M3D4: Transmission Electron Microscopy (TEM)

1. Prelab Discussion
2. One group at a time to TEM(Koch)
3. Class works on research proposal (Presentations in one week!)

Only three 20.109 days left!

Figures
TEM
capacity data
elemental mapping

- **M3 Assignments**
  - Research proposal (20%) 5/9 by 1pm
    - Upload slides to Stellar by deadline
    - Bring 1 print-out of your slides to 16-336
  - Mini-report (5%) 5/13 by 10pm
    - No abstract, no methods section
    - Background/Motivation, Figures and combined Results/Discussion
  - Final blog post 5/11 by 10pm
- **Extra Office Hours:**

Please email us if you plan to come so we can schedule the time and prepare to discuss your topic

- M 2pm-5pm Leslie
- W 10am-12pm Noreen
- W 5:30pm-7:30pm Leslie
- Th 10am-12pm Noreen
- Email us to set up a time outside of these

MIT BE BIOLOGICAL ENGINEERING Communication Lab *Make Comm Lab appointments!*

Electron microscopy pushes past a fundamental limit of light microscopy

Wavelength	Illumination Source	Resolution Limit
700 nm	Red Light	250 nm (*Diffraction*)
400 nm	Purple Light	140 nm (*Diffraction*)
0.1 nm	Electrons	0.2 nm (*beam width*)

M13 Phage 6 × 900 nm

Au-Au Spacing 0.3 nm

EM 5 orders of magnitude higher resolution than light

TEM: foundations

~3X order of mag

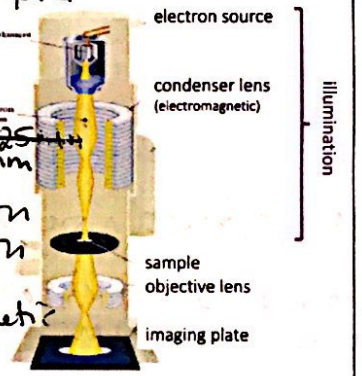
1931 Ernst Ruska (1986 Nobel Physics)

- High resolution 1 Å = 0.1nm
  - light microscope: $\lambda_{(red\ light)}$ ~ 250 nm
  - TEM: de Broglie wavelength $\lambda_{(e-)}$ ~ ~~0.0025 nm~~ 0.1nm
  - Rayleigh $R_{light} = 0.61 * \lambda / NA$ (numerical aperture) ~ 1

Resolution limit depends on wavelength

- Electron source:
  - Thermionic emission by tungsten
  - Accelerating voltage ~ 200 kV
  - Focusing lenses electromagnetic
  - Vacuum

gas diffuses e-

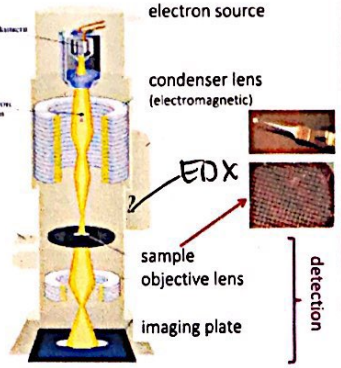


Copper Conductive: allows heat or electrons to pass through

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



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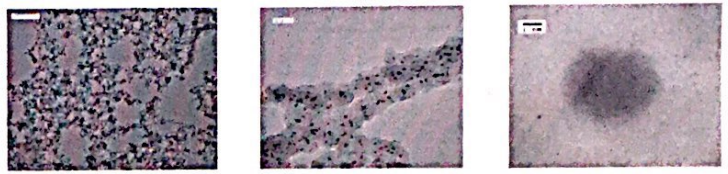
Results/Discussion

What information do you learn from TEM micrographs?

- At low resolution: uniformity, morphology of biomin length (or) diameter, estimate of NP per phage
- At high resolution:

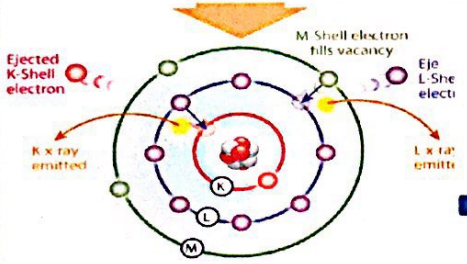
Size of NP, amorphous v crystalline $FePO_4$

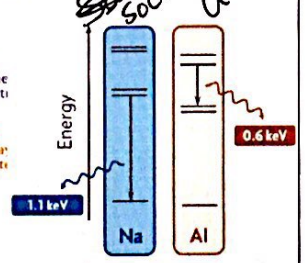


low — from Spring 2016 20.109 — high

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

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





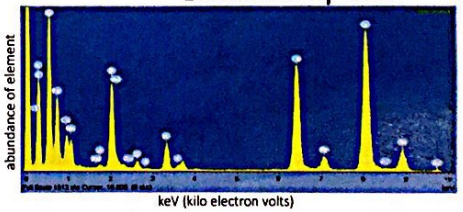
Salt Sodium Aluminum

Results Discussion

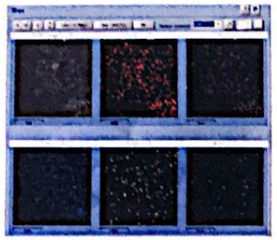
EDX analysis on JEOL, JEM2100

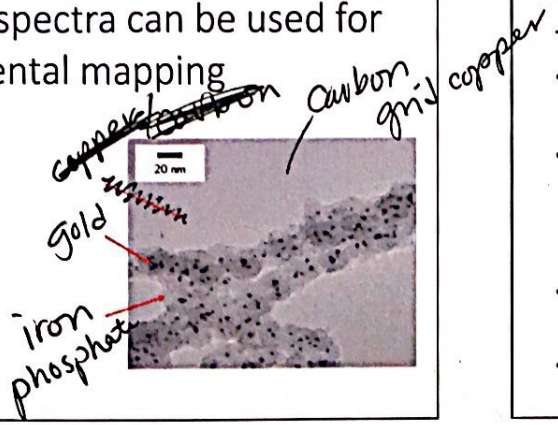
EDX: energy-dispersive X-ray spectroscopy analysis

- Atomic composition of heavier elements in material
- X-ray emission spectrum is characteristic of unique atomic structure of element
- Expected elements: iron, phosphate, oxygen, gold, copper
- Contaminating elements: sodium, calcium, silicon carbon



X-ray emission spectra can be used for elemental mapping





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 cathode) battery in 10 hrs, handwritten or emailed calculations are fine, turn in individually
- Reminder: Quiz Tuesday M3D5