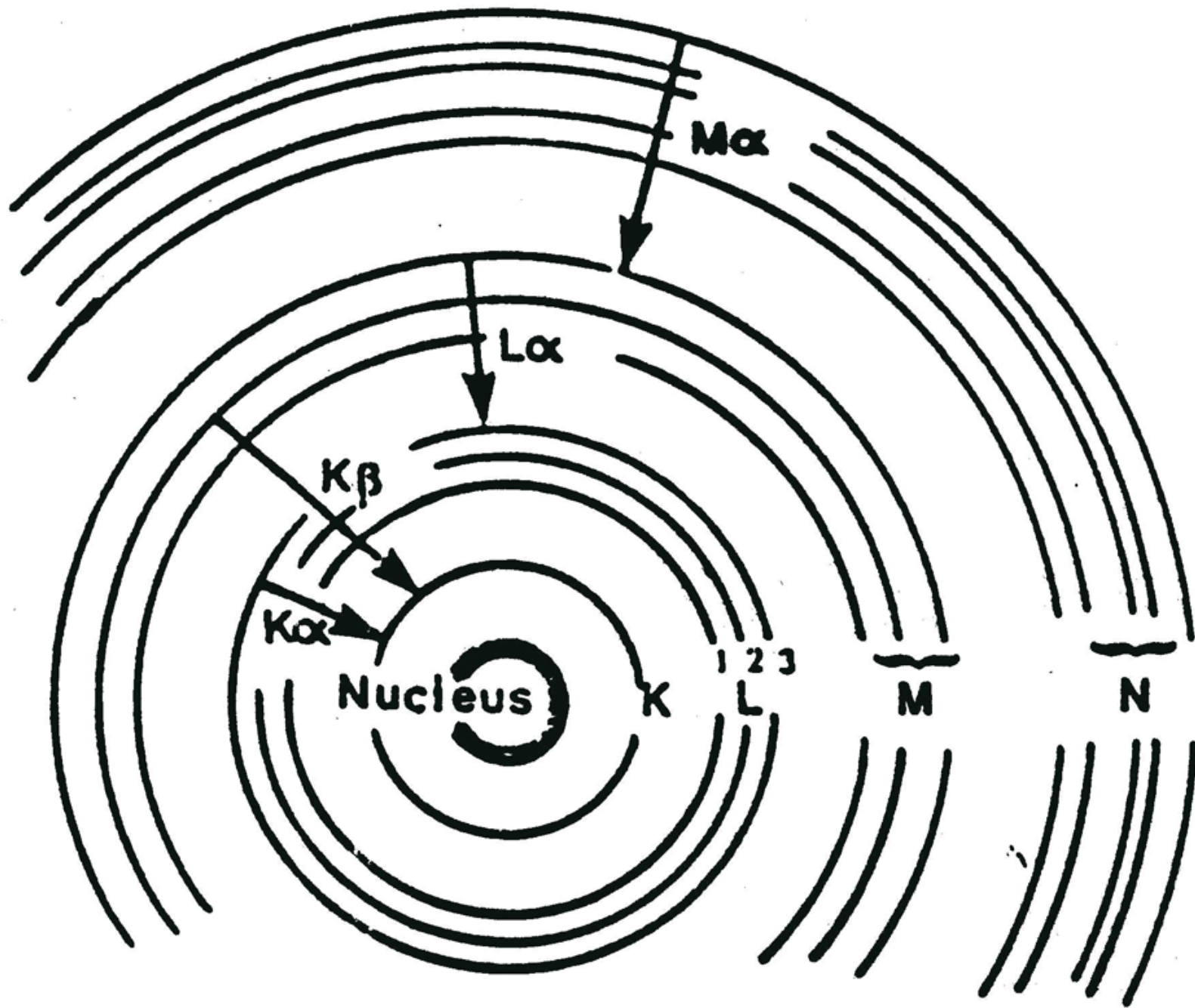


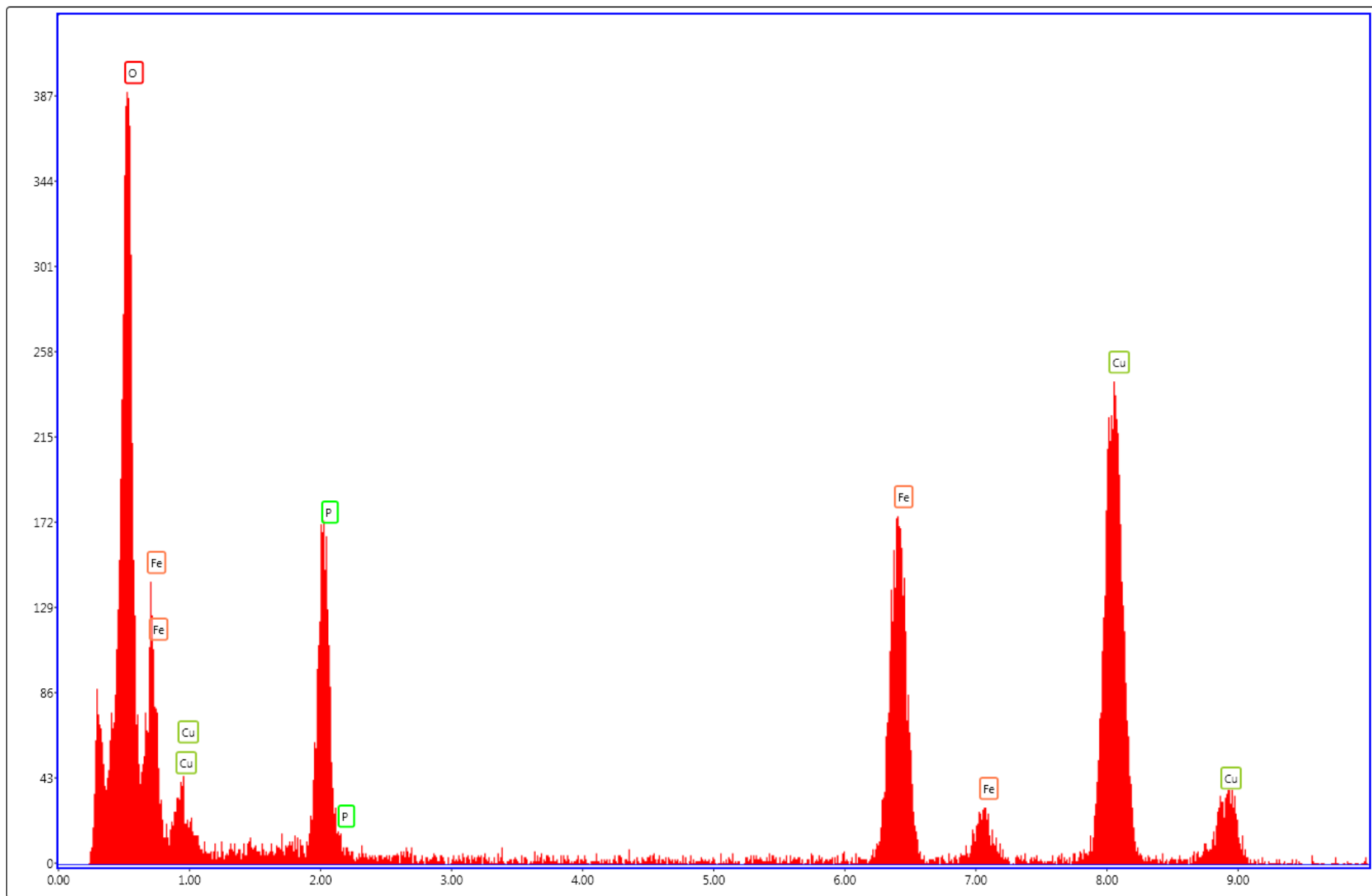


3022

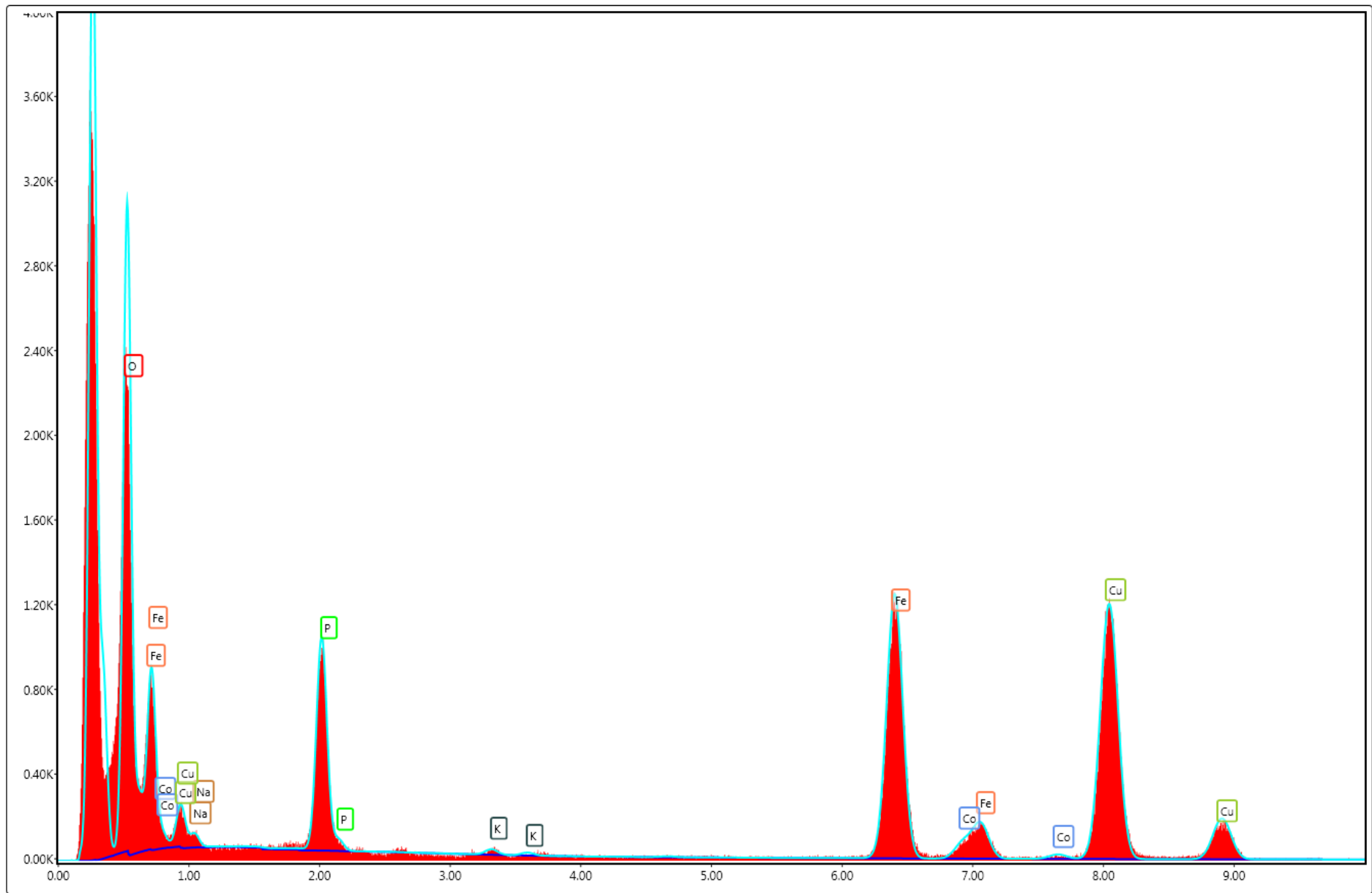


keV

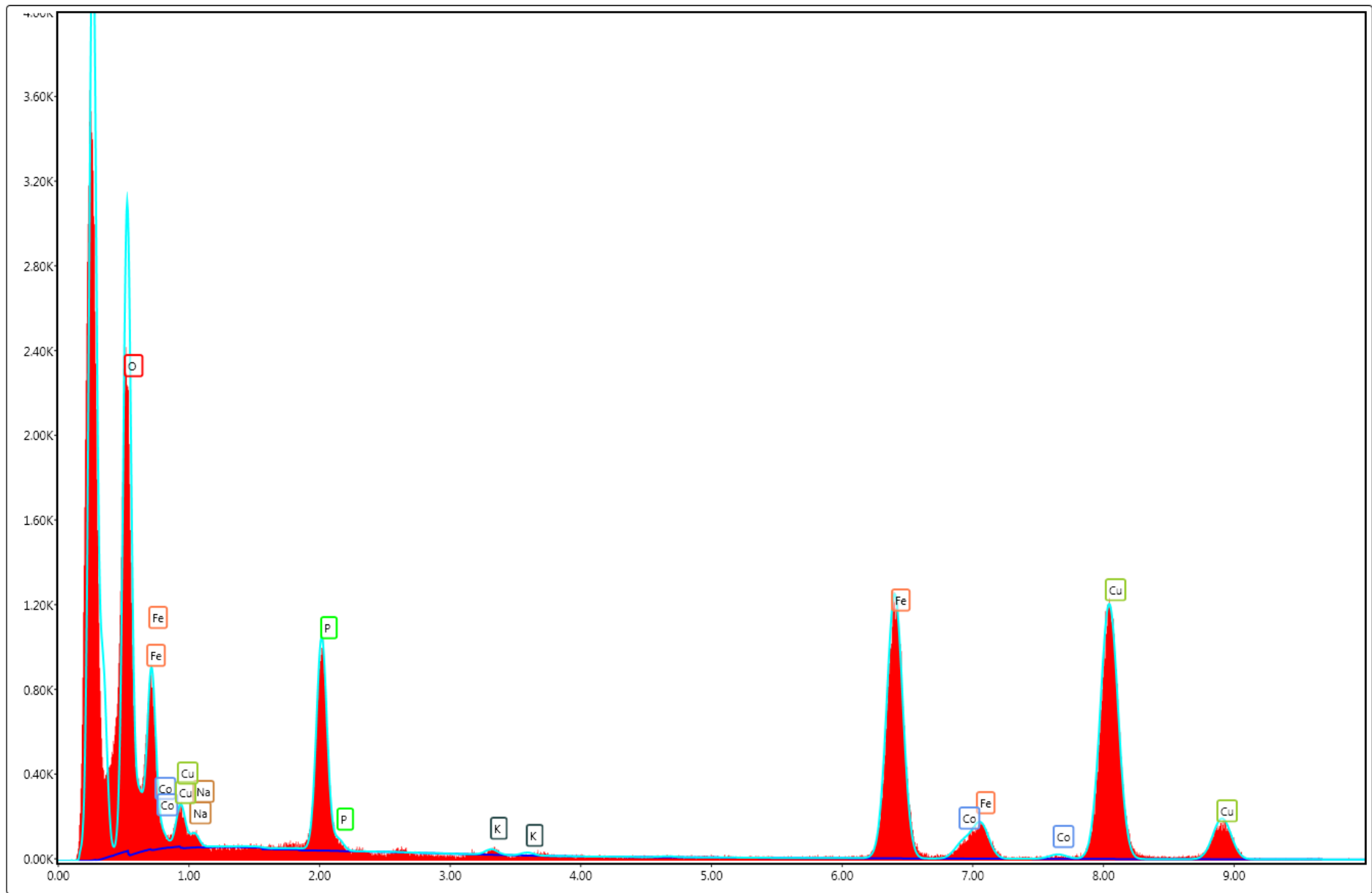




Status: Idle CPS: 4026 DT: 1.4 Lsec: 10.0 0 Cnts 0.000 keV Det: Apollo XLT2 Windowless

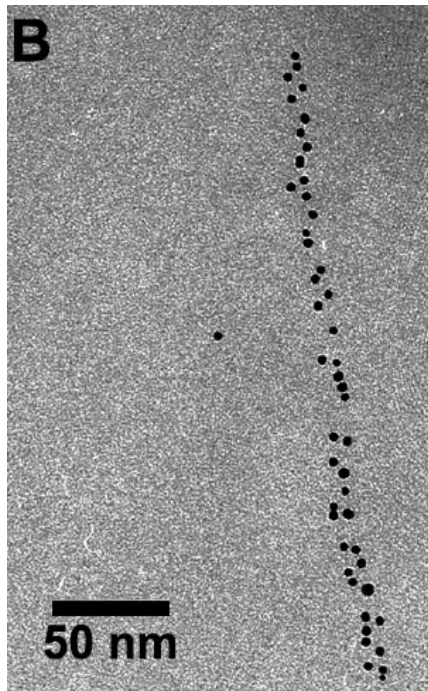


Status: Idle CPS: 22096 DT: 6.7 Lsec: 15.0 52 Cnts 2.275 keV Det: Apollo XLT2 Windowless

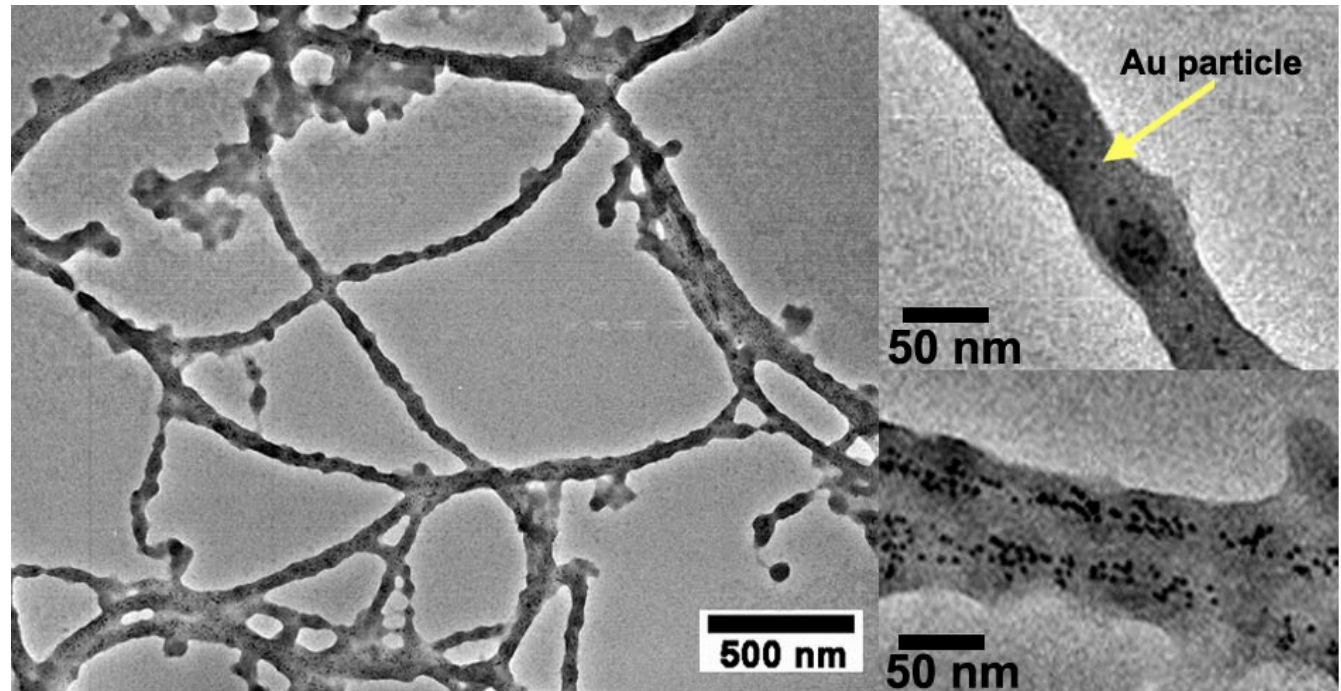


Status: Idle CPS: 22096 DT: 6.7 Lsec: 15.0 52 Cnts 2.275 keV Det: Apollo XLT2 Windowless

Genetic Modification Produces New Hybrid Anodes for Increased Capacity Au-Co₃O₄ Nanowire

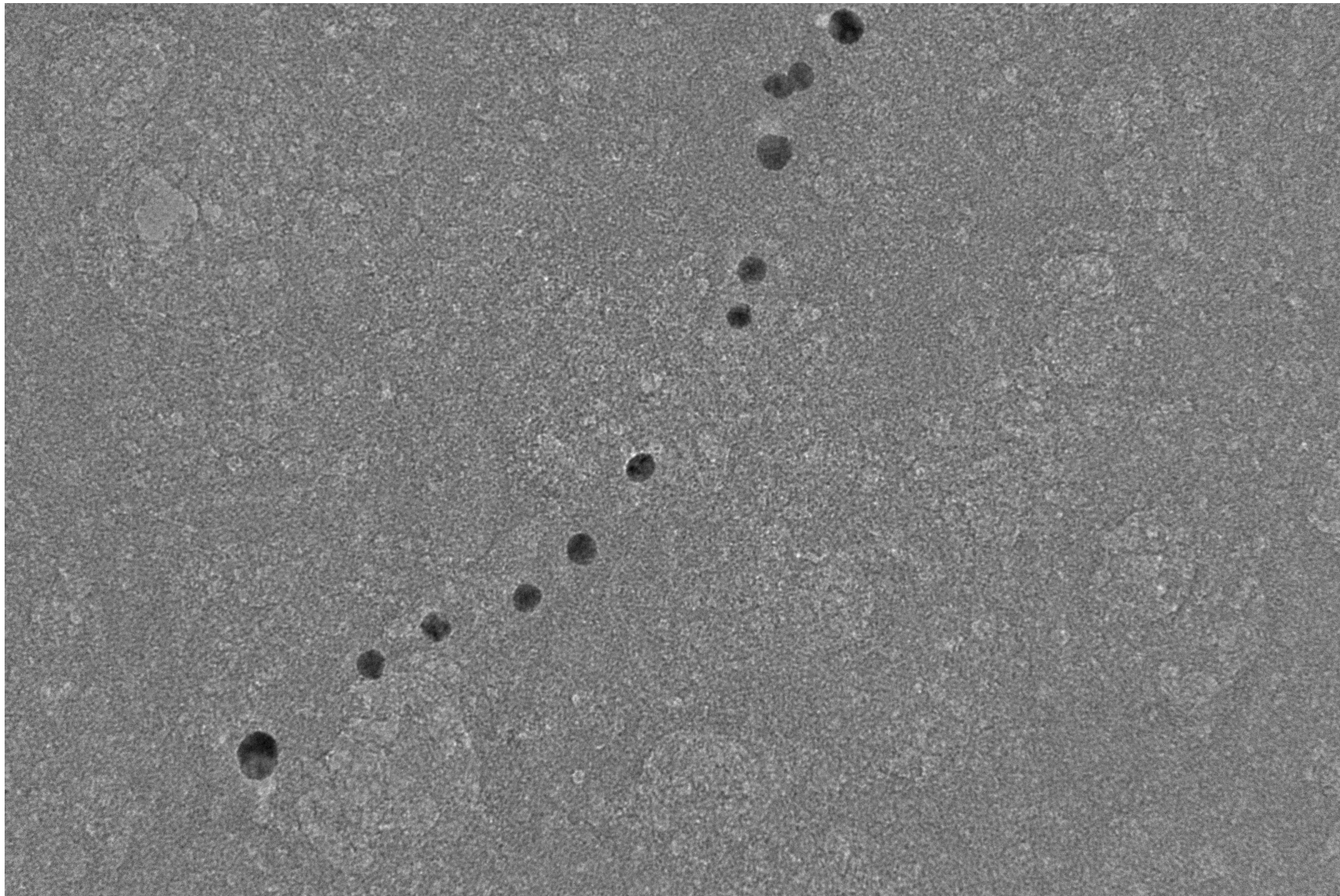


Gold nanoparticles bound on the virus



Cobalt oxide nucleation & growth

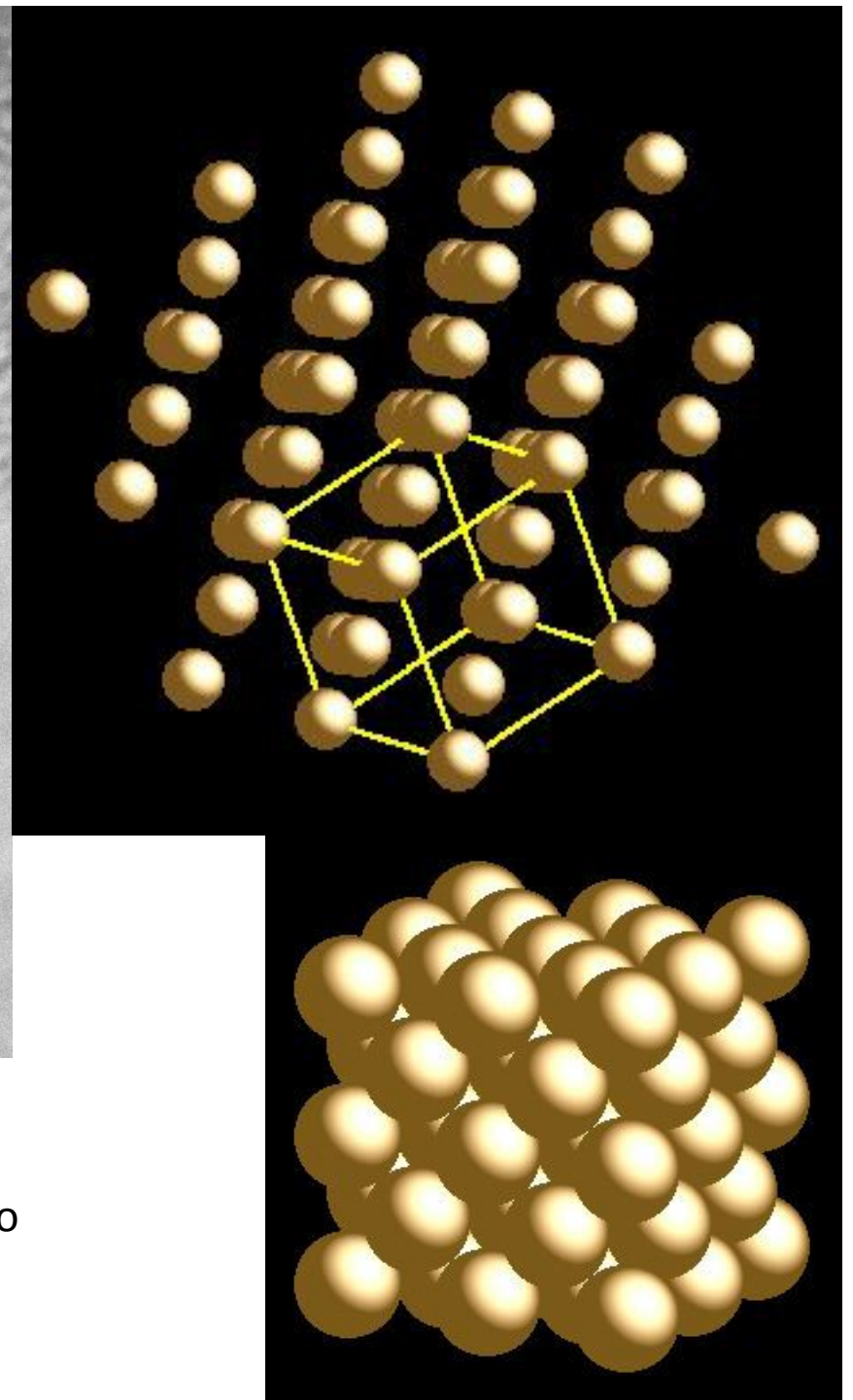
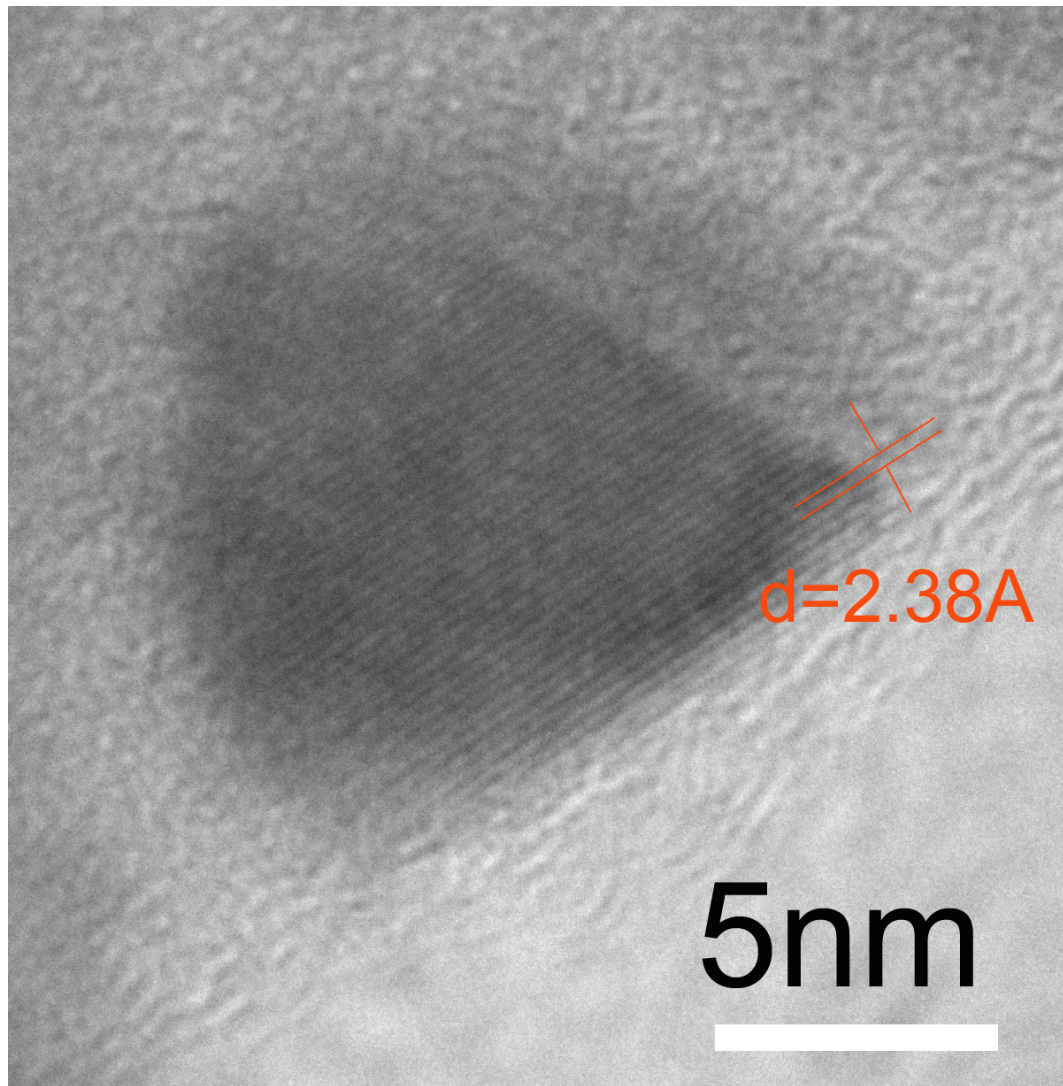
Has gene to grow co oxide and gene to bind gold



.tif
rint Mag: 81900x @ 51 mm
5:27 05/06/15

20 nm
HV=200kV
Direct Mag: 50000x

Purple MW 5nm

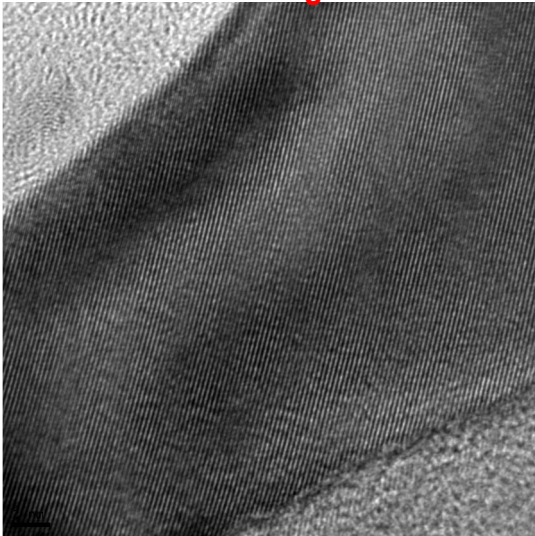


lattice distance is about 2.38Å, very close to the gold (111) plane's distance 2.36Å

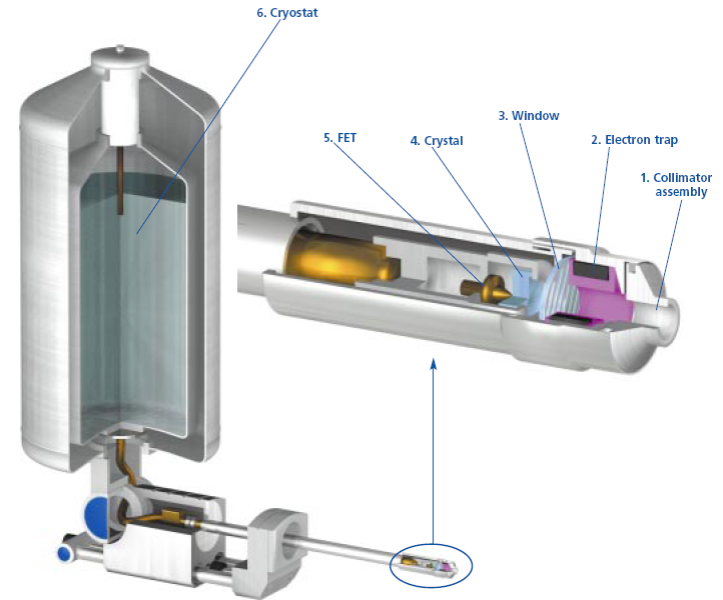
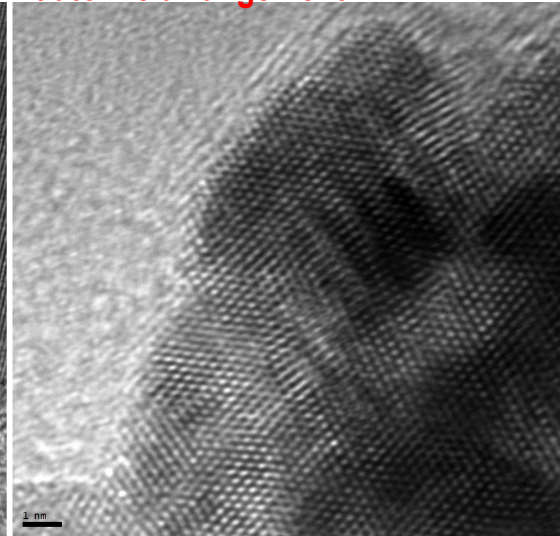
High Resolution Image and Element Analysis

EDS Detector Image

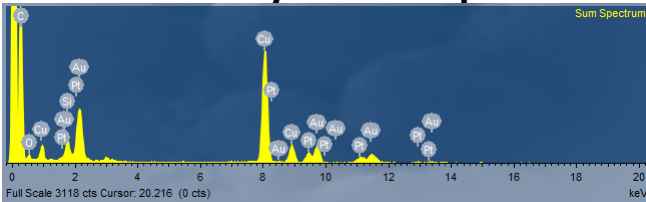
Au Nanowire HR image



Pt atomic arrangement



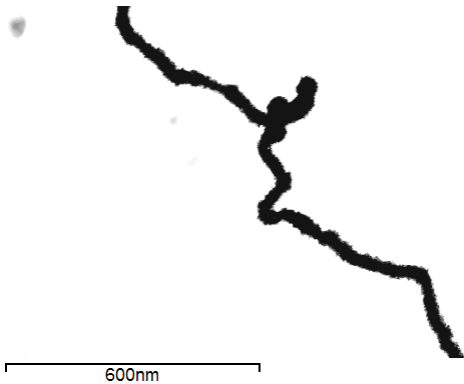
Chemical Analysis Examples -EDS



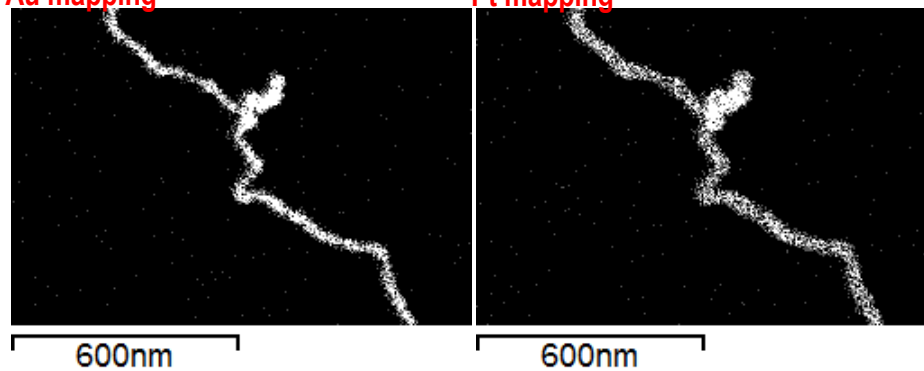
EDS SYSTEM

1. Detector : convert X-ray into electronic signal
2. Pulse Processor : determine the energy of each X-ray detected
3. MCA(Multi-Channel Analyzer) : display and interpret X-ray data

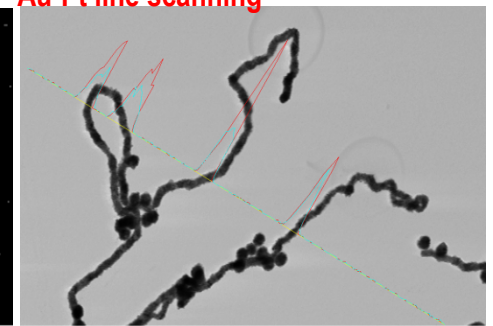
Au mapping



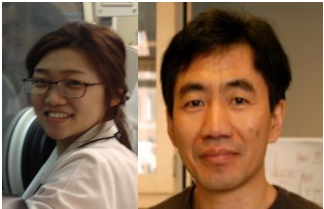
Pt mapping



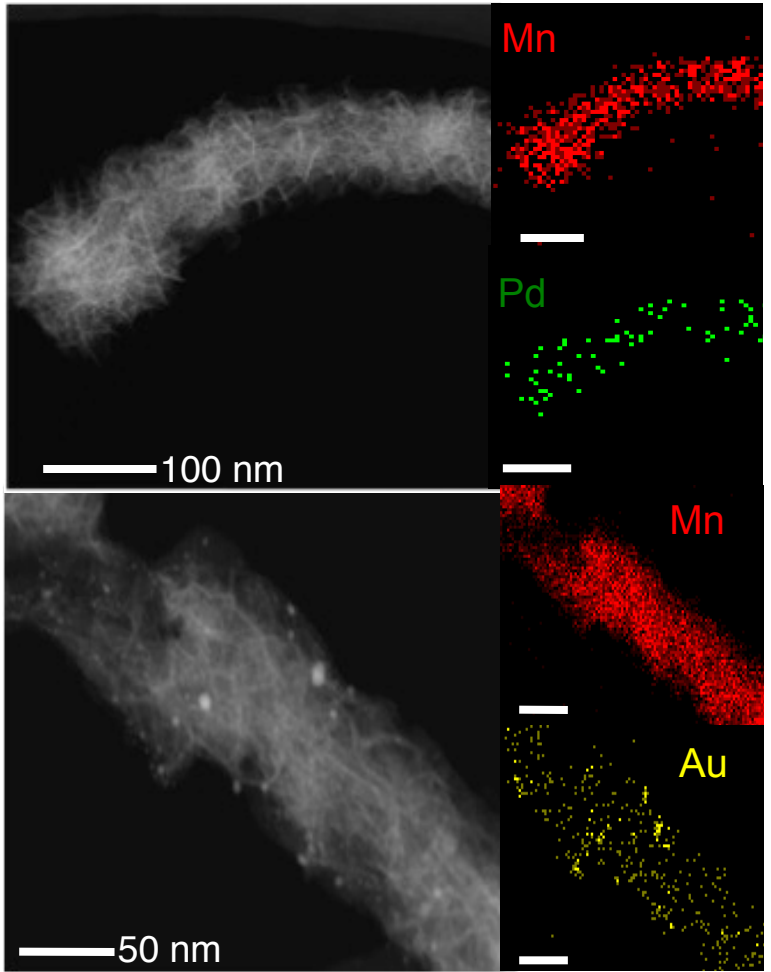
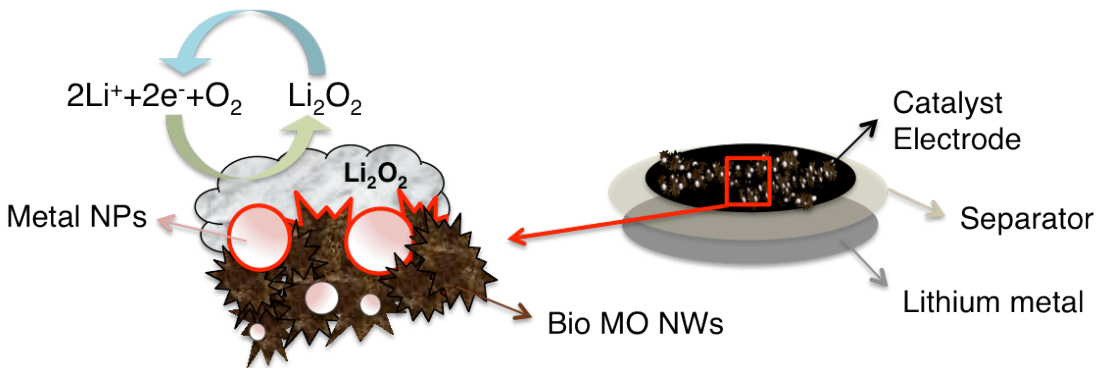
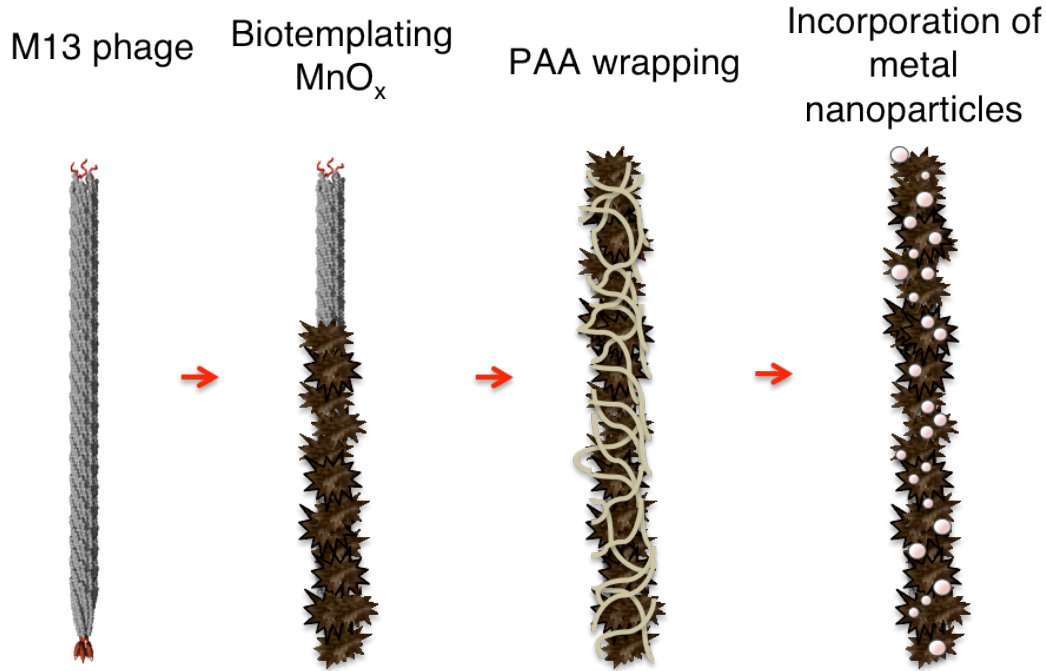
Au-Pt line scanning



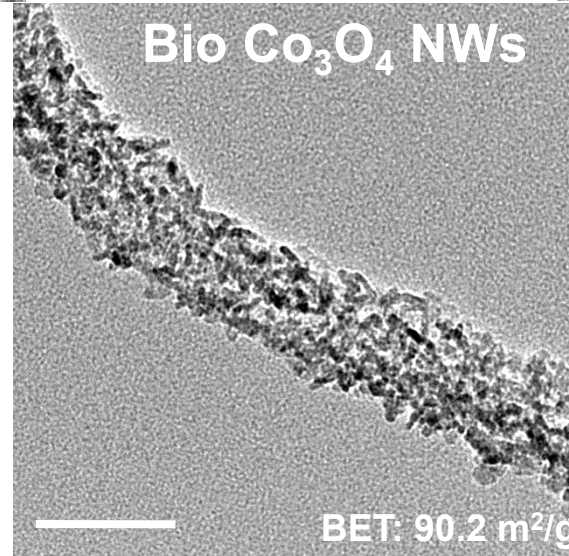
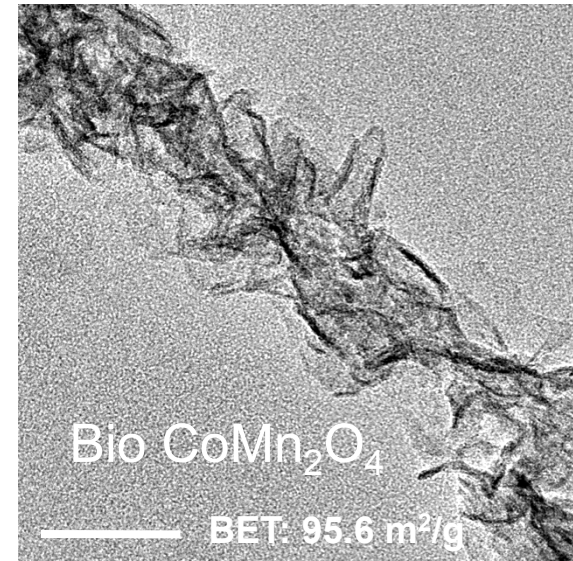
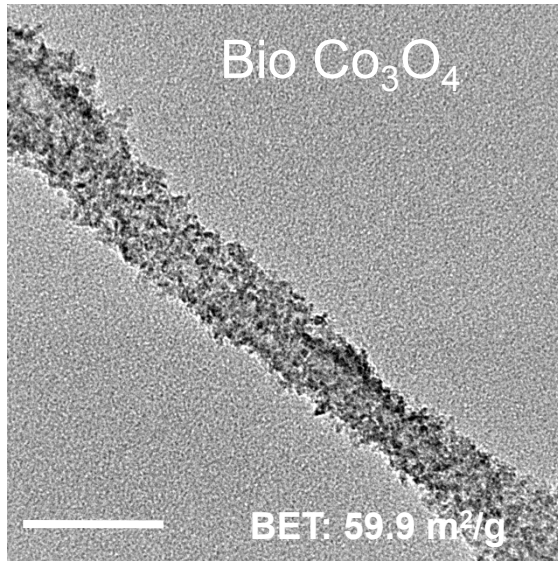
More improvement in catalytic activities by compositing small amounts of Pd nanoparticles



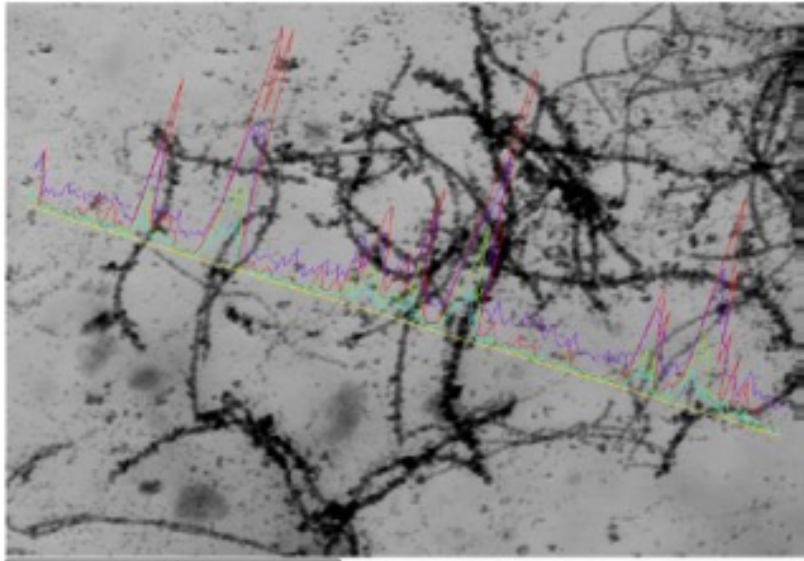
- Synthesis steps



Bio-templated $Mn_xCo_{3-x}O_4$ ($x=0,1,2$) nanowires for Li-air battery

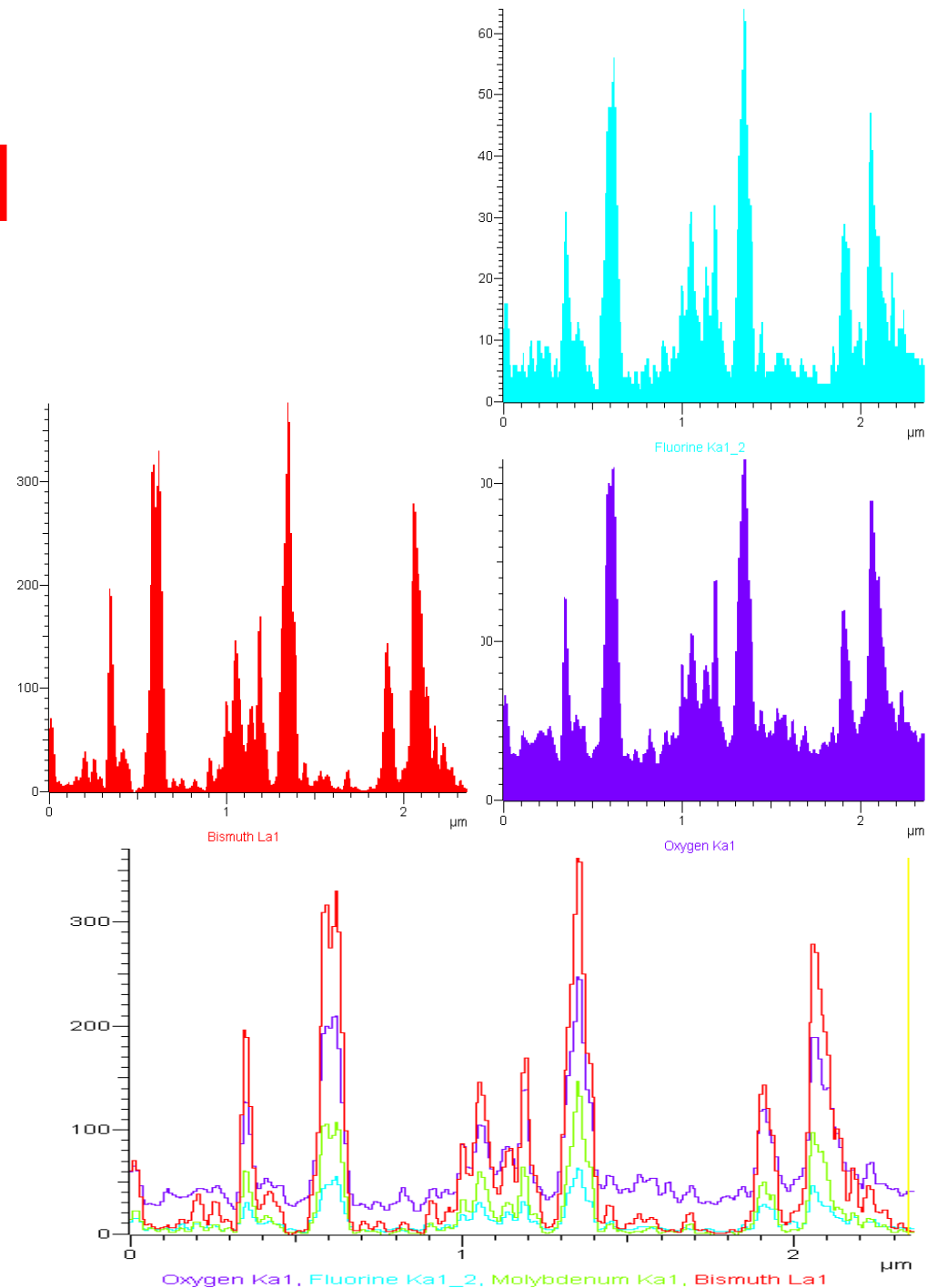


STEM

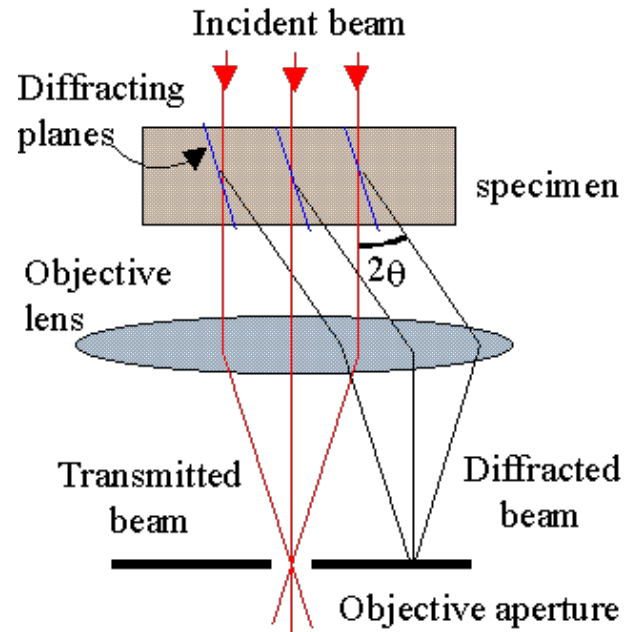


Bright field image of BiF_3 on M13 bacteriophage,

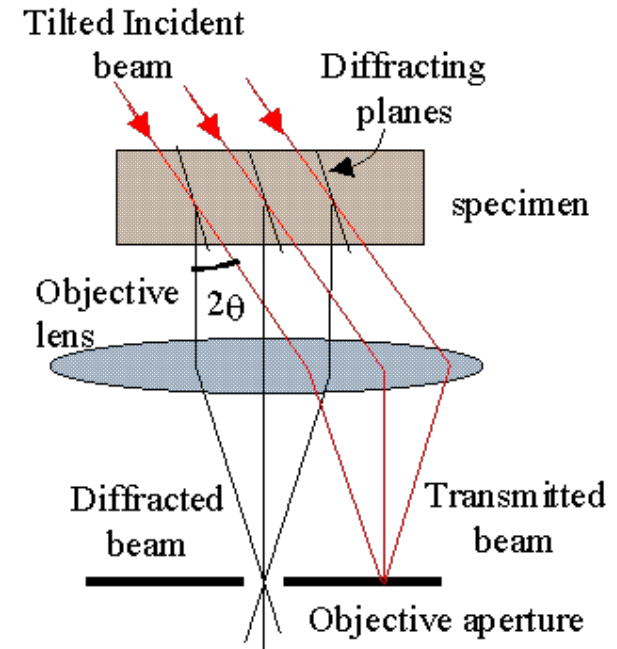
Each graph corresponds to a line scan showing where each element (Bismuth, Fluorine...) are present



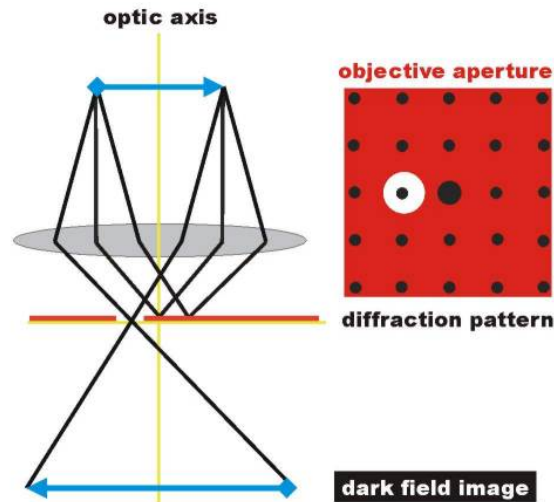
Dark Field



Bright Field Imaging

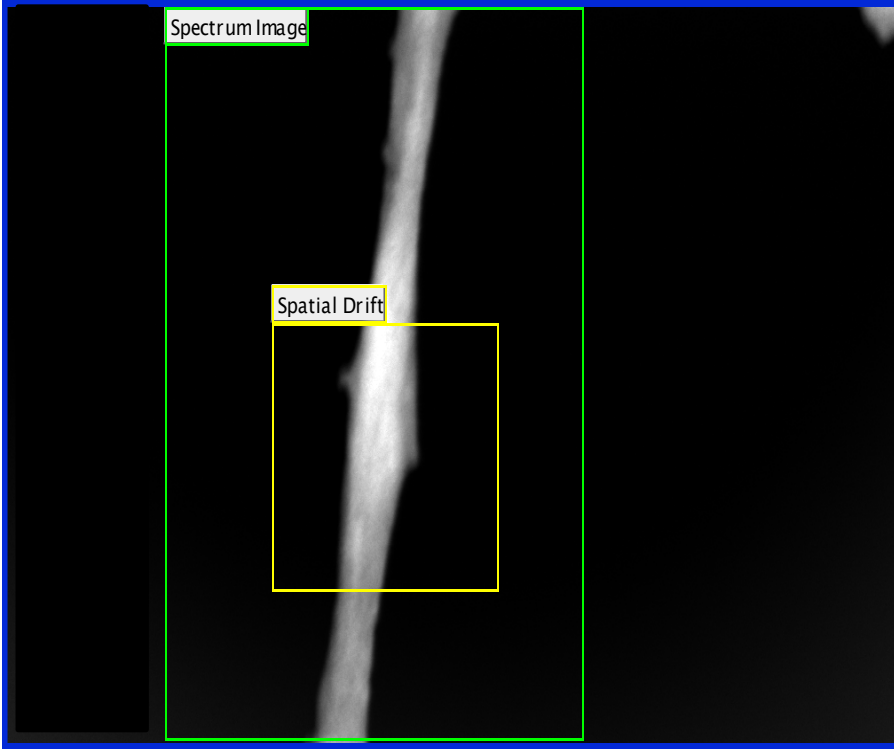


On-axis Dark Field

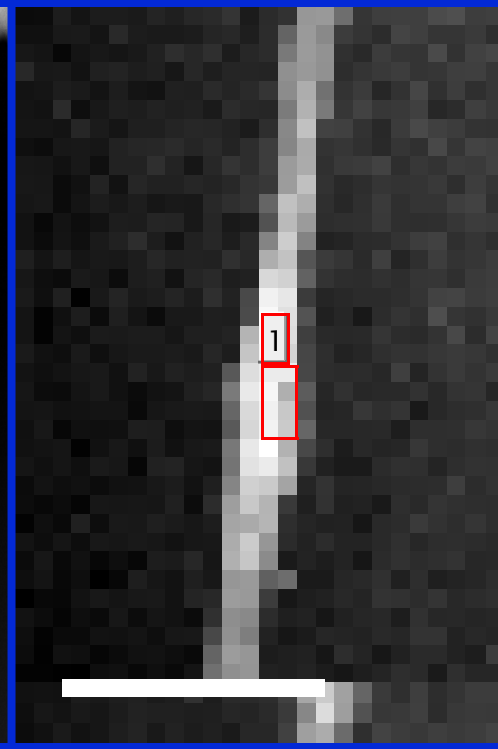


STEM-EELS

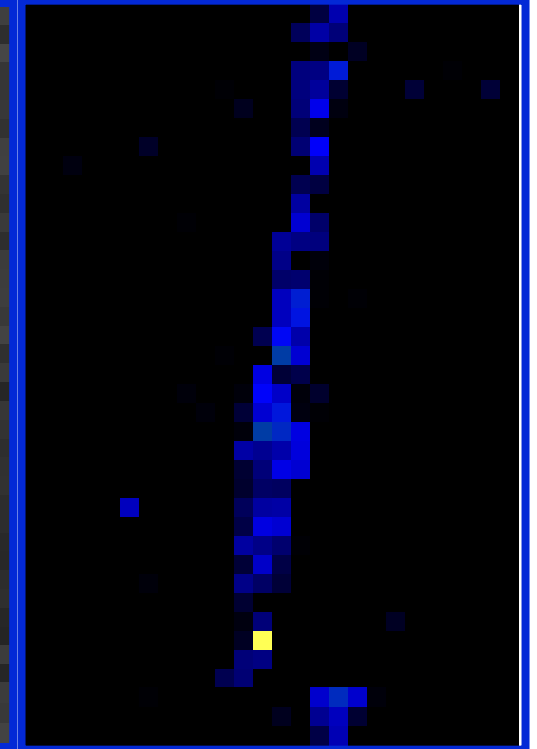
STEM-Dark Field Image



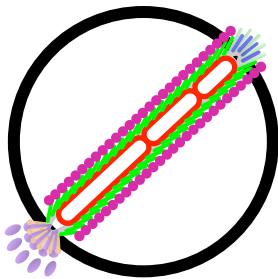
EELS Imaging from Green square Area



Fe L_{2,3} Core-edge Mapping



Observation area of Holey TEM Grid



The Belcher group

Extracted EELS spectrum from 1

