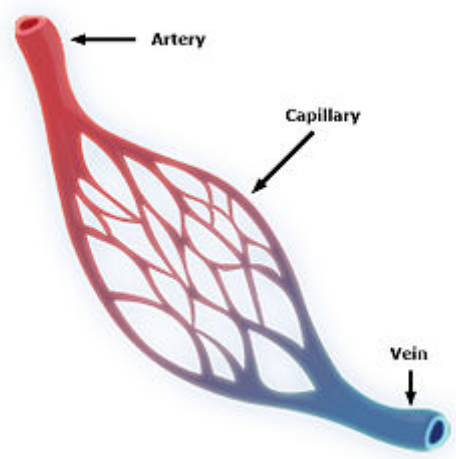
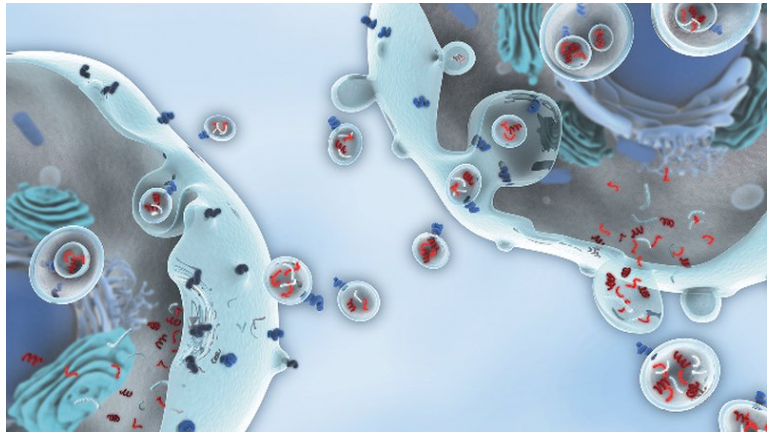
Capillary μ-RheoSANS: Lipid Vesicle Nanostructure and Rheology at High Shear

Marshall Nakatani

Motivation

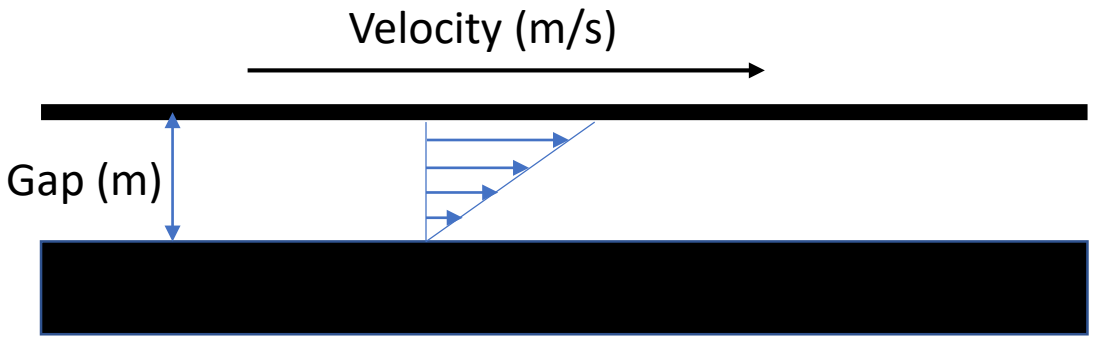




- 1,000,000 s^{-1}

Shear Rate

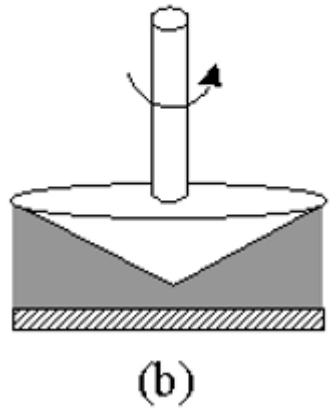
- What is shear rate?



$$\dot{\gamma} = \frac{v}{h} = \frac{m/s}{m} = s^{-1}$$

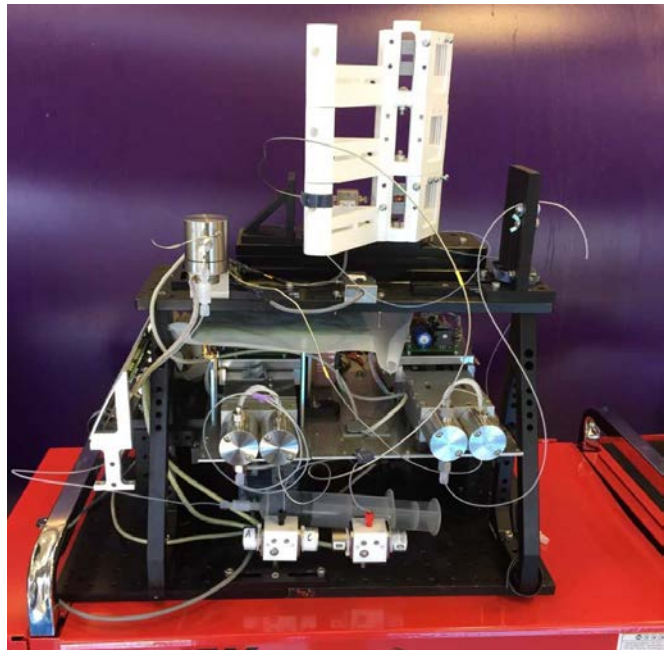
$$\underbrace{\tau}_{\text{Shear Stress}} = \underbrace{\eta}_{\text{Viscosity}} \times \underbrace{\dot{\gamma}}_{\text{Shear Rate}}$$

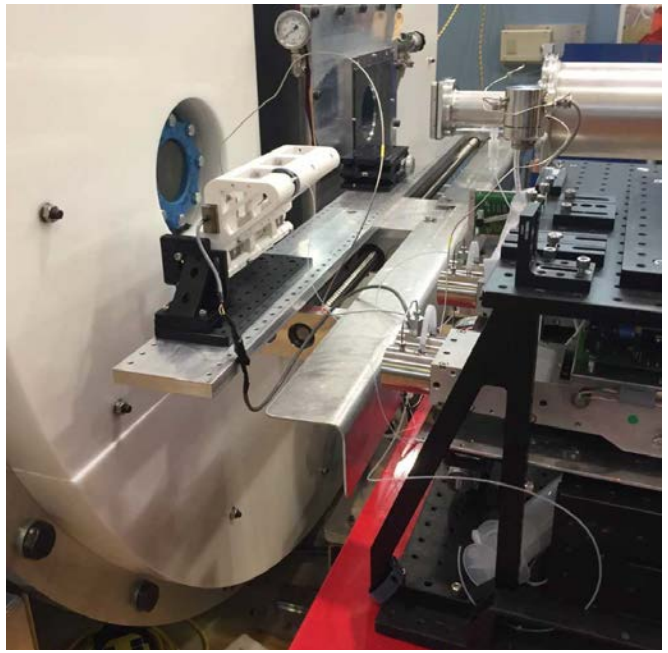
- How is it measured?

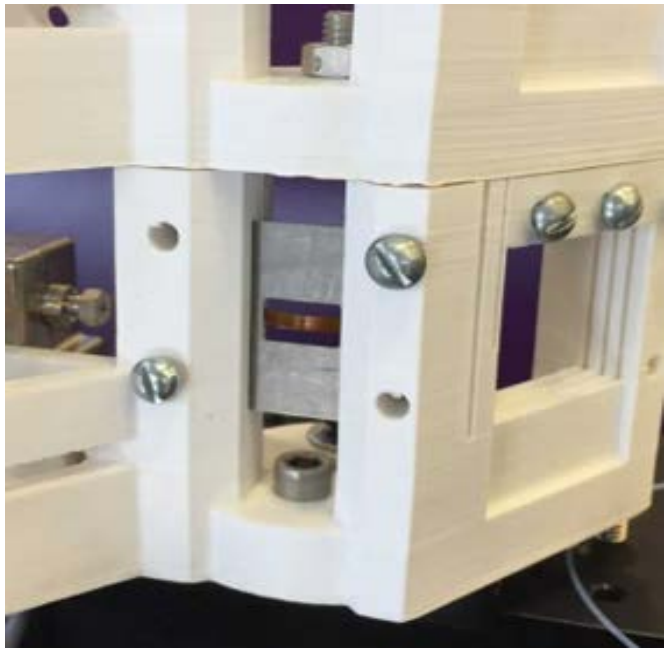


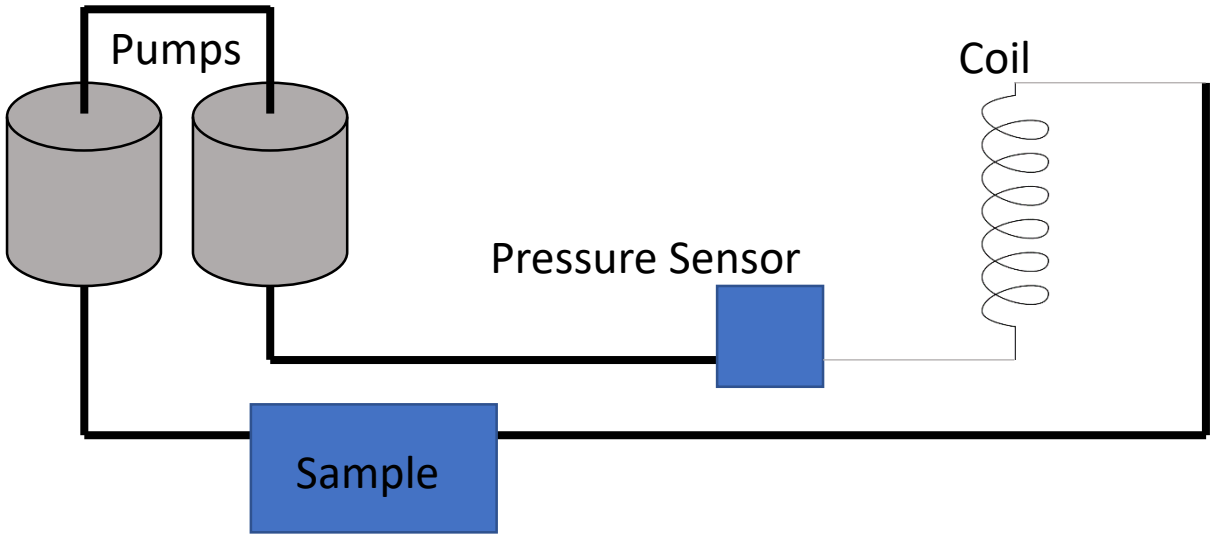
3,000 s^{-1} – 5,000 s^{-1}

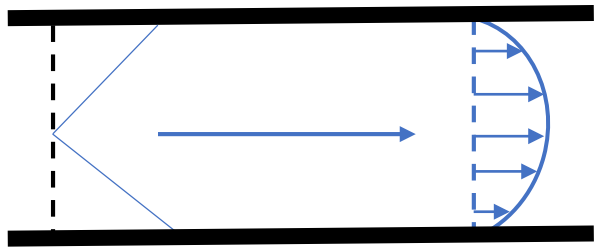
Capillary μ-RheoSANS Device





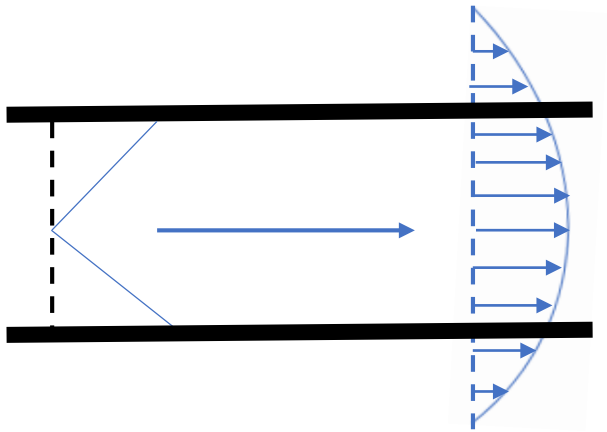


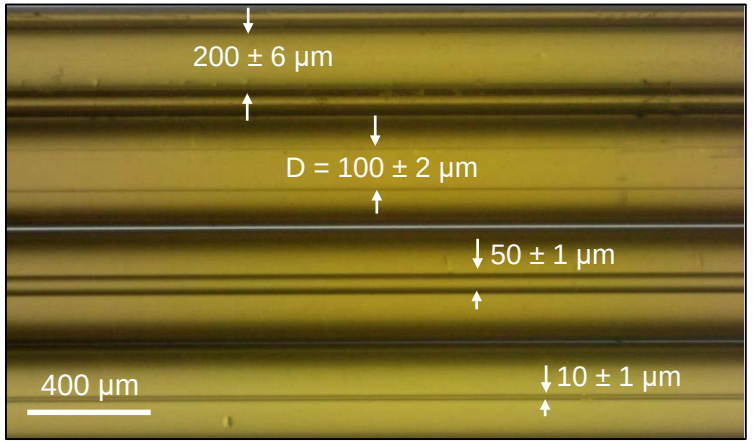


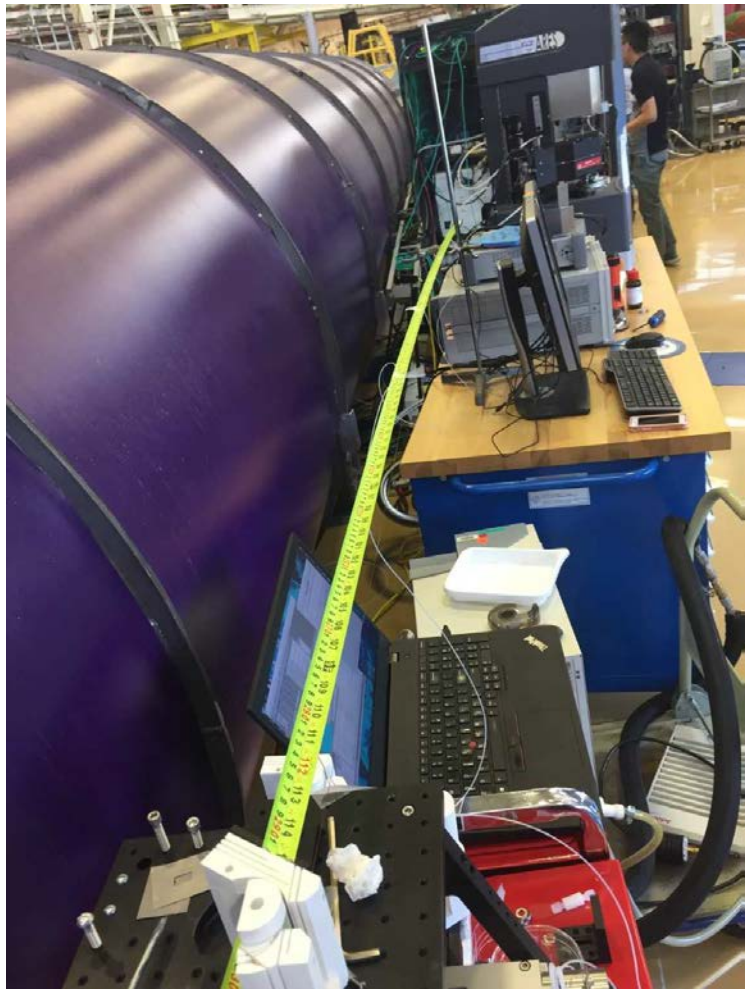


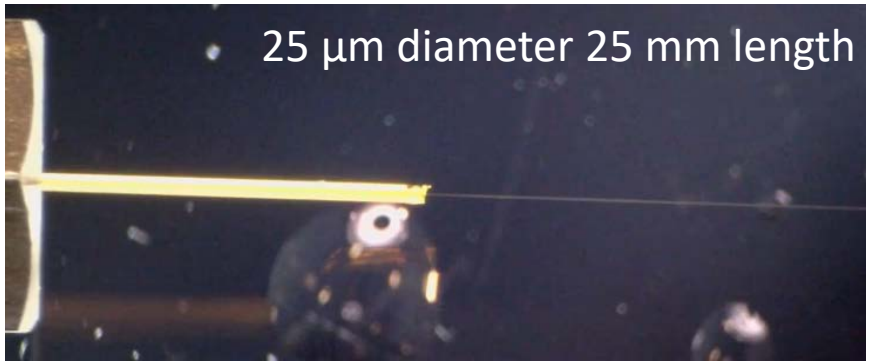
10,000,000 s^{-1}

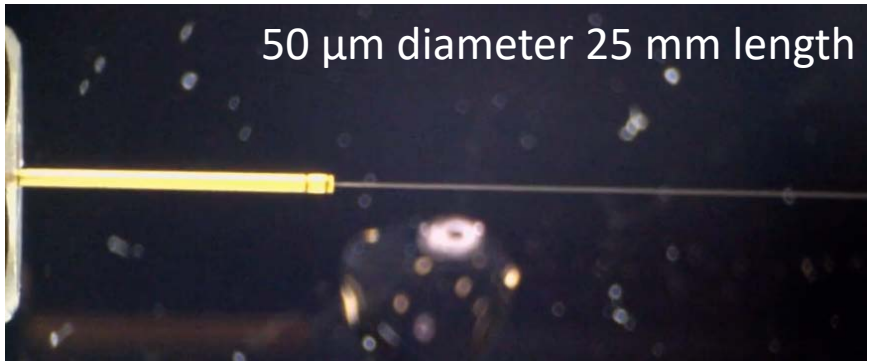
Slip, Coiling, and End Effects



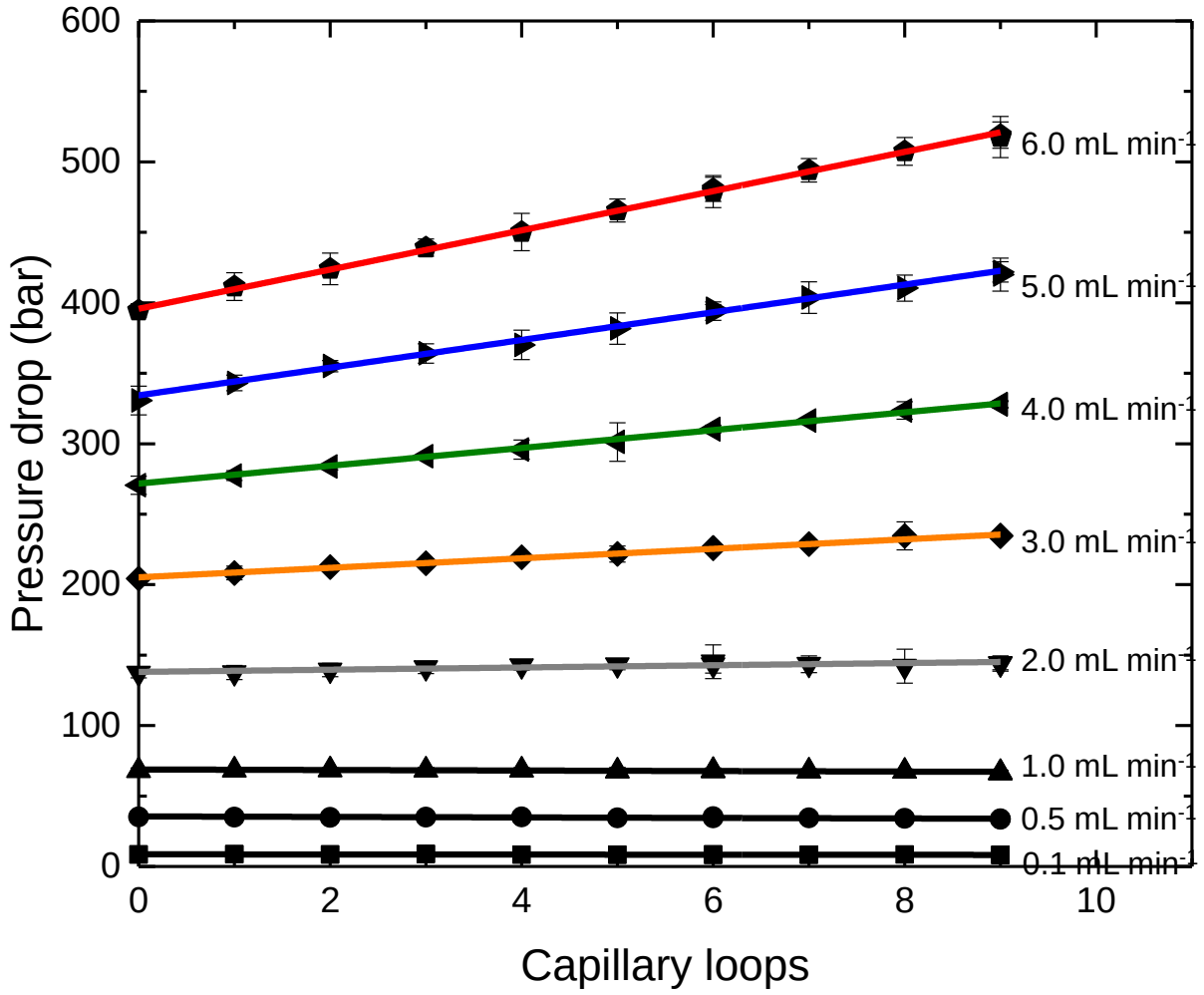


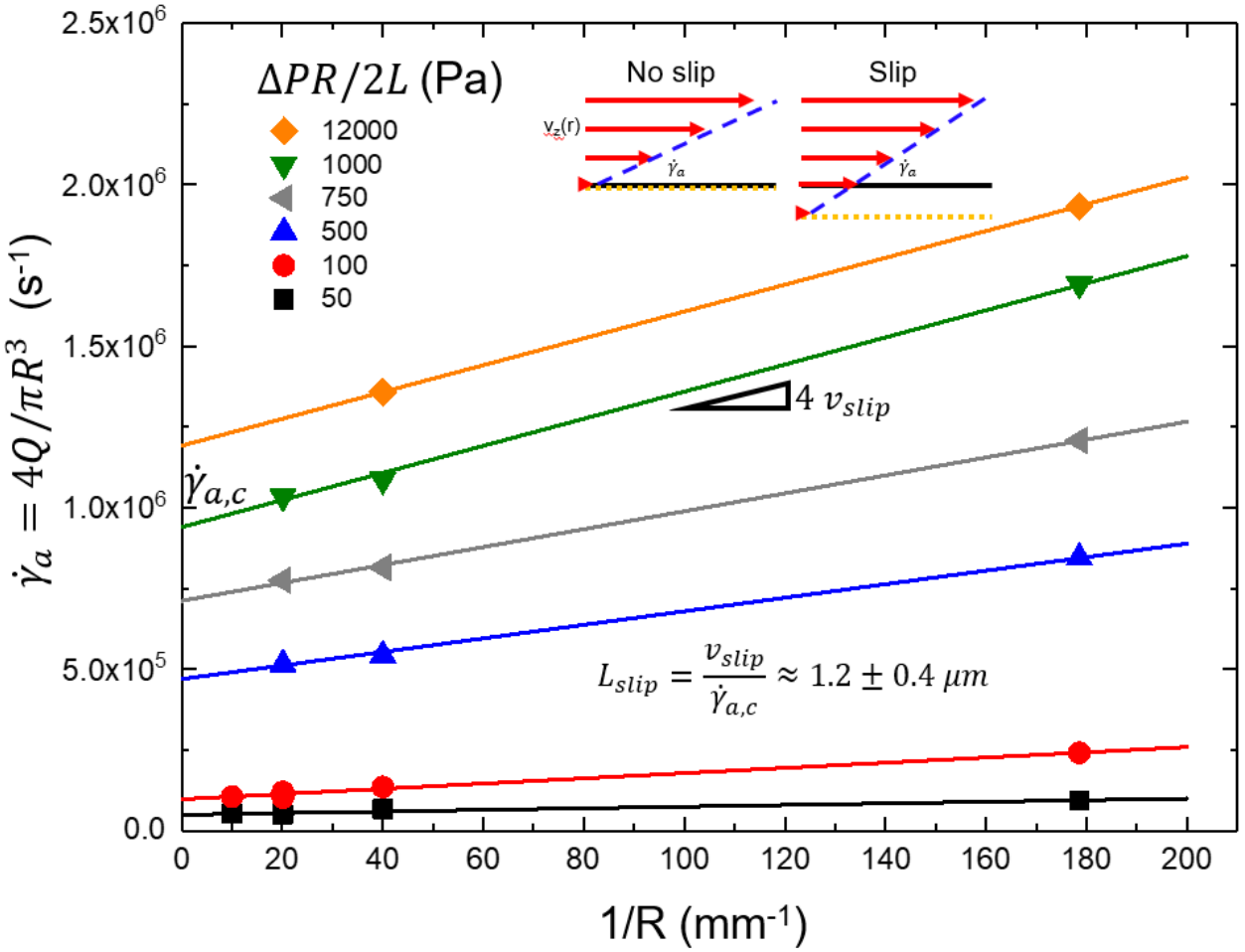






Slip, Coiling, and End Effects

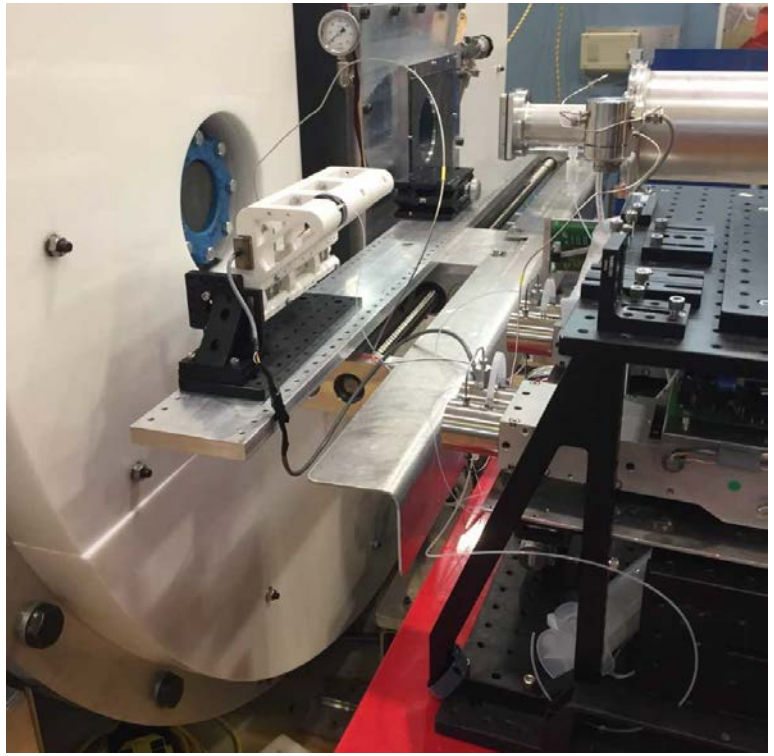




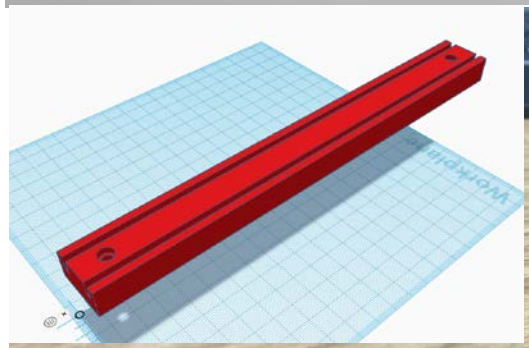
End effects within error of pressure sensors (< 1 bar)

Temperature Control

- $Q = (1/R)(A)(\Delta T)$
- $Q = (1/7.4)(10\ ft^2)(122\ °F)$
- $Q = 164.86$ BTU/hour

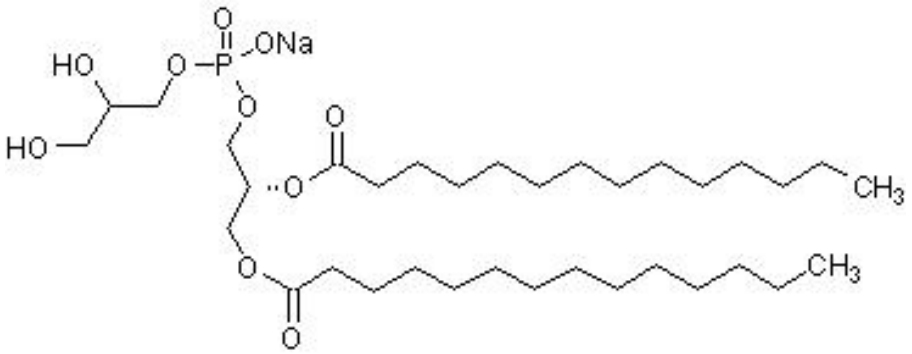


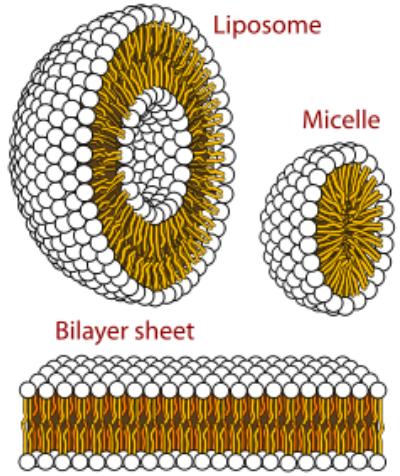
10 °C to 60 °C

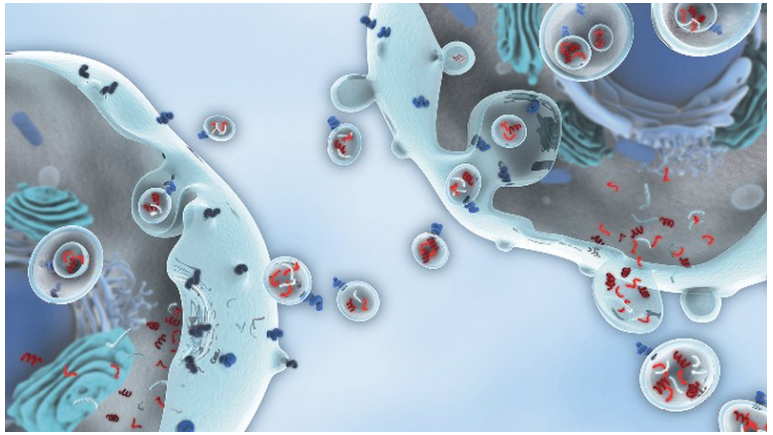


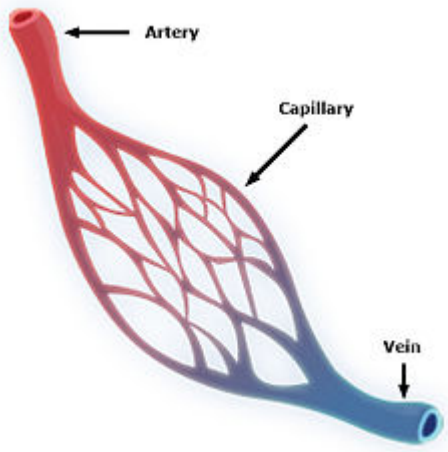
Application

- Lipid DMPG: 1,2-Dimyristoyl-sn-glycero-3-phosphorylglycerol sodium salt









c&en CHEMICAL & ENGINEERING NEWS

TOPICS MAGAZINE COLLECTIONS VIDEOS JOBS

START-UPS

Meet the exosome, the rising star in drug delivery

Companies are hoping to use the vesicles to package small-molecule, protein, and RNA drugs or even use them as therapies themselves

by Ryan Cross

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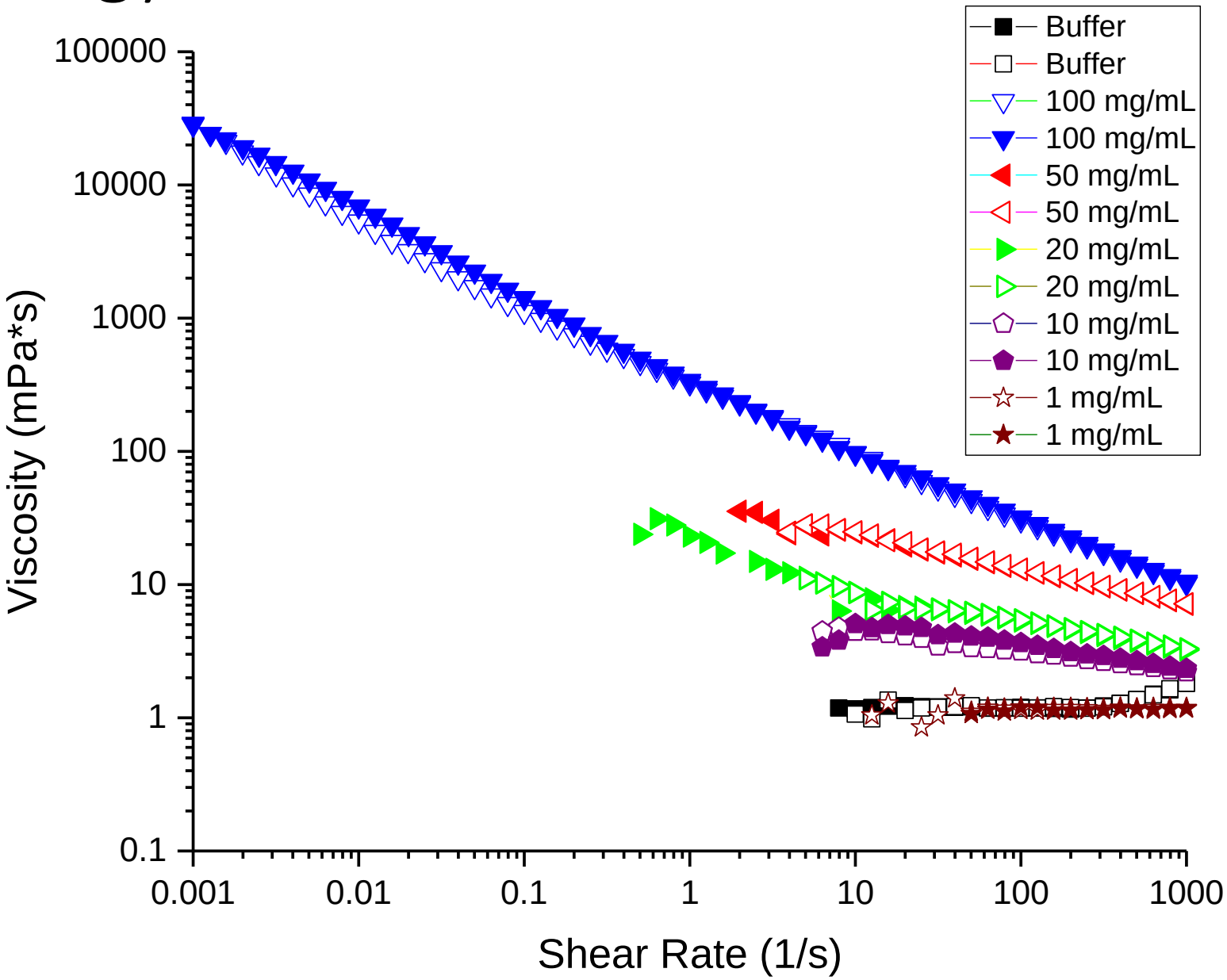
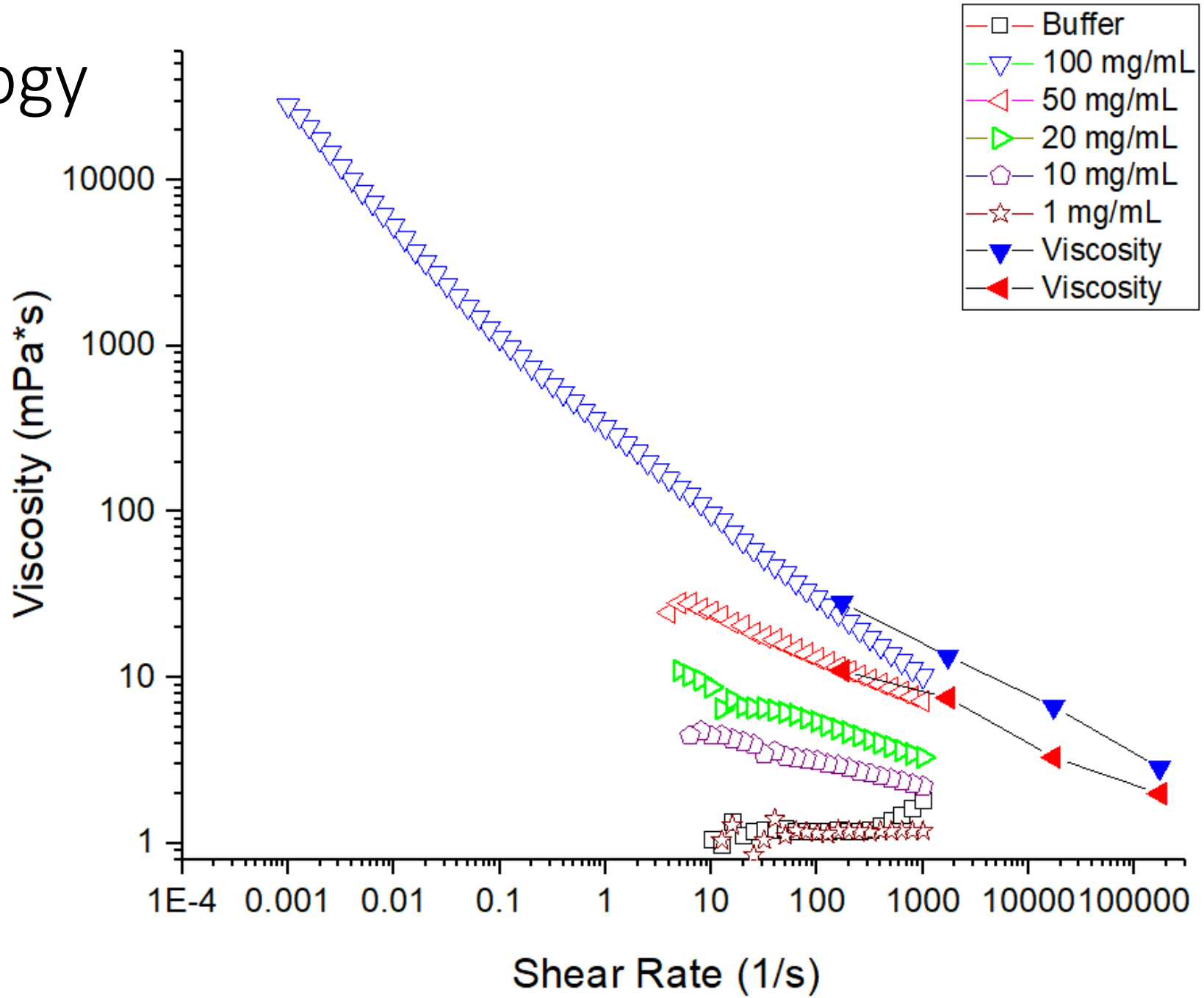
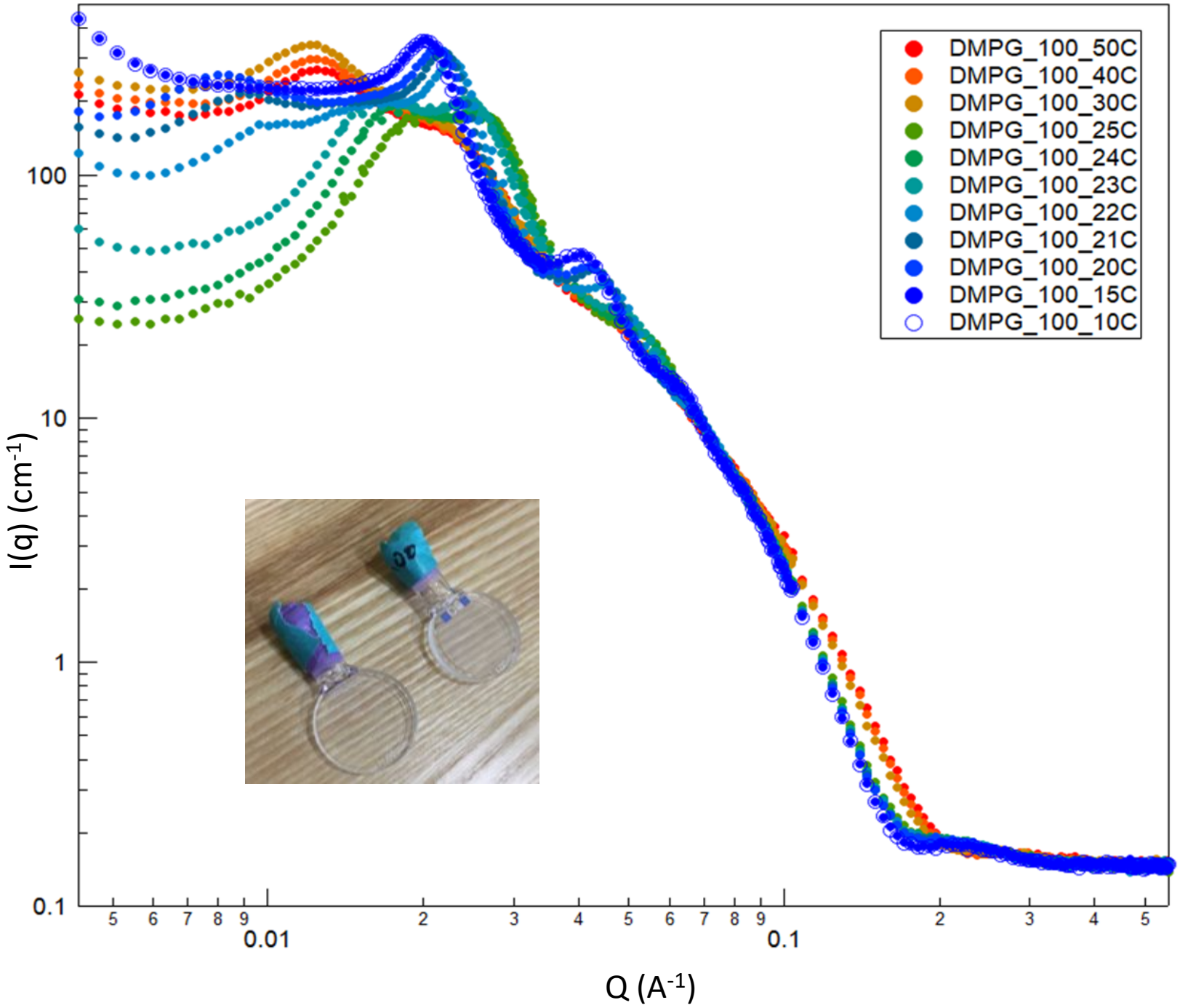
Rheology


Buffer
Buffer
100 mg/mL
100 mg/mL
50 mg/mL
50 mg/mL
20 mg/mL
20 mg/mL
10 mg/mL
10 mg/mL
1 mg/mL
1 mg/mL
Viscosity (mPa*s)
100000
10000
1000
100
10
1
0.1
0.001
0.01
0.1
1
10
100
1000
Shear Rate (1/s)

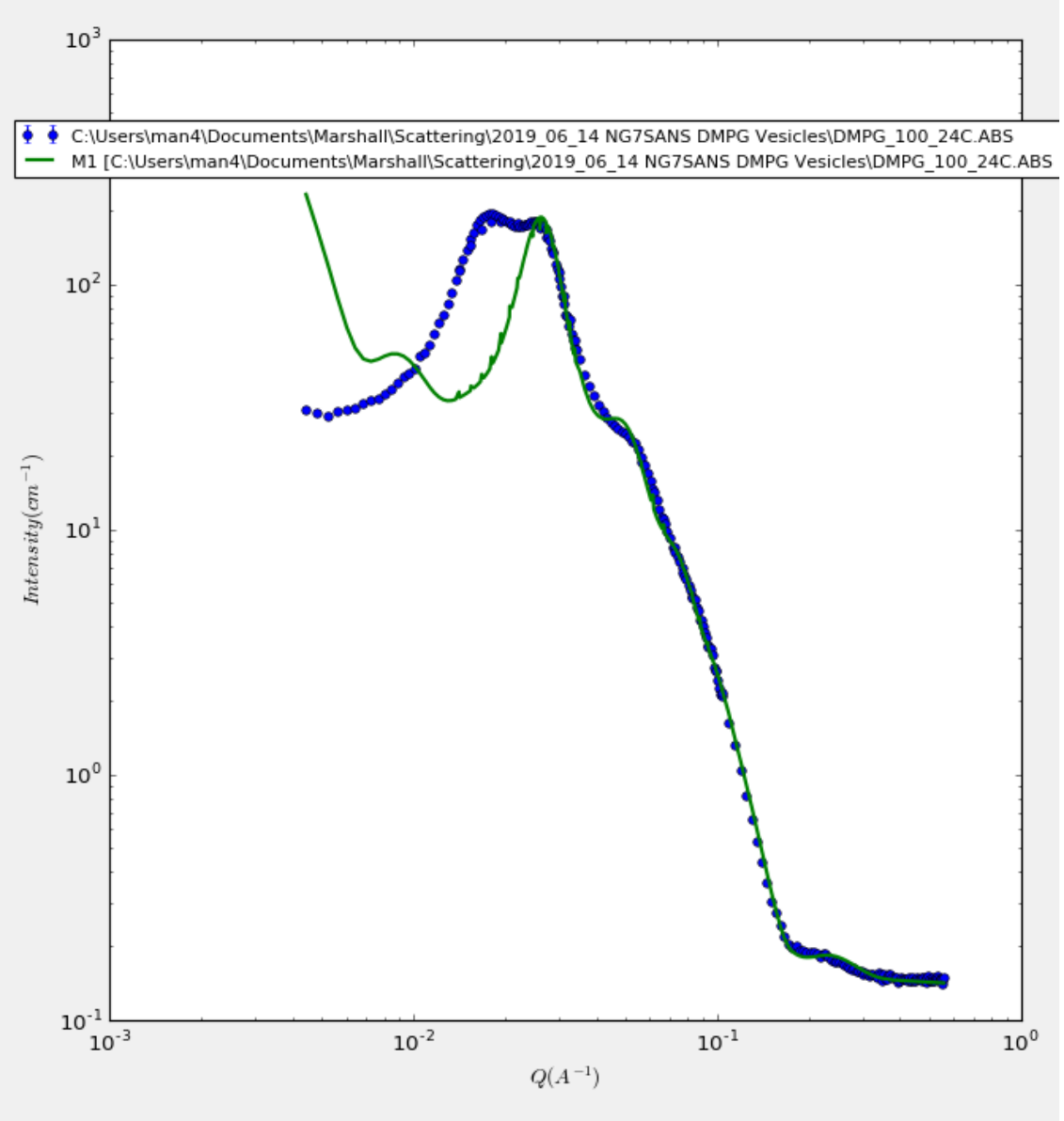
Rheology

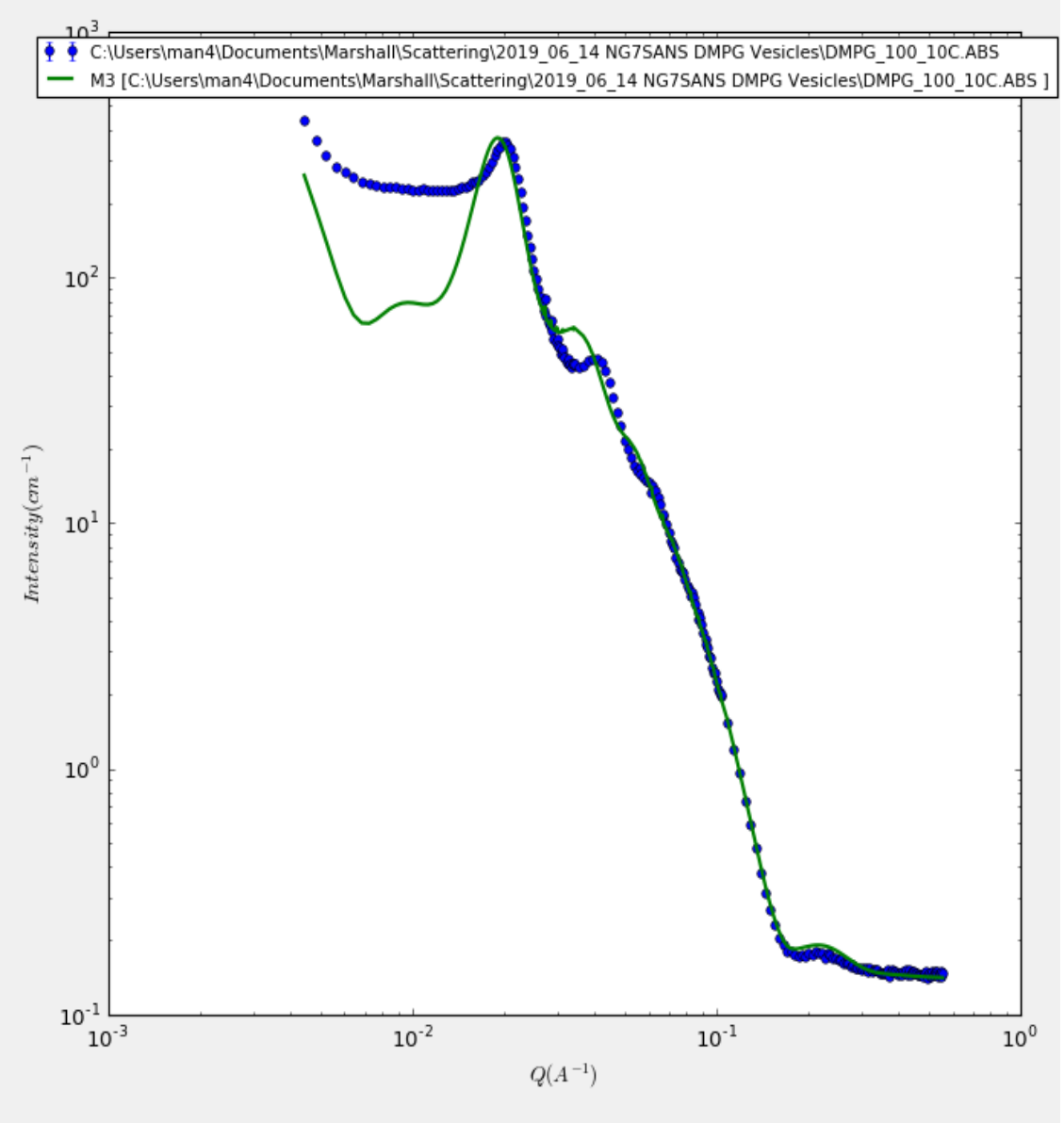

Buffer
100 mg/mL
50 mg/mL
20 mg/mL
10 mg/mL
1 mg/mL
Viscosity
Viscosity
Viscosity (mPa*s)
10000
1000
100
10
1
1E-4
0.001
0.01
0.1
1
10
100
1000
10000
100000
Shear Rate (1/s)

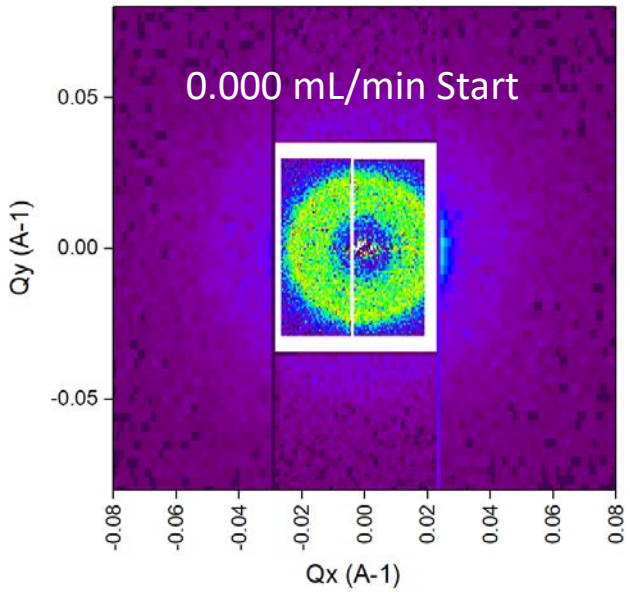
SANS

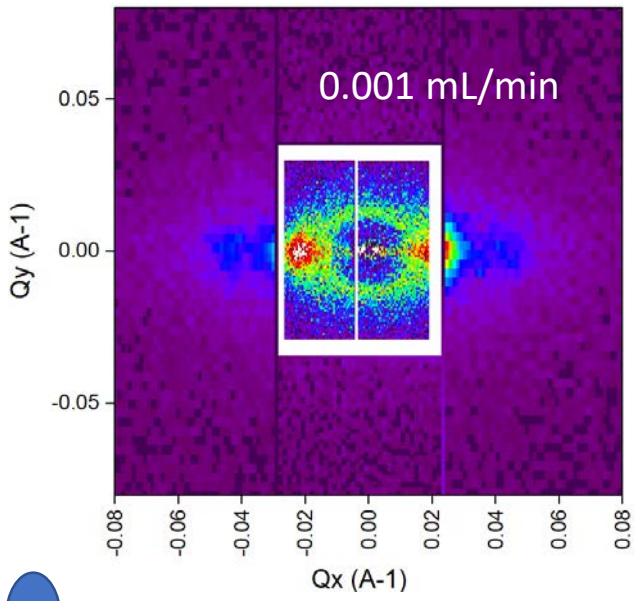

DMPG_100_50C
DMPG_100_40C
DMPG_100_30C
DMPG_100_25C
DMPG_100_24C
DMPG_100_23C
DMPG_100_22C
DMPG_100_21C
DMPG_100_20C
DMPG_100_15C
DMPG_100_10C
100
10
1
0.1
I(q) (cm-1)
0.01
0.1
Q (A-1)

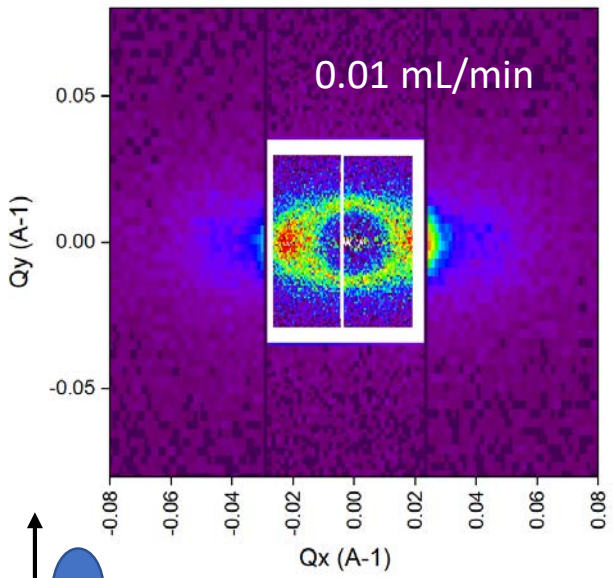
Fitting Data

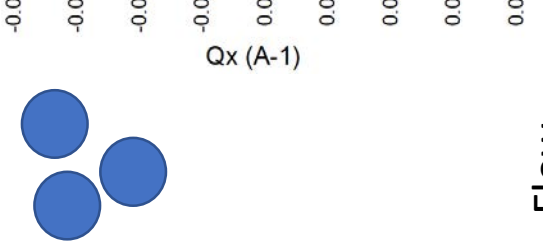








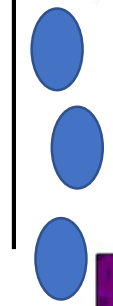


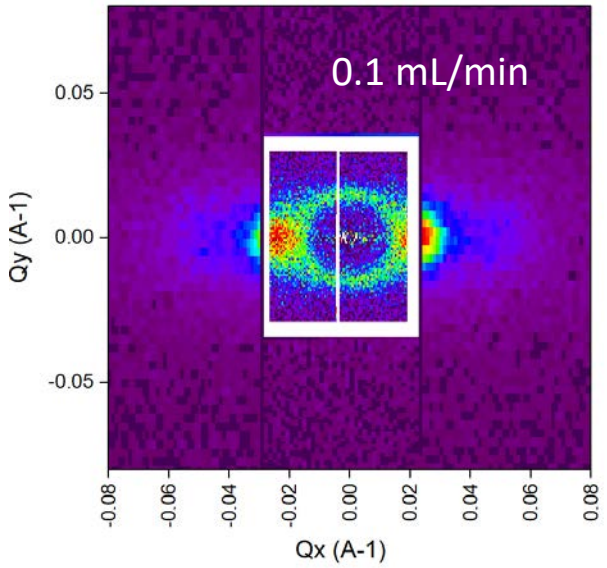


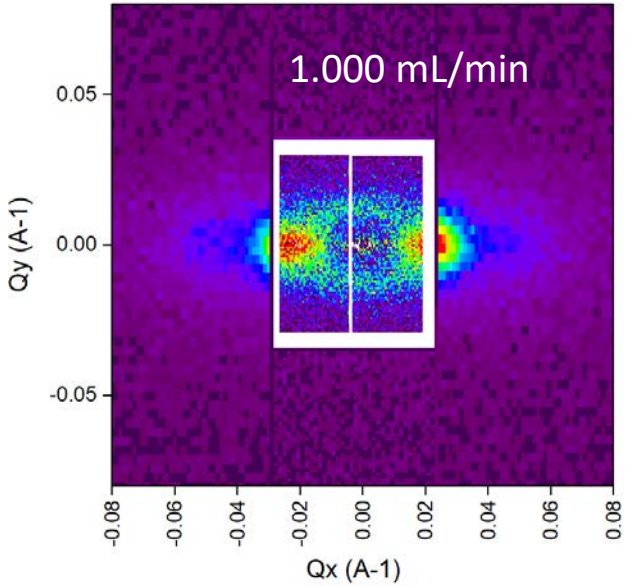
Flow

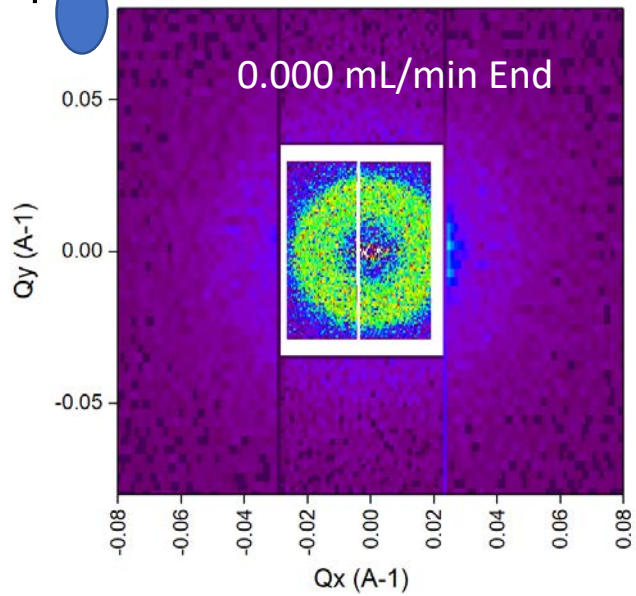
VSANS Data

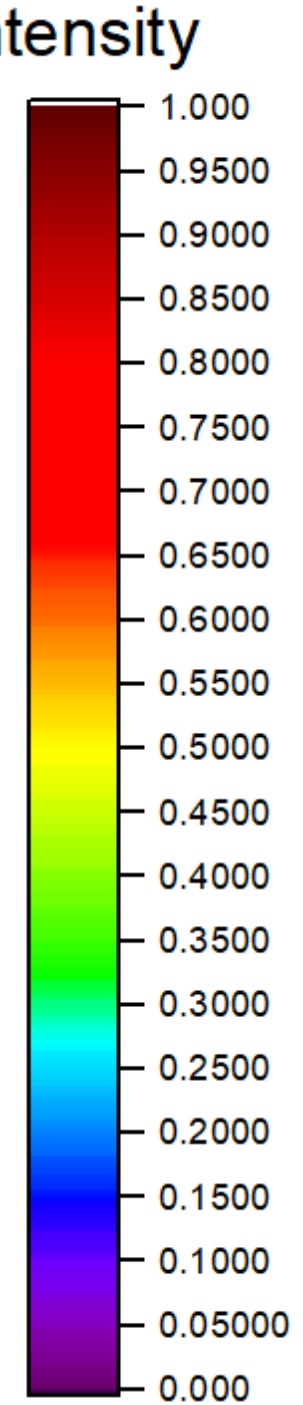
Flow



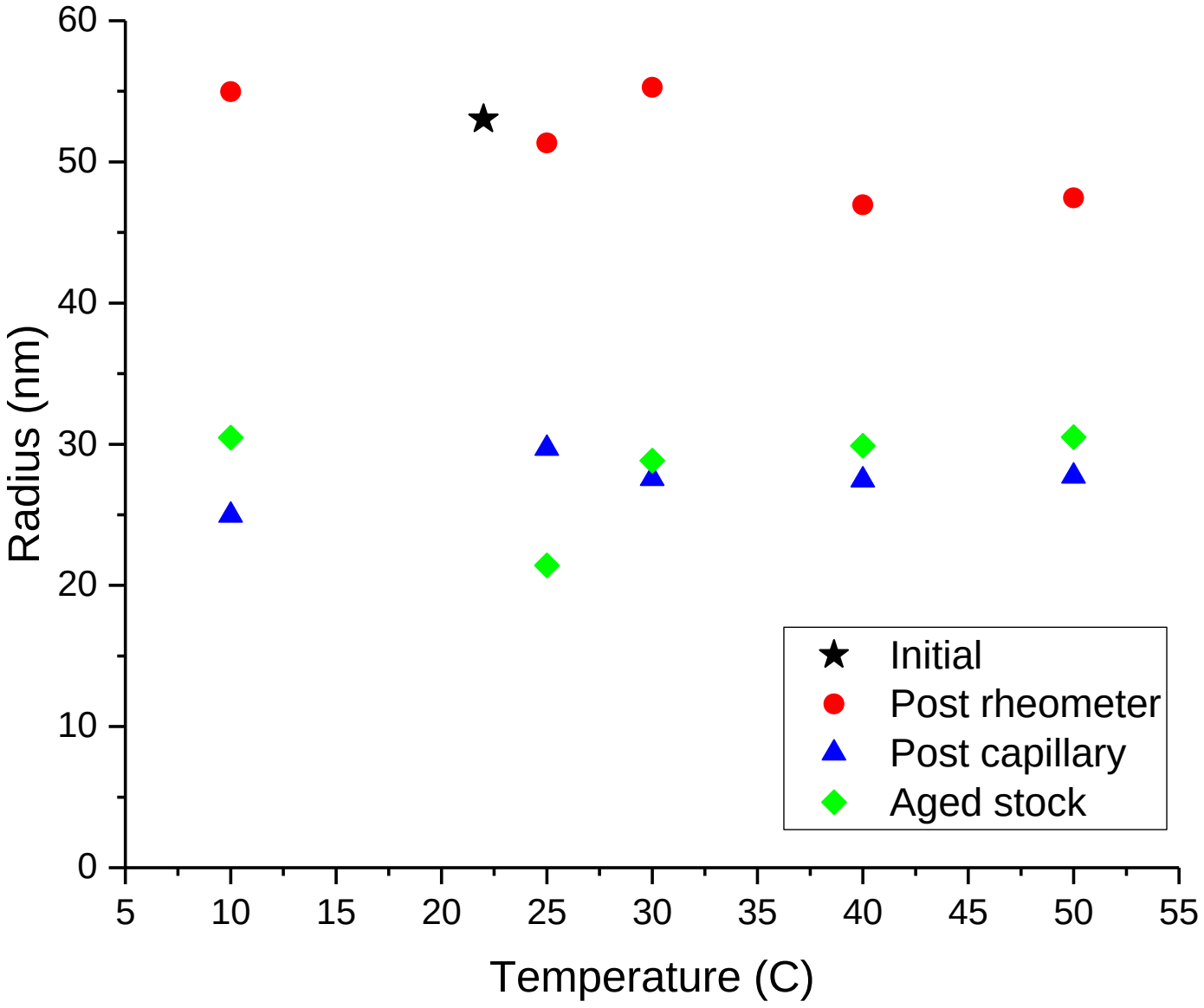


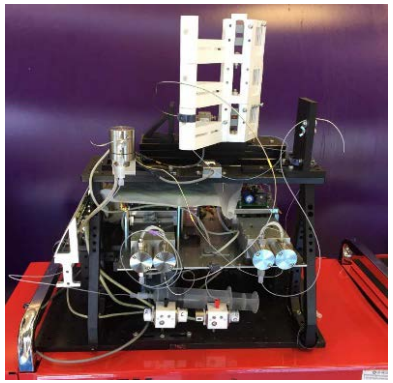






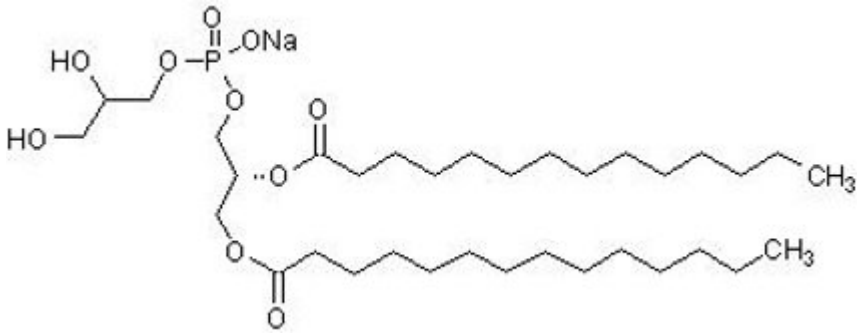
Size

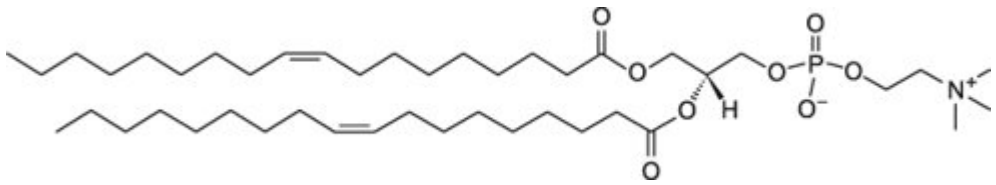

Radius (nm)
Temperature (C)
0
10
20
30
40
50
60
5
10
15
20
25
30
35
40
45
50
55
Initial
Post rheometer
Post capillary
Aged stock

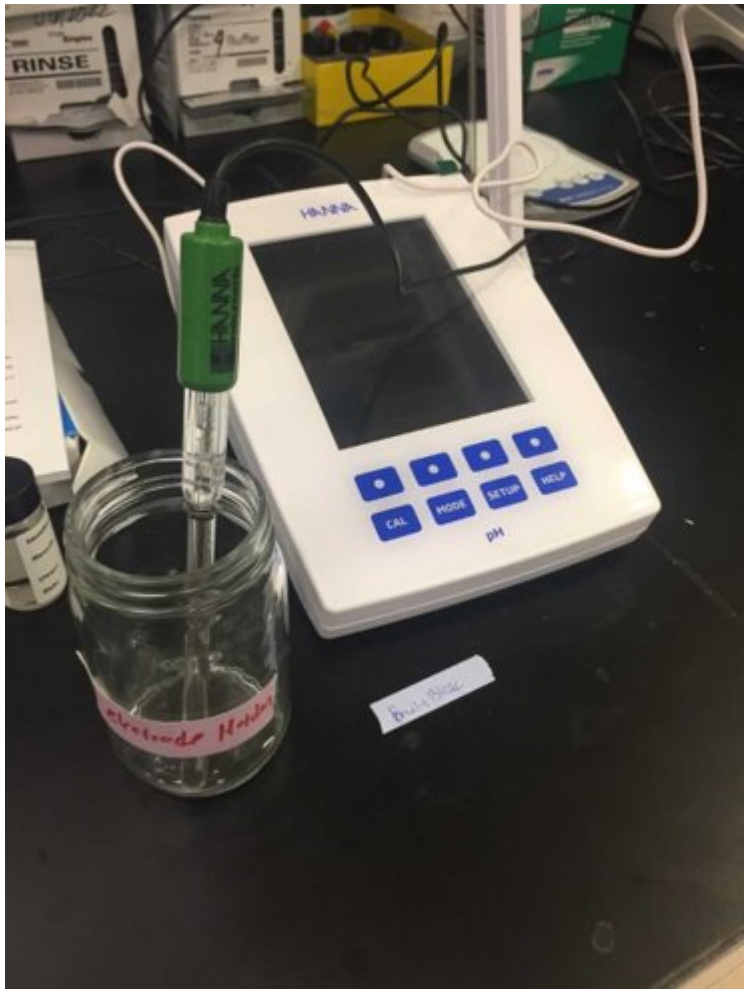


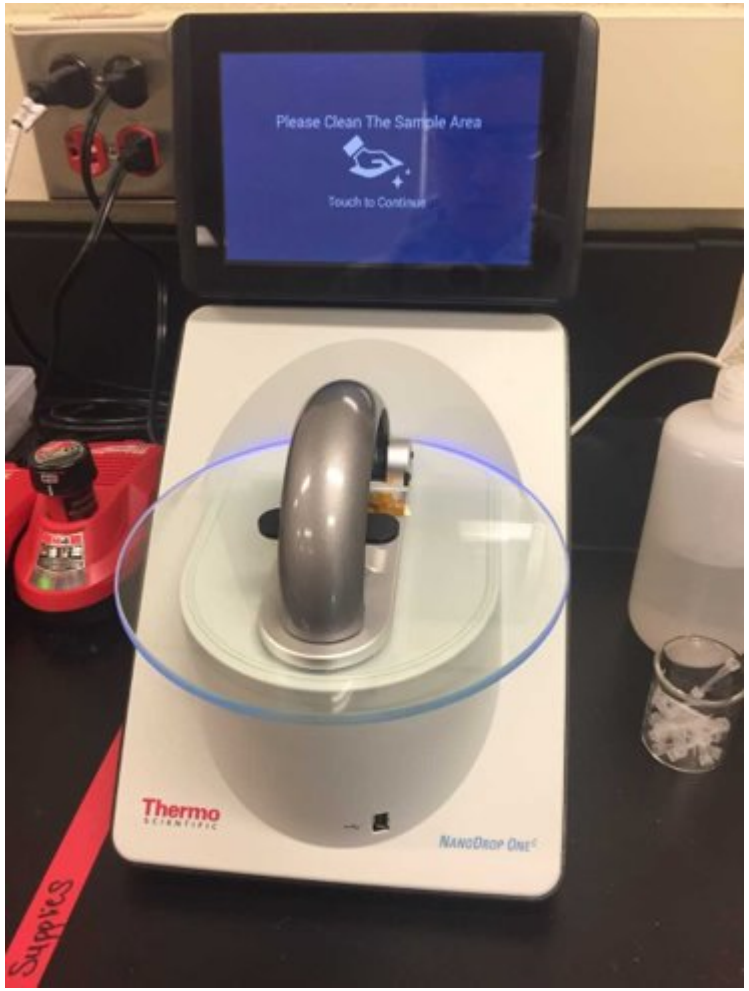
Degradation?

- Oxidation or hydrolysis
- Sample pH 7.004
- Buffer pH 7.088
- 0% Free lipid (no color change)

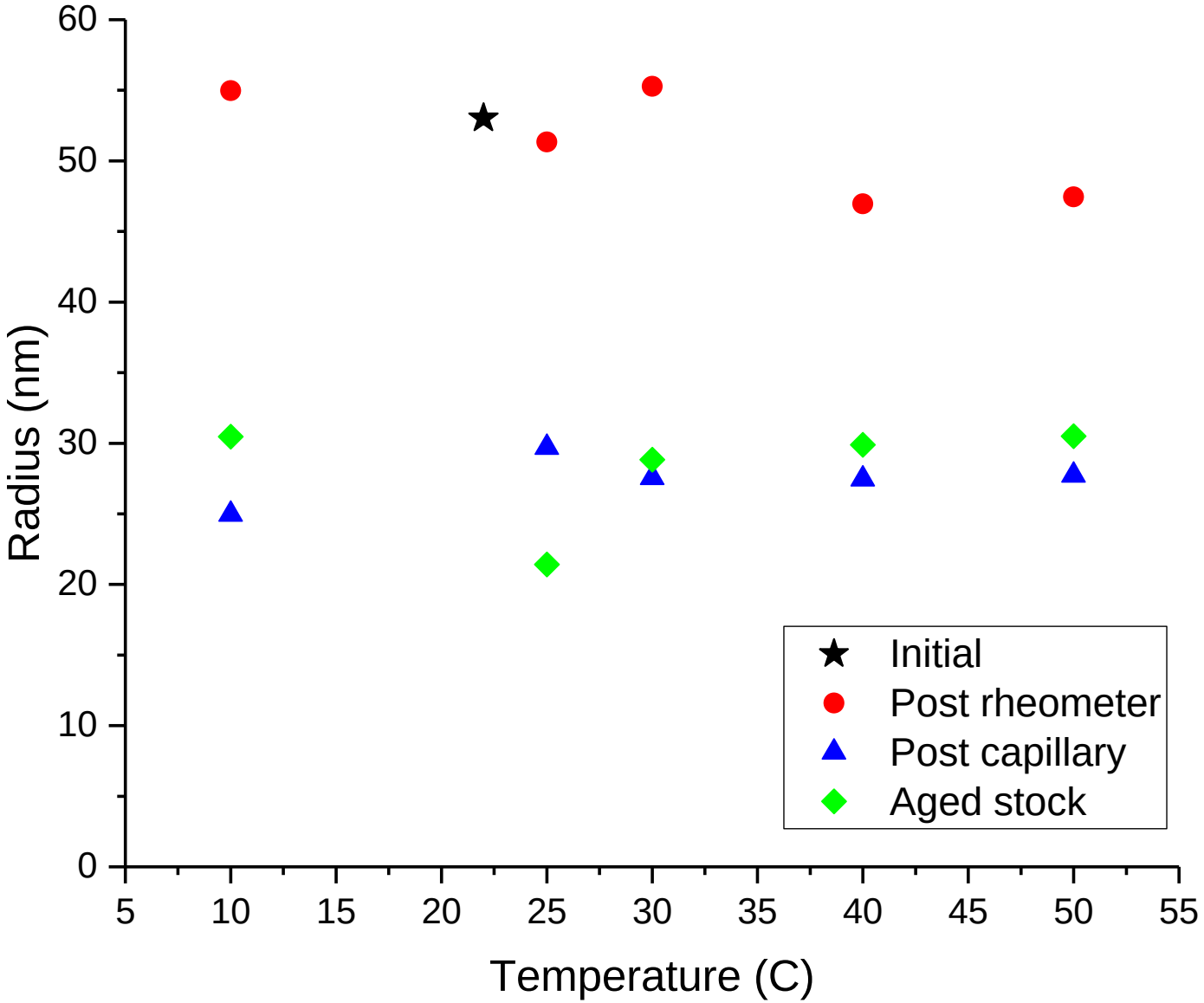








Size


Radius (nm)
60
50
40
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20
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0
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25
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40
45
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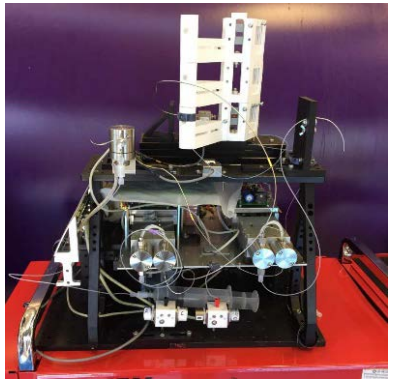
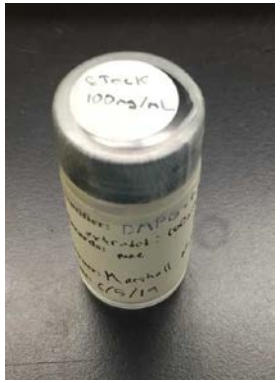
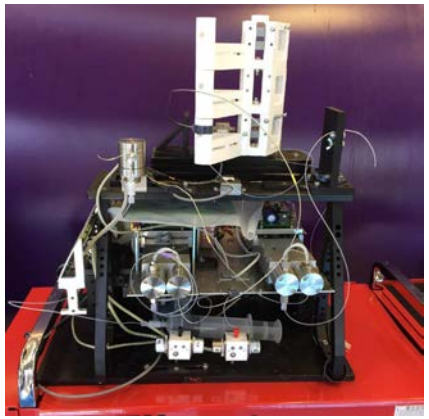
55
Temperature (C)
Initial
Post rheometer
Post capillary
Aged stock



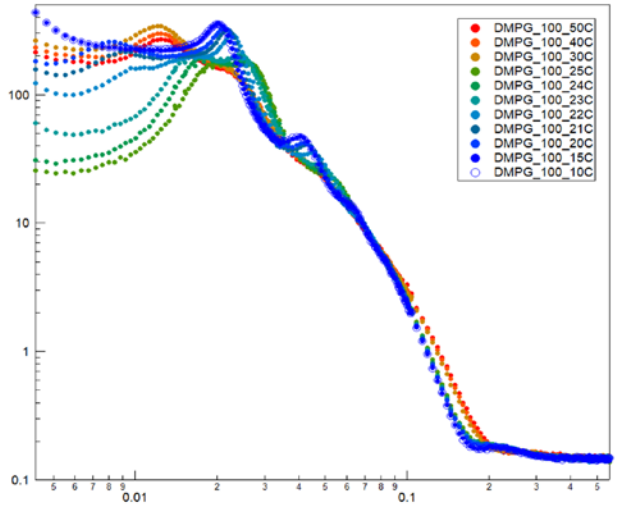


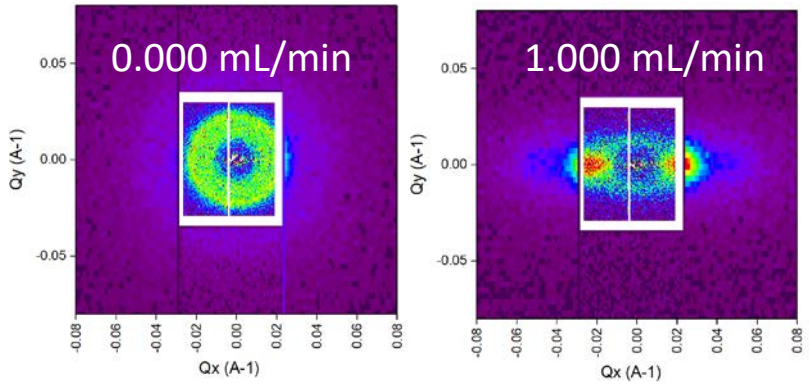
Summary

- Device Development
  - Slip, Coiling and End Effect Calibration
  - Temperature Control



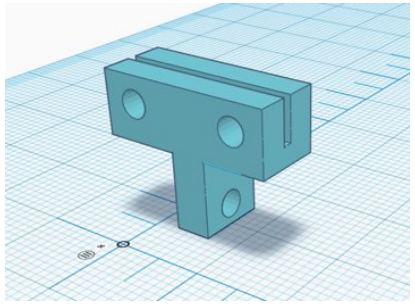
- Lipid Studies
  - Shear Thinning Rheology
  - Vesicle Hard sphere model with another form factor
  - Anisotropy suggests deformation and chaining
  - Size change not from degradation

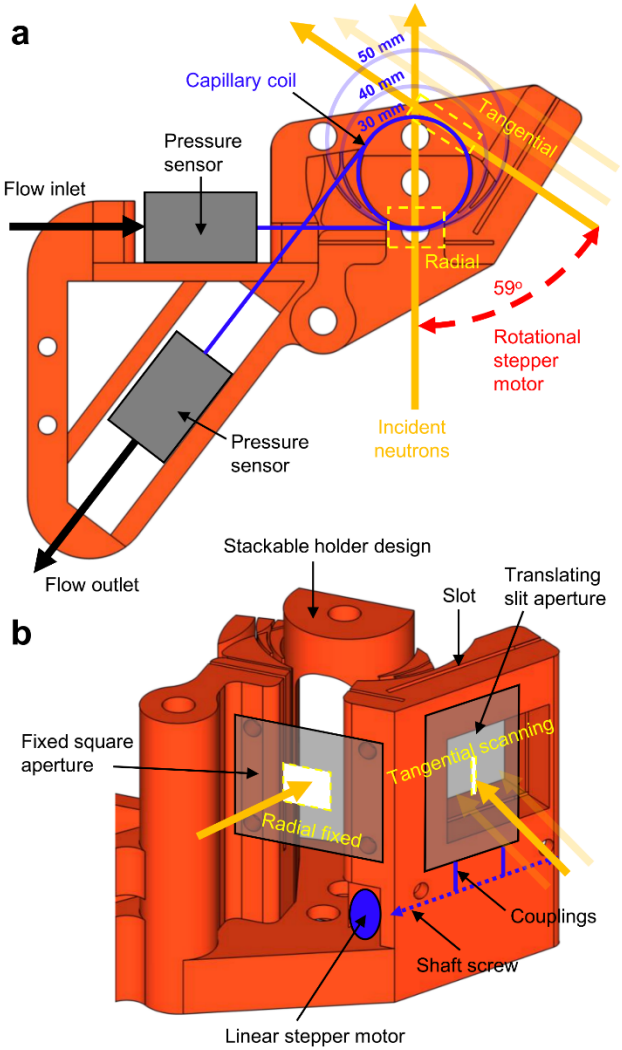




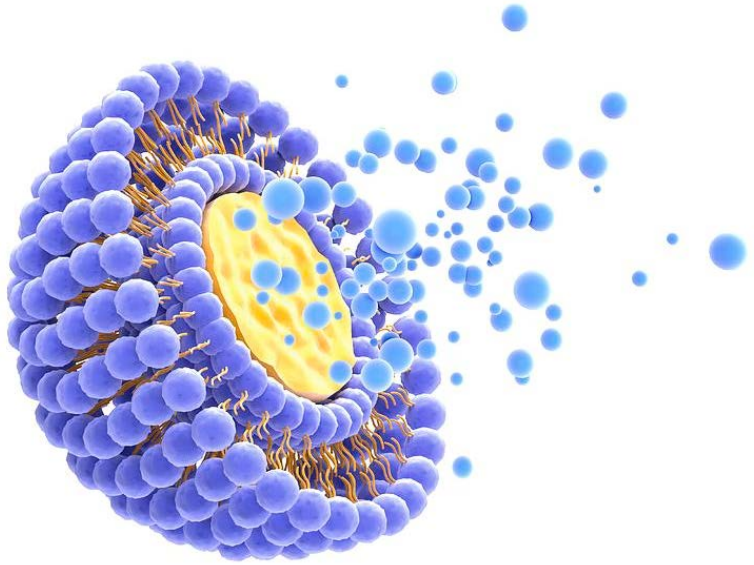
Future Work

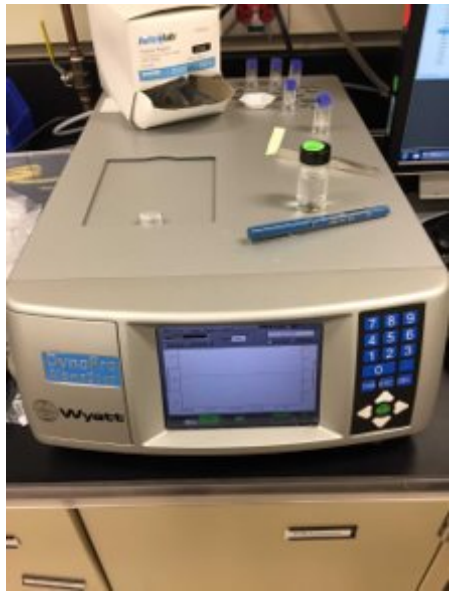
- Device Improvement





- Vesicle Study





Acknowledgements

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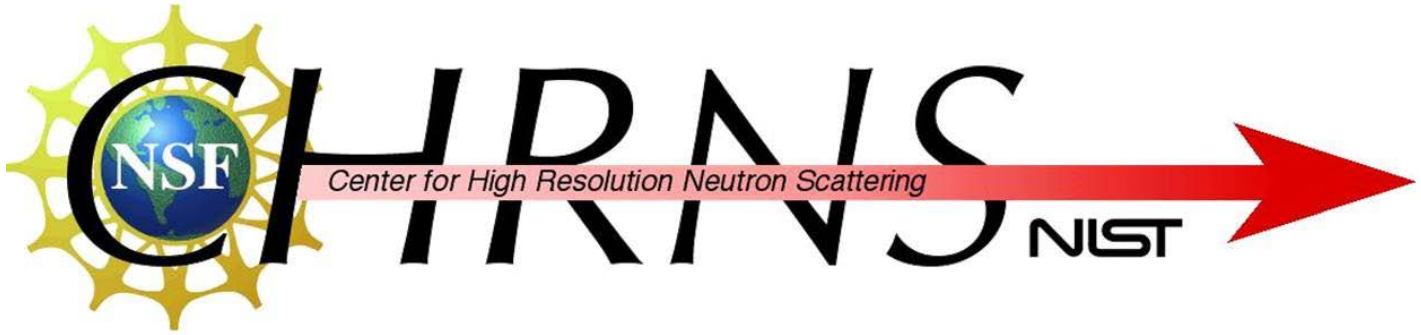
- Gamitha Wijekoon (SURF)



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