M3D5:
Battery assembly and testing

05/06/2016

The final countdown…

- Lab notebook entry
  - M3D2 graded (share with jonas_m@)
- M3 mini-report
  - due on Stellar at 10pm tonight
  - extra office hours: 6pm – 10pm in 16-220
- M3 research proposal
  - extra office hours: Sunday, May 8th, 11am – 5pm in 56-302
  - slides due on Stellar Wednesday, May 11th at 1pm
  - bring one print-out of your slides to 16-336
- Blog post(s)
  - due Saturday, May 14th at 11am
- Visit BE Communication Lab

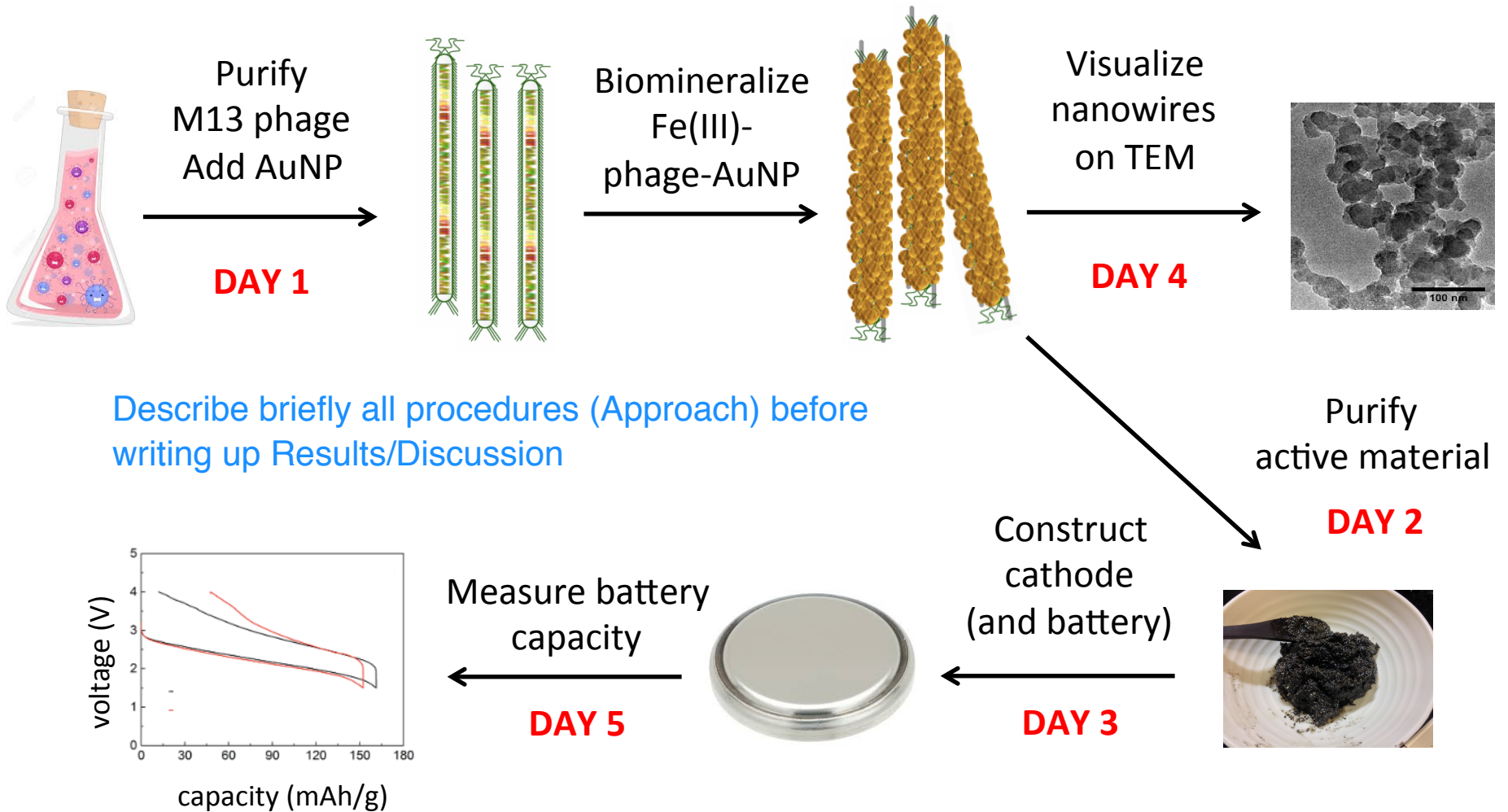# Module 3 overview: biomaterials engineering

Purify
M13 phage
Add AuNP

DAY 1

Biomineralize
Fe(III)-
phage-AuNP

Visualize
nanowires
on TEM

DAY 4

Describe briefly all procedures (Approach) before
writing up Results/Discussion

Purify
active material

DAY 2

Construct
cathode
(and battery)

DAY 3

Measure battery
capacity

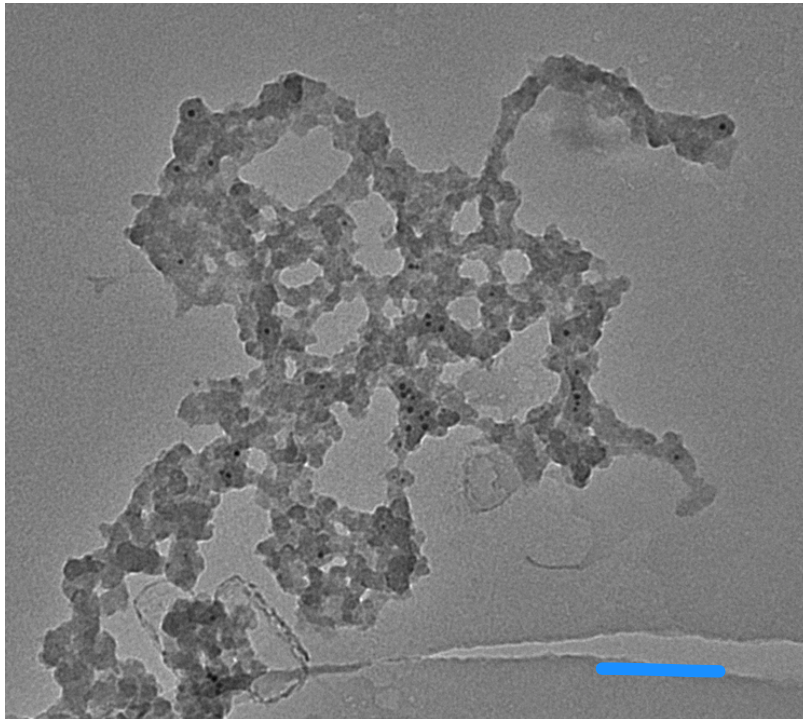**DAY 5**

voltage (V)

capacity (mAh/g)

Figure: TEM images

- at low magnification:
  - extent of biomineralization
  - distribution of gold
  - overall structure & density
  - uniformity
  - length of nanowires

- at high magnification:
  - size of gold nanoparticles
  - lattice of gold atoms (*i.e.* 111)
  - amorphous vs. crystal Fe(III)PO$_4$
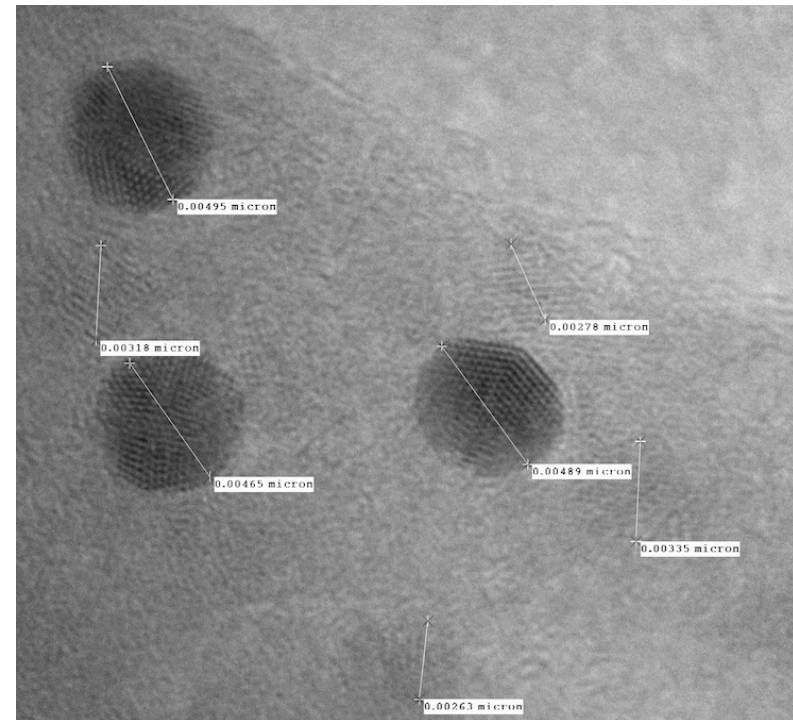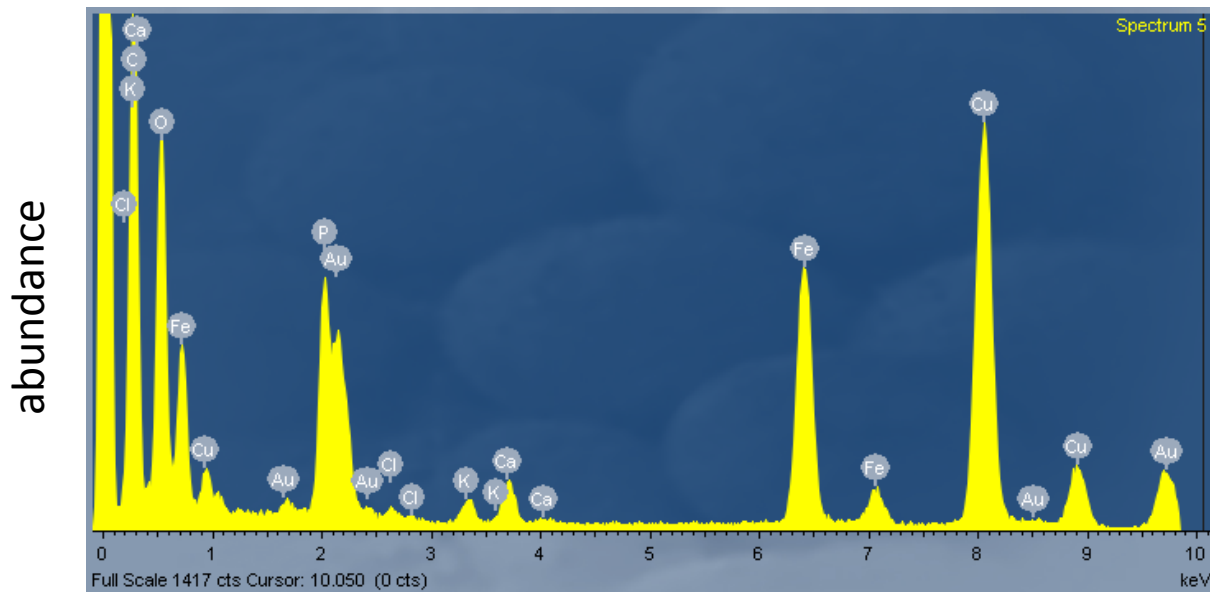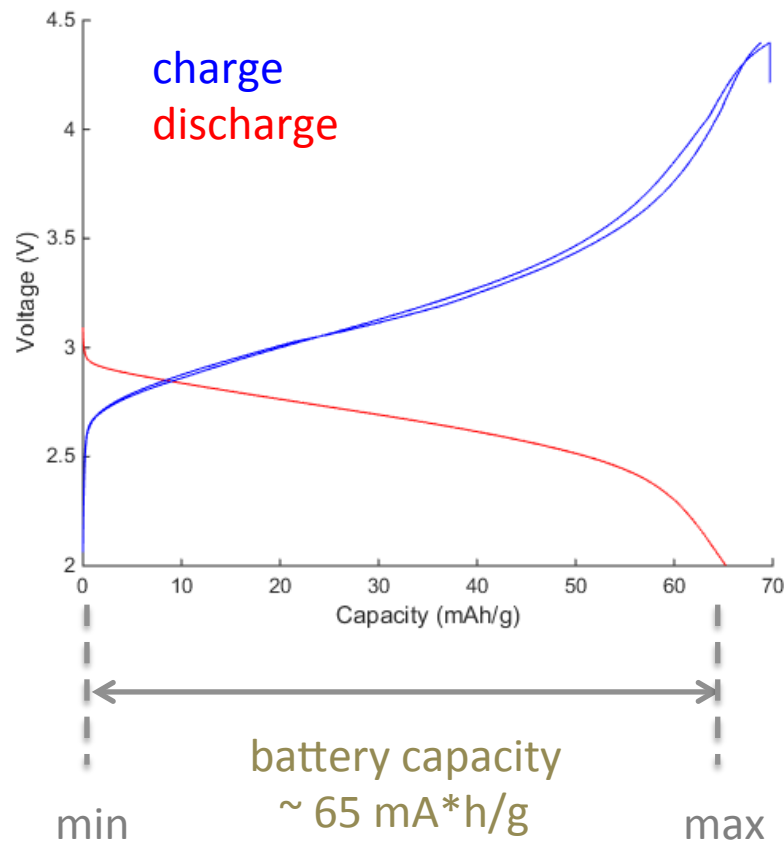 - diameter of nanowires

scale bar

Figure: EDX elemental mapping

- expected: Fe, P, O, Au, (Cu)
  - contamination? Na, Cl, K, Ca (from diH$_2$O)
  - Si   X-ray detector
  - stoechiometric ratios?   iron : phosphate = 1 : 1?

Element	Atomic%
C K	55.01
O K	22.88
P K	5.04
Cl K	0.24
K K	0.46
Ca K	0.77
Fe K	5.46
Cu K	9.34
Au L	0.79
Totals	

Result / figure: Battery capacity

charge
discharge

battery capacity
~ 65 mA*h/g

min   max

- Theoretical capacity of Li – LiFe(II)PO4 battery: 178 mA*h/g

- Practically
    - analyze cycling data
    - summary by Jifa in *test summary.xlsx*

- Galvanostat:
    - keep current constant (- 17.8 mA/g for 10h discharge)
    - record voltage (ideally constant)
    - as charge (capacity) stored in battery fluctuates (drops during discharge)

Battery capacity calculation

|	Time	Voltage (V)	Current (A)	Charge (Ah)	Capacity (Ah/g)	during discharge:
1	Time	Voltage (V)	Current (A)	Charge (Ah)	Capacity (Ah/g)	during discharge:
2	00:01.0	3.086303711	-0.000000005	-2E-12		M = max capacity
3	00:02.0	3.086791992	-0.000000006	-3E-12		m = min capacity
4	00:03.0	3.087158203	-0.000000005	-5E-12		
5	00:04.0	3.087524414	-0.000000004	-6E-12		battery capacity = M - m
6	00:05.0	3.087890625	-0.000000005	-7E-12		
7	00:06.0	3.088256836	-0.000000005	-8E-12		

- Ensure capacity units are A*h/g
- Remember cathode is (in weight)
  - 70% active material: 63% $Fe(III)PO_4$ + 7% phage
  - 25% Super P carbon
  - 5% PTFE binder

Does gold size/quantity affect battery capacity?
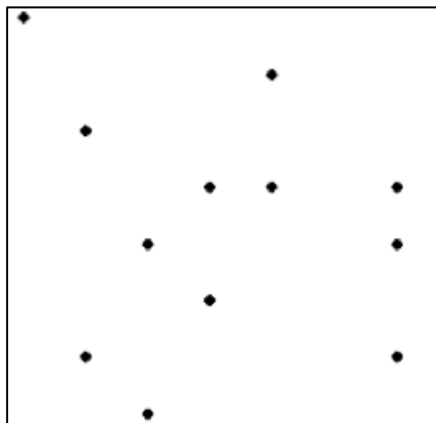
- Use class-wide data
  - *test summary.xlsx* from Jifa for all capacities
  - M3D5 Discussion page for AuNP size & quantity

Today in lab:
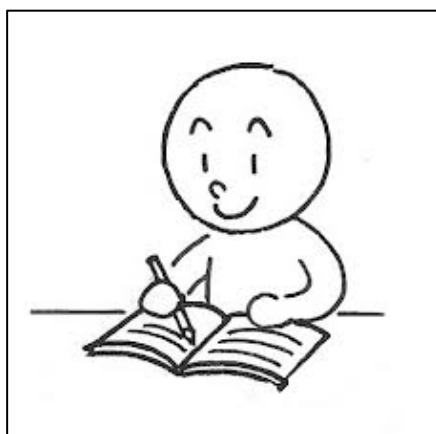
- Demo in Belcher Lab
  - 1:45pm: blue / pink
  - 2:45pm: red / orange / purple
- Finish your M3 mini-report early!