M3D4: Transmission Electron Microscopy (TEM)

5/3/2018

1. *Quick* Prelab Discussion
2. Two groups at a time go to TEM (Koch)
3. Class works on research proposal (**Presentations in one week! 20% of your grade!**)

Only three 20.109 days left!

- **M3 Assignments**
  - Research proposal (20%) 5/10 by 1pm
    - Upload slides to Stellar by deadline
    - Bring **1** print-out of your slides to 16-336
  - Mini-report (5%) 5/14 by 10pm
    - No abstract, no methods section
    - Background/Motivation, Figures and combined Results/Discussion
  - Final blog post about Mod 3: 5/12 by 10pm

Figures
elemental mapping (EDX)
TEM micrographs
capacity measurements

- **Extra Office Hours:**
  - Monday 5/7, 2-5pm, Noreen (16-317)
  - Tuesday 5/8, 10-11am, Leslie & Josephine (56-322)
  - Tuesday 5/8, 2-5pm, Noreen (16-317)
  - Wednesday 5/9, 10-12:30pm, Leslie & Josephine (56-322)
  - Wednesday 5/9, 2-5pm, Noreen (16-317)
  - Thursday 5/10, 10-11am, Josephine (56-341c)

MIT BE BIOLOGICAL ENGINEERING | Communication Lab

Make Comm Lab appointments!

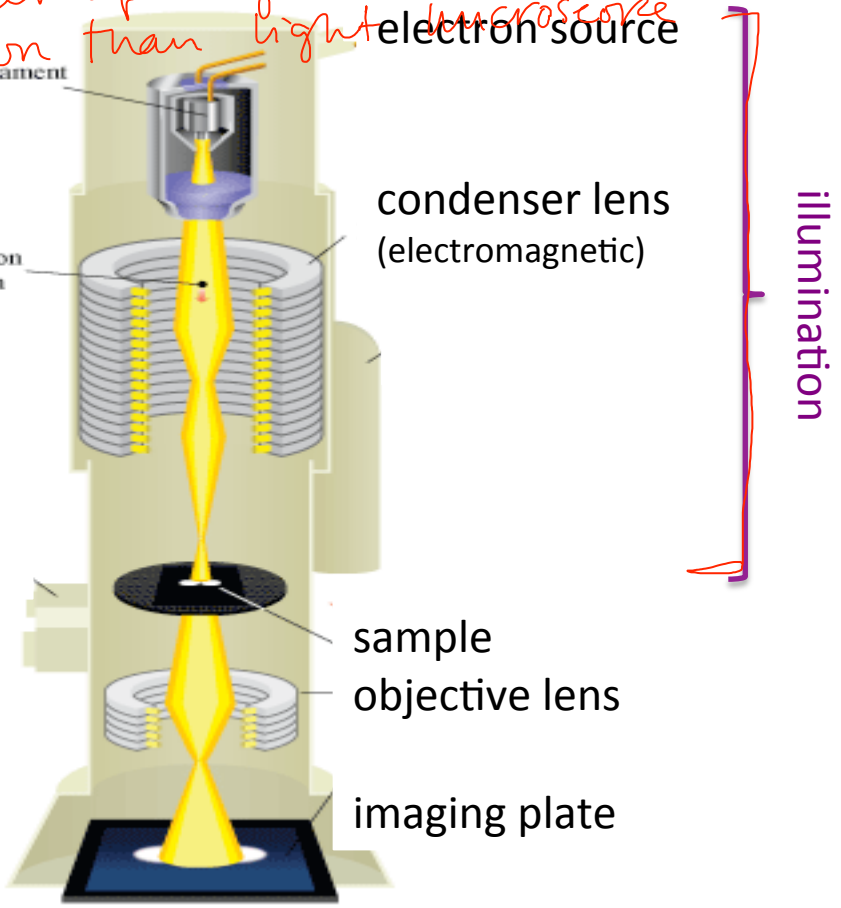
TEM: foundations

1931 Ernst Ruska (1986 Nobel Physics)

EM 5 order of magnitude higher resolution than light microscope

- High resolution ~ 1 Å = 0.1 nm
  - de Broglie wavelength $\lambda_{(e-)}$ ~ 0.0025 nm
  - Compare to $\lambda_{(\text{blue light})}$ ~ 400 nm
  - Rayleigh $R_{light} = 0.61 * \lambda / NA$

- Electron source:
  - Thermionic emission by tungsten
  - Accelerating voltage ~ 200 kV
  - Focusing lenses electromagnetic
  - Vacuum b/c gas diffuses e^-

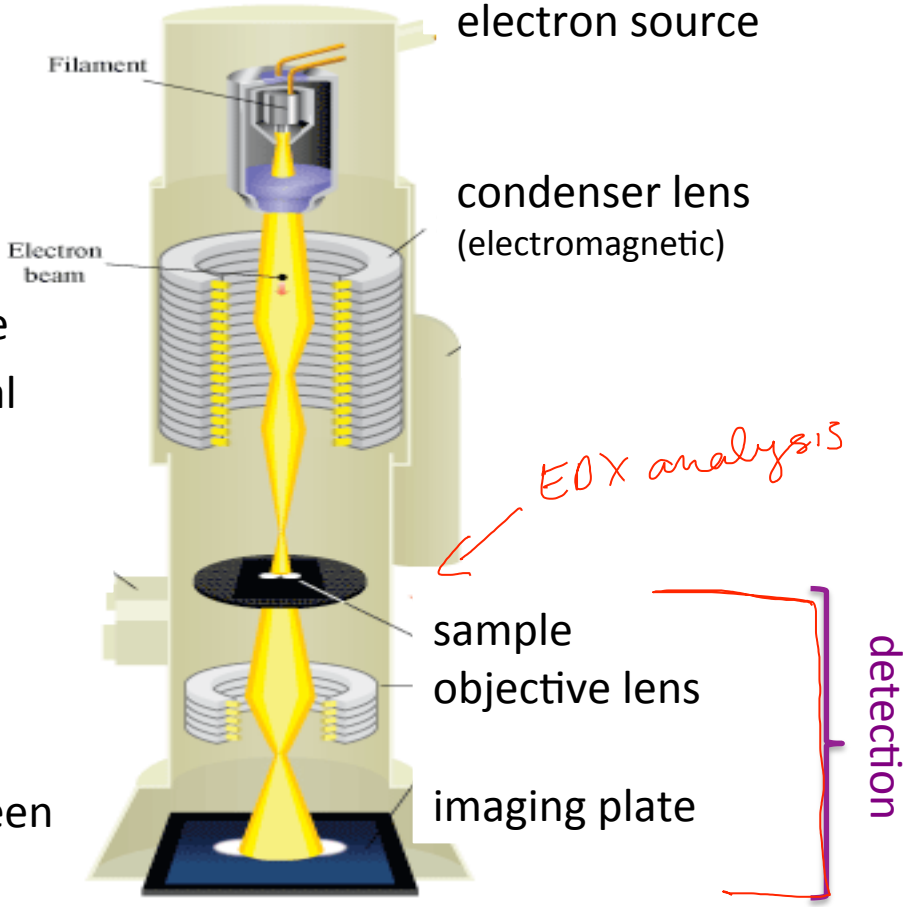


TEM: foundations

1931 Ernst Ruska (1986 Nobel Physics)

- Sample preparation
  - Thin and sturdy (10nm –100µm)
  - Grid: copper —sturdy and conductive
  - Biomaterials coated in e^- dense material

- Image ≈ sample electron density
  - e^- pass through & are also scattered
  - phosphor screen (visualization by eye), YAG-coupled CCD (capture image)
  - e^- → photons, image on film or screen



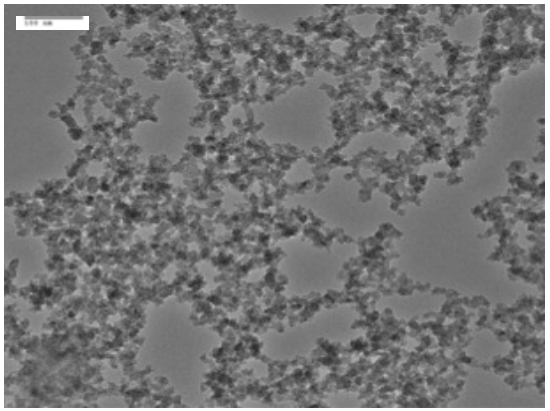
hk-phy.org

TEM micrographs

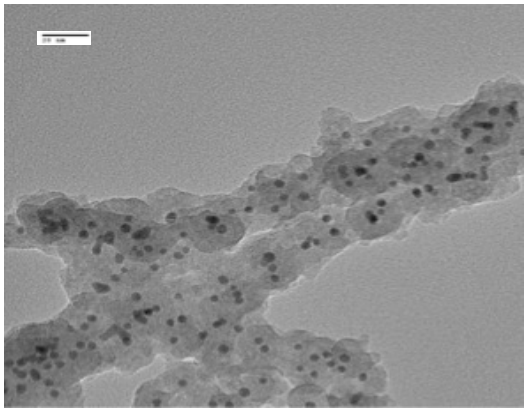
Results/Discussion

What will you learn?

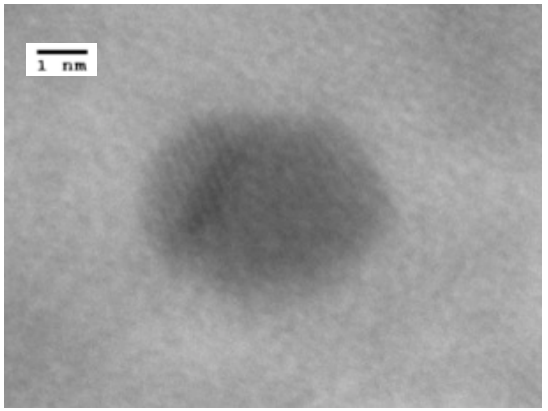
- At low resolution: uniformity, morphology of biomineralization
  length or diameter of nanowires, estimate # NPs per phage (800-900 nm)
- At high resolution:
  size of NP in active material, amorphous vs. crystalline FePO4
  material type



low



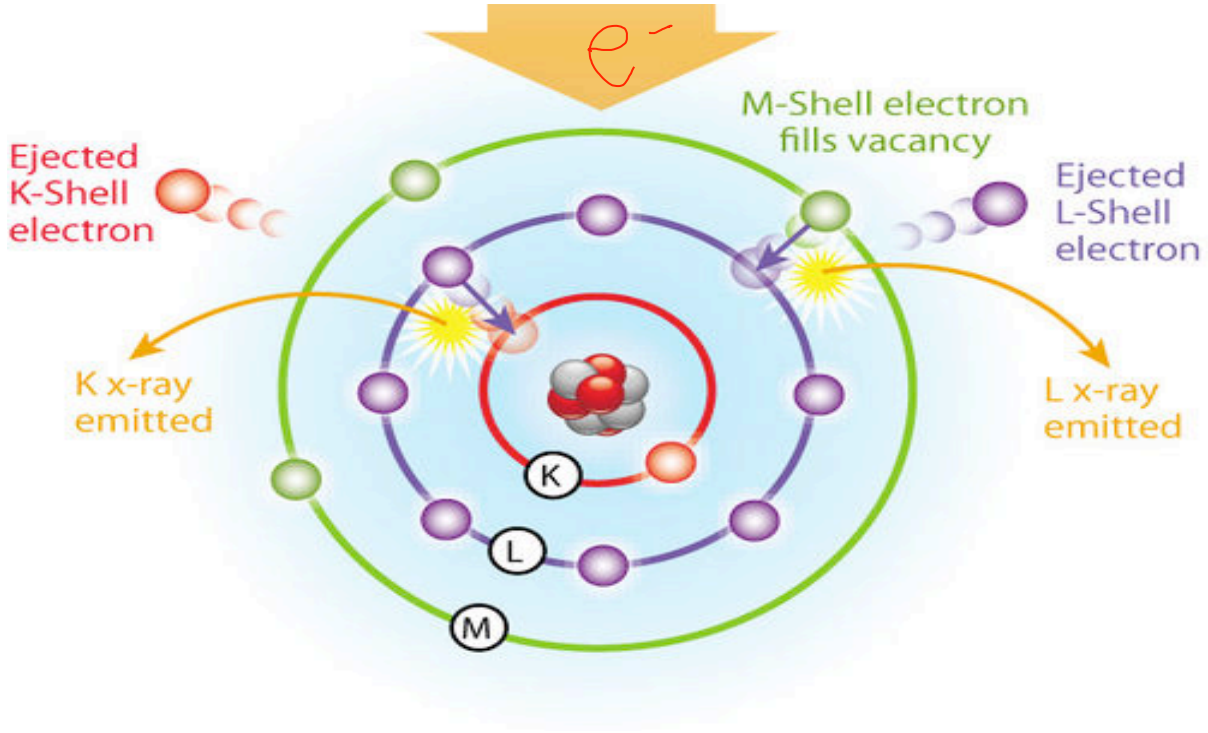
from Spring 2016 20.109



high

Elemental mapping by energy dispersive x-ray spectroscopy (EDX)

- X-ray emission spectrum is characteristic of unique atomic structure of element



EDX analysis on JEOL, JEM2100

Results/ Discussion

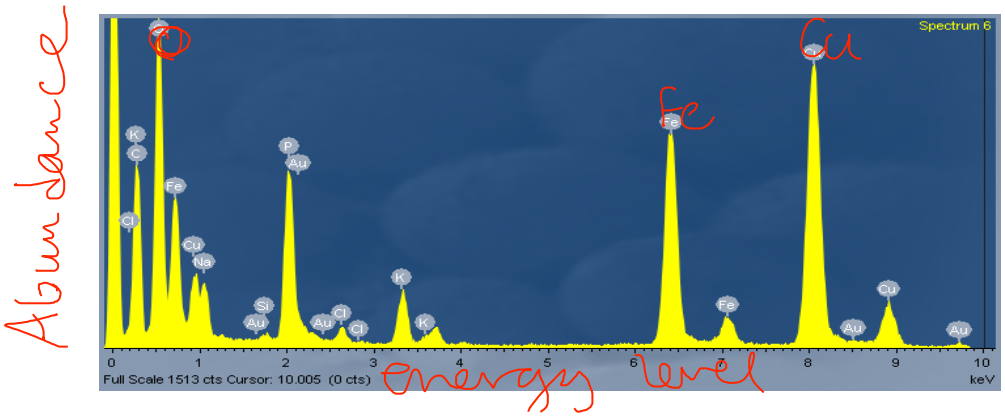
EDX: energy-dispersive X-ray spectroscopy analysis

- Atomic composition of heavier elements in material
- X-ray emission spectrum is characteristic of unique atomic structure of element
- Expected:

iron, phosphate, oxygen, gold, copper, carbon

- Contamination:

Sodium, calcium, silicon



Today in lab…

- TEM in Koch basement
  - ➢ What can your TEM images suggest about the phage biomineralization and AuNP binding? Are the NP the size expected?
- *Use your time wisely:*
  - draft your research proposal slides
  - discuss how the presentation speaking parts will be shared
  - draft talking point notes for presentation
  - **Review rubric** on wiki to make sure you are including all components necessary
- M3D5HW: Calculate mA needed to discharge your experimental battery (choose 1 cathode weight if had more than 1) battery in 10 hrs, handwritten or emailed calculations are fine, **turn in individually**
- Reminder: Quiz M3D5 on Tuesday