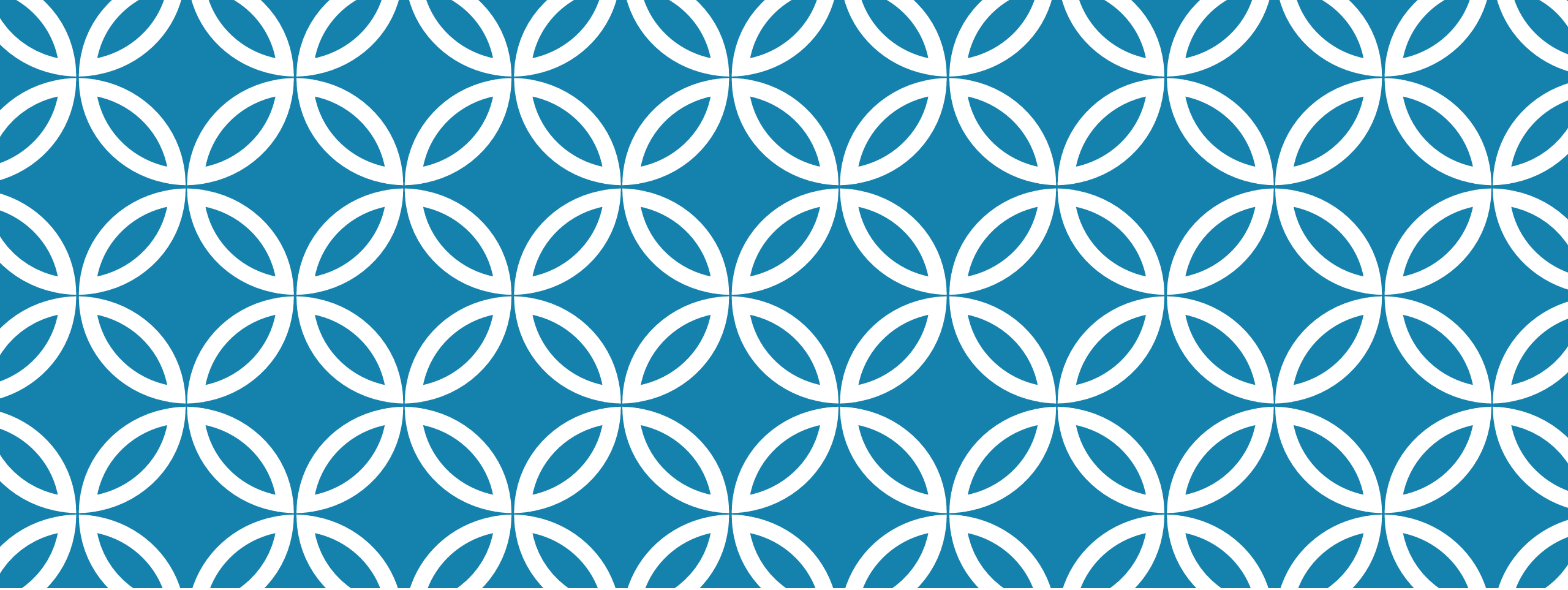
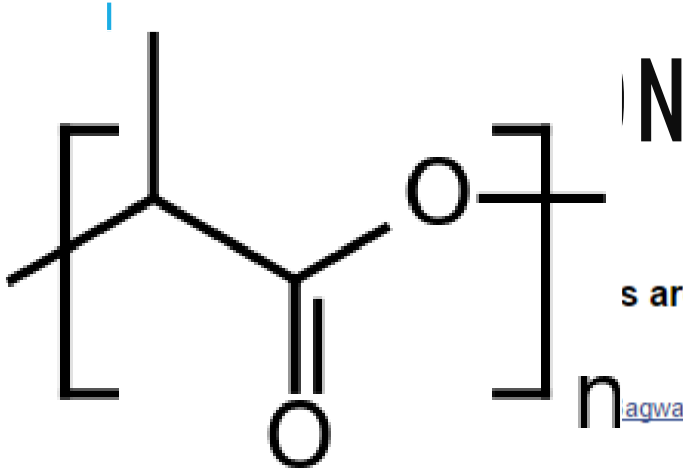


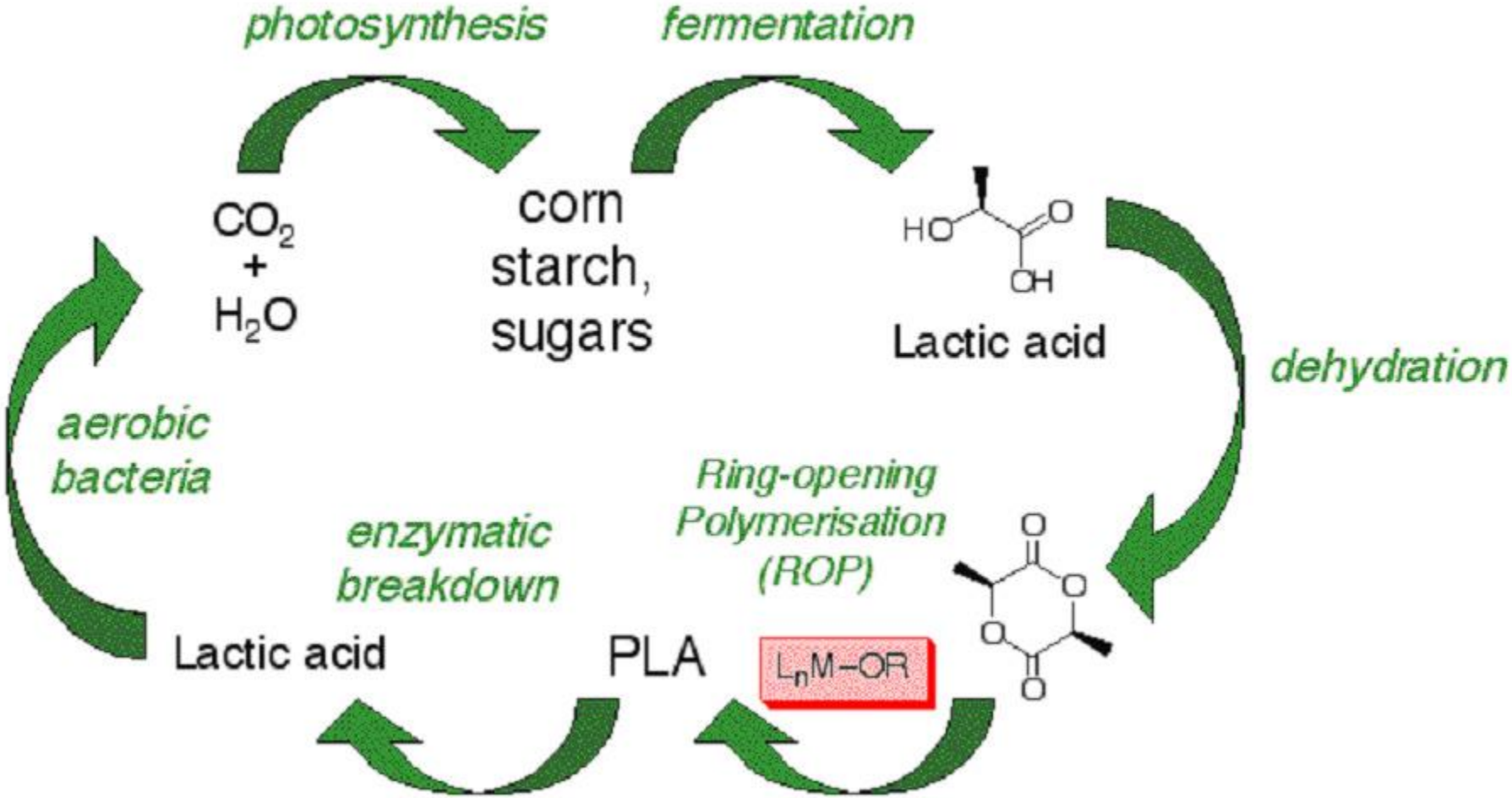
3D PRINTED PLA SCAFFOLDS

Shankhabrata Nag
Kaushik Chatterjee



More than 121,000 people in the Uni
waiting list for a lifesaving organ tra

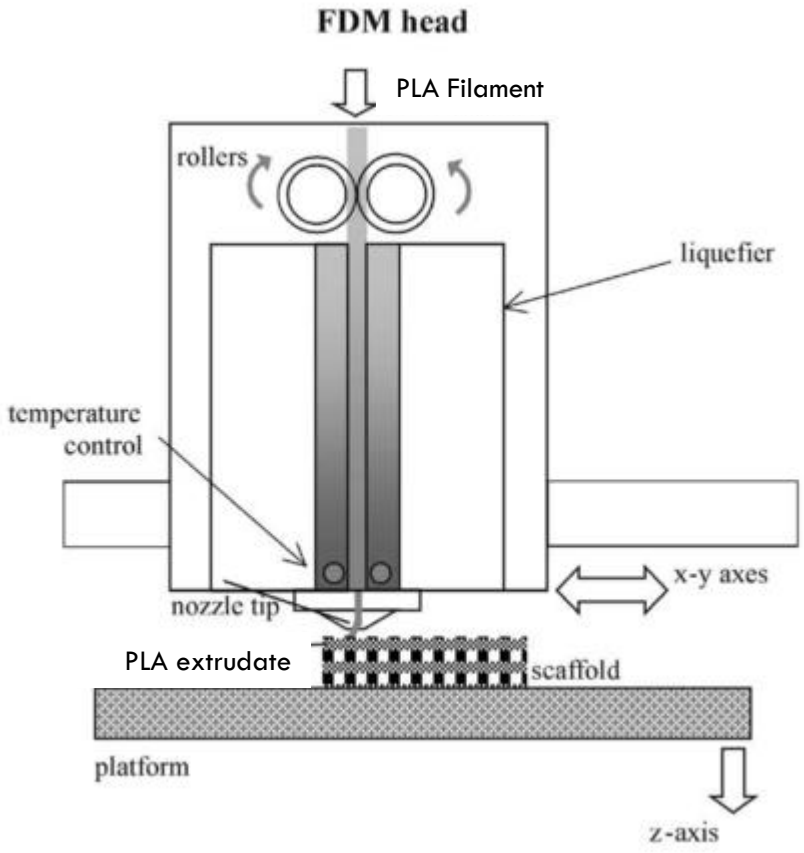
- Another name is added to the **every 10 minutes**.
- On average, **22 people die e** available organs for transplant

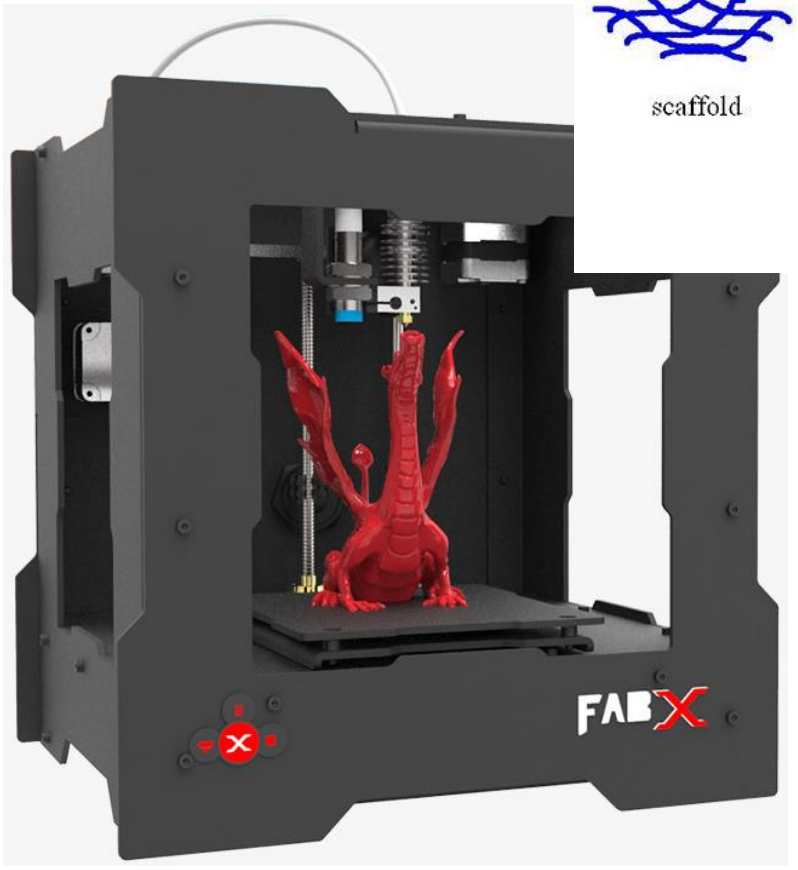


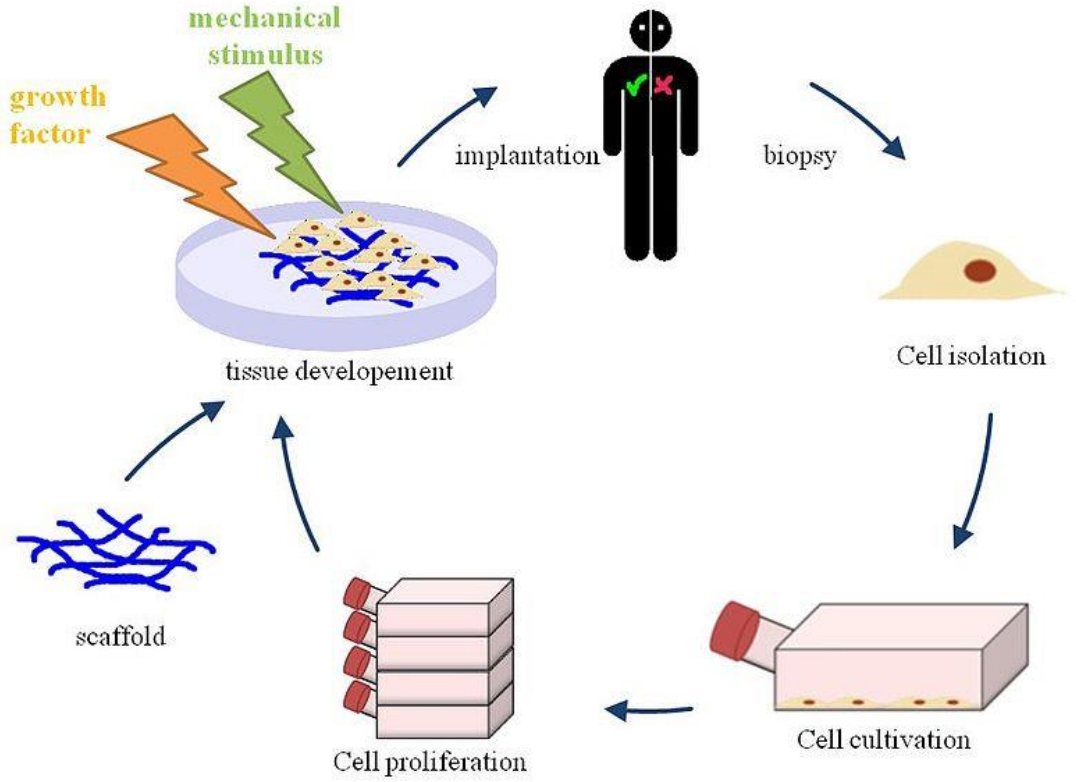
American Transplant Foundation
National Health Service, 2013

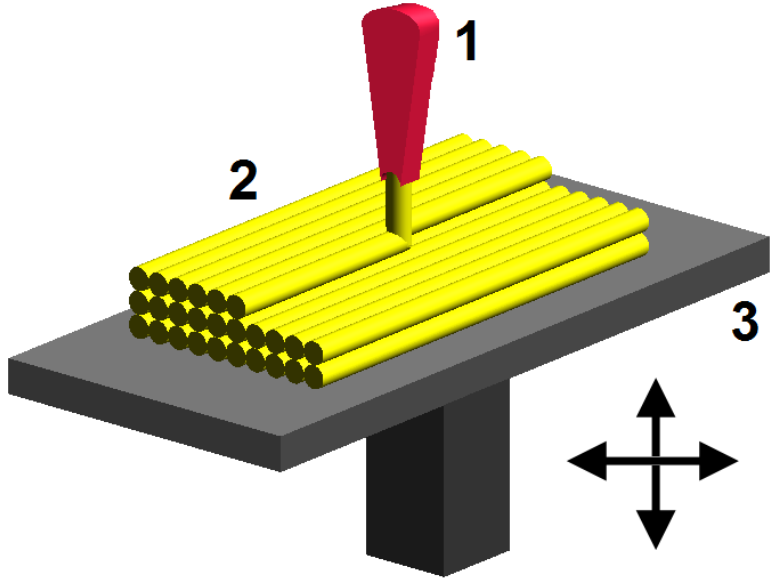
http://www.ch.ic.ac.uk/vgibson/research5.htm

WHAT IS 3D PRINTING



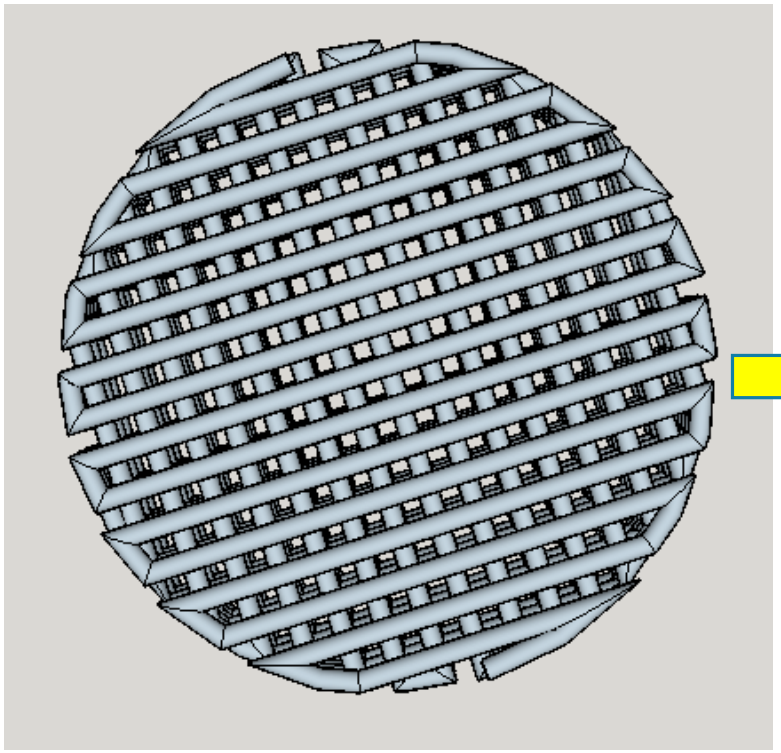




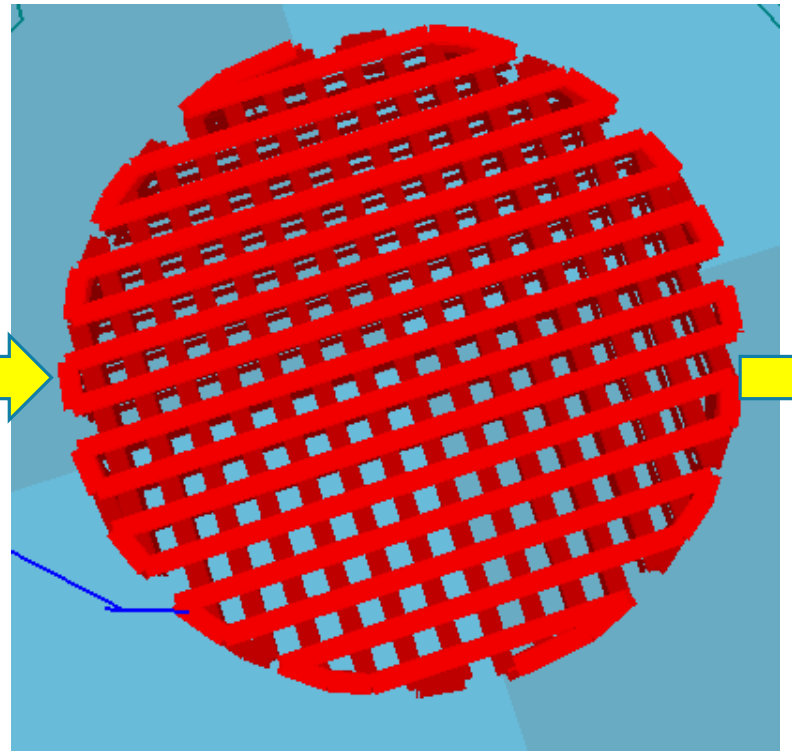


Zein et al (2002), *Biomaterials Vol23*

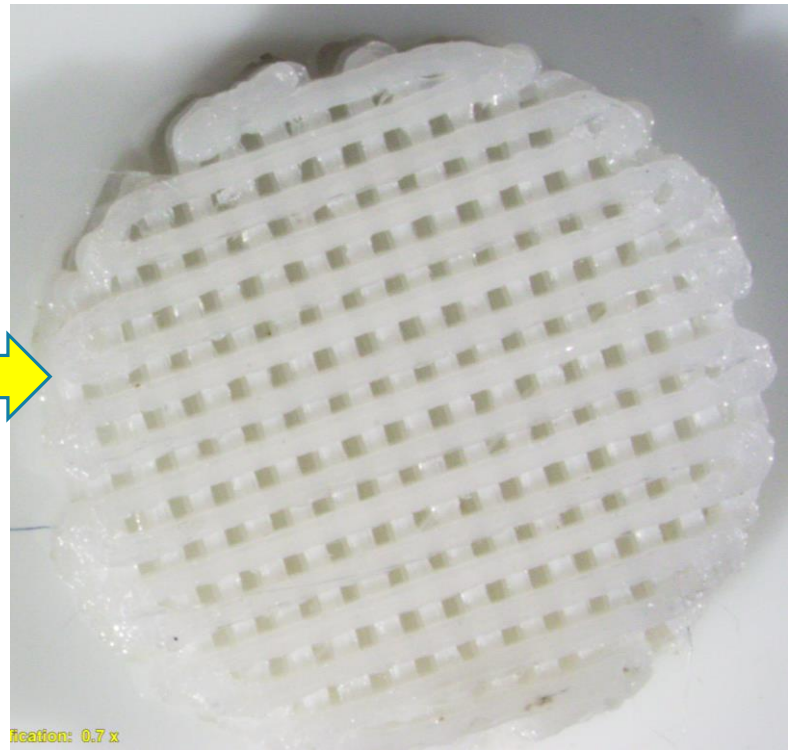
DESIGN AND SCAFFOLD DEVELOPMENT



CAD
Sketch Up

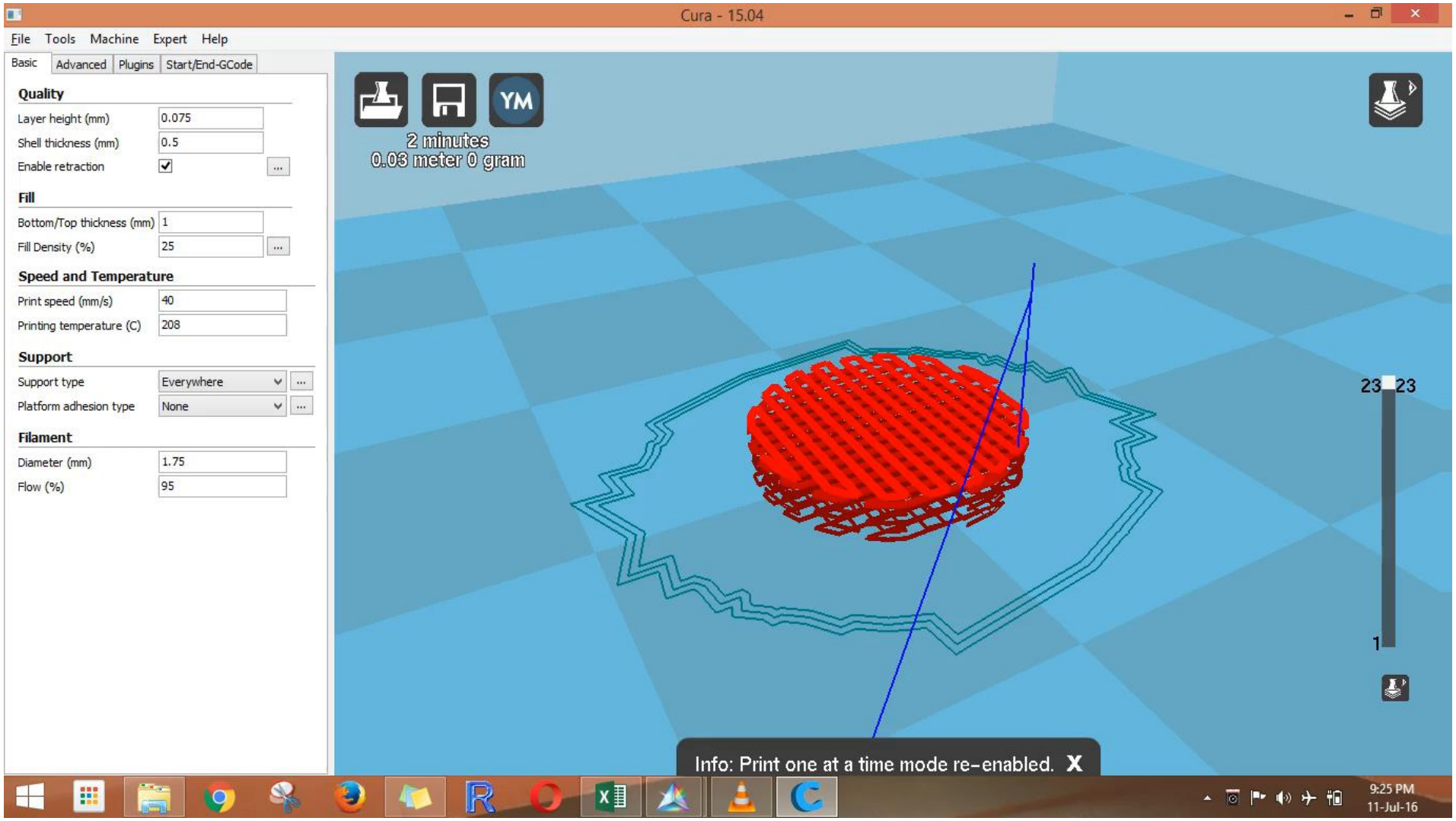


Slicing Software
Cura

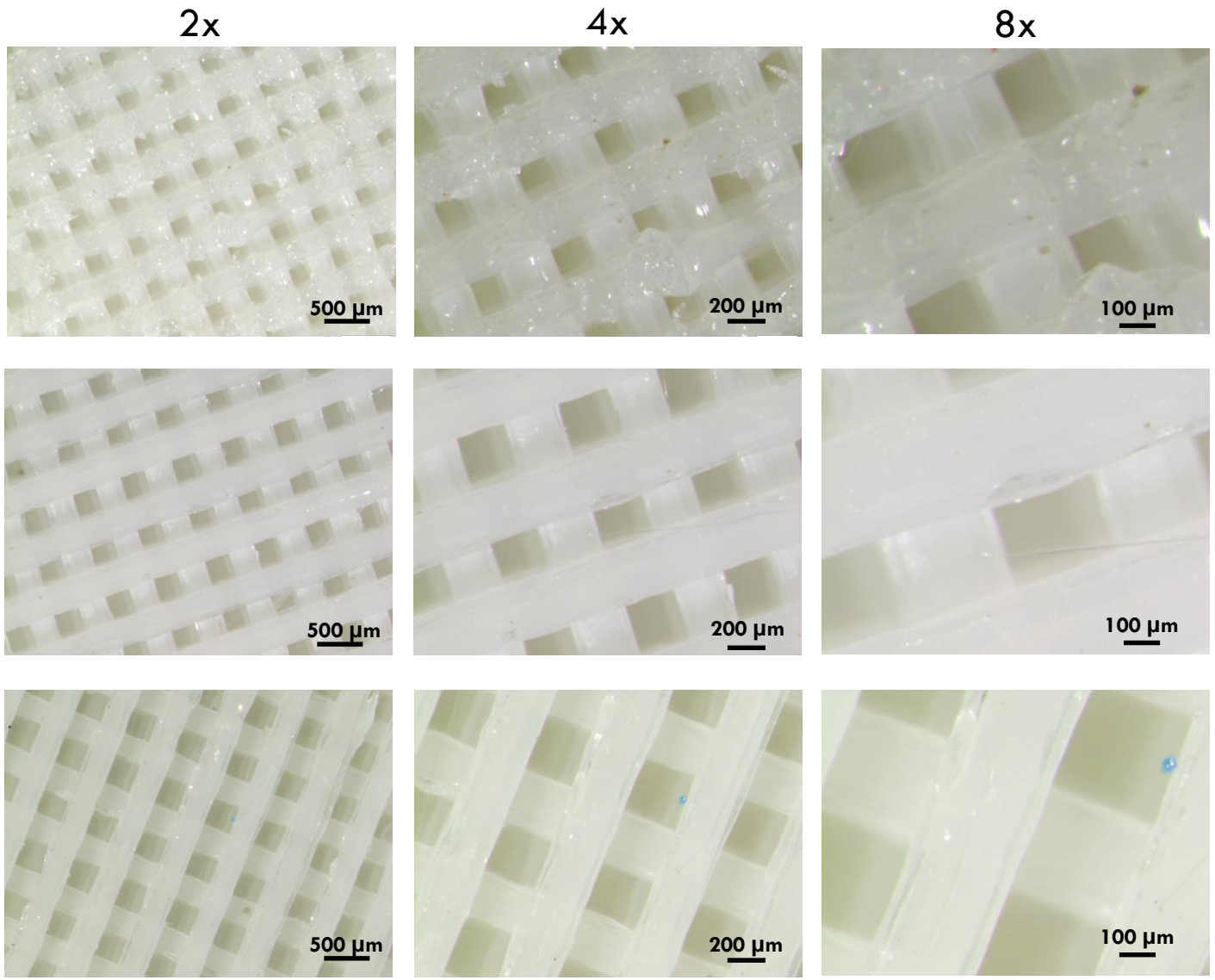


Final Model

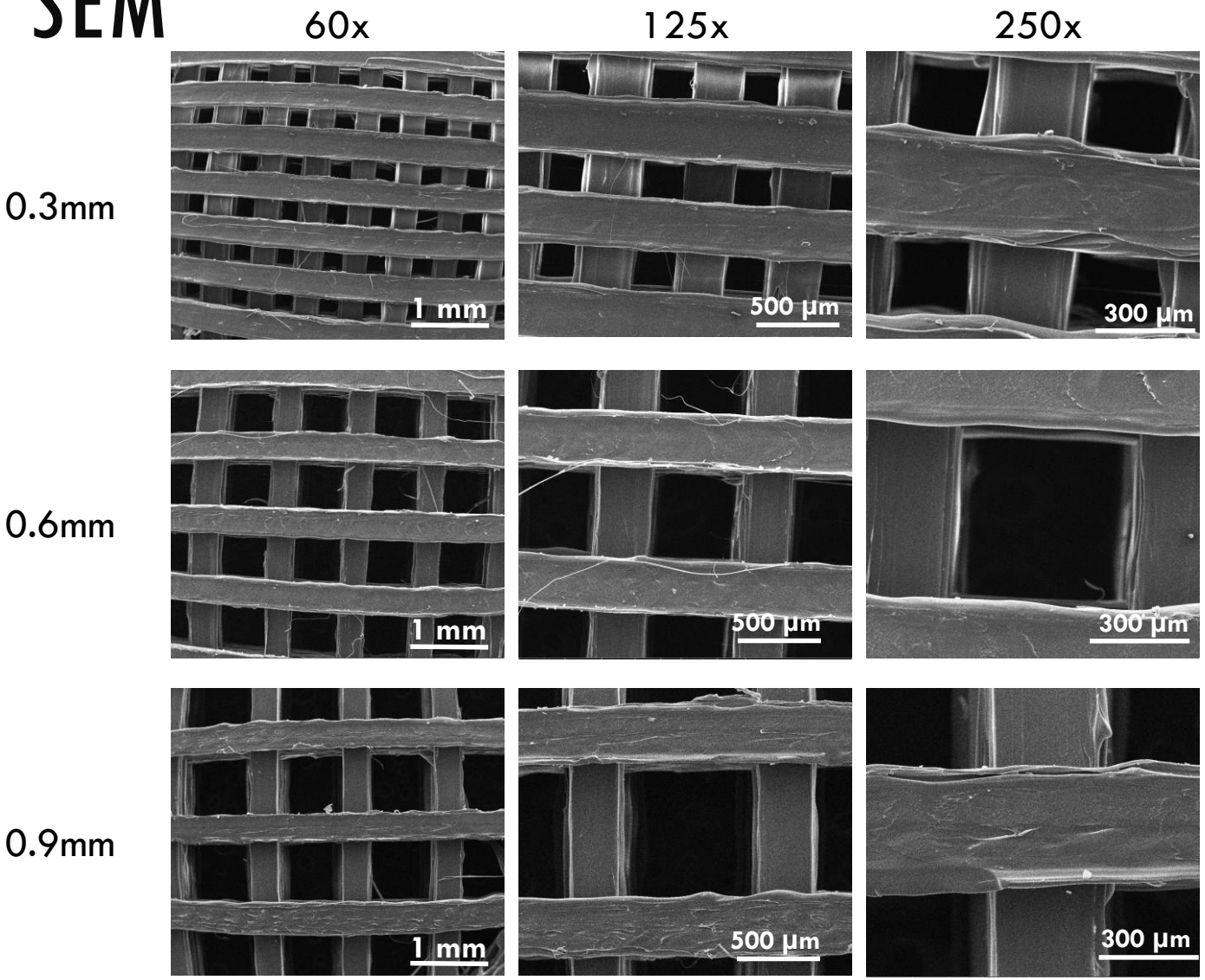
CURA

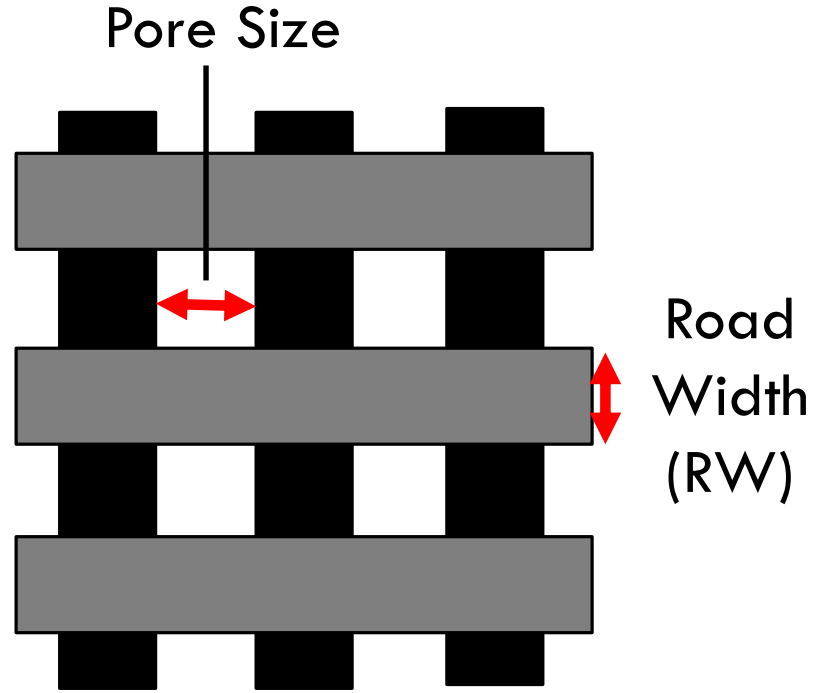

Cura - 15.04
File Tools Machine Expert Help
Basic Advanced Plugins Start/End-GCode
Quality
Layer height (mm) 0.075
Shell thickness (mm) 0.5
Enable retraction
Fill
Bottom/Top thickness (mm) 1
Fill Density (%) 25
Speed and Temperature
Print speed (mm/s) 40
Printing temperature (C) 208
Support
Support type Everywhere
Platform adhesion type None
Filament
Diameter (mm) 1.75
Flow (%) 95
YM
2 minutes
0.03 meter 0 gram
23 23
1
Info: Print one at a time mode re-enabled. X
9:25 PM
11-Jul-16

OPTIMIZATION

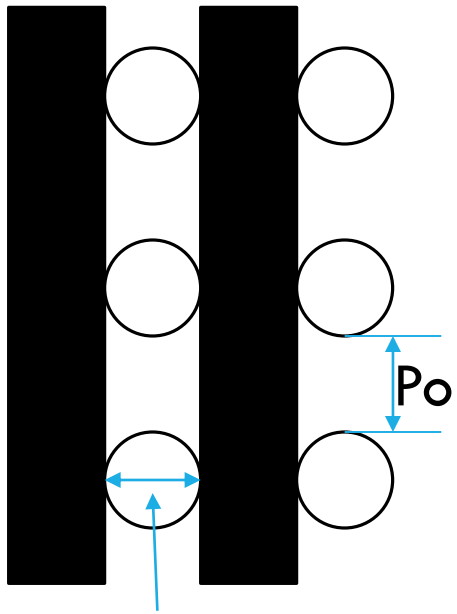


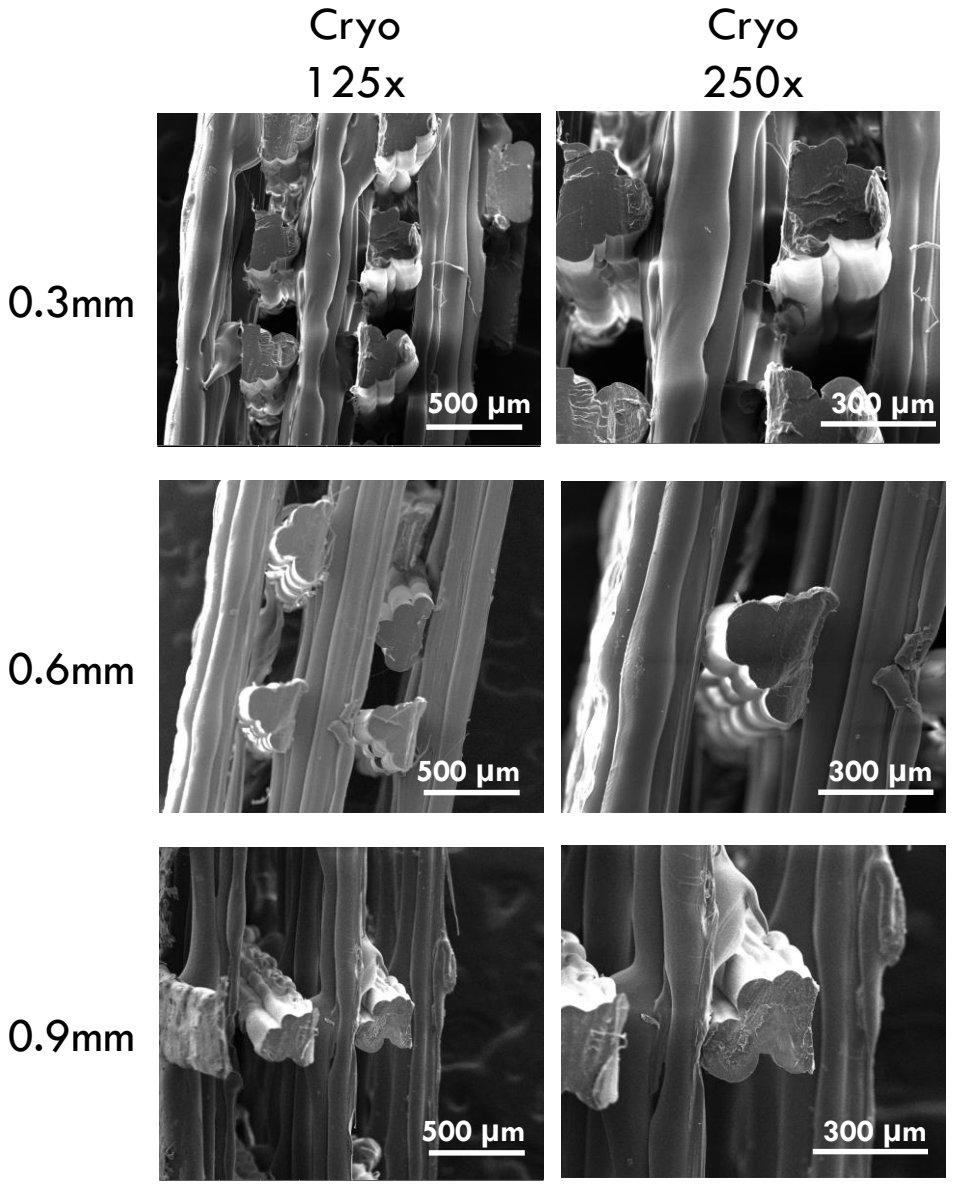
SEM


60x
125x
250x
0.3mm
0.6mm
0.9mm
1 mm
500 µm
300 µm


Pore Size
Road Width (RW)

CRYO


Pore Size
Road Width
(RW)


Cryo
125x
Cryo
250x
0.3mm
0.6mm
0.9mm
500 µm
300 µm
500 µm
300 µm
500 µm
300 µm

DIMENSIONS

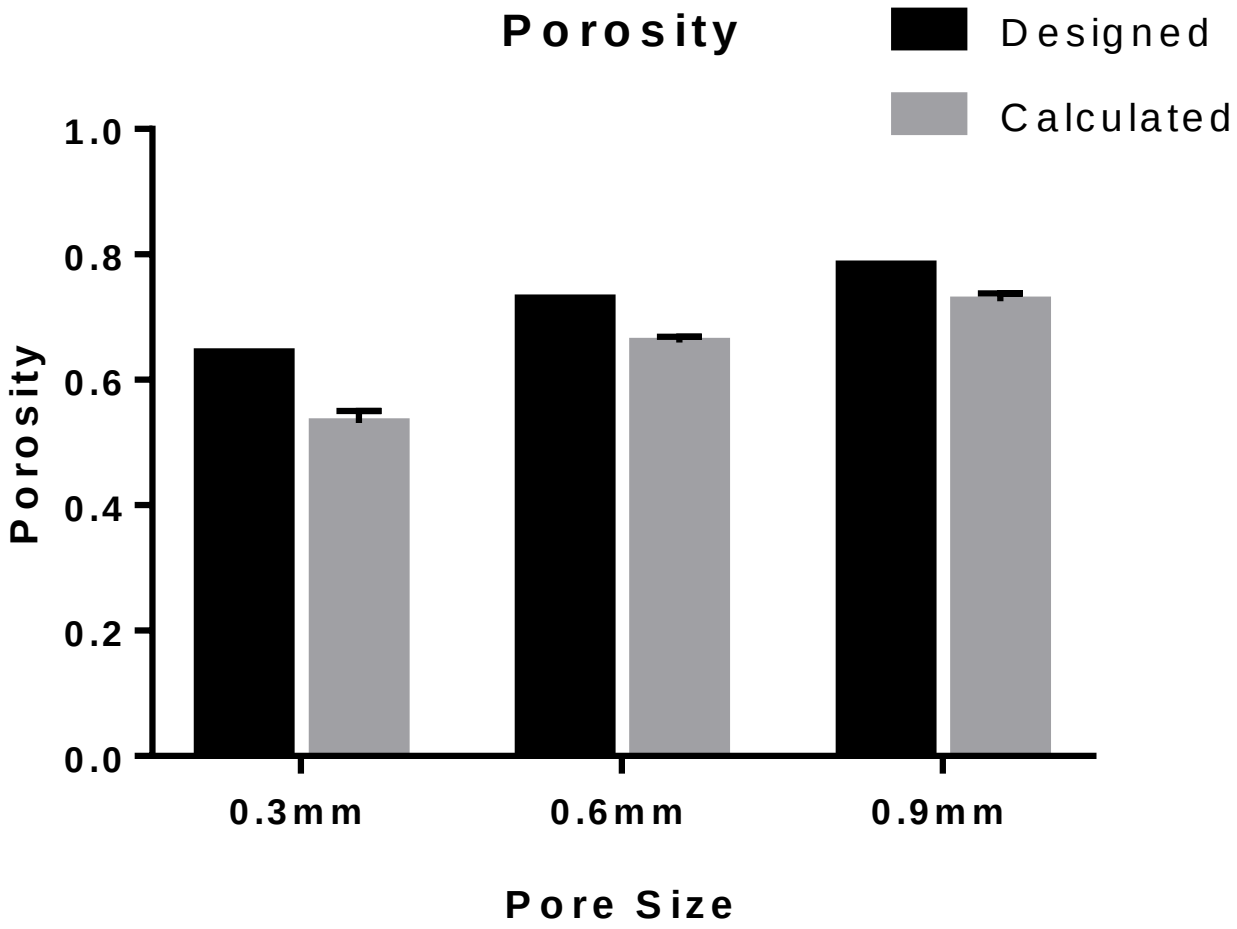
Scaffold	Diameter(mm)	Height(mm)	Pore Size(mm)	RW(mm)	Weight(mg)
0.3mm	9.44±0.06	1.82±0.03	0.275±0.024	0.319±0.026	71.2±3.0
0.6mm	9.46±0.07	1.77±0.03	0.588±0.022	0.338±0.015	50.4±2.7
0.9mm	9.54±0.04	1.83±0.02	0.851±0.025	0.343±0.021	42.7±2.5

POROSITY

$$Porosity = 1 - \frac{\rho_{scaffold}}{\rho_{material}}$$

$$Scaffold\ Volume = \frac{\pi d^2 h}{4}$$

$$\rho_{material} = 1.184\ g/cc$$

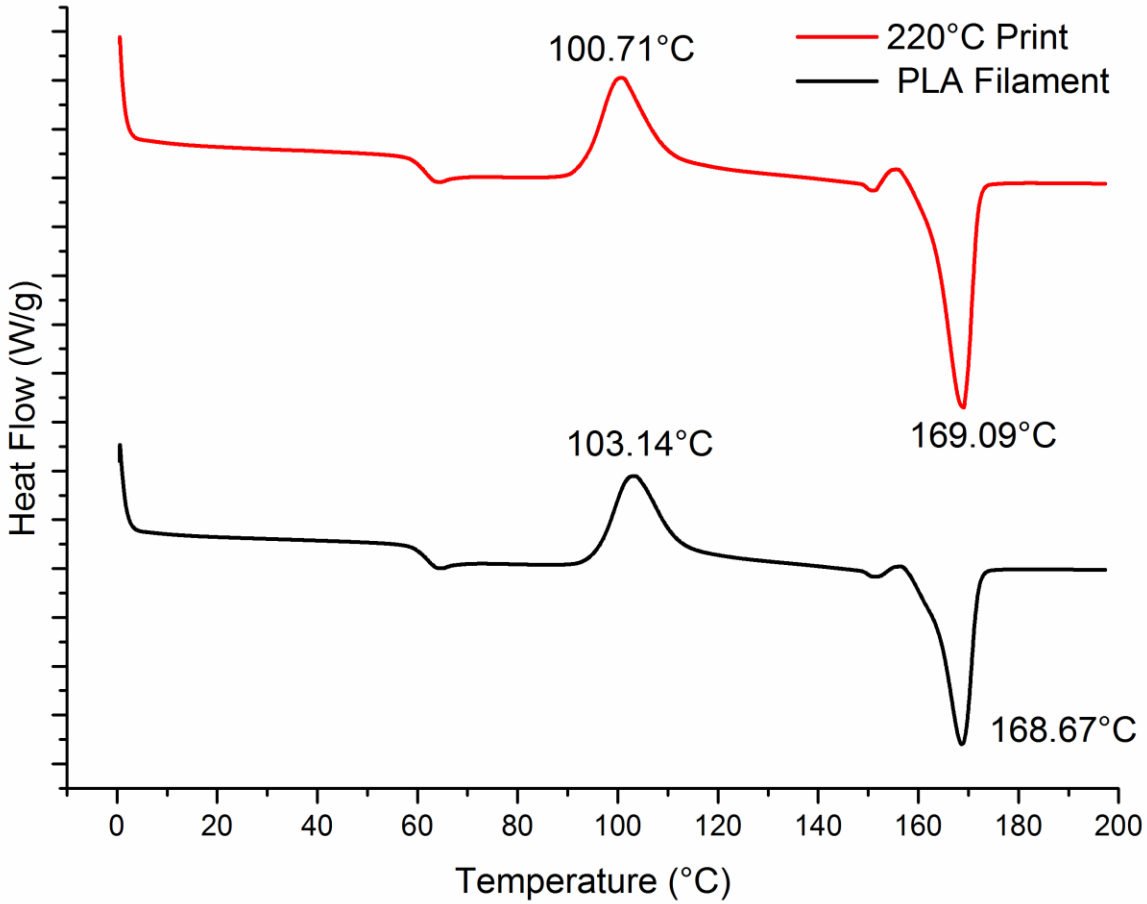


DSC

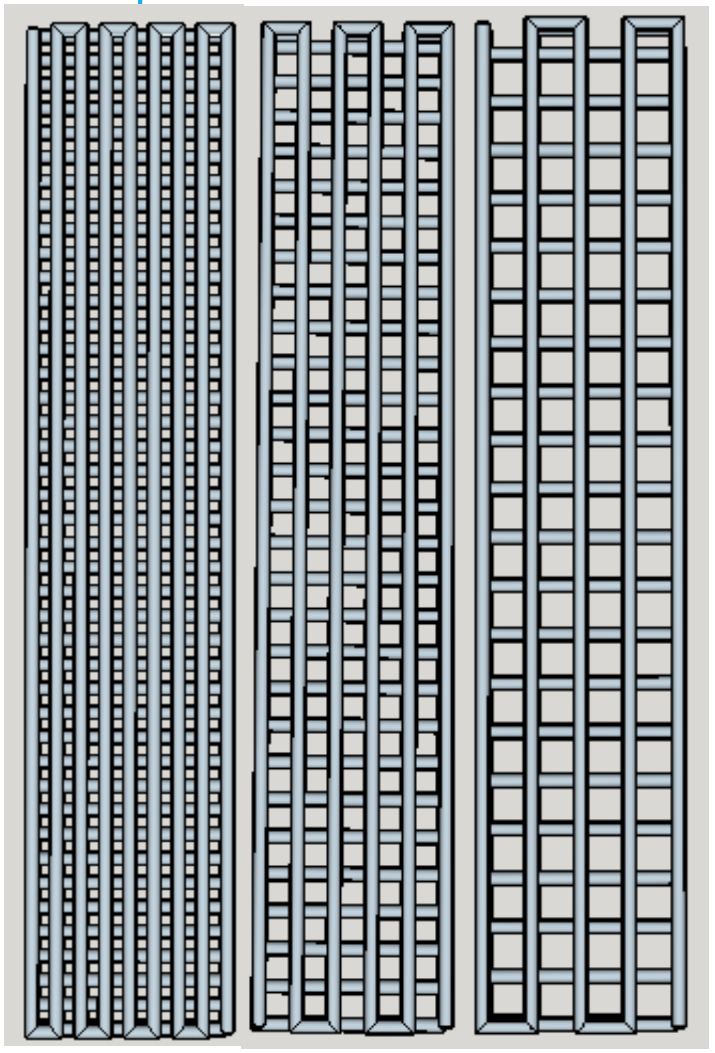
Sample	$T_{crystallization}$	$T_{melting}$	% Crystallinity
PLA Filament	103.14°C	169.09°C	33.1%
220°C Print	100.71°C	168.67°C	42.6%

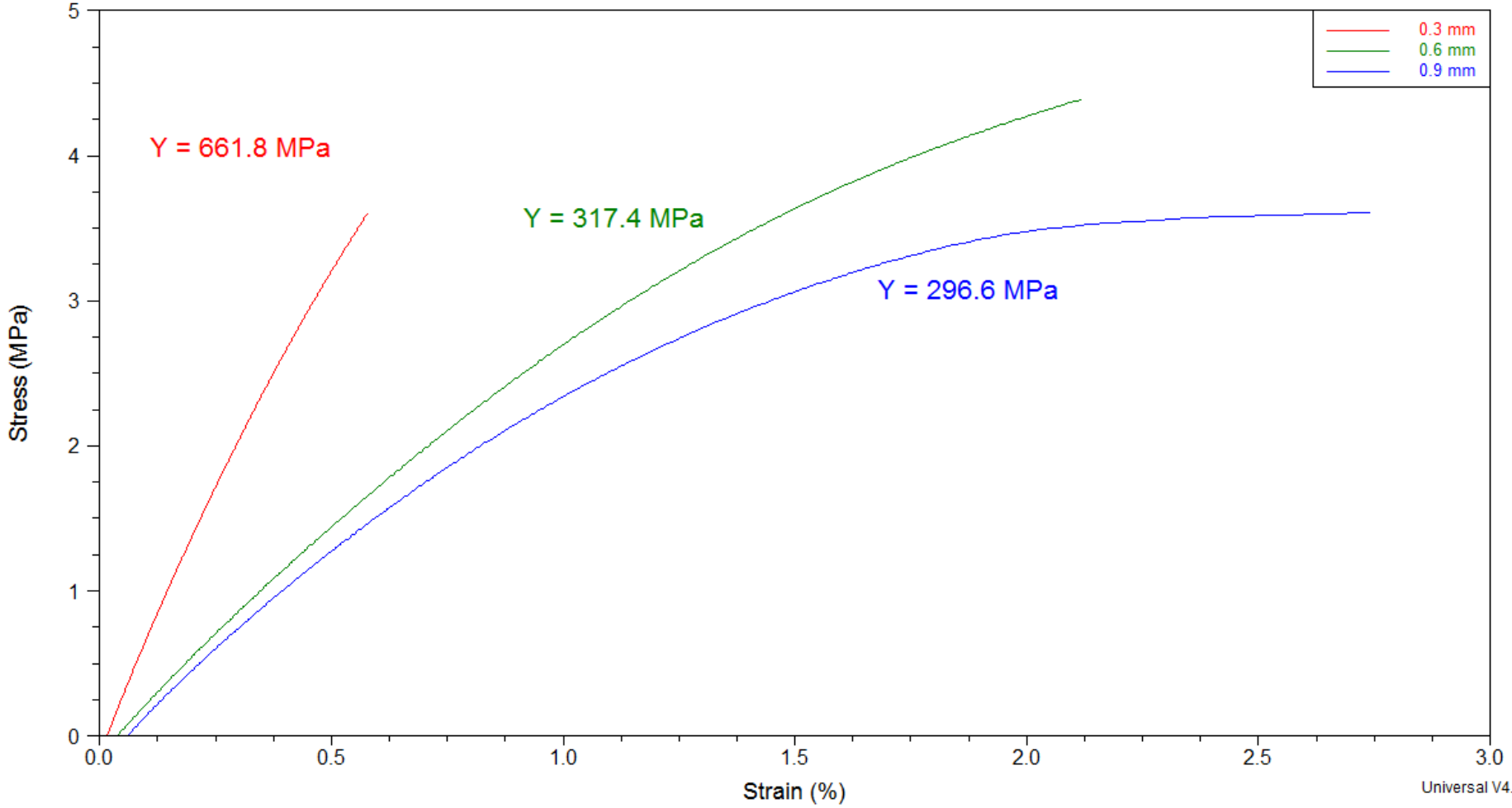
$$\% \, Crystallinity = \frac{\Delta H_{fusion}}{\Delta H^{\circ}} * 100$$

$$\Delta H^{\circ} = \Delta H_{fusion} \, for \, pure \, crystalline \, PLA$$
$$= \; 91 \pm 3 \; J/g$$

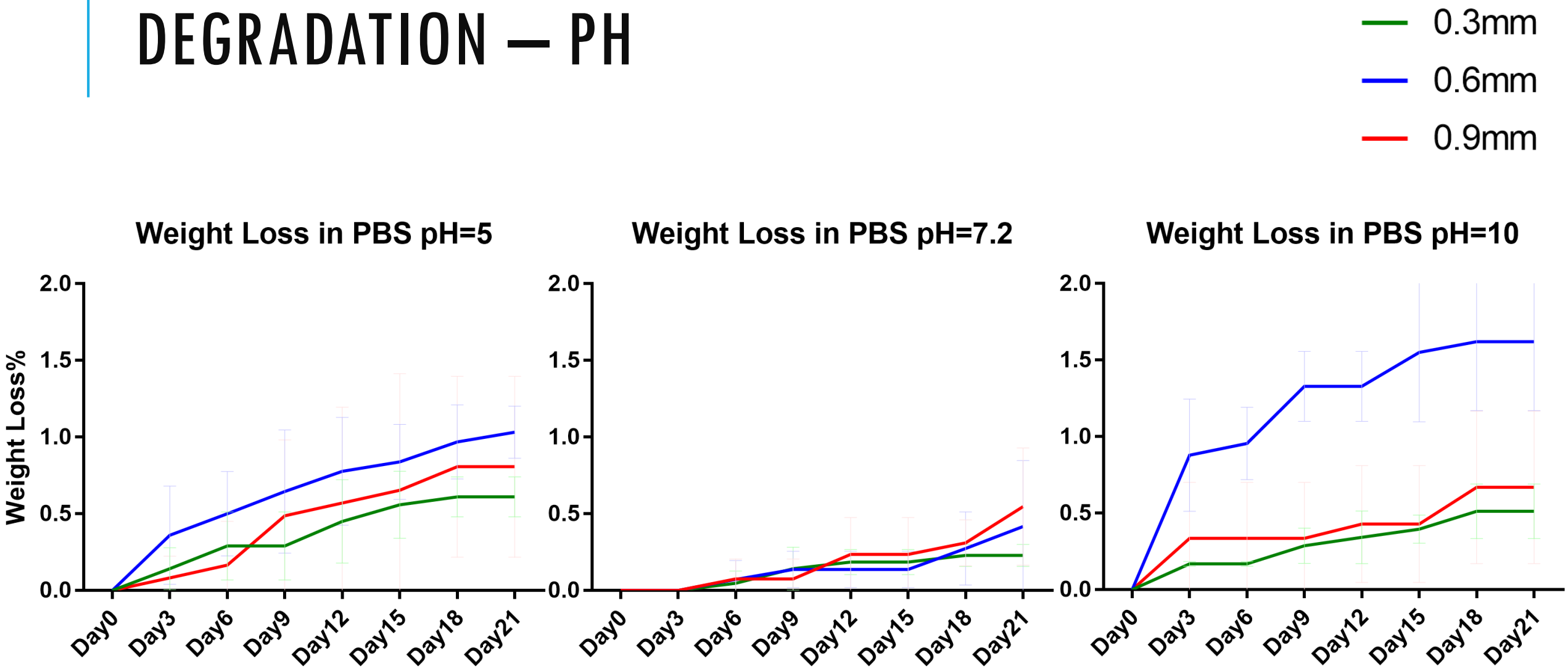


DMA

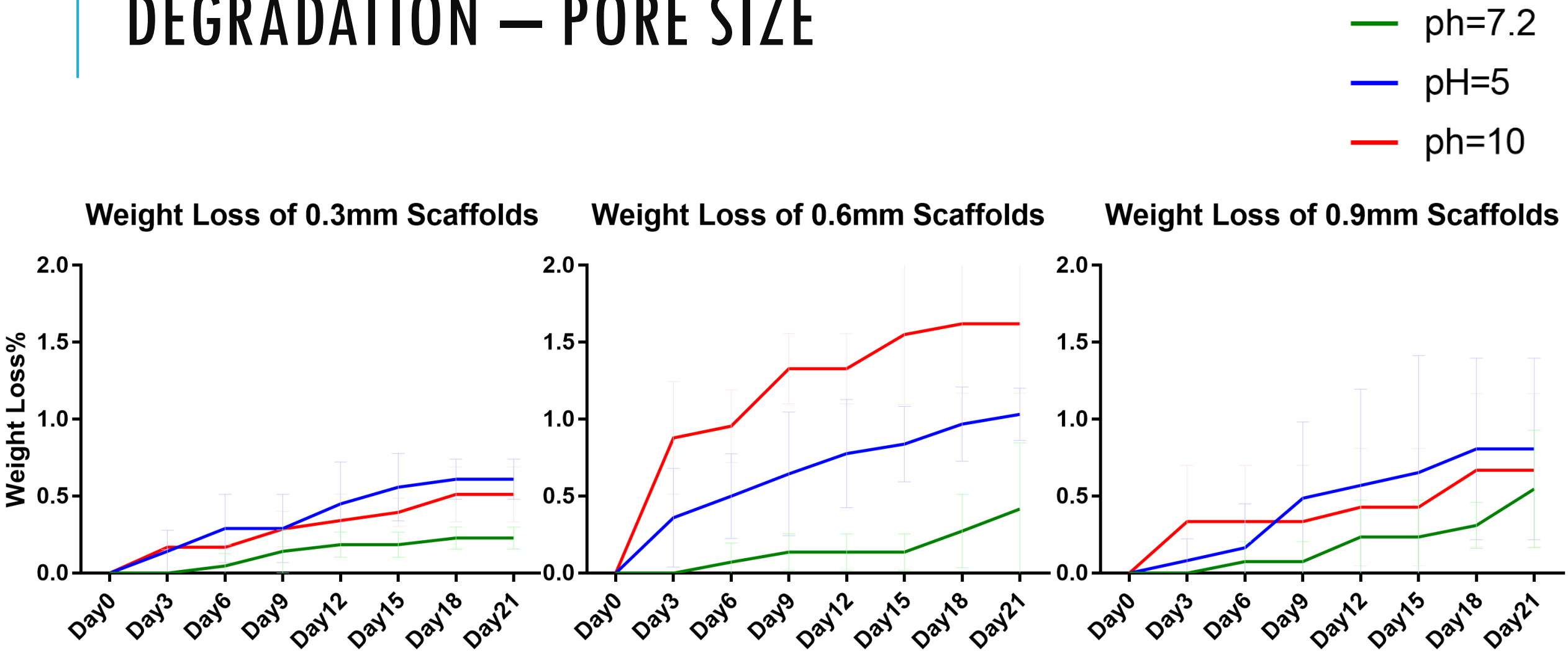



0.3 mm
0.6 mm
0.9 mm
Y = 661.8 MPa
Y = 317.4 MPa
Y = 296.6 MPa
Stress (MPa)
Strain (%)
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Universal V4.

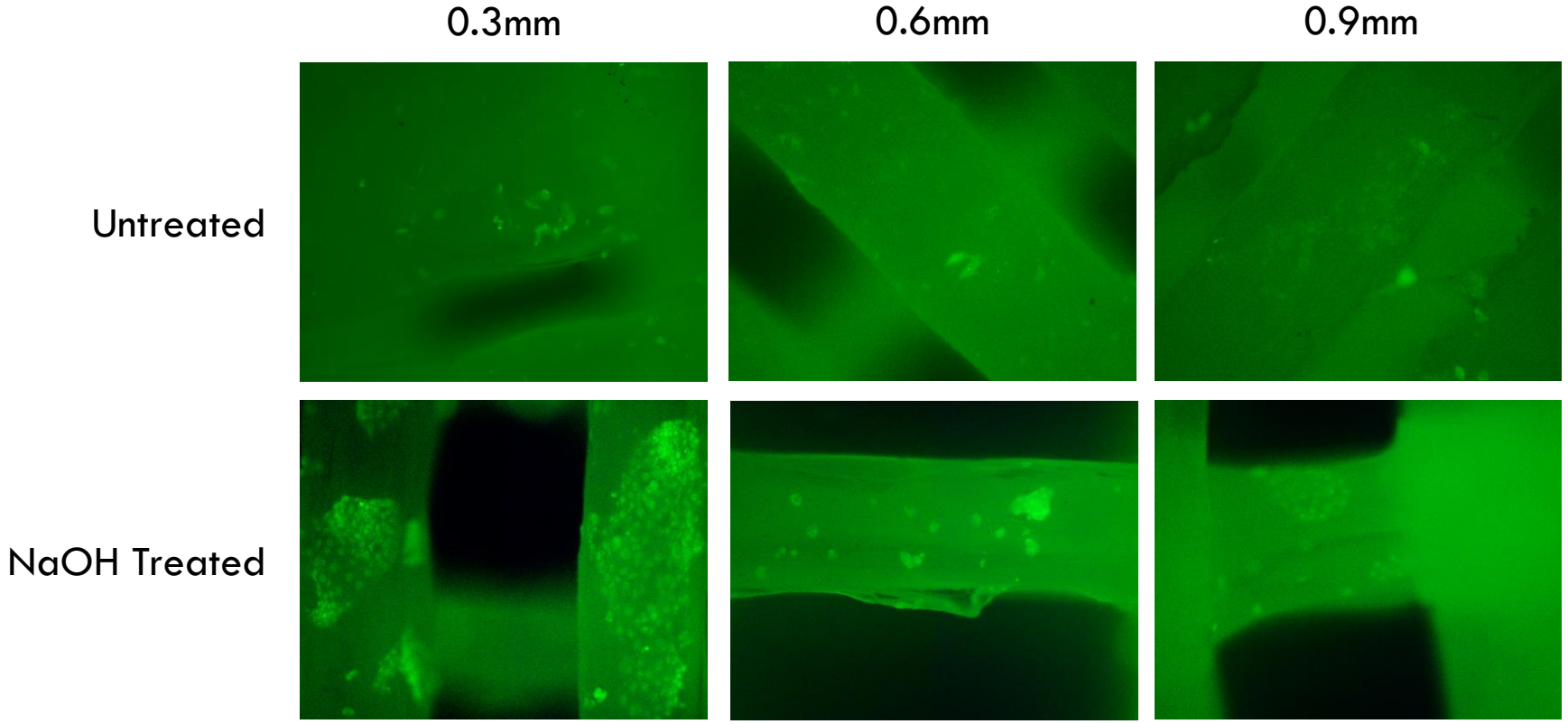
DEGRADATION – PH



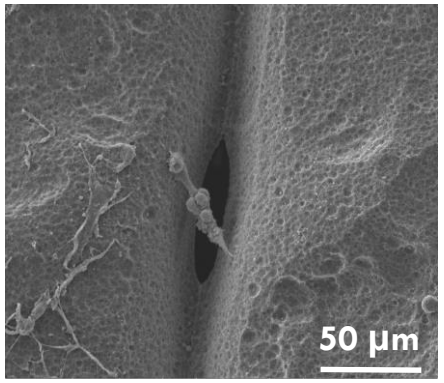
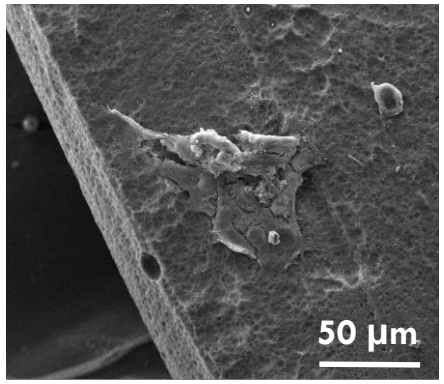
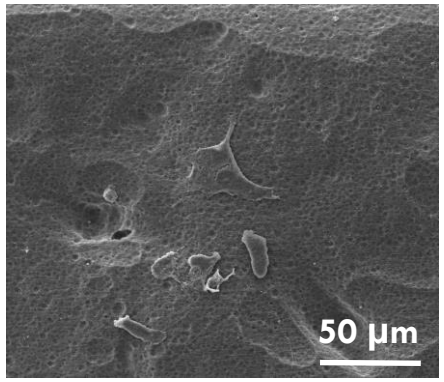
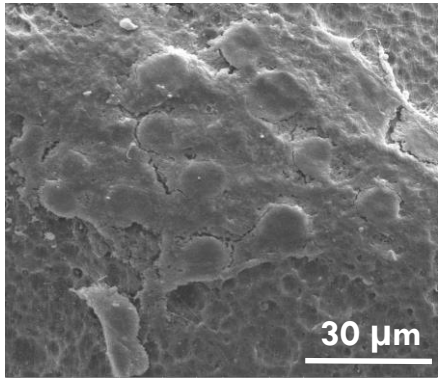
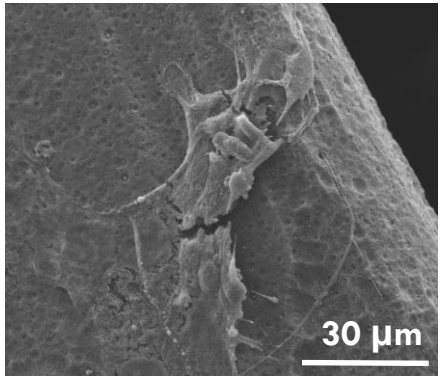
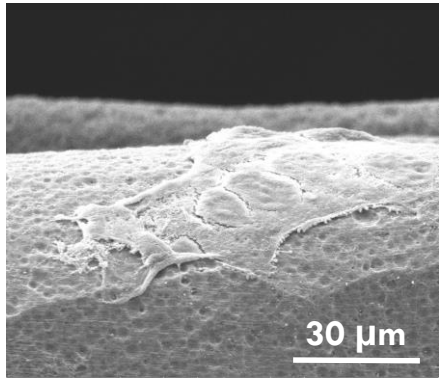
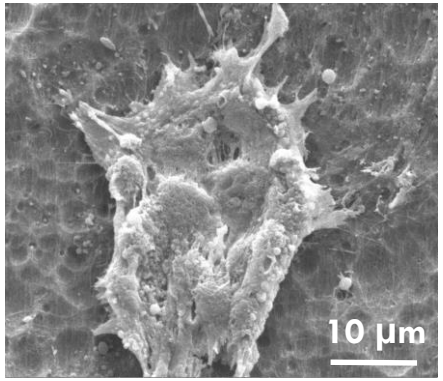
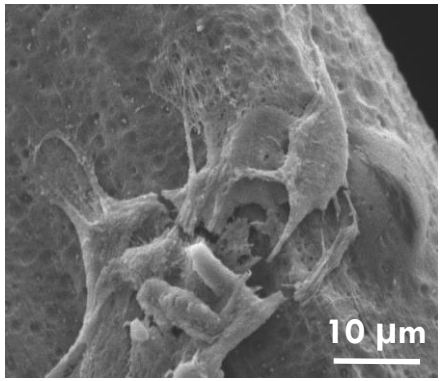
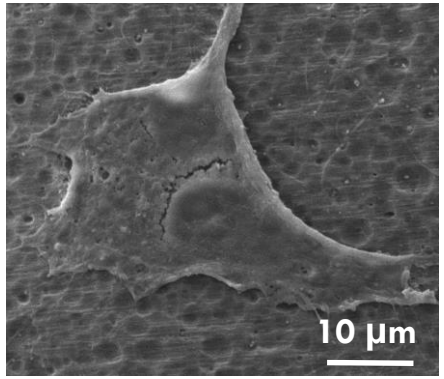
DEGRADATION – PORE SIZE



BIOLOGICAL STUDY



BIOLOGICAL STUDY

	0.3mm	0.6mm	0.9mm
SEM 1200x			
SEM 2400x			
SEM 5000x			

FUTURE WORK

Conduct biological study for a longer periods and observe extent of coverage

Use composites to vary the scaffold properties

Use PCL and other materials and observe changes in biodegradability and compatibility

Redesign extruder to get continuous, precise filaments

Directly print using biogels

SUMMARY

3D Printed PLA scaffolds were developed using an FDM print

Dimensions of the scaffolds were in good agreement with the designed models

Porosity of the scaffolds increased with pore size

There was no change in Melting and Crytsallization point, but a change in %crystallinity

Smaller the pore size, stiffer the scaffold

Scaffolds degraded faster at pH 5 and 10 as compared to pH 7.2

Scaffolds were not toxic to cells and allowed the attachment of cells to the surface

Treatment with NaOH improved cell attachment

ACKNOWLEDGEMENTS

SN would like to thank LRJ for his constant support and guidance

Vikas for his help handling the 3D printer

Sachin and Queeny for their help in carrying out the DMA and DSC analysis

Sai and Vipul for their continued help and motivation

SN would like to thank KC and BSSE for the opportunity to work on this project

The authors would like to acknowledge the Division of Interdisciplinary Research and BSSE, Indian Institute of Science for the financial assistance.

THANK YOU