Formulating Inks for Developing 3D Printable Casting Molds

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Background

- Boiling: bringing a liquid to the temperature at which it bubbles and turns to vapor
    - Applications: thermal inkjet printing
- Metastable Boiling: departure from equilibrium conditions where a bubble is immediately formed from a short, intense energy pulse without being at the fluid's boiling point
    - Bubble quickly collapses due to rapid cooling by cooler surrounding fluid
    - Volume expansion pushes ink out of nozzle

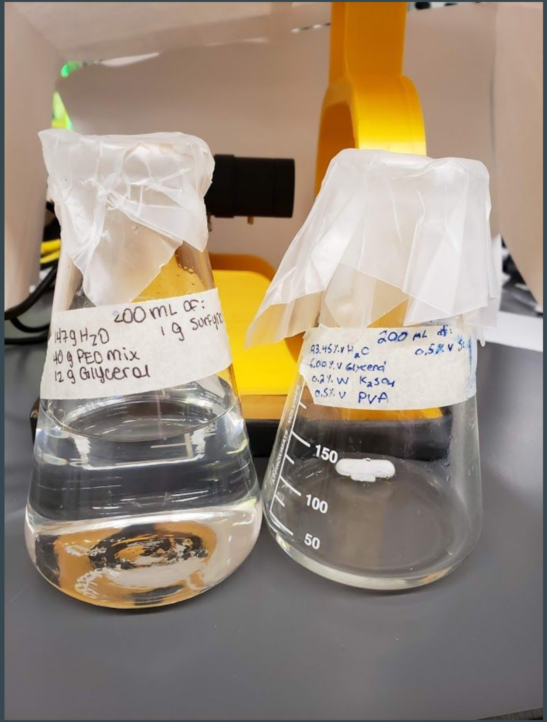
Ink Formulas

Formula 1. (200 mL)

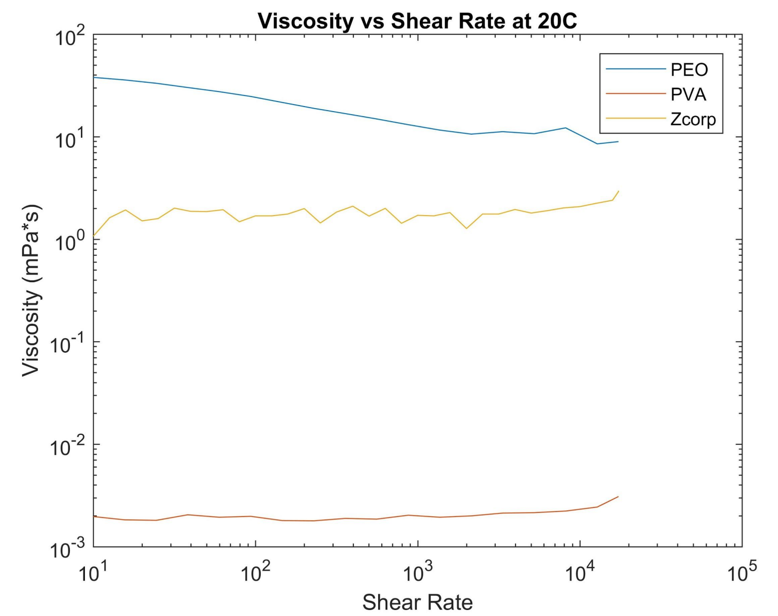
93.45% H2O, 6% Glycerol, 0.2% K2SO4, 0.5% PVA, 0.5% Surfynol

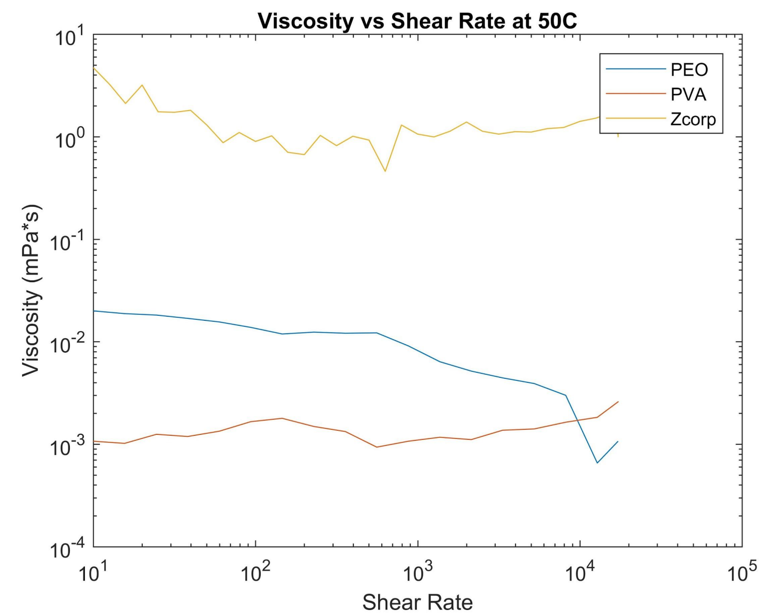
Formula 2. (200 mL)

73.5% H2O, 6% Glycerol, 20% PEO, 0.5% Surfynol



Viscosity Testing with Rheometer





Surface Tension Assembly

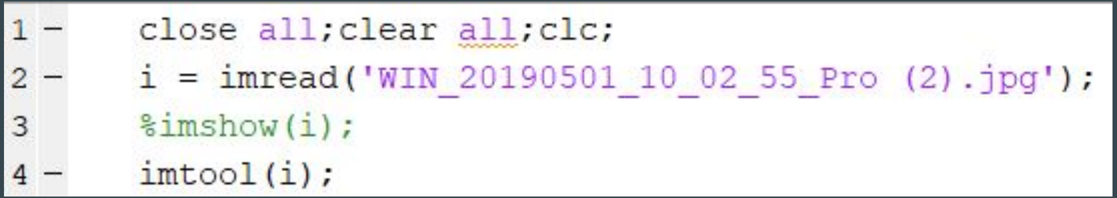
- USB Camera
- Syringe with needle tip
- Camera and syringe holder
- Interfacial MATLAB[1]

[1]. Mohan-Nair, K. “Measuring Interfacial Tension with the Pendant Drop Method” (2014)

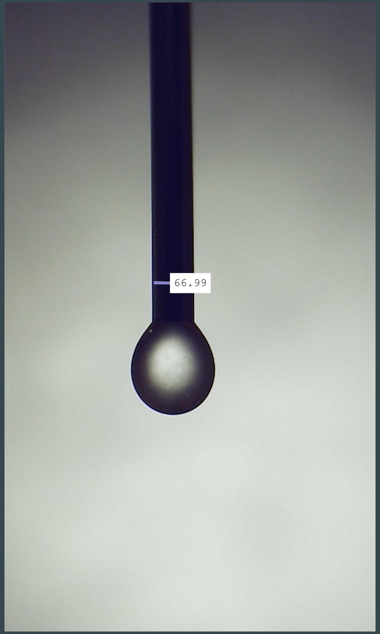
Calibration (Pixel to mm Ratio)

MATLAB img tool

Manually measure width of tip (pixels)

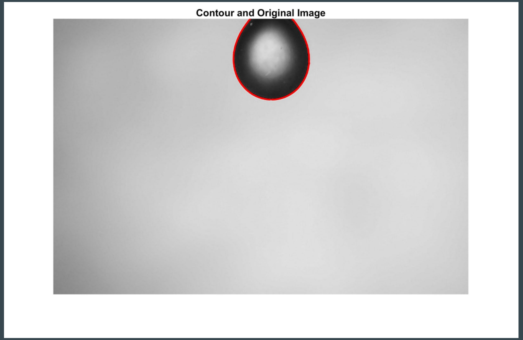


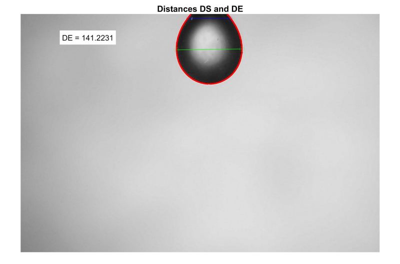
```
close all;clear all;clc;
i = imread('WIN_20190501_10_02_55_Pro (2).jpg');
%imshow(i);
imtool(i);
```

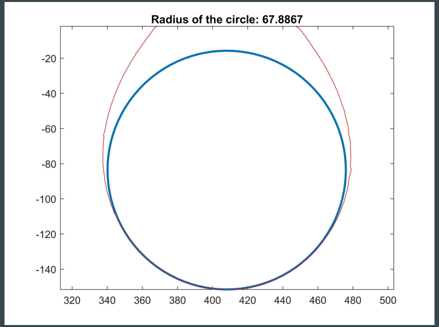


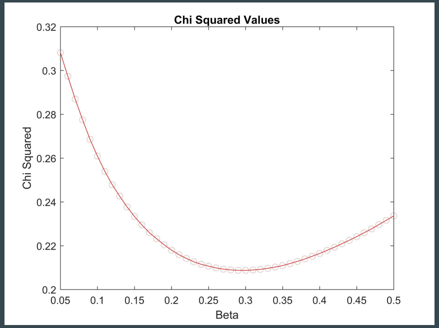
Measuring Interfacial Tension with the Pendant Drop Method [1]

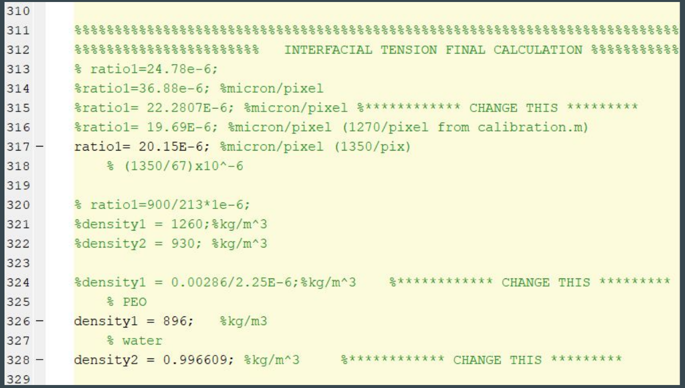
Water







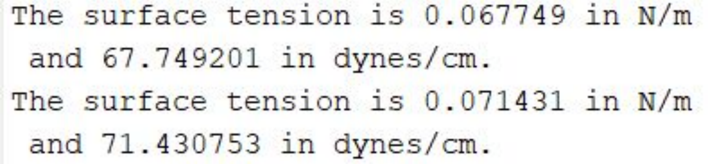




```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%   INTERFACIAL TENSION FINAL CALCULATION %%%%%%%%%%%
% ratio1=24.78e-6;
%ratio1=36.88e-6; %micron/pixel
%ratio1= 22.2807E-6; %micron/pixel %************ CHANGE THIS *********
%ratio1= 19.69E-6; %micron/pixel (1270/pixel from calibration.m)
ratio1= 20.15E-6; %micron/pixel (1350/pix)
    % (1350/67)x10^-6

% ratio1=900/213*1e-6;
%density1 = 1260;%kg/m^3
%density2 = 930; %kg/m^3

%density1 = 0.00286/2.25E-6;%kg/m^3    %************ CHANGE THIS *********
    % PEO
density1 = 896;   %kg/m3
    % water
density2 = 0.996609; %kg/m^3     %************ CHANGE THIS *********
```

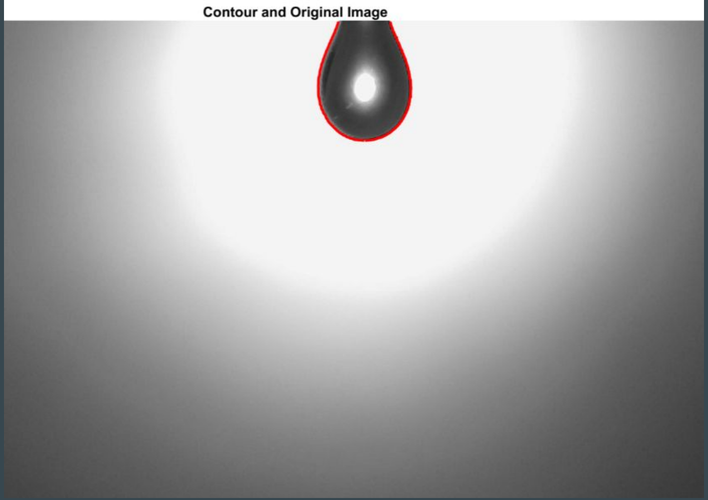


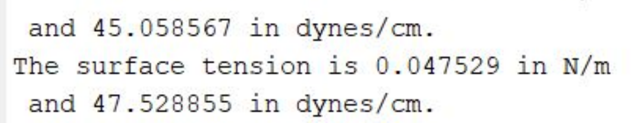
```
The surface tension is 0.067749 in N/m
 and 67.749201 in dynes/cm.
The surface tension is 0.071431 in N/m
 and 71.430753 in dynes/cm.
```

[1]. Mohan-Nair, K. “Measuring Interfacial Tension with the Pendant Drop Method” (2014)

Surface Tension of PEO and PVA Recipes

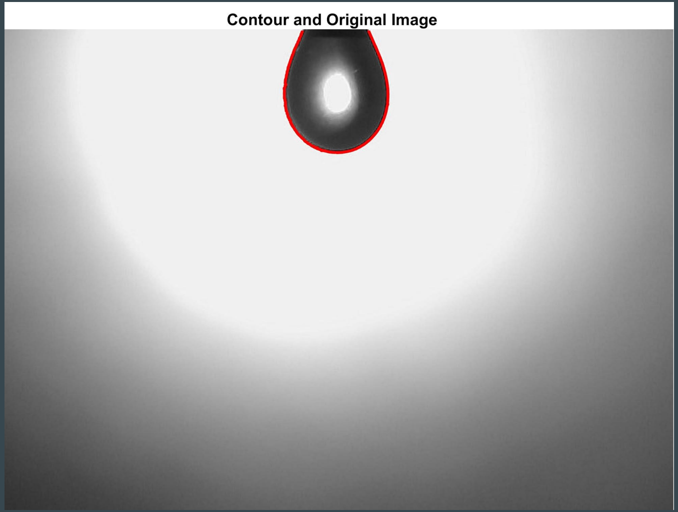
PEO

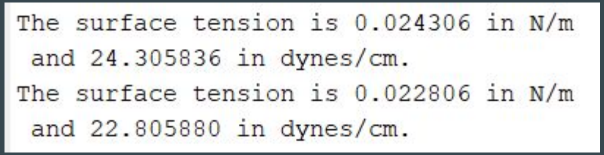




```
The surface tension is 0.045059 in N/m
 and 45.058567 in dynes/cm.
The surface tension is 0.047529 in N/m
 and 47.528855 in dynes/cm.
```

PVA





```
The surface tension is 0.024306 in N/m
 and 24.305836 in dynes/cm.
The surface tension is 0.022806 in N/m
 and 22.805880 in dynes/cm.
```

Ink Jettability

- PEO
  - Low surface tension due to surfynol and high viscosity (at lower temperatures)
  - Clogged printhead
  - Wet needle tip when performing surface tension analysis - bigger error
  - Inks with 0.1 < Oh < 1 are jettable

$$Oh = \frac{\mu}{\sqrt{\rho\sigma L}} = \frac{0.01031}{\sqrt{1271.1 * 5.67 \cdot 10^{-8} \cdot 0.1151}} = 3.58$$

- PVA
  - About half the surface tension as PEO mix
  - Consistently lower viscosity than Z-corp ink
  - Jettable?

$$Oh = \frac{\mu}{\sqrt{\rho\sigma L}} = \frac{0.00140}{\sqrt{776 * 5.67 \cdot 10^{-8} \cdot 0.1074}} = 0.646$$

Note: Oh calculated using average viscosity (SI units) at 50 C