# M3D4:
# TEM

12/01/2015

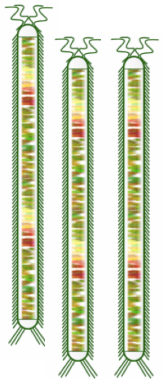
# Only 3 days left ?!#?

- M3 mini-report **2-3 pages , IN TEAMS**
  - *officially* due Thursday, Dec. 3rd at 10pm
  - **practically, Stellar will be downloaded at 7am on Monday**
- M3 research proposal
  - feedback on your M3D4 homework on Dec. 3rd
  - office hours on Sunday, Dec. 6th 10am – 5pm in 56-302
  - slides due Tuesday, Dec. 8th at 1pm
  - bring **two** print-outs of your slides
- Quiz on M3D5
- Blog
  - due Saturday, Dec. 12th at 5pm

# Module 3: biomaterials engineering

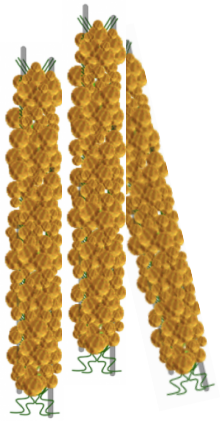
Purify
M13 phage

**DAY 1**



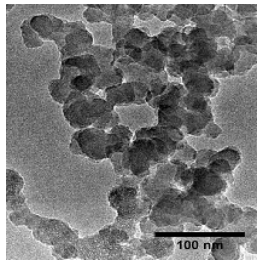
Biomineralize
Fe(III)-phage

active material



Visualize
nanowires
on TEM

**DAY 4**




Purify
active material

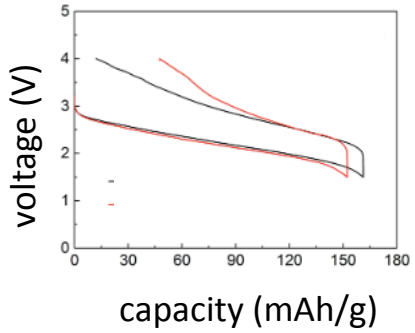
**DAY 2**

Construct
cathode
(and battery)

**DAY 3**

Measure battery
capacity

**DAY 5**

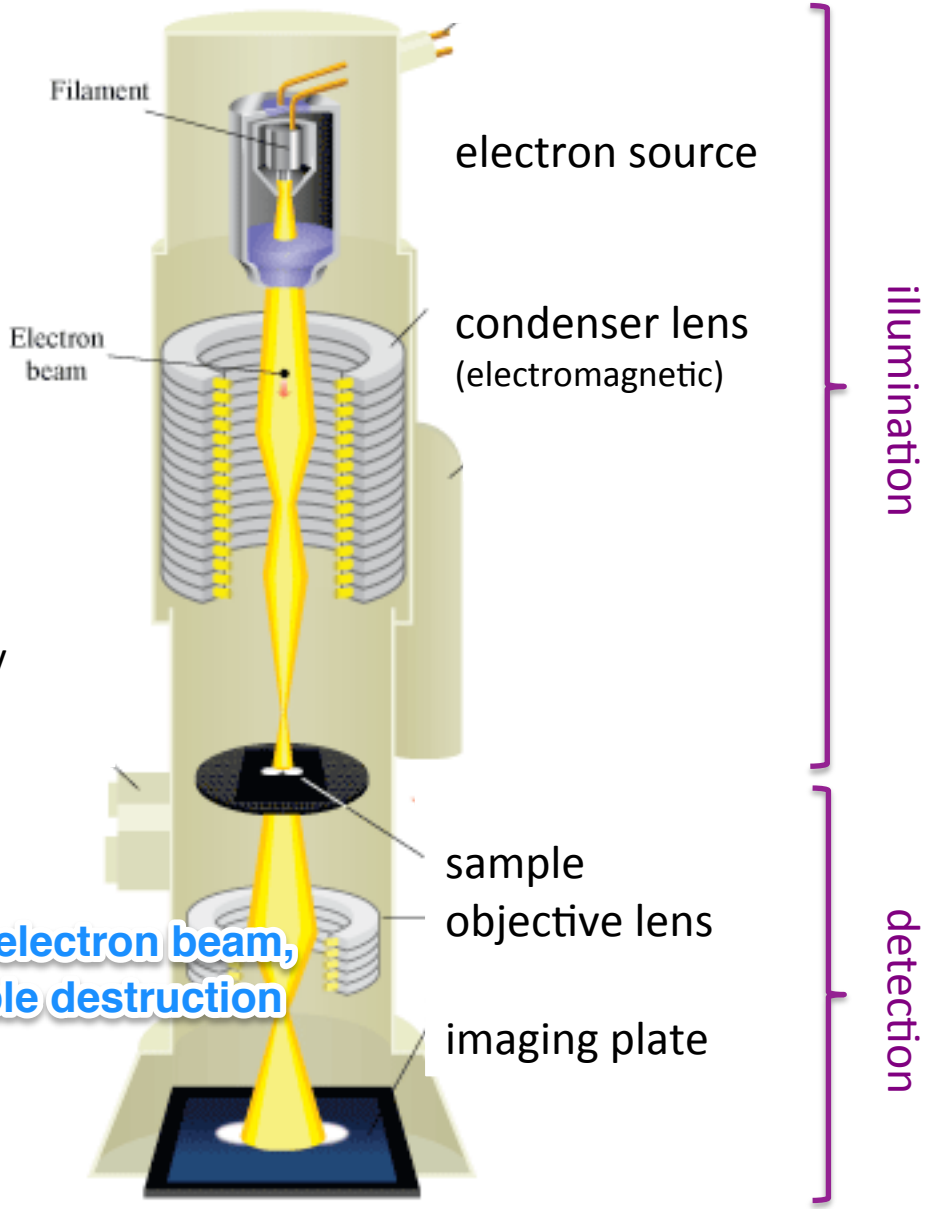


# TEM: foundations

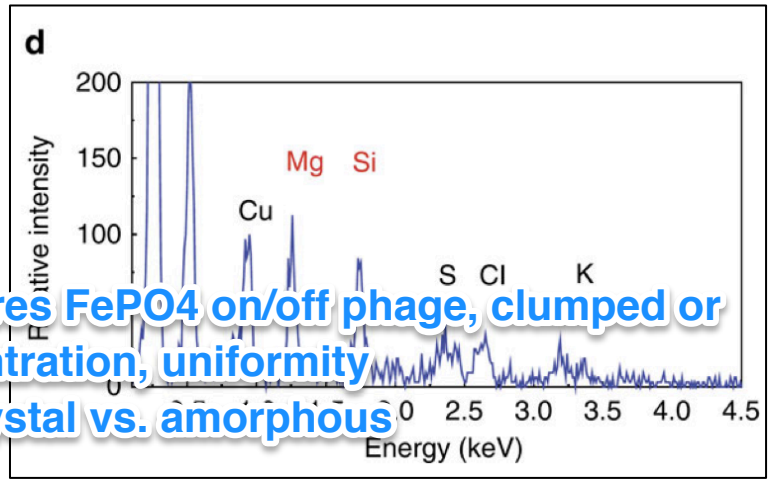
## transmission electron microscopy

1931 Ernst Ruska (1986 Nobel Physics)

- High resolution ~ **0.1 nm = 1 A**
  - de Broglie wavelength $\lambda_{(e-)}$ ~ **5 pm**
  - compare to $\lambda_{(blue\ light)}$ ~ 400 nm
  - Rayleigh $R_{light} = 0.61 * \lambda / NA$
- Electron source:
  - thermionic emission by tungsten, ~ 100 kV
  - vacuum and focusing lenses
- Sample preparation
  - thin and sturdy **10 nm - 100 um**
  - grid: **copper, conductive disperses electron beam,**
  - biology: not *in situ* **prevents sample destruction**
- Image ≈ sample *density*
  - $e^-$ pass through & are also scattered
  - phosphor screen, YAG-coupled CCD



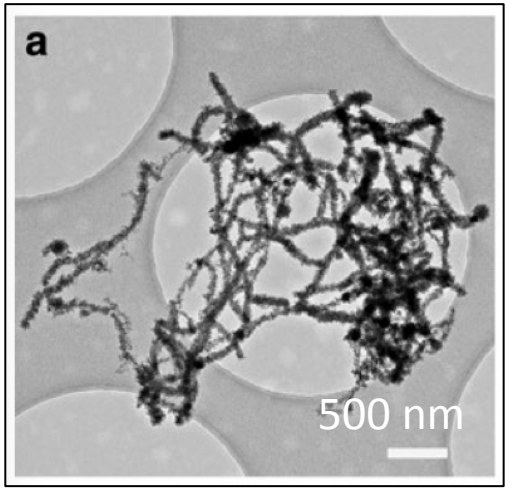
# TEM: your experiment

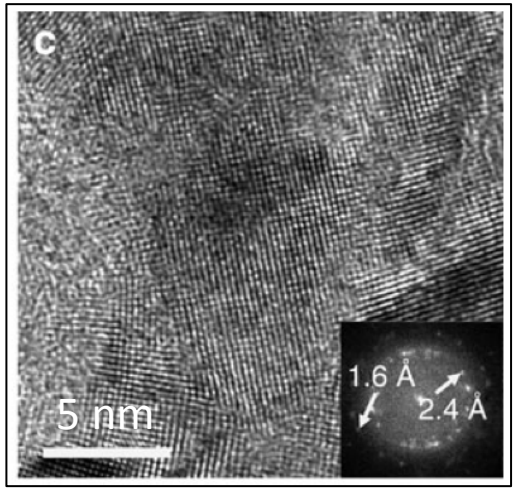


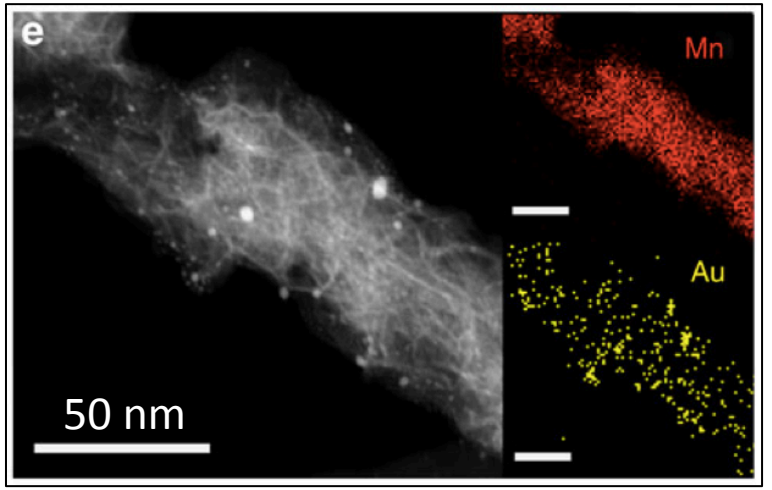

- What will you learn?
- at low resolution: - overall shape of nanowires $FePO_4$ on/off phage, clumped or elongated, length, concentration, uniformity
- at high resolution: - diameter ~ 10-15 nm, crystal vs. amorphous
- EDX:

energy-dispersive X-ray spectroscopy analysis

- atomic composition of heavier elements in material (> $Na^{11}$)
- X-ray emission spectrum is characteristic of unique atomic structure of element
- expected: Fe, P, (Cu)




from Belcher Lab's *Nature Communications* 2013, doi:10.1038/ncomms3756

# Today in lab

- TEM in 13-1012
  - 1:45pm: pink/blue/orange
  - 3:15pm: red/green teams
  - ➢ How do TEM images relate to phage number ?

    M3D1: you chose 2 x $10^{11}$, or 2 x $10^{12}$, or 2 x $10^{13}$ M13 bacteriophage

- Get ahead!
  - M3 research proposal
  - Blog
  - M3 mini-report
  - Any other class in life?