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Professor Tim Cooley
MET 436 Pneumatic Motion Control Systems
Purdue University, Purdue Polytechnic New Albany
15 March 2020

Project 3 Microfluidics Closure Document

The little bubble maker.

Executive Summary

This document details the Project Closure Document for Project 3 for MET 436 Pneumatic Motion Control Systems and describes the progress up to the point at which the project was terminated due to the United States National Emergency of the 2019 Novel Coronavirus (COVID-19).

This Engineer's recommendation is if cost were not an option the process of using a FormLabs Form 3 3D printer would lead to the highest reliability and repeatability for manufacturing, while if cost were the primary decision driver then a sandwiched process approach of 2 layers of vinyl between 2 layers of acrylic cut with a vinyl cutter and laser respectively would most likely lead to a low-cost option.

I was tasked by The Really Cool Engineering Co. (the customer) with the design, build, test, and iteration in 7 weeks of a microfluidic device manufacturing process that makes fluid encapsulated bubbles. Three of five processes were tested, two were selected which would most likely lead to successful completion of the original goal, one of which has been demonstrated via previously published research to generate microfluidic bubbles. (See attached research notes for reference.)

For grading purposes, attached to this document is a 106 page PDF of the images and photographs, a 112 page PDF of the raw digital notes and research, and a 3 page PDF of the hand-drawn drawing package, as I have not had access to SOLIDWORKS or AutoCAD in ~1.5 weeks.

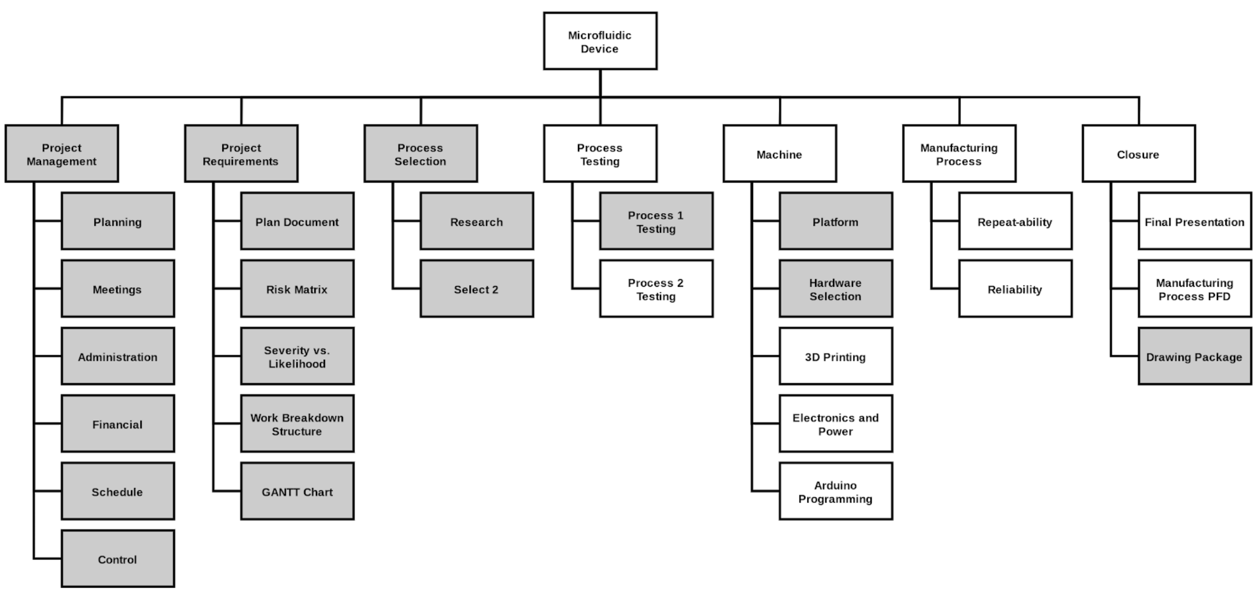
Deliverables

Items marked with a check were completed, items marked with an X were prevented from completion due to project closure.

1. Demonstration of Working Microfluidic Device ✓
    a. Microfluidic Device ✓
    b. Fluid Delivery System ✓
        i. Tubing ✓
        ii. Pressure Vessel ✓
        iii. Electronics X
        iv. Arduino Programming X
    c. Broth Mixture showing fluid encapsulated bubbles X
2. Manufacturing Process Instructions X
3. (Modified) Drawing Package ✓
4. Closure Document ✓

Work Breakdown Structure (WBS)

The items marked in grey were completed successfully.

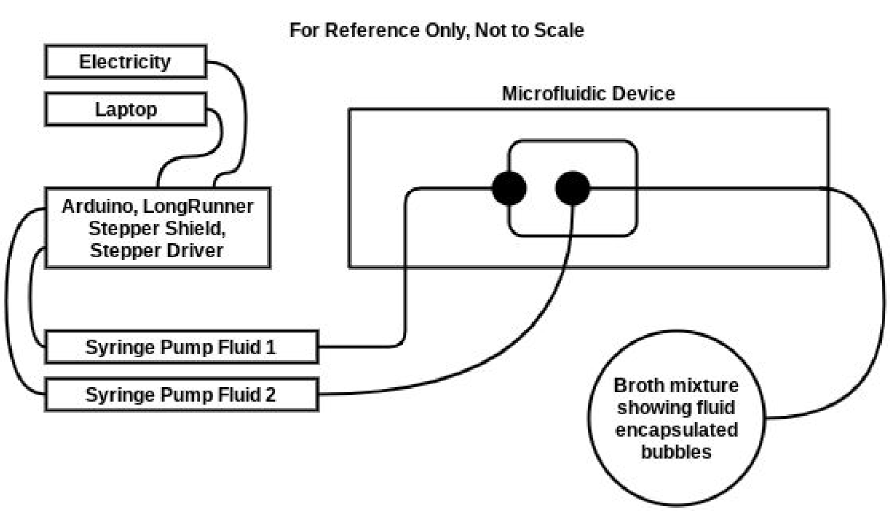


GANTT Chart

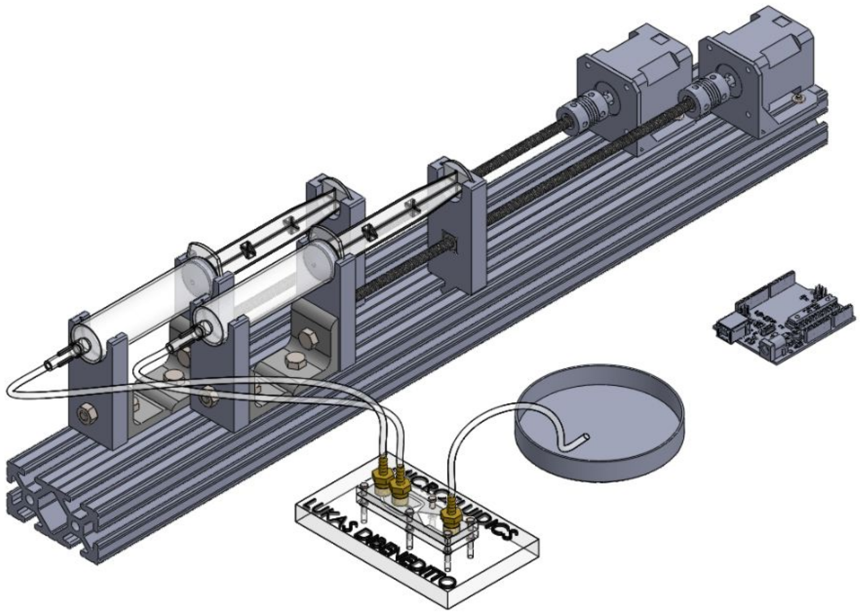
Items marked in grey were completed successfully and within the allocated and budgeted GANTT Chart timeframes.

					Week Ending On								
		Start	Due	Days	2/28	3/6	3/13	3/20	3/27	4/3	4/10	4/17	4/24
Project Management													
	Planning	2/27	2/28	1									
Project Requirements													
	Plan Document	2/27	2/28	1									
	Risk Matrix	2/27	2/28	1									
	Severity vs. Likelihood	2/27	2/28	1									
	Work Breakdown Structure	2/27	2/28	1									
	GNATT Chart	2/27	2/28	1									
Process Selection													
	Research	2/29	3/6	6									
	Select 2	2/29	3/6	6									
Process Testing													
	Process 1 Manufacturer	3/7	3/13	6									
	Process 2 Manufacturer	3/7	3/13	6									
Machine													
	Platform	3/7	3/27	20									
	Hardware Selection	3/7	3/27	20									
	Liquid Selection	3/7	3/27	20									
	3d Printing	3/7	3/27	20									
	Electronics and Power	3/7	3/27	20									
	Arduino Programming	3/7	3/27	20									
Manufacturing Process													
	Repeatability	3/21	4/3	13									
	Reliability	3/21	4/3	13									
Closure													
	Final Presentation	4/4	4/17	13									
	Manufacturing Process PFD	4/4	4/17	13									
	Drawing Package	4/4	4/17	13									

System Reference Drawing

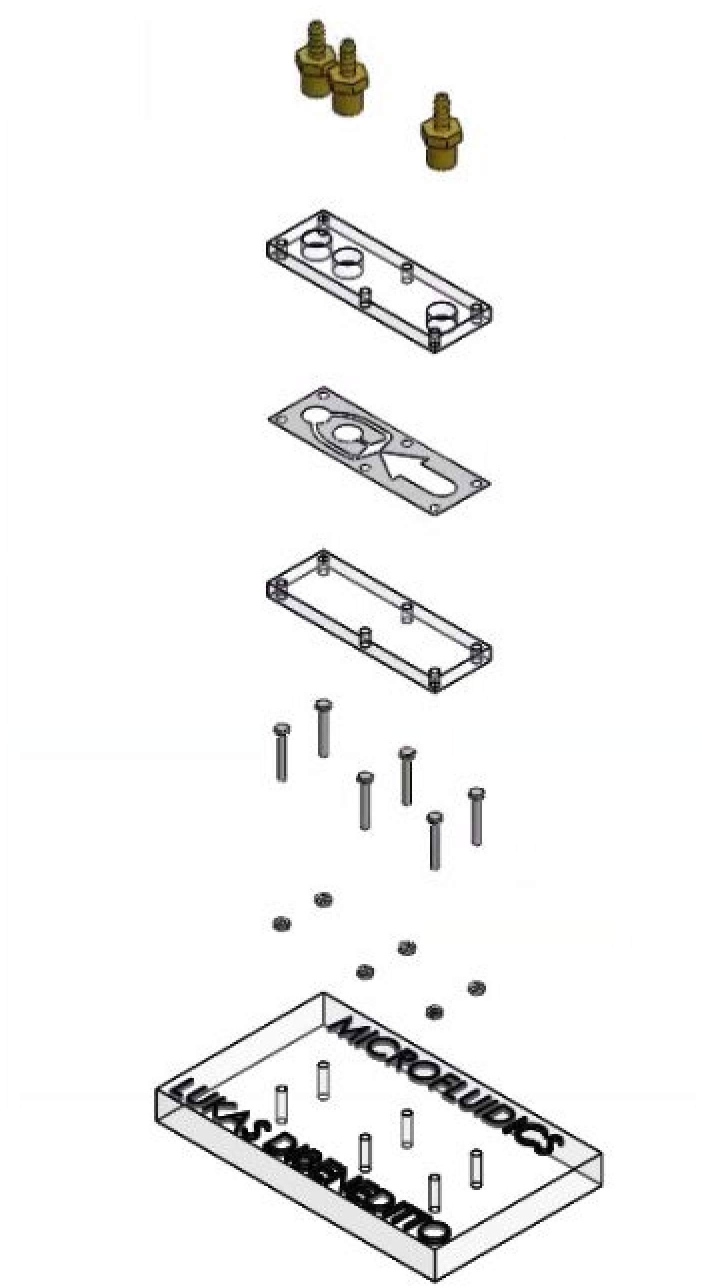


CAD Drawing Microfluidic Device Overall System



CAD drawing of Microfluidic Device Overall System, counterclockwise from the top right: 80/20 T-slot Aluminum Building System, NEMA stepper motors and bracket mounts, steel threaded rod, steel nuts, custom 3D printed ABS or milled Delrin to hold the syringe, L-brackets, 30 mL NIPRO disposable syringe, extension set with female Luer Lock connector and Spin-Lock connector 21 in 3 mL, Microfluidic Device (see next page), broth mixture catch basin, and Arduino to control the NEMA stepper motors.

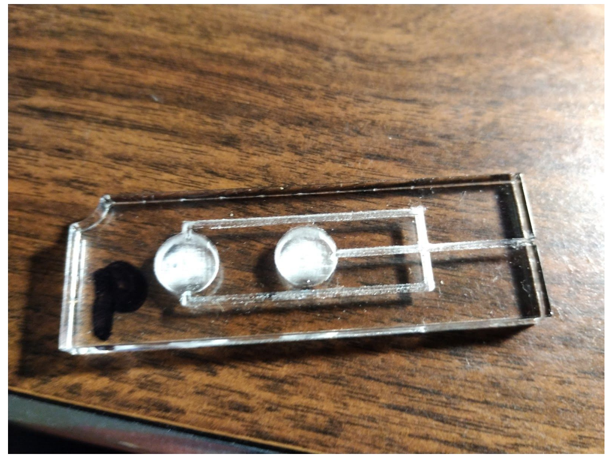
CAD Drawing Microfluidic Device



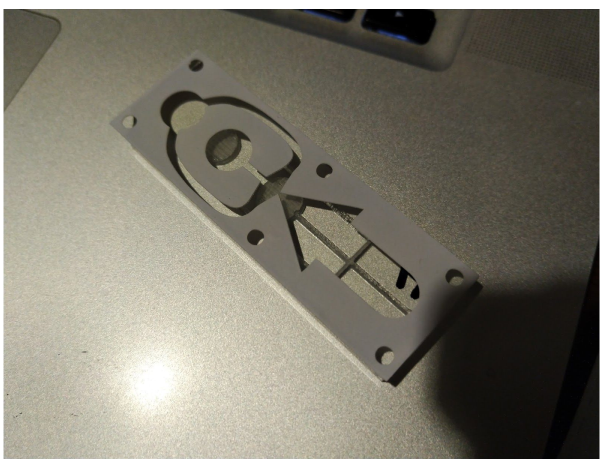
Exploded view CAD drawing of Microfluidic Device, from the top to the bottom:
brass low-pressure barbed tube fittings, laser cut acrylic, 2 layers of vinyl, laser cut acrylic,
10-32 screws, 10-32 nuts, and laser cut and etched acrylic base.

Photographs

Microfluidic pressure vessel syringe with a portion of Arduino controlled fluid delivery system.



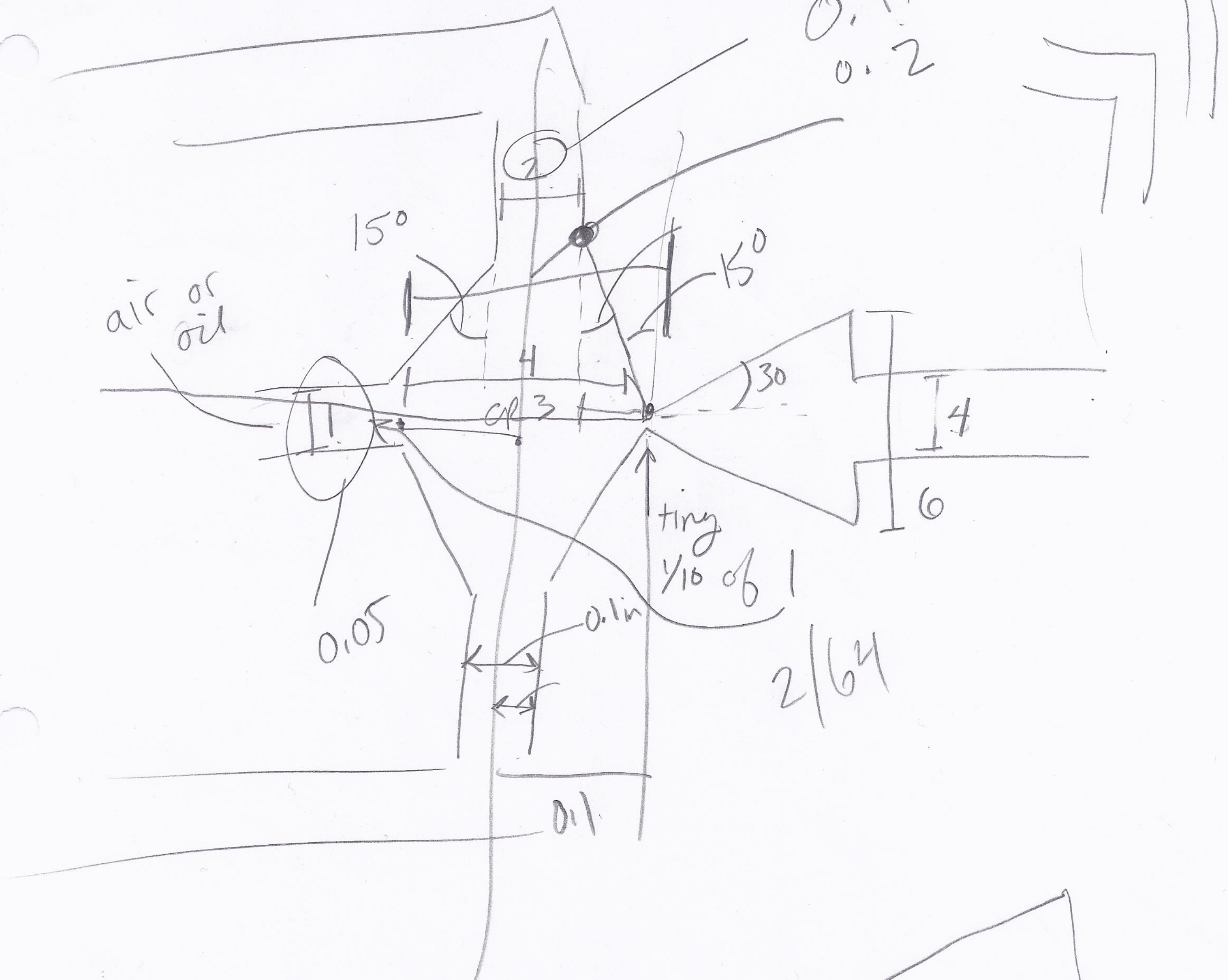
3 in X 1 in X 0.22 in Acrylic, 2 layer Acrylic with solvent and 2 part epoxy (total 6 test samples) all either leaked or sealed channel which had undesirable effects.

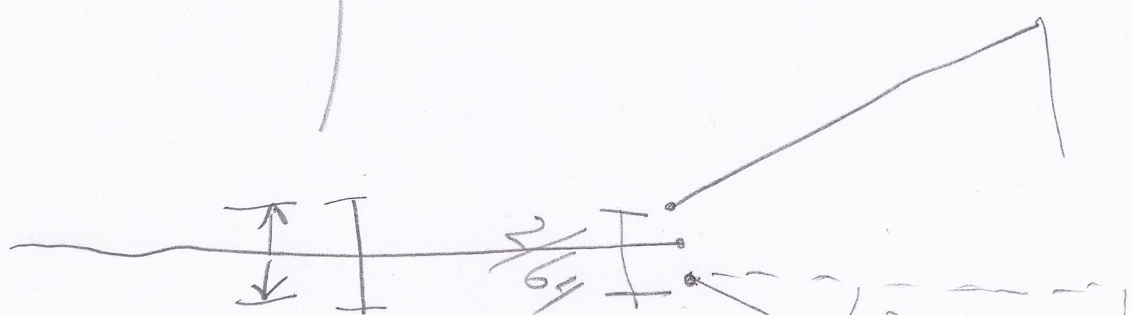


3 in X 1 in X 0.22 in Acrylic, with 2 layers of 0.0035 ± 0.005 in white vinyl, and a 0.007 ± 0.005 in microfluidic channel bubble generation gap.

3D printed FormLabs Form 3 Clear Resin microfluidic working sample.

MET-436
2020-03-10





vinyl matt
blade
1 0.004 vinyl
force 10
speed 5

white
0.035
0.0035

0.004 vinyl thickness

0.0035
~~0.004~~
0.007
0.007
~~0.008~~

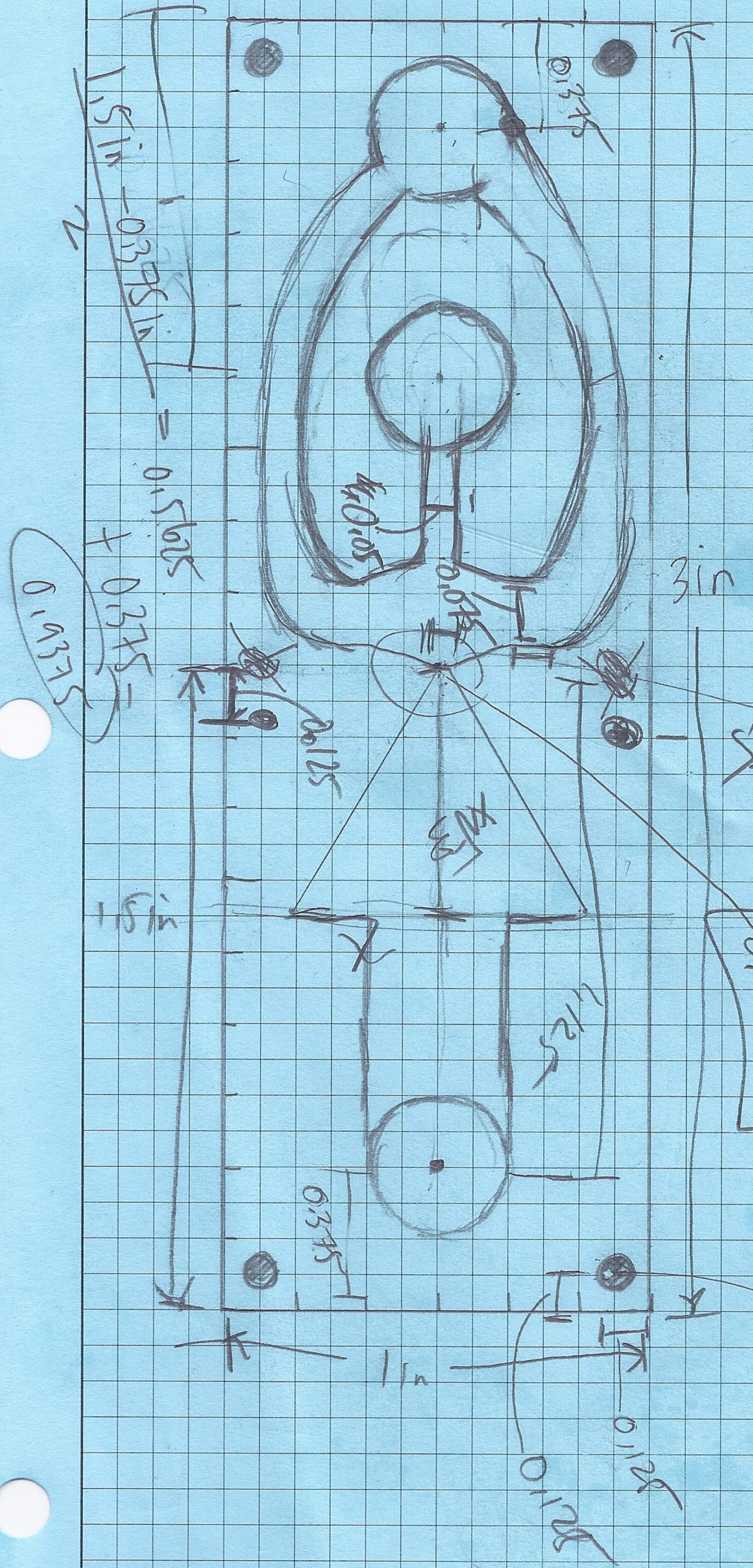
Now
0.008 for 2 sheets of vinyl

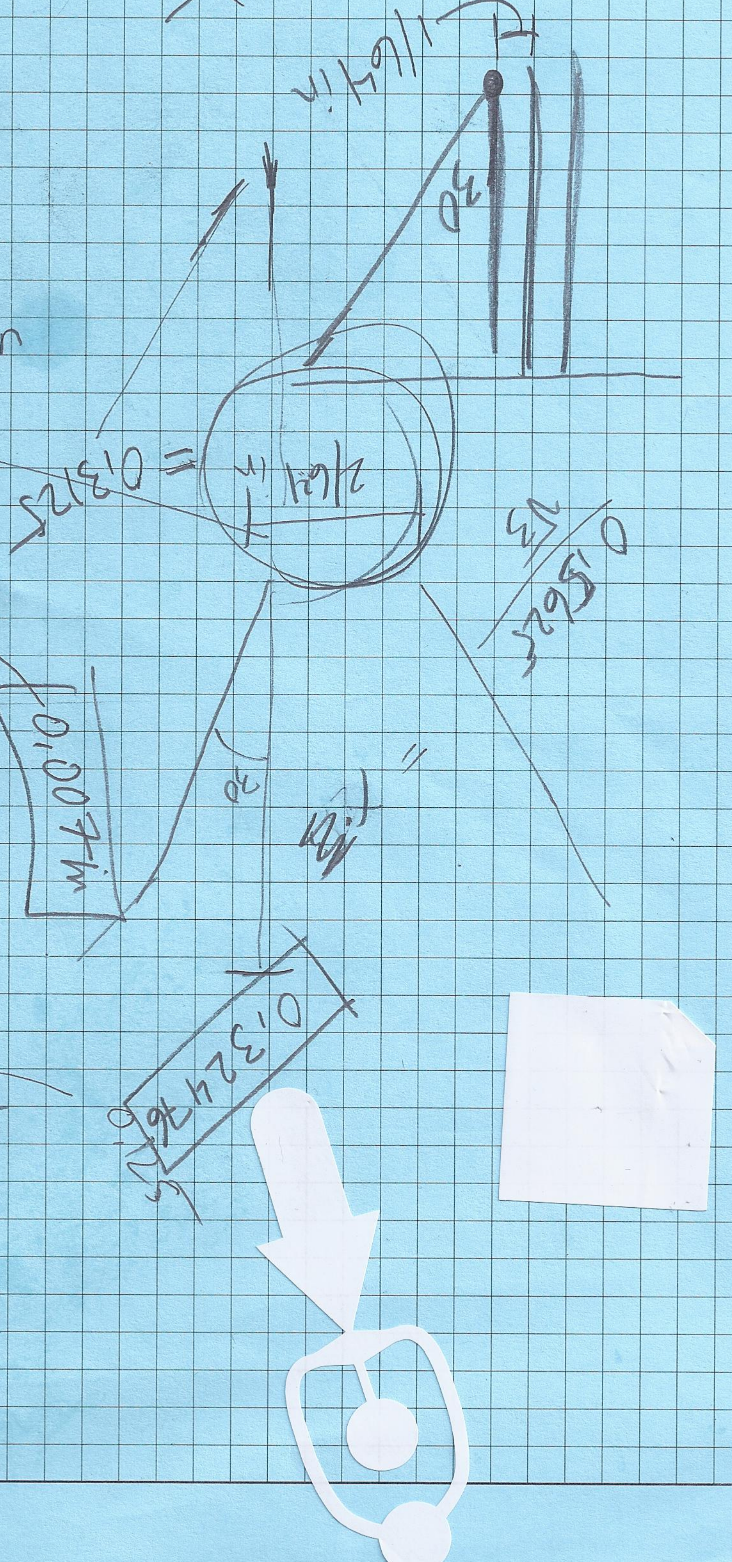
sme

MET 436
2020-03-10

300 px = 1 in

$\frac{300\ px}{12} = 25\ px = \frac{1}{12}\ in$



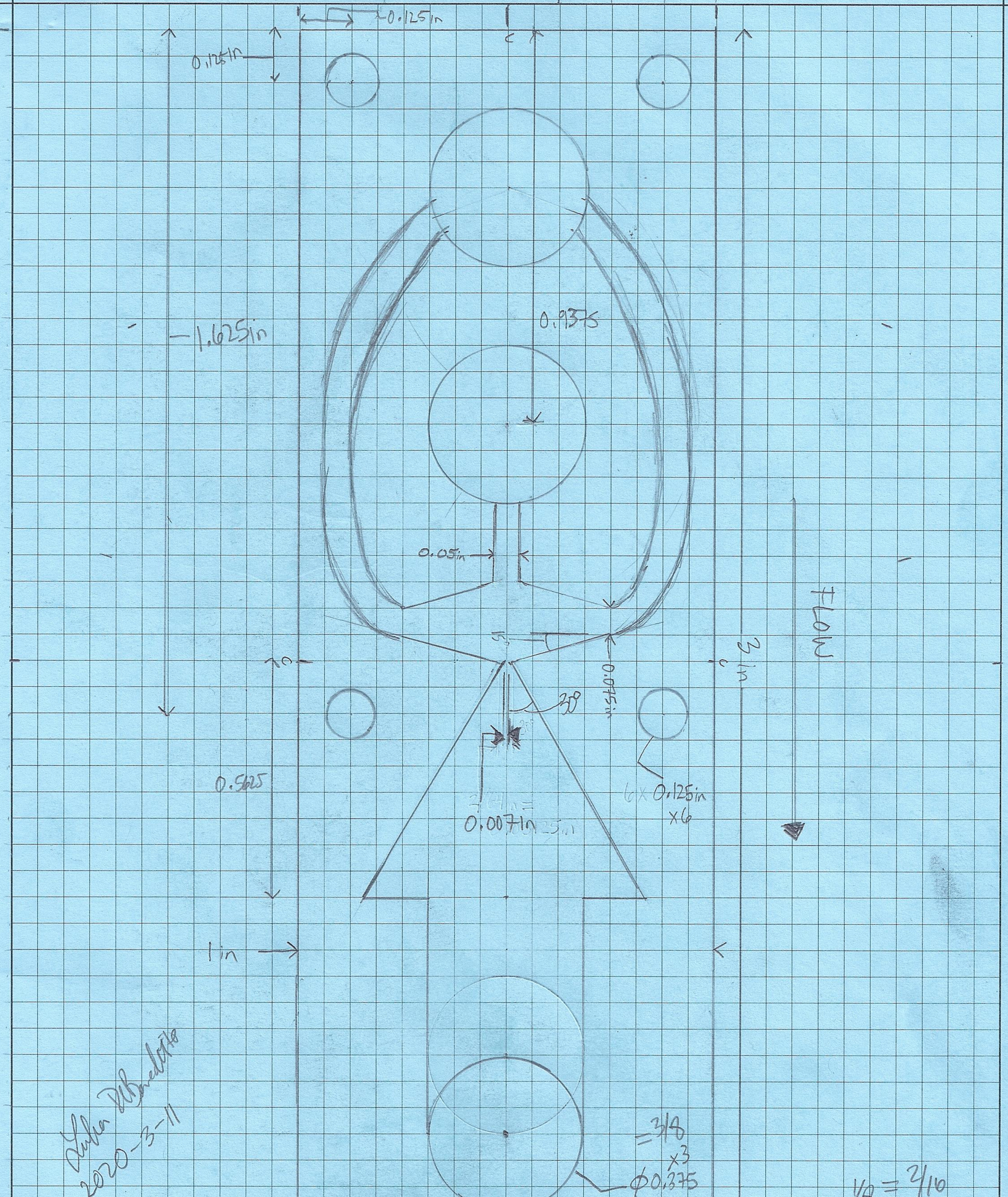


1 in = 3.1 in actual

$\frac{1}{16}$ in ÷ $\frac{3.1 \text{ in actual}}{1 \text{ in}}$ = 0.197 in actual

MET 436
2020-03-11

1 square = 1/16 inch




Viewer
System
Diagnostics
Materials Database
Manual Control
150W CO2 (10.6µ) Laser Settings for PLS6.150D
Color Mode Power Speed PPI Z-Axis Laser
Black Rast/Vect 85.0% 1.6% 1000 Off Both
Red Rast/Vect 85.0% 100% 1000 Off Both
Green Rast/Vect 85.0% 90% 1000 Off Both
Yellow Rast/Vect 85.0% 80% 1000 Off Both
Blue Rast/Vect 85.0% 70% 1000 Off Both
Magenta Rast/Vect 85.0% 60% 1000 Off Both
Cyan Rast/Vect 85.0% 50% 1000 Off Both
Orange Rast/Vect 85.0% 40% 1000 Off Both
Power
Speed
PPI
Z Axis
Laser:
Mode:
Z-Axis:
Raster
Vector
Engraving Field
Normal
Frame Rasters
Image Density
(Quality)
(Throughput)
1 2 3 4 5 6 7
Print Direction
Dithering
Halftone
Error Diffusion
Black and White
Image Enhancement
Disabled
Contrast
Definition
Density
Apply
Defaults
Load
Save
OK
Cancel

Viewer
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150W CO2 (10.6µ) Laser Settings for PLS6.150D
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Black Rast/Vect 85.0% 1.6% 1000 Off Both
Red Rast/Vect 85.0% 100% 1000 Off Both
Green Rast/Vect 85.0% 90% 1000 Off Both
Yellow Rast/Vect 85.0% 80% 1000 Off Both
Blue Rast/Vect 85.0% 70% 1000 Off Both
Magenta Rast/Vect 85.0% 60% 1000 Off Both
Cyan Rast/Vect 85.0% 50% 1000 Off Both
Orange Rast/Vect 85.0% 40% 1000 Off Both
Power
Speed
PPI
Z Axis
Laser:
Mode:
Z-Axis:
Raster
Vector
Engraving Field
Normal
Frame Rasters
Image Density
[Quality]
[Throughput]
1 2 3 4 5 6 7
Print Direction
Dithering
Halftone
Error Diffusion
Black and White
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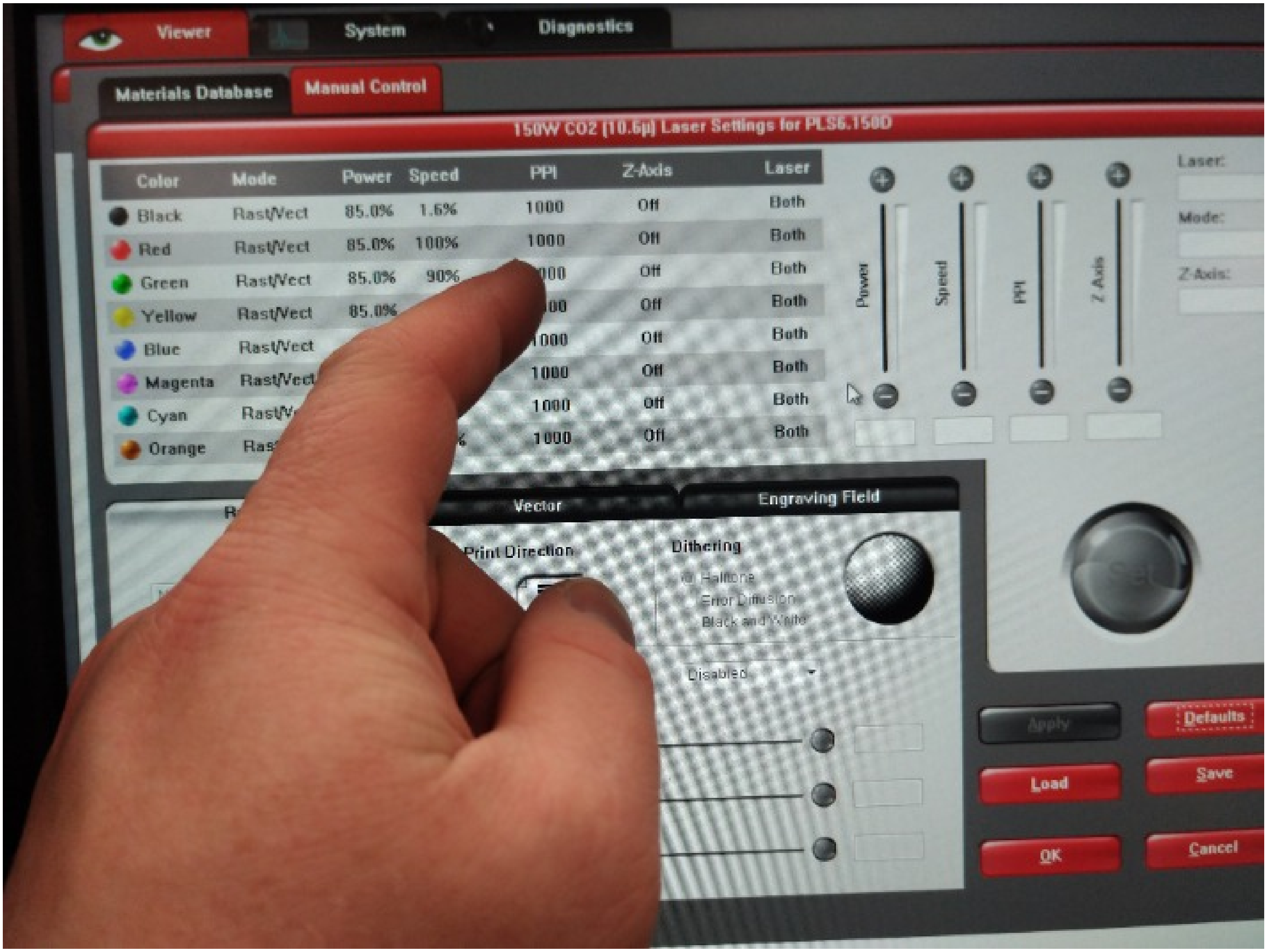
Contrast
Definition
Density
Apply
Defaults
Load
Save
OK
Cancel


Viewer
System
Diagnostics
Materials Database
Manual Control
150W CO2 (10.6µ) Laser Settings for PLS6.150D
Color Mode Power Speed PPI Z-Axis Laser
Black Rast/Vect 85.0% 1.6% 1000 Off Both
Red Rast/Vect 85.0% 100% 1000 Off Both
Green Rast/Vect 85.0% 90% Off Both
Yellow Rast/Vect 85.0% Off Both
Blue Rast/Vect 1000 Off Both
Magenta Rast/Vect 1000 Off Both
Cyan 1000 Off Both
Orange 1000 Off Both
Power
Speed
PPI
Z Axis
Laser:
Mode:
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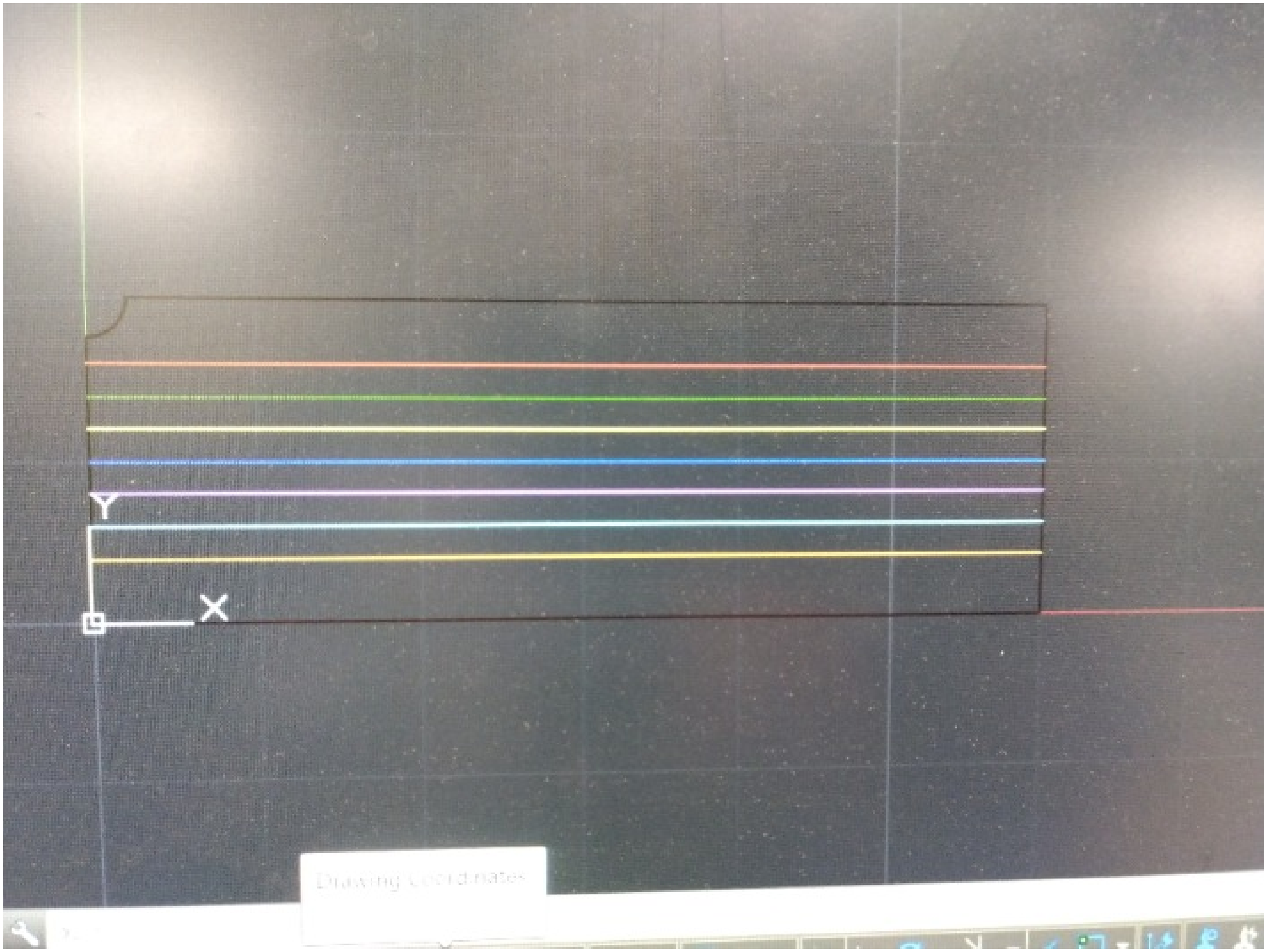
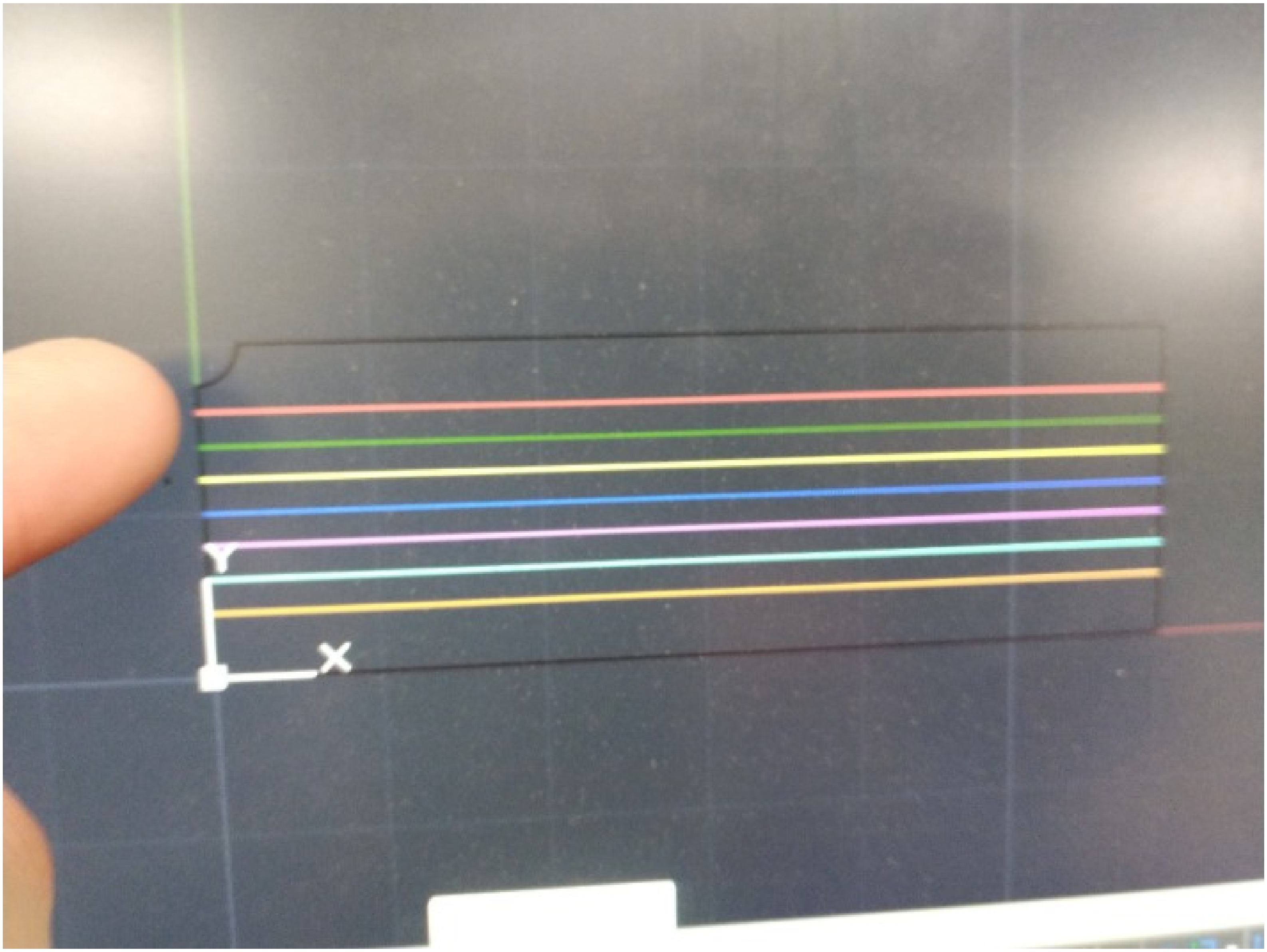
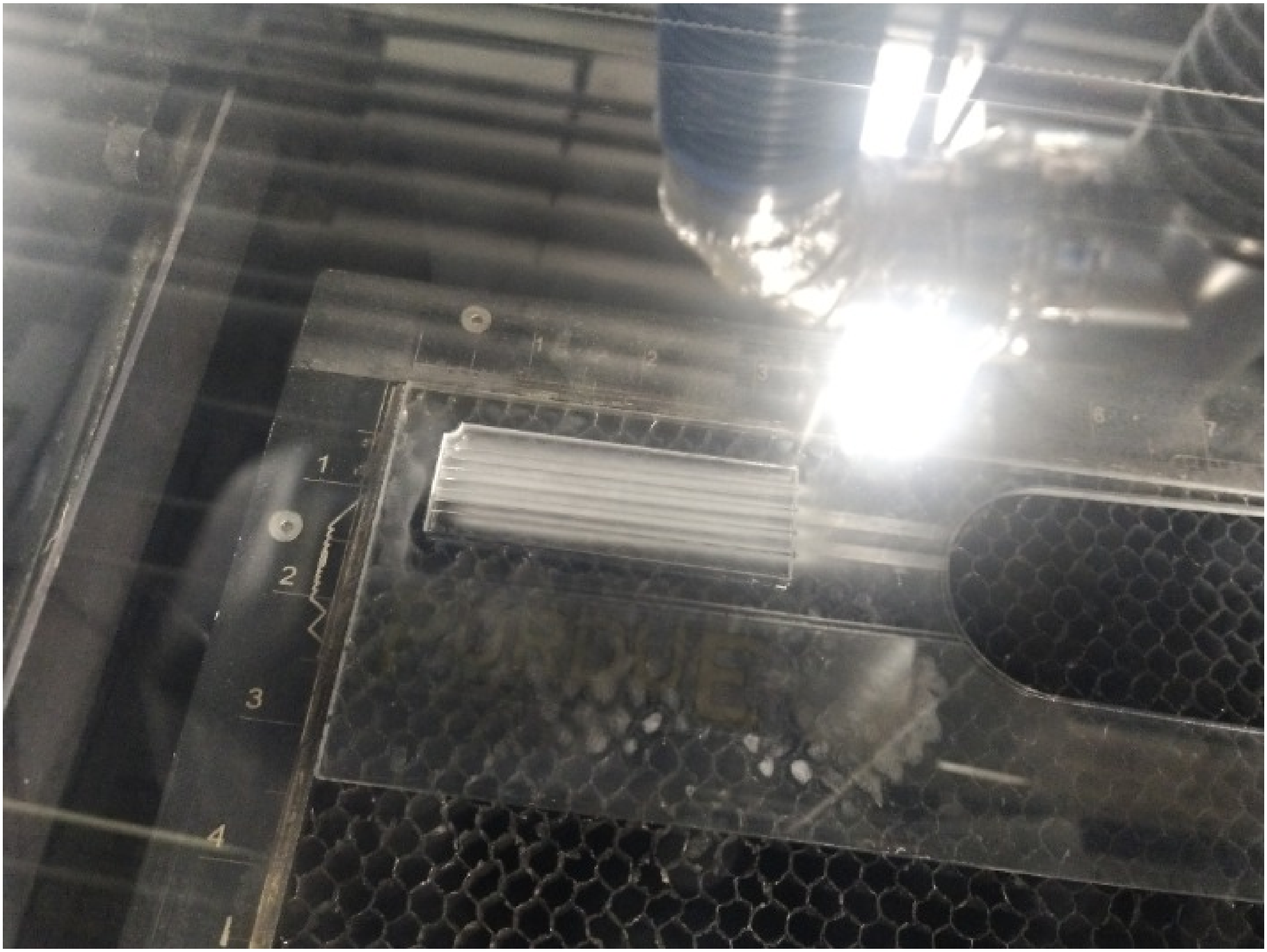


Y
X
Drawing Coordinates


Y
X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2
3
6
7
1
2
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4


1
2
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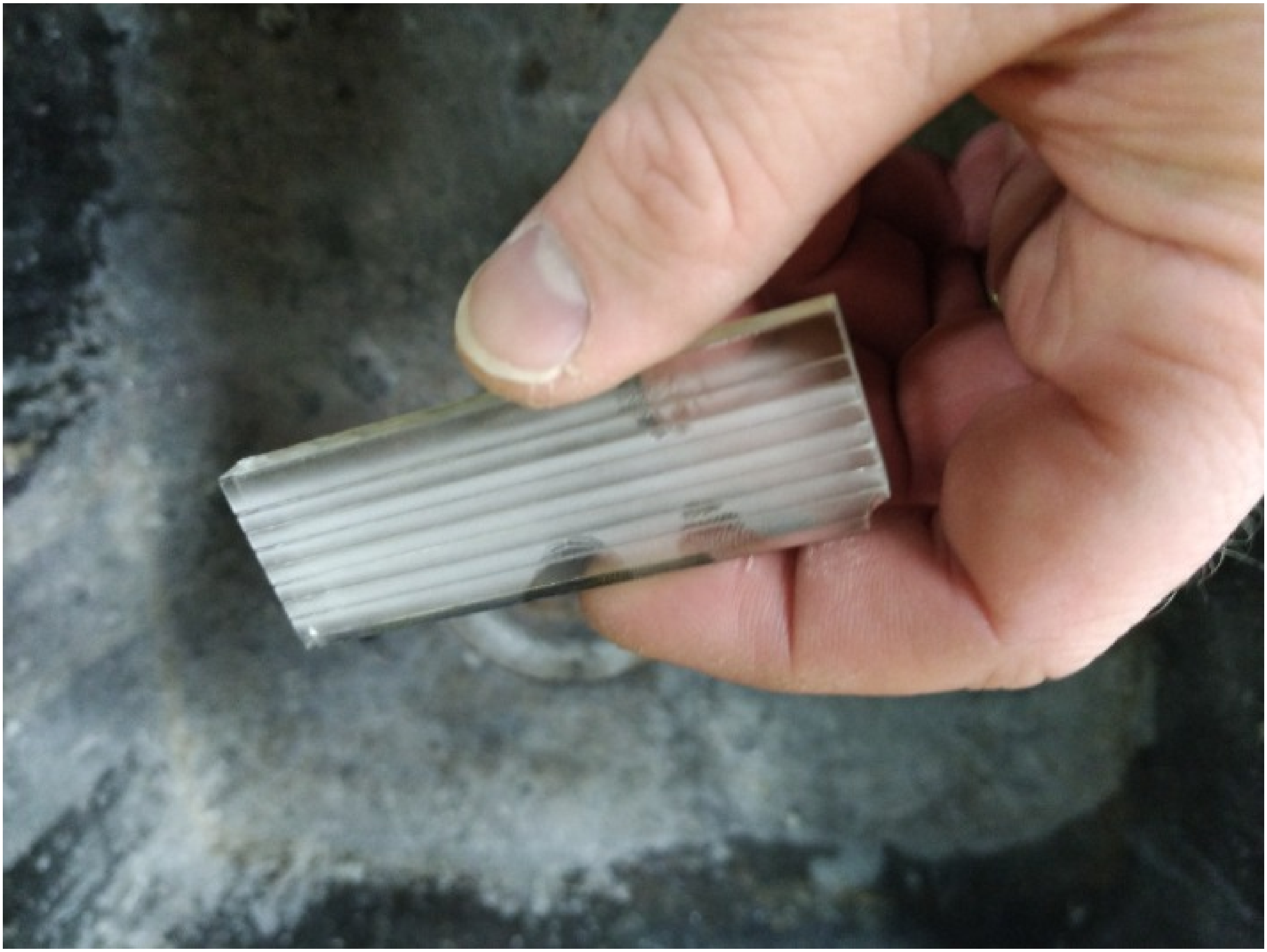
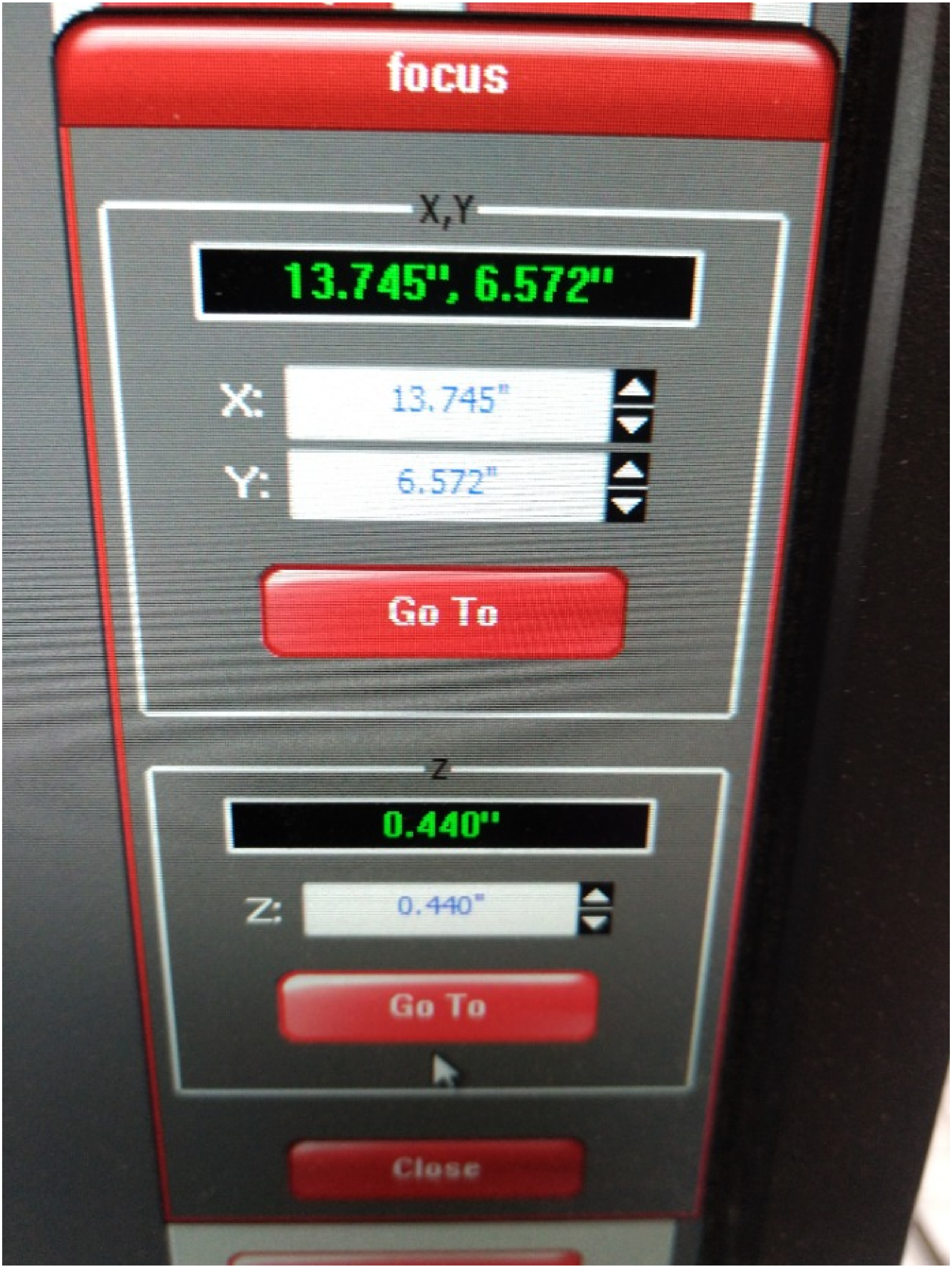
5

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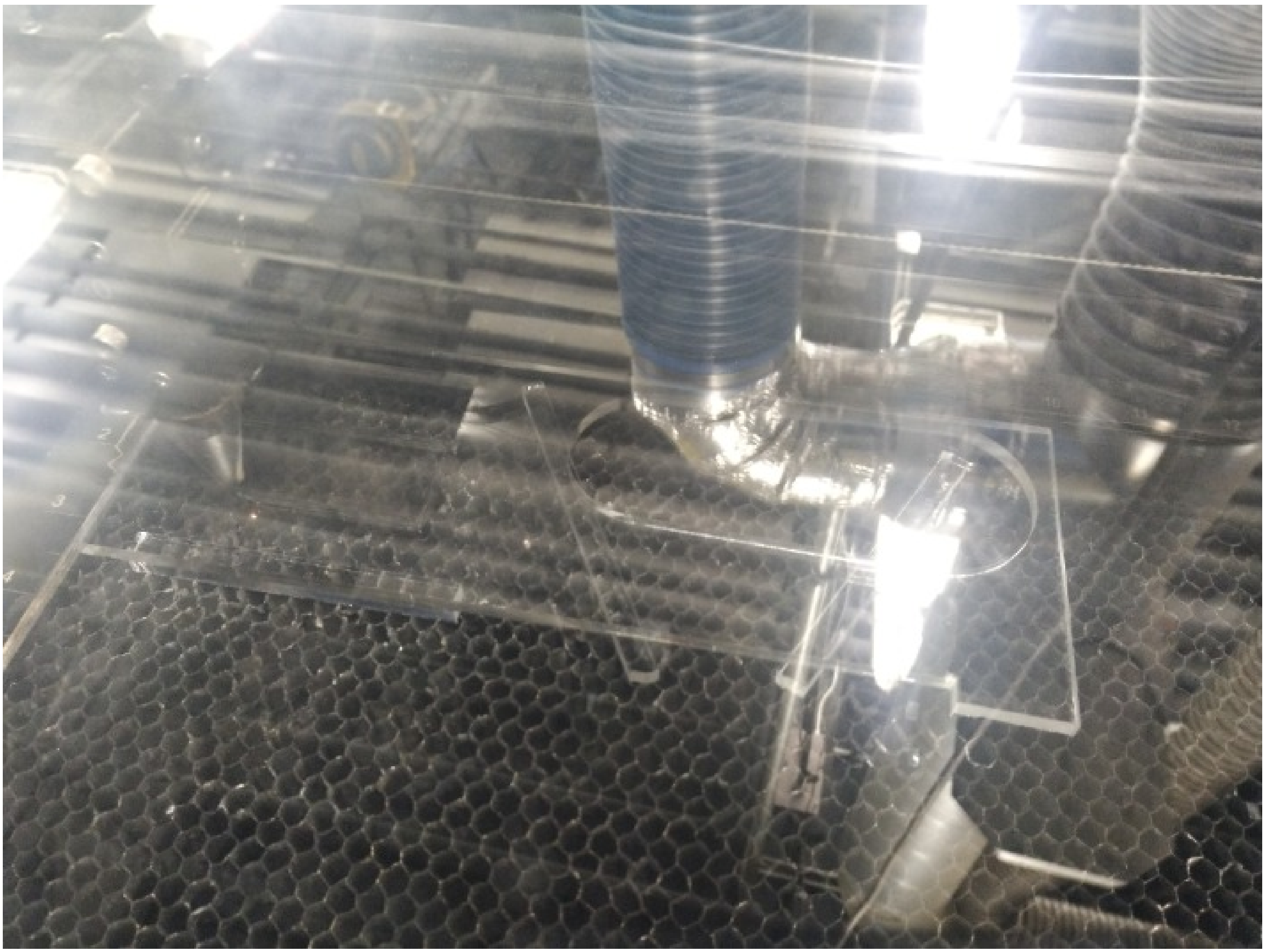
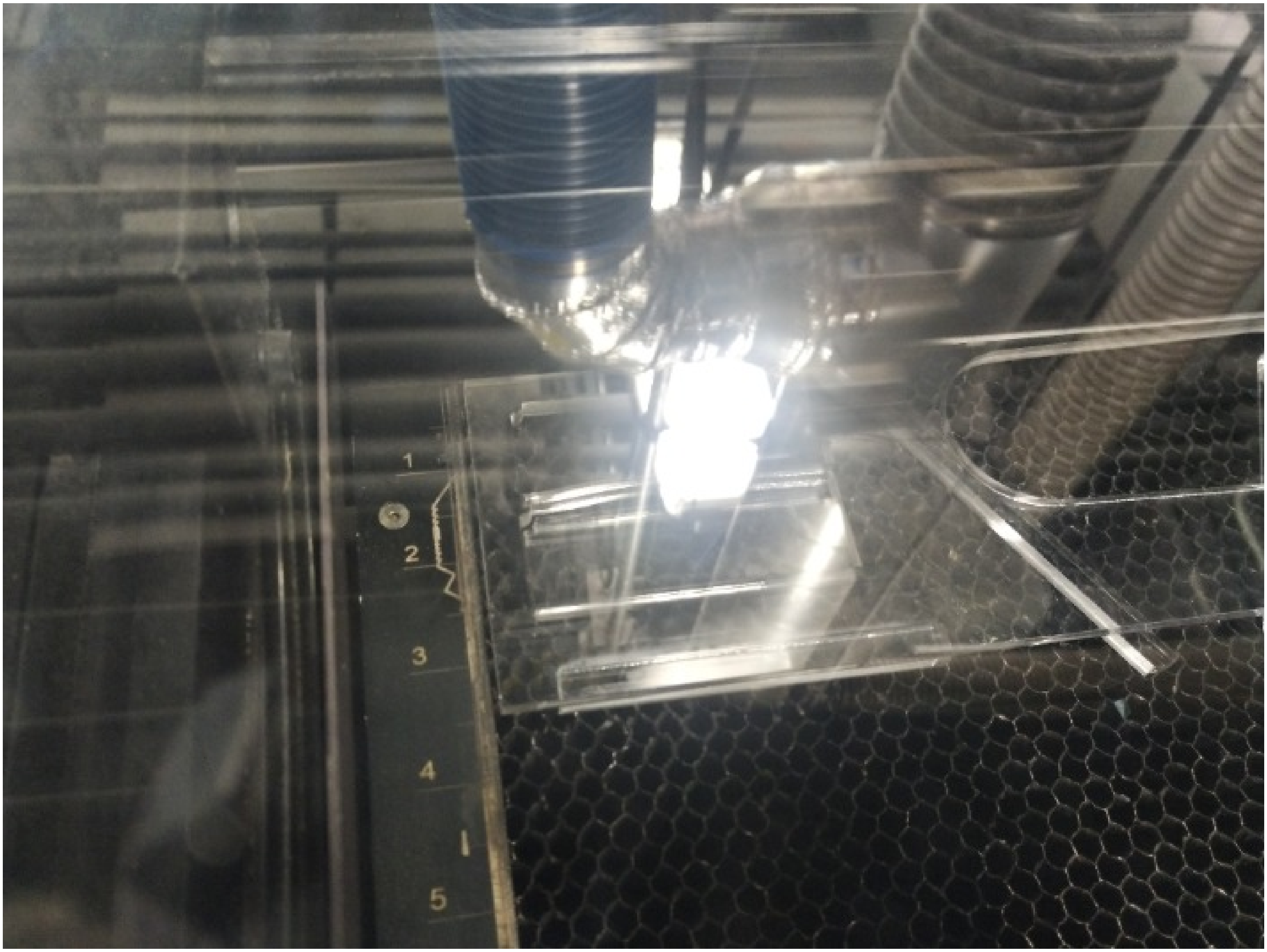
X,Y
13.745", 6.572"
X: 13.745"
Y: 6.572"
Go To
Z
0.440"
Z: 0.440"
Go To
Close

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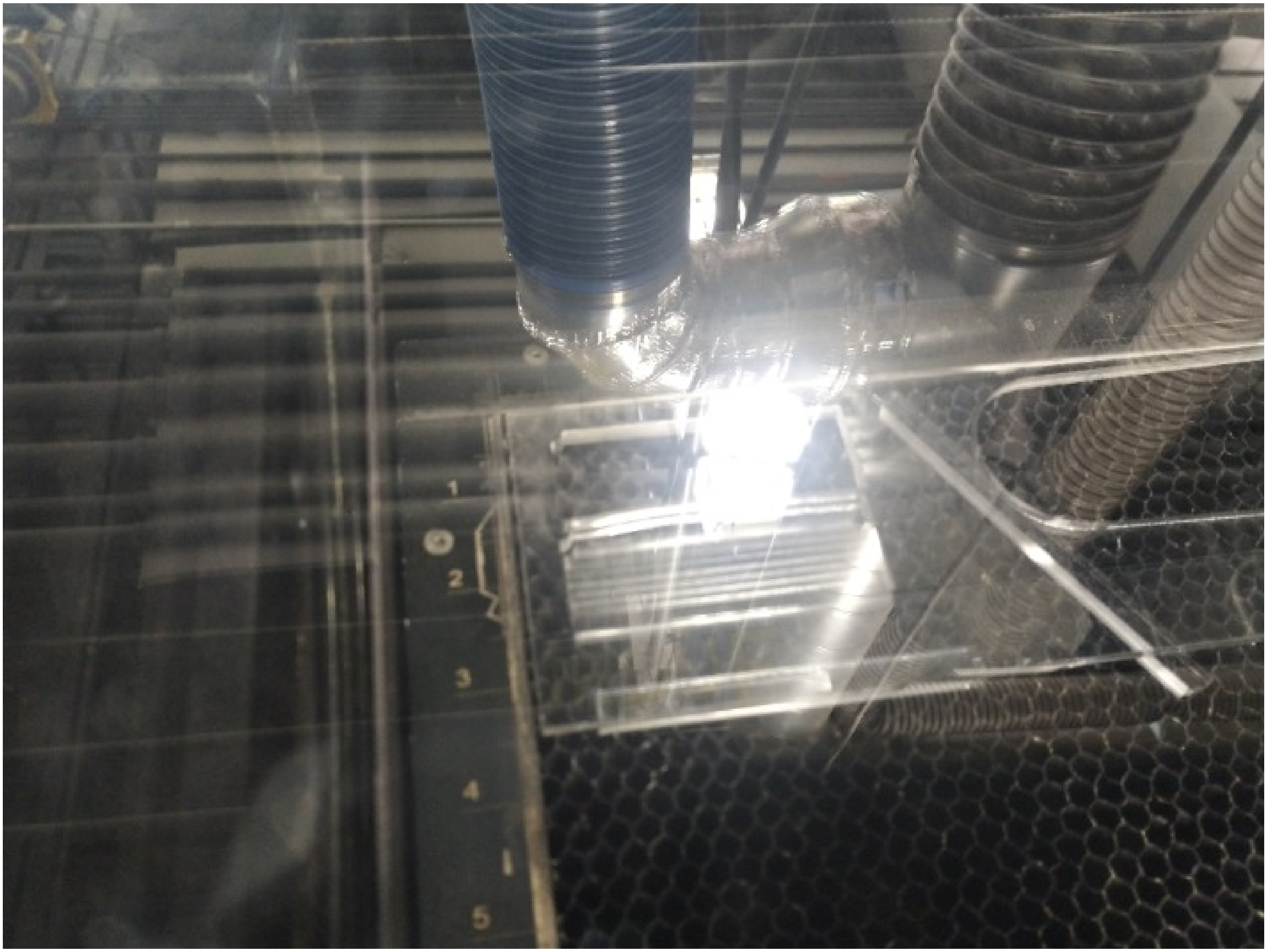
1
2
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4
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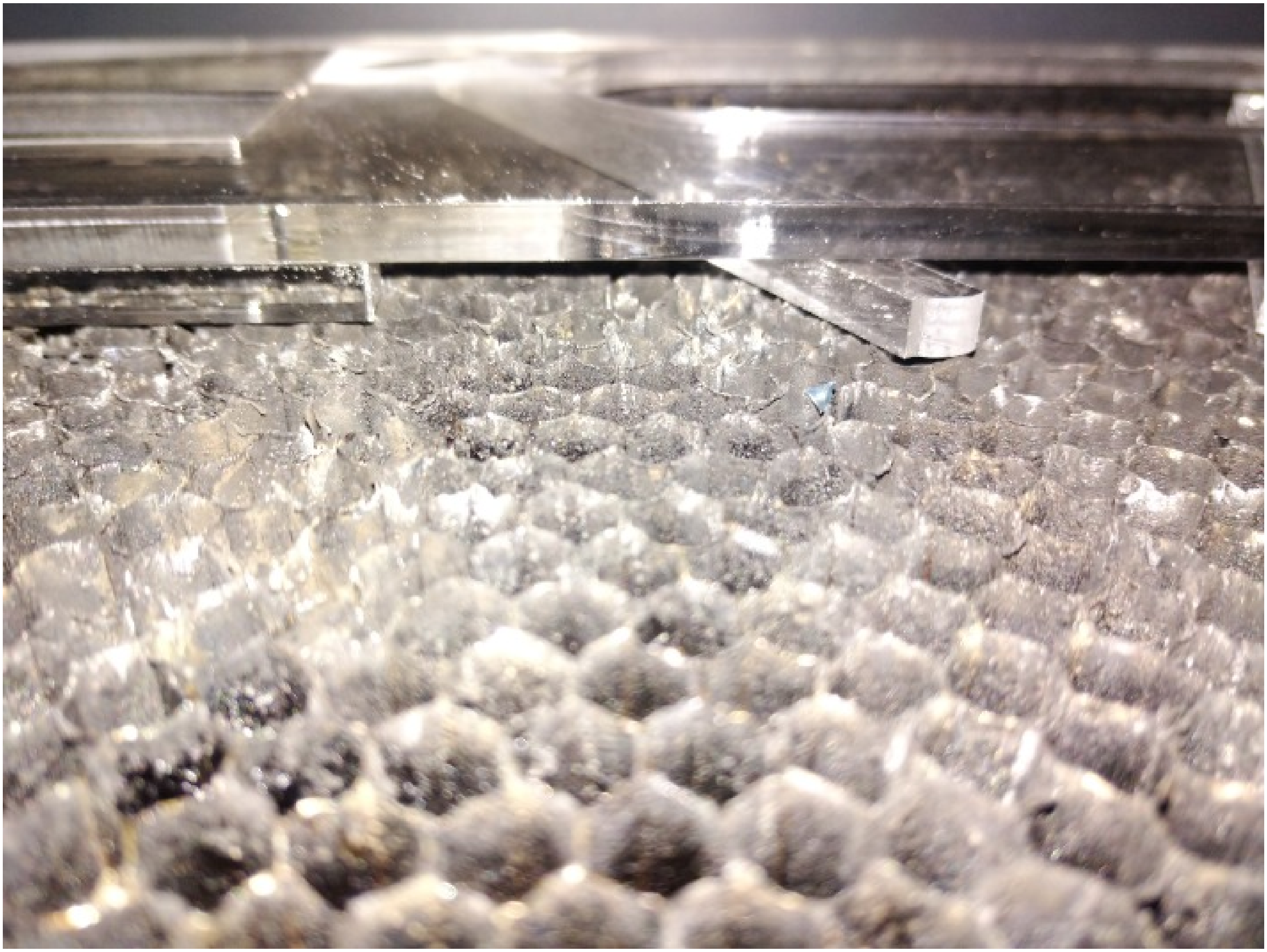
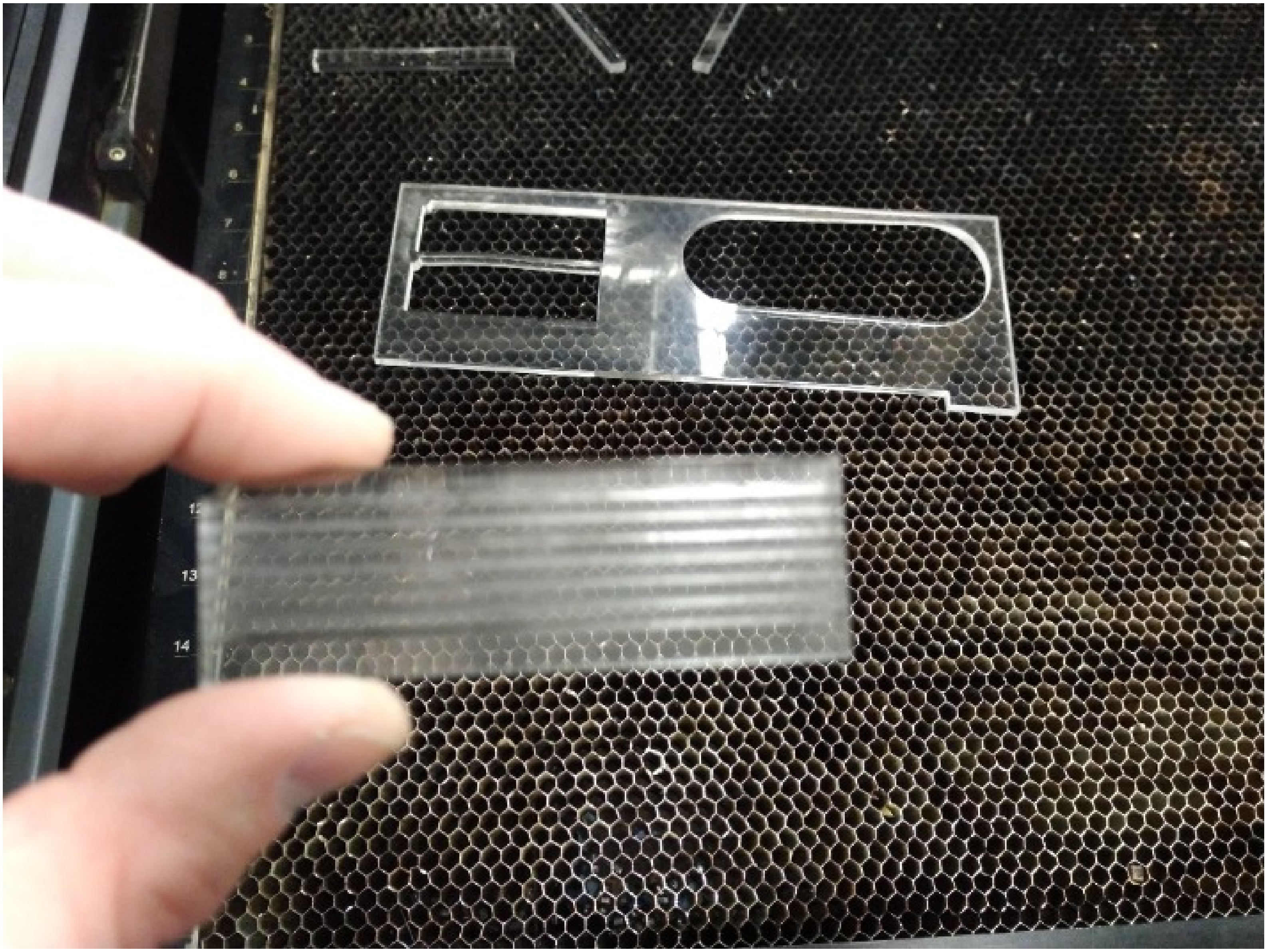
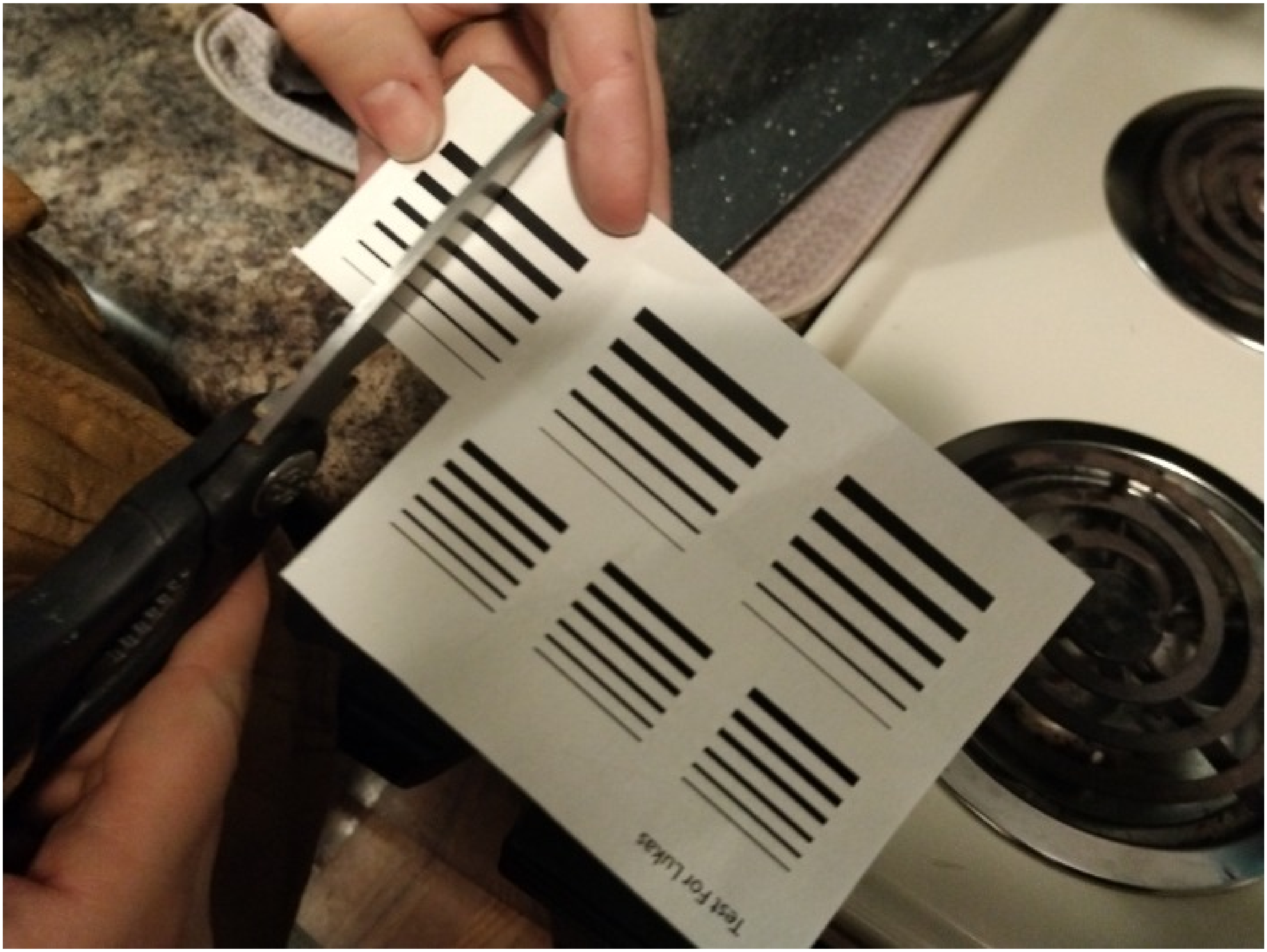
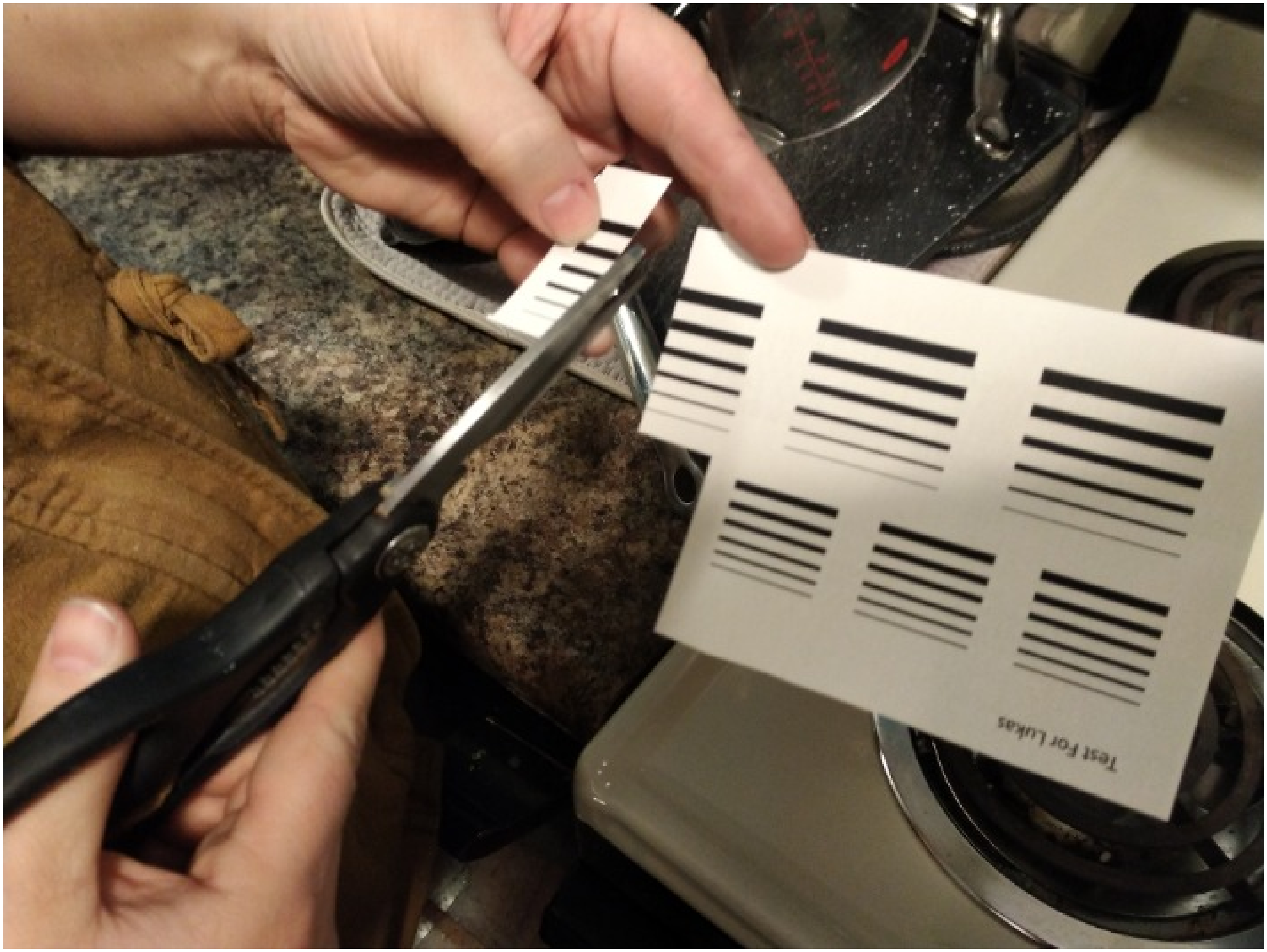
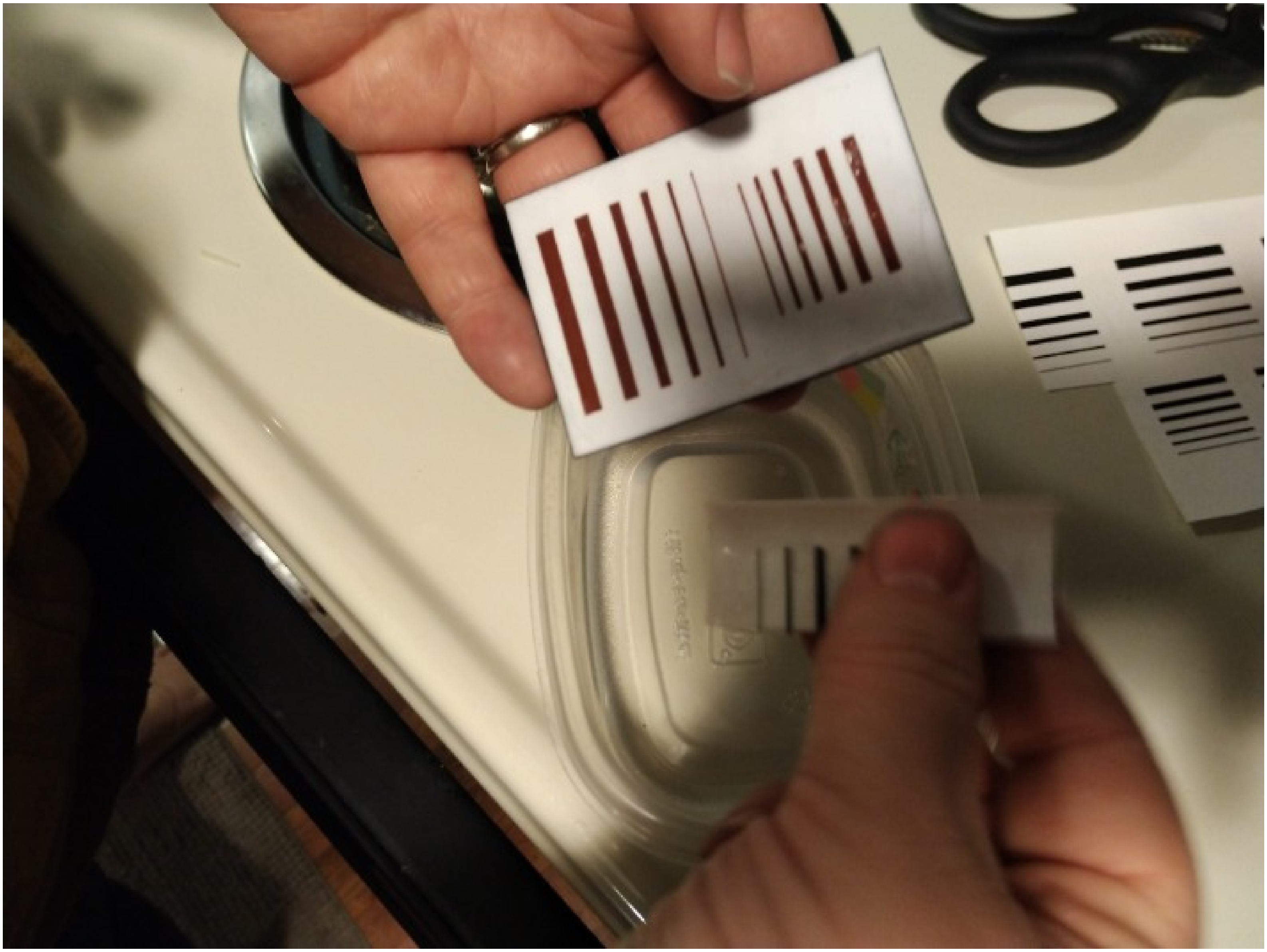
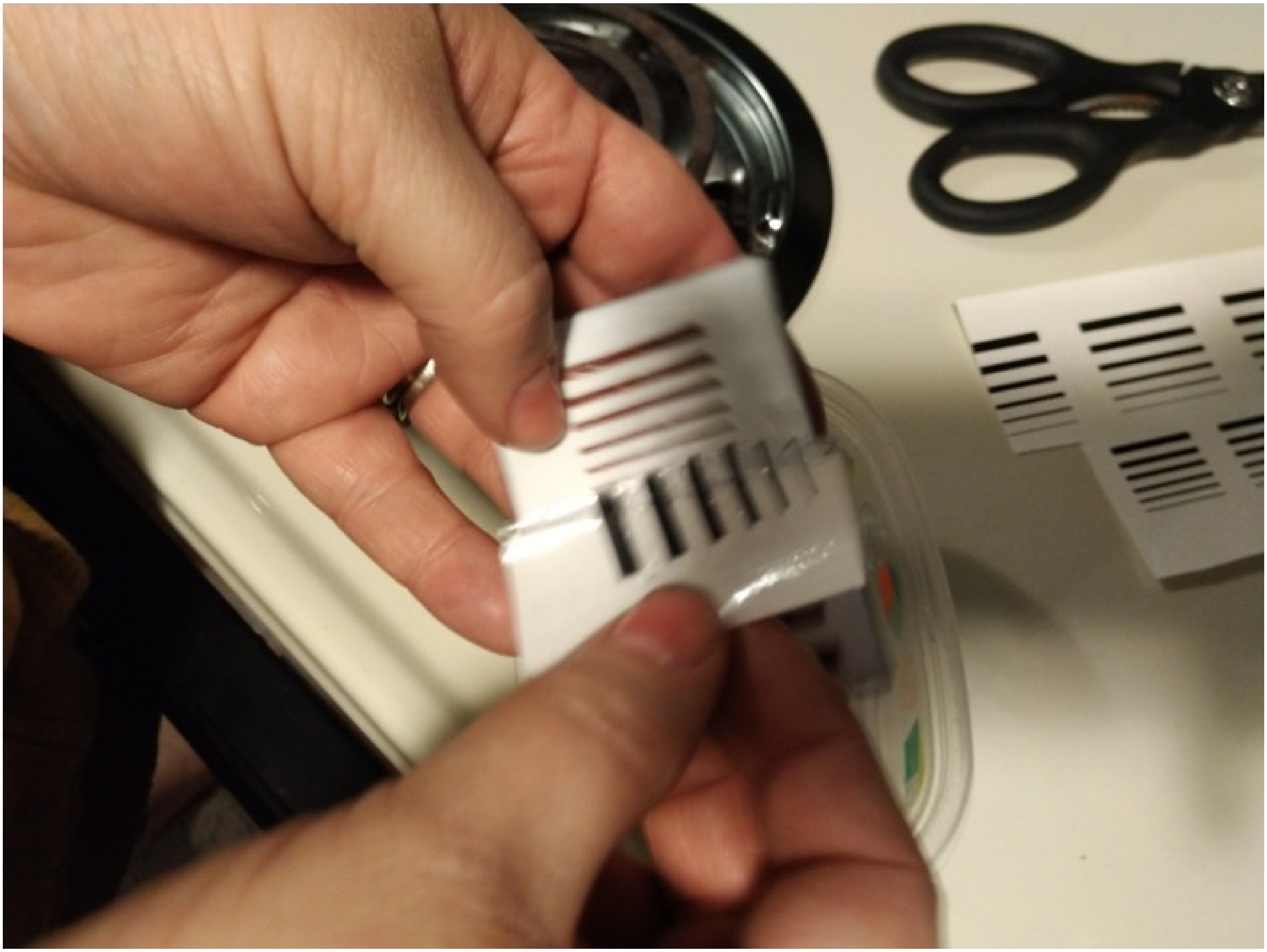


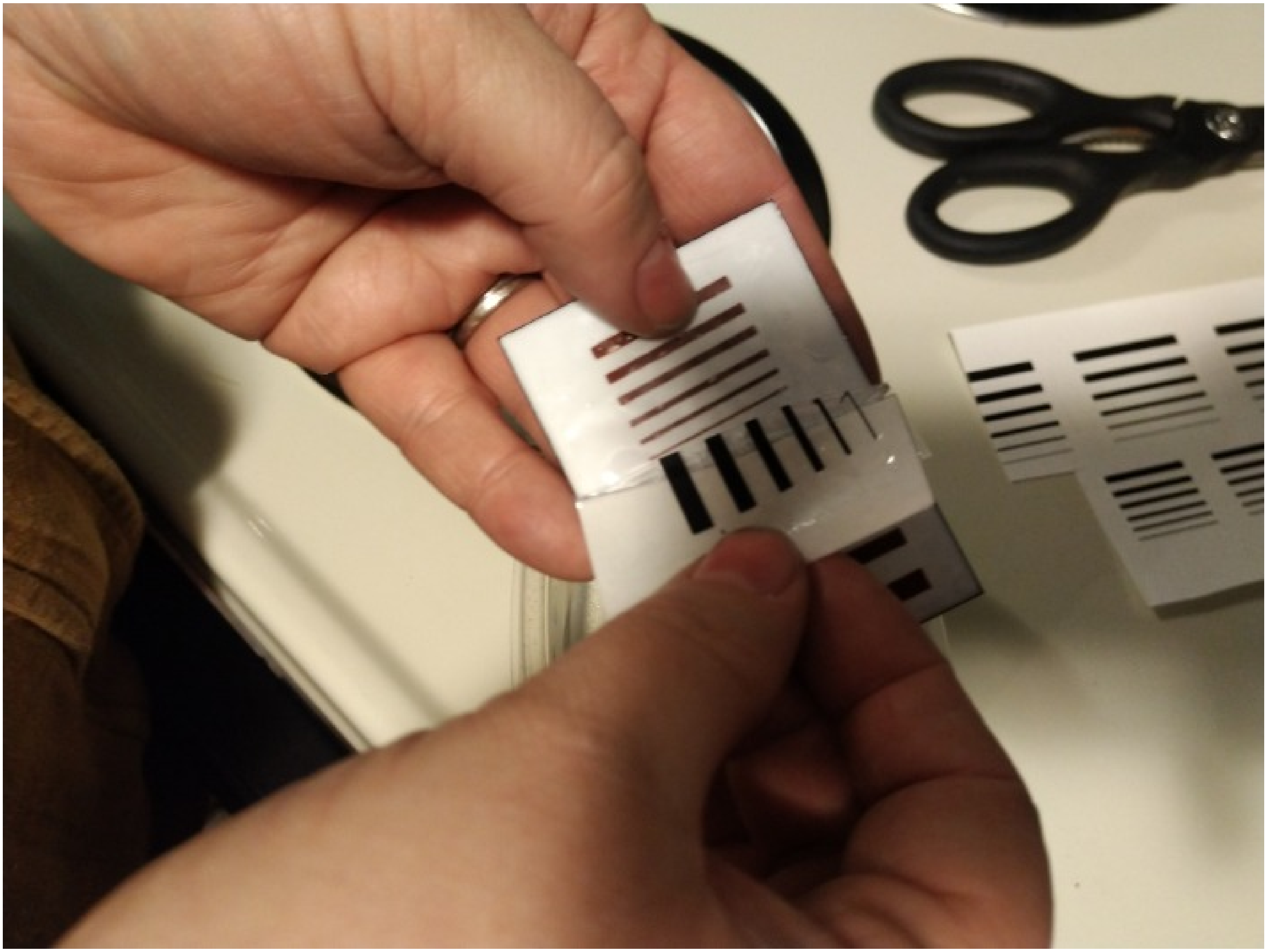


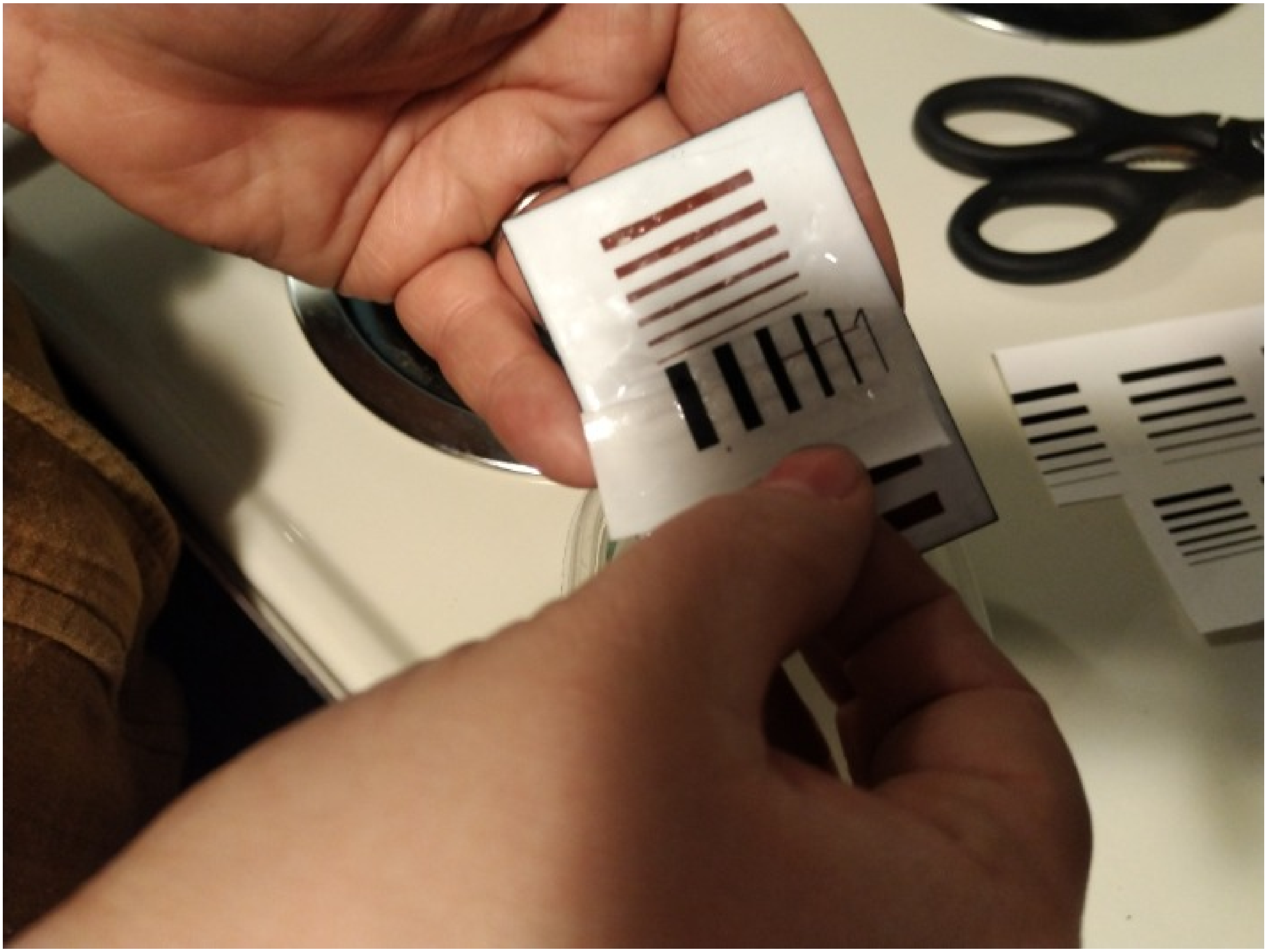

Test For Lukas

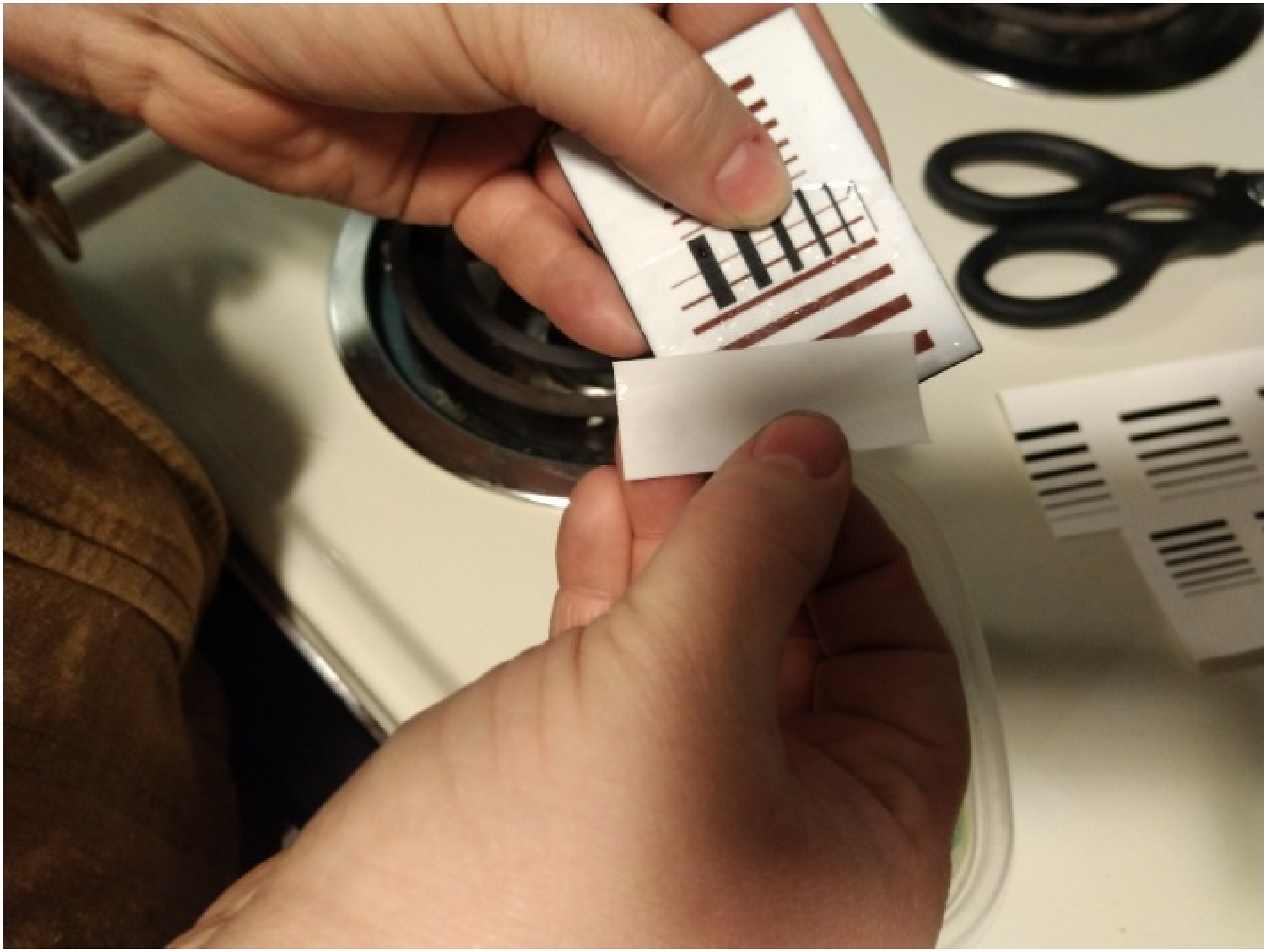

Test For Lukas

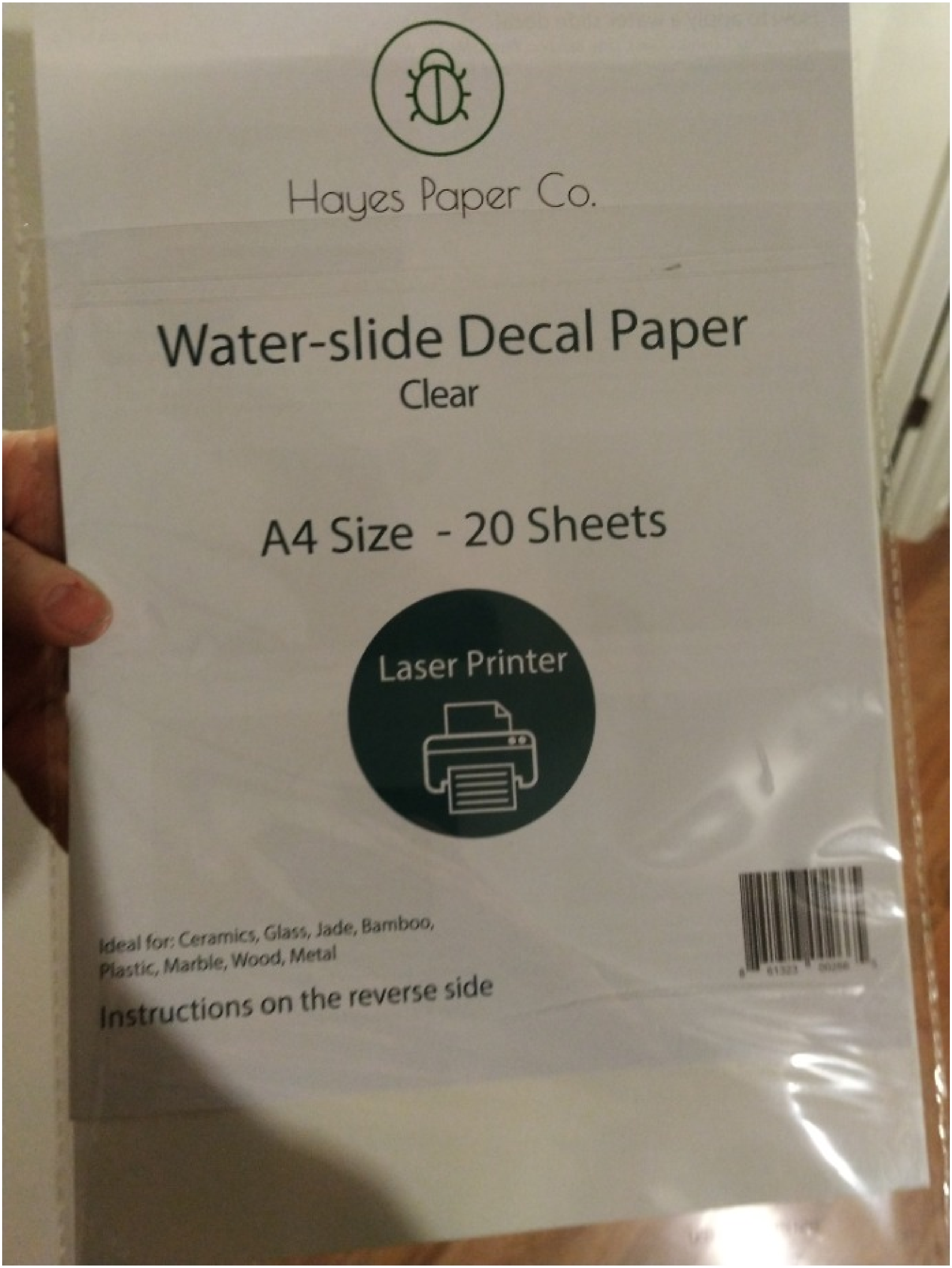




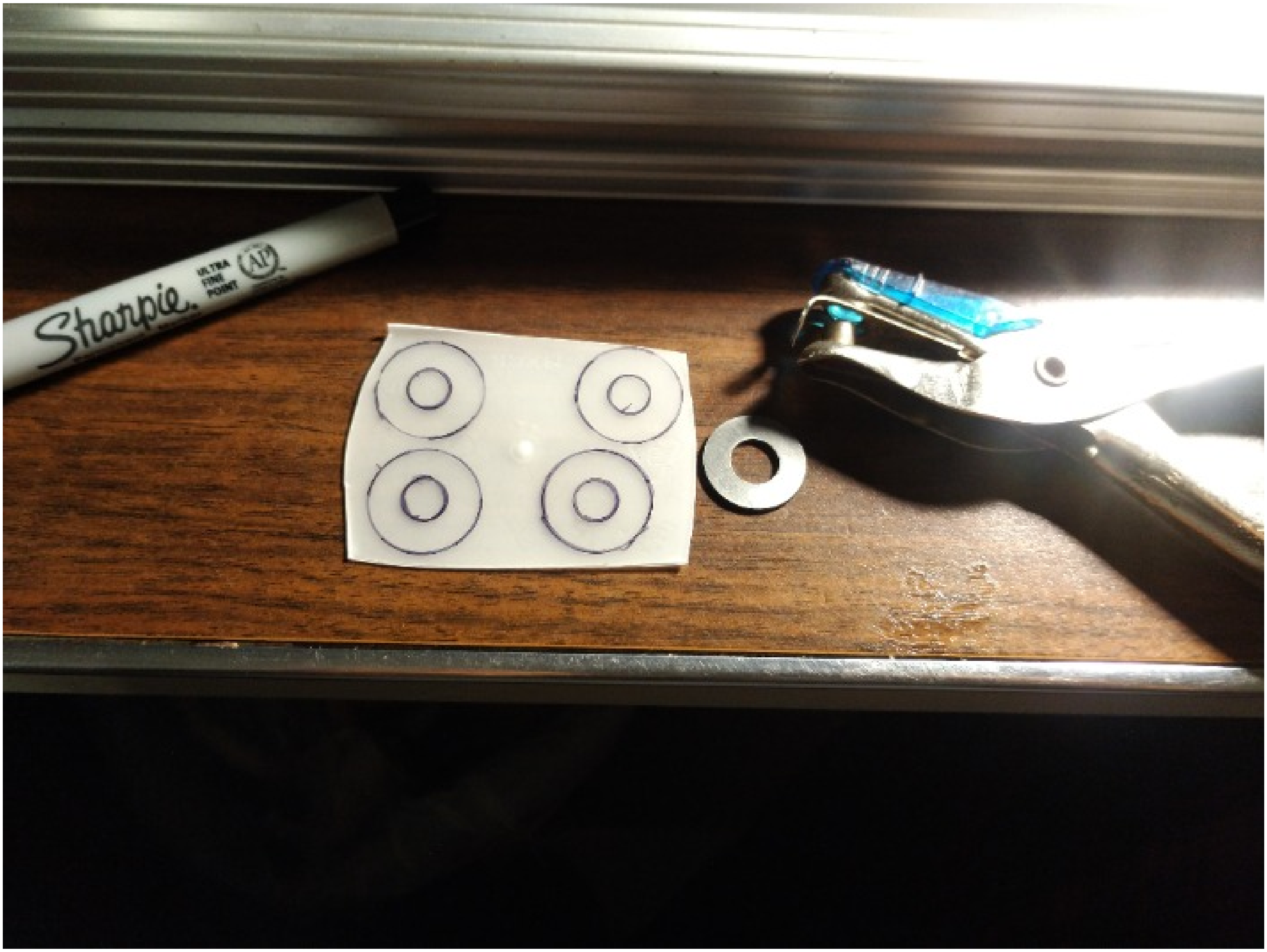


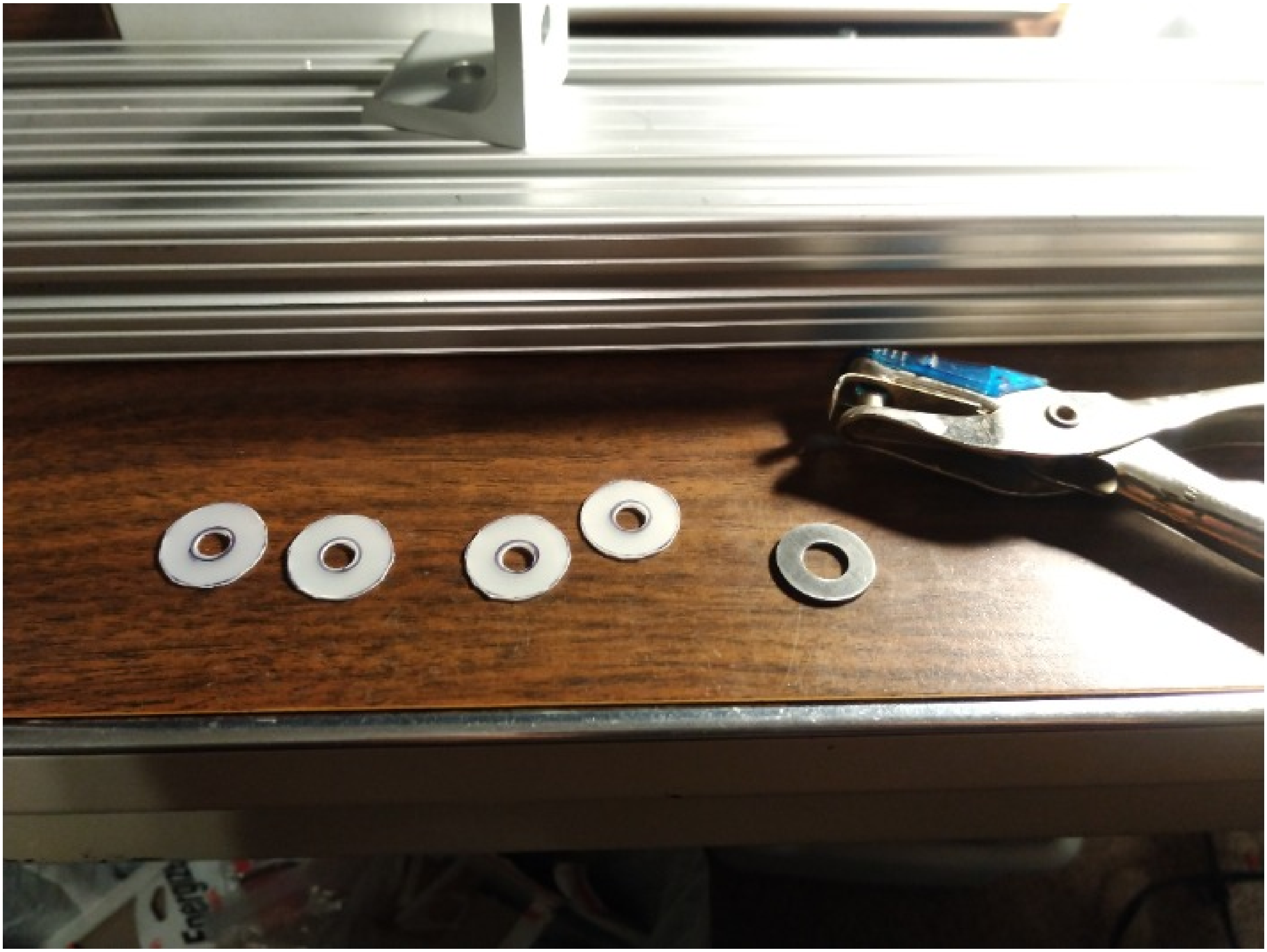





Hayes Paper Co.
Water-slide Decal Paper
Clear
A4 Size - 20 Sheets
Laser Printer
Ideal for: Ceramics, Glass, Jade, Bamboo,
Plastic, Marble, Wood, Metal
Instructions on the reverse side


Test For Lukas


Sharpie
ULTRA
FINE
POINT
AP

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DISPOSABLE SYRINGE
STERILE R
SINGLE USE ONLY
30mL
LATEX FREE


REF V5408
Extension Set
with Female Luer Lock Connector
and Spin-Lock® Connector
21 in.
LENGTH 21 in. (53 cm) (approx.)
PRIMING VOLUME 3 mL (approx.)
STERILE EO
NONPYROGENIC
in unopened,
undamaged package.
Rx only
For single use only.
Do not resterilize.
Components do not
contain DEHP or
natural rubber latex.
P-6342-3 REV. 5/11
PRECAUTION: Not intended for
use with power injectors.
Instructions for Use: Use Aseptic Technique.
• Replace set per CDC guidelines
institutional protocol.


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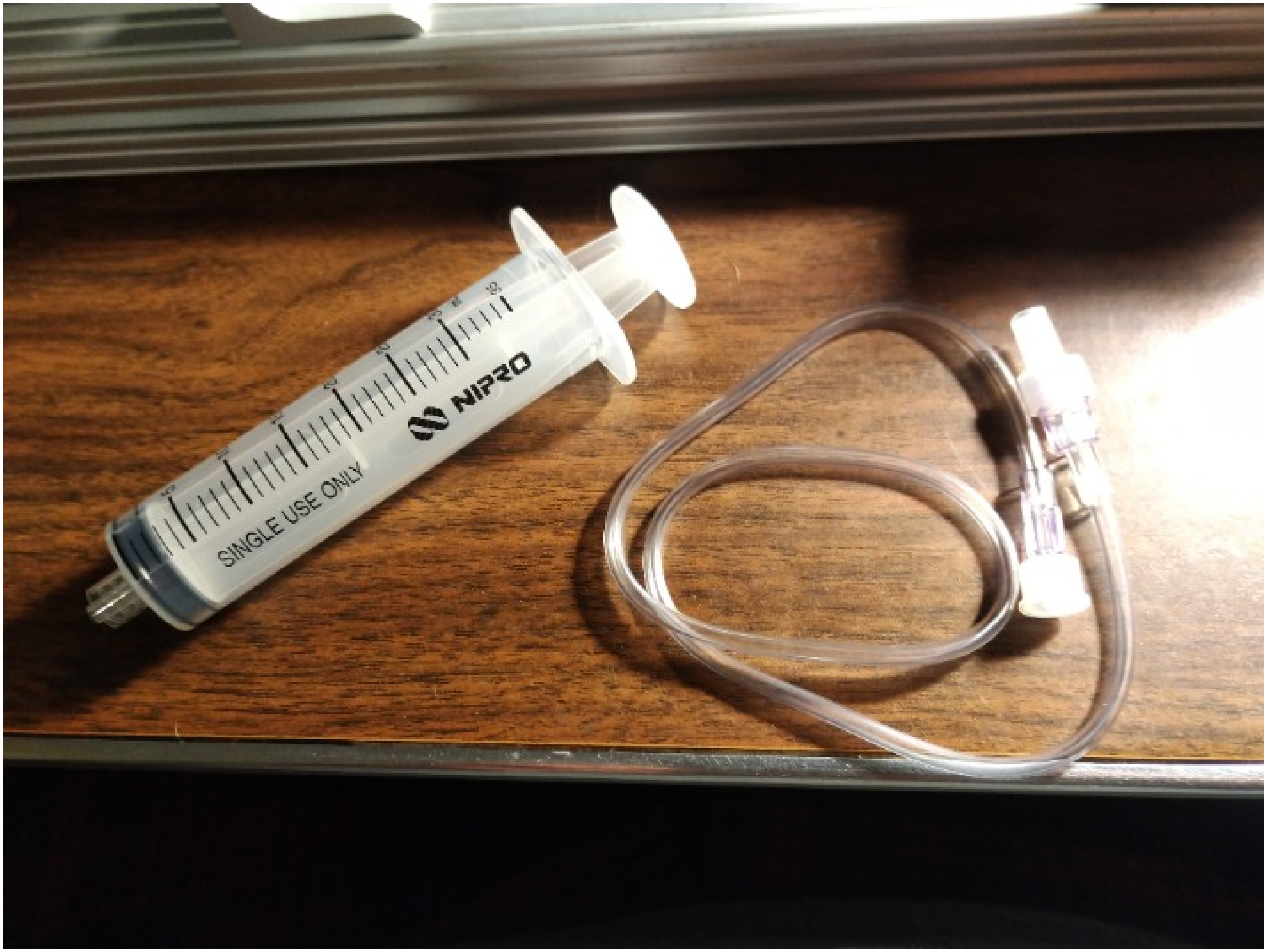
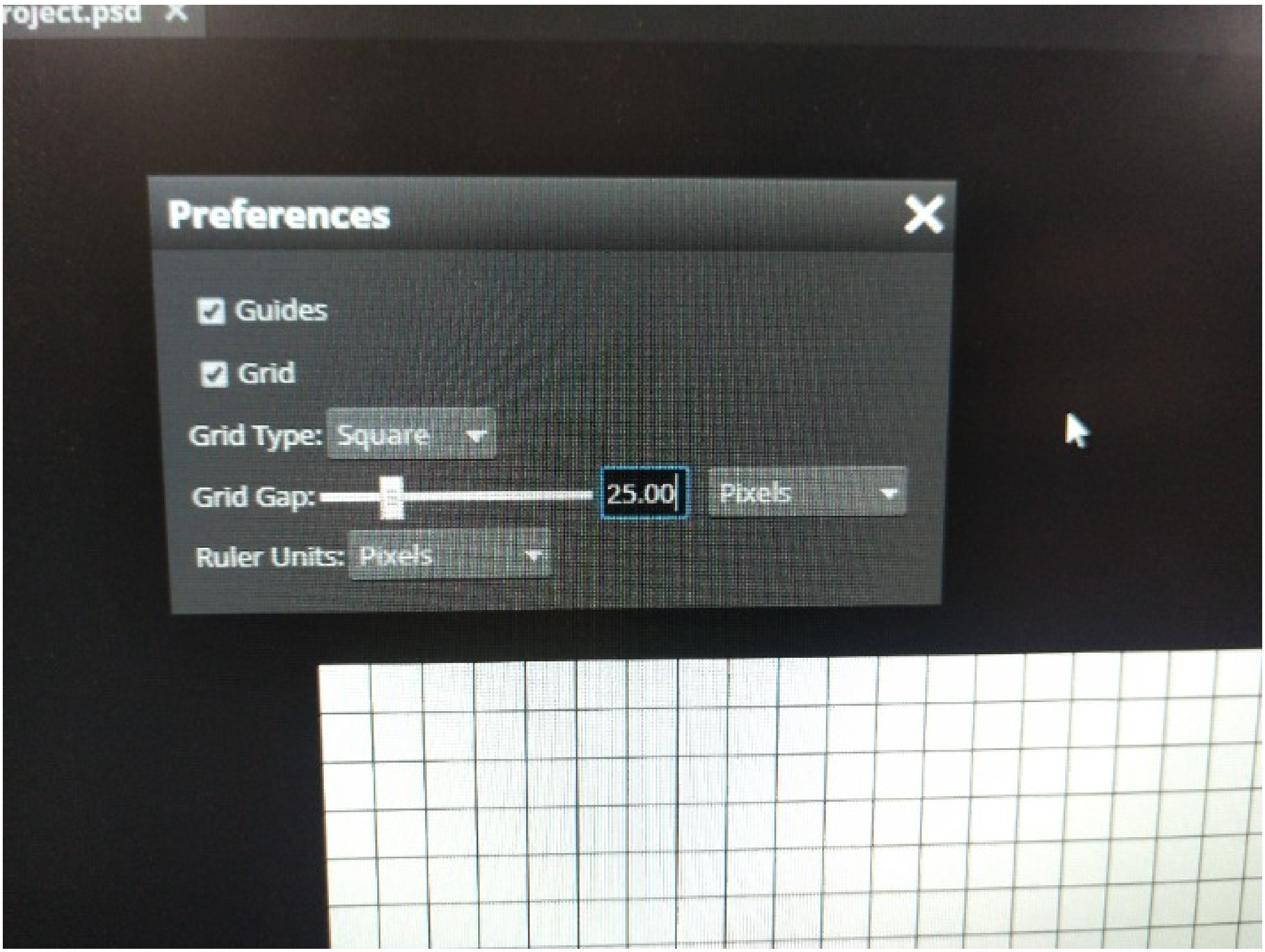
30 m
STERILE R
SINGLE USE ONLY
Non - toxic, Pyrogen - Free
Distributed by
NIPRO MEDICAL CORPORATION
3150 N.W. 107 Ave. Miami, Florida 33172 US
NIPRO
NIPRO CORPORATION
3-9-3,Honjo-Nishi,Kita-ku,Osaka,Japan


NIPRO
SINGLE USE ONLY


NIPRO
SINGLE USE ONLY



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Preferences
Guides
Grid
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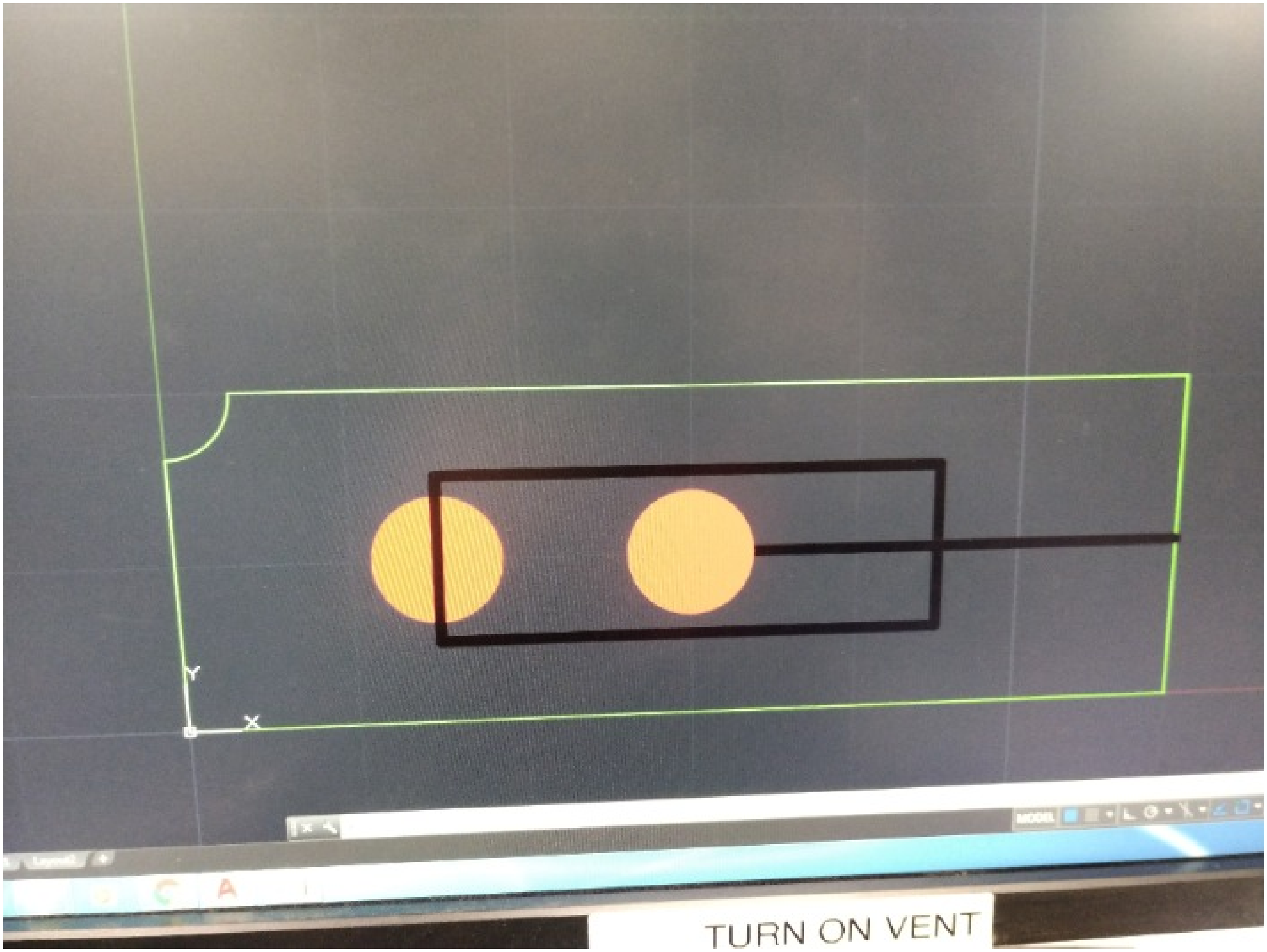
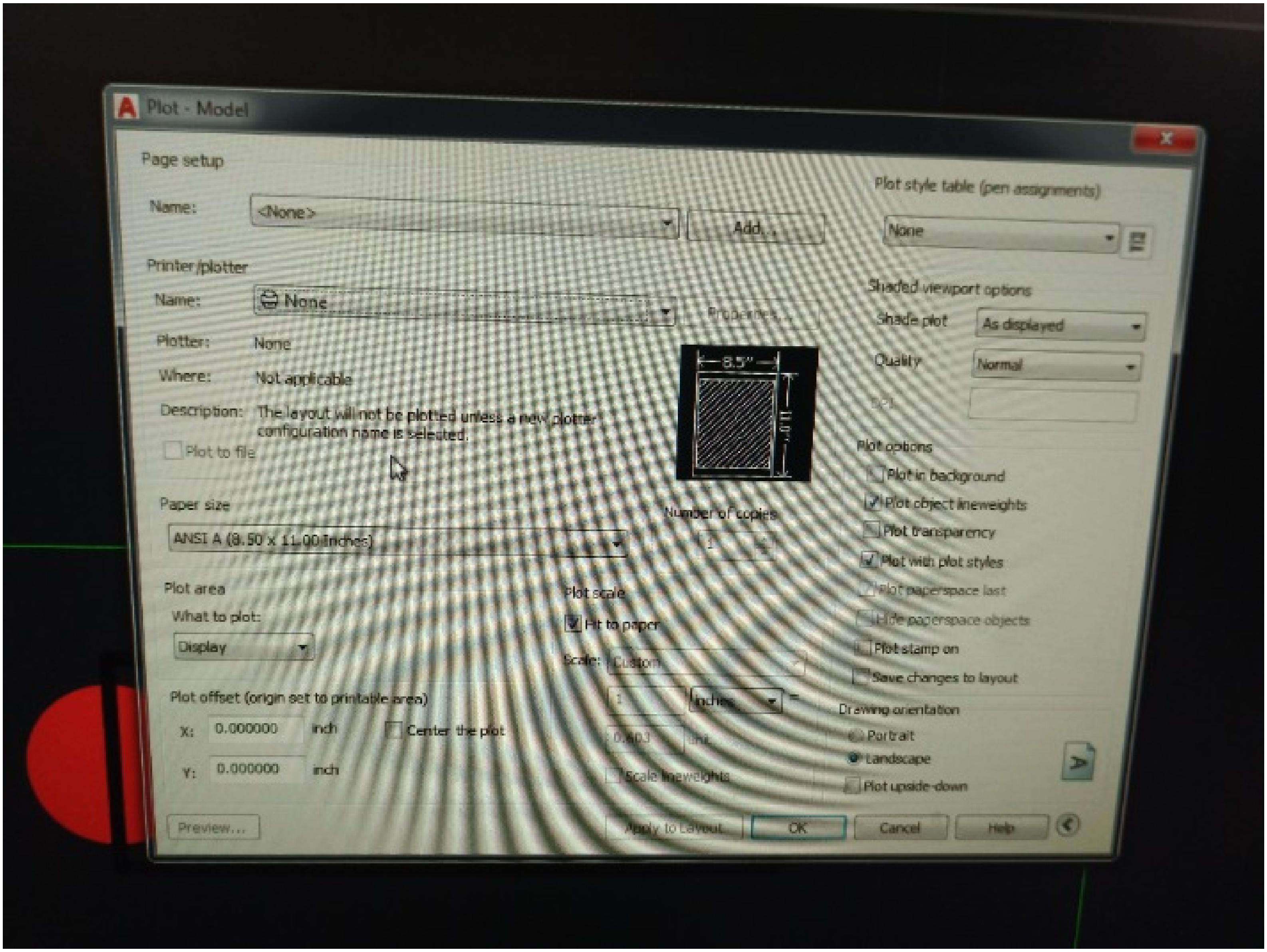
Grid Gap: 25.00 Pixels
Ruler Units: Pixels


Y
X
TURN ON VENT


Plot - Model
Page setup
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Add...
Printer/plotter
Name:
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Properties...
Plotter:
None
Where:
Not applicable
Description:
The layout will not be plotted unless a new plotter configuration name is selected.
Plot to file
8.5"
Paper size
ANSI A (8.50 x 11.00 Inches)
Number of copies
1
Plot area
What to plot:
Display
Plot scale
Fit to paper
Scale:
Custom
1
inches
0.603
unit
Scale lineweights
Plot offset (origin set to printable area)
X:
0.000000
inch
Center the plot
Y:
0.000000
inch
Plot style table (pen assignments)
None
Shaded viewport options
Shade plot
As displayed
Quality
Normal
DPI
Plot options
Plot in background
Plot object lineweights
Plot transparency
Plot with plot styles
Plot paperspace last
Hide paperspace objects
Plot stamp on
Save changes to layout
Drawing orientation
Portrait
Landscape
Plot upside-down
Preview...
Apply to Layout
OK
Cancel
Help


Viewer
System
Diagnostics
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150W CO2 (10.6µ) Laser Settings for PLS6.150D
Color
Mode
Power
Speed
PPI
Z-Axis
Laser
Black
Red
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Yellow
Blue
Magenta
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Orange
Rast/Vect
85.0%
30%
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Both
Power
Speed
PPI
Z-Axis
Laser:
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Vector Performance
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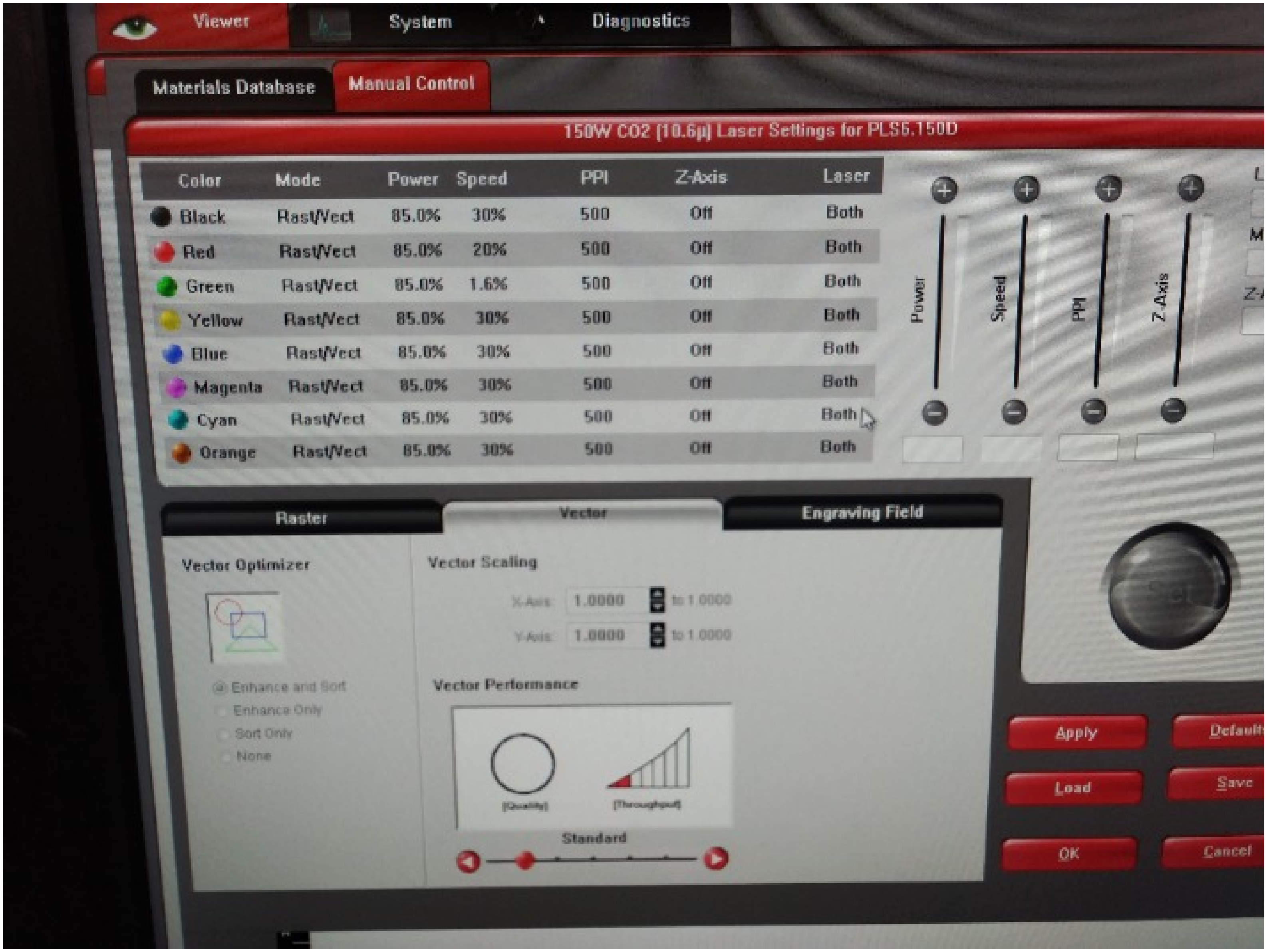
Defaults
Load
Save
OK
Cancel


Viewer
System
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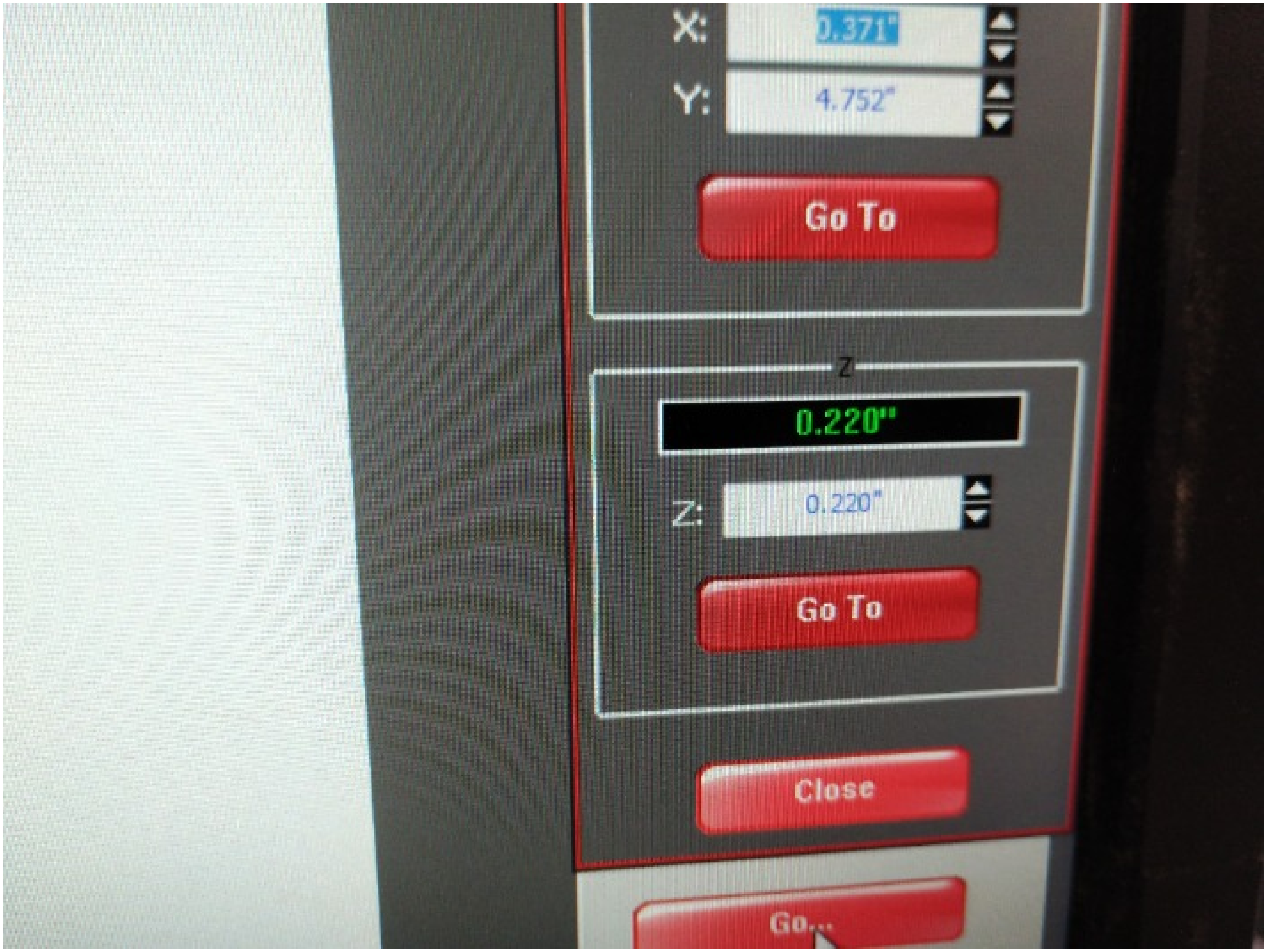
Materials Database
Manual Control
150W CO2 (10.6μ) Laser Settings for PLS6.150D
Color Mode Power Speed PPI Z-Axis Laser
Black Rast/Vect 85.0% 30% 500 Off Both
Red Rast/Vect 85.0% 20% 500 Off Both
Green Rast/Vect 85.0% 1.6% 500 Off Both
Yellow Rast/Vect 85.0% 30% 500 Off Both
Blue Rast/Vect 85.0% 30% 500 Off Both
Magenta Rast/Vect 85.0% 30% 500 Off Both
Cyan Rast/Vect 85.0% 30% 500 Off Both
Orange Rast/Vect 85.0% 30% 500 Off Both
Power
Speed
PPI
Z-Axis
Raster
Vector
Engraving Field
Vector Optimizer
Enhance and Sort
Enhance Only
Sort Only
None
Vector Scaling
X-Axis: 1.0000 to 1.0000
Y-Axis: 1.0000 to 1.0000
Vector Performance
[Quality]
[Throughput]
Standard
Apply
Load
OK
Save
Cancel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Z
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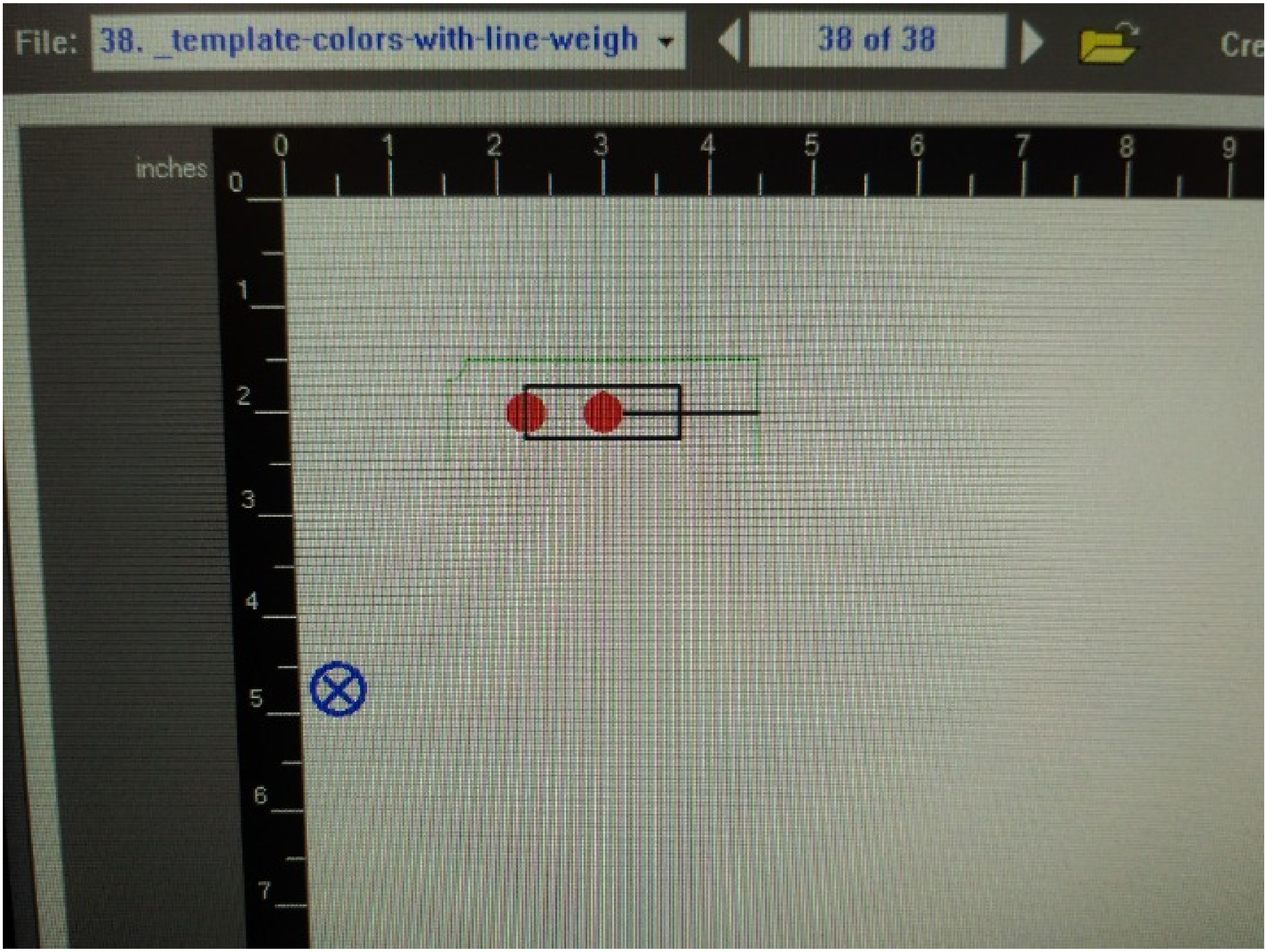
Z:
0.220"
Go To
Close
Go...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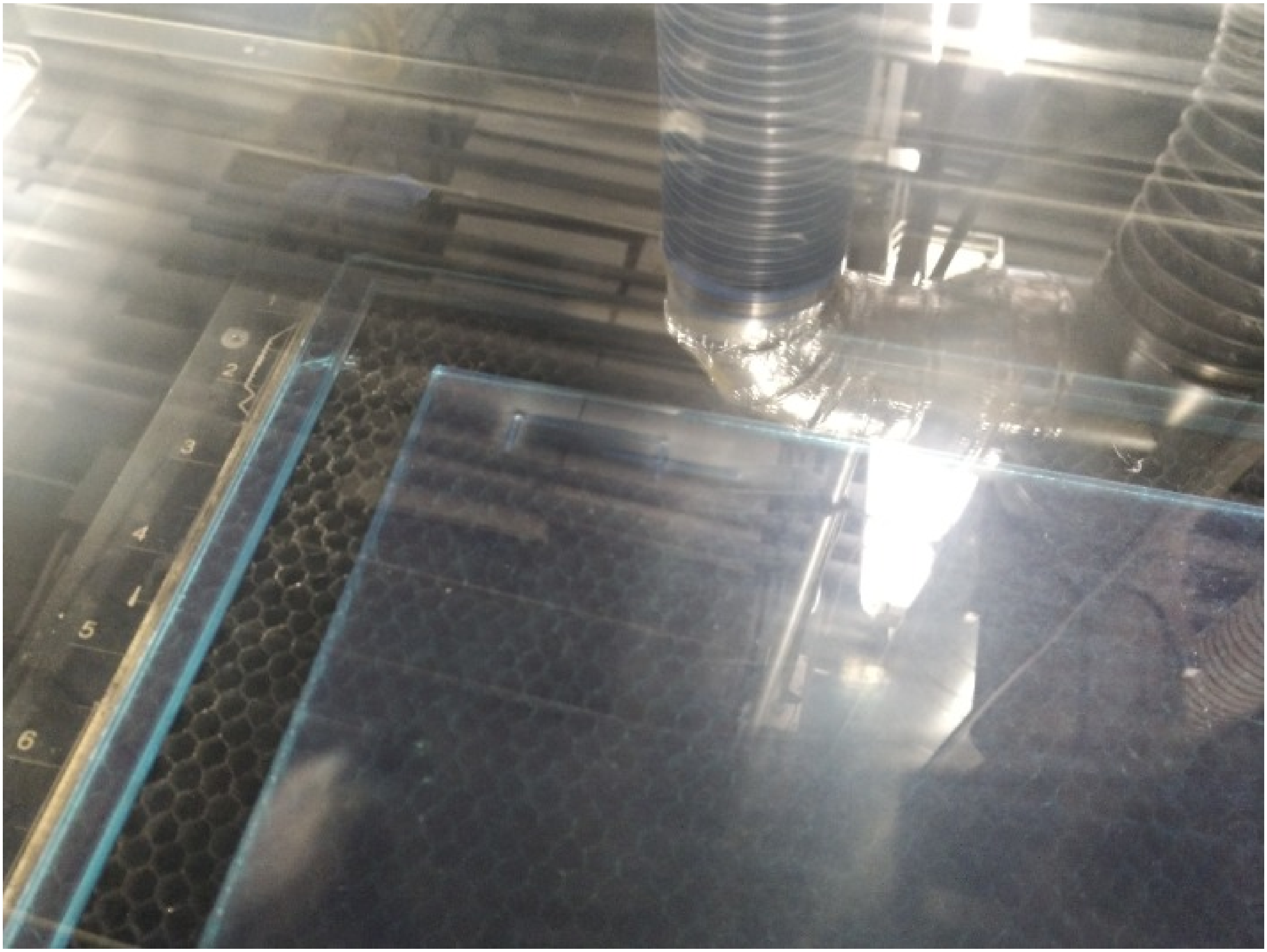
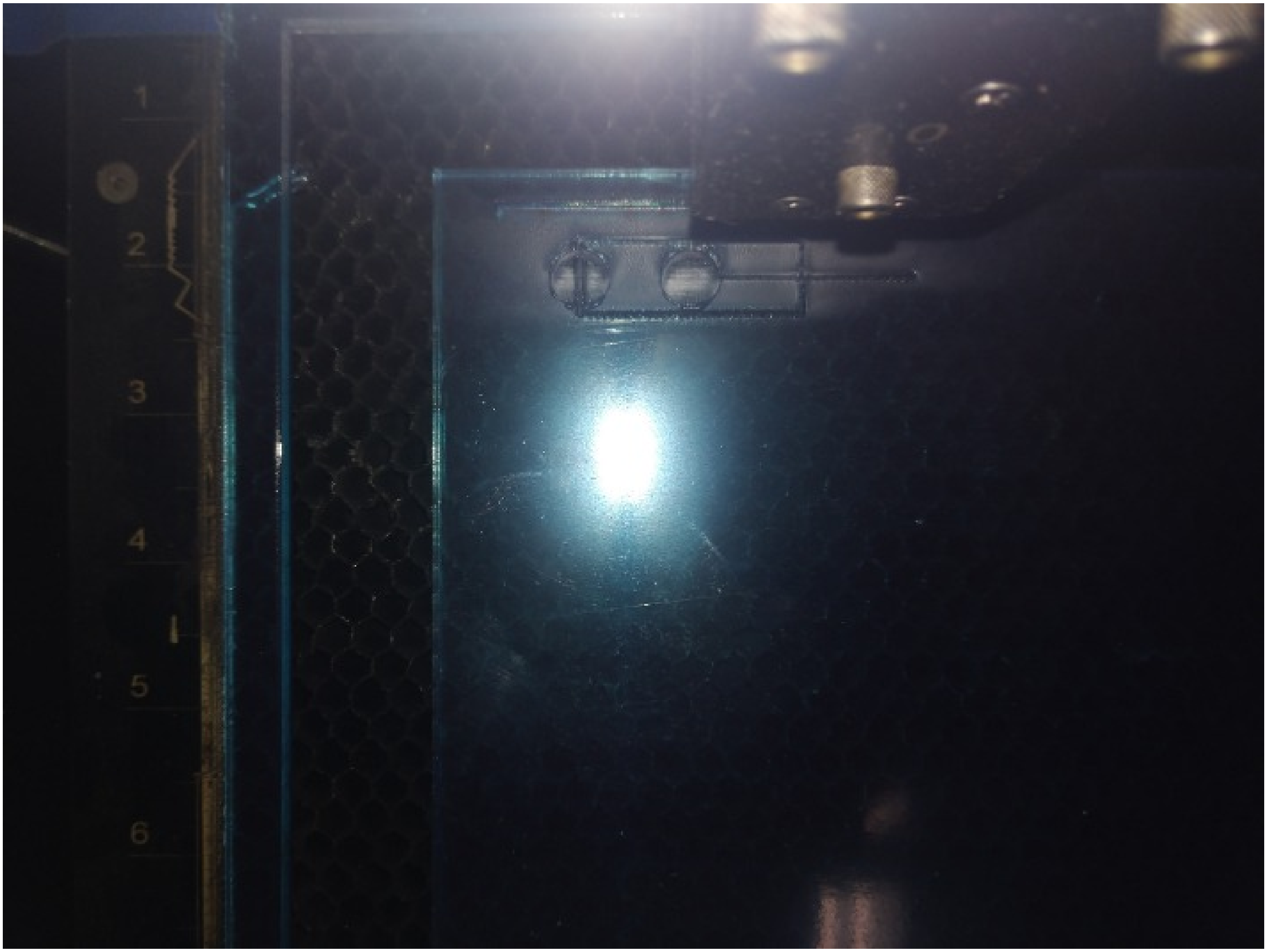
38 of 38
Cre
inches
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7




1
2
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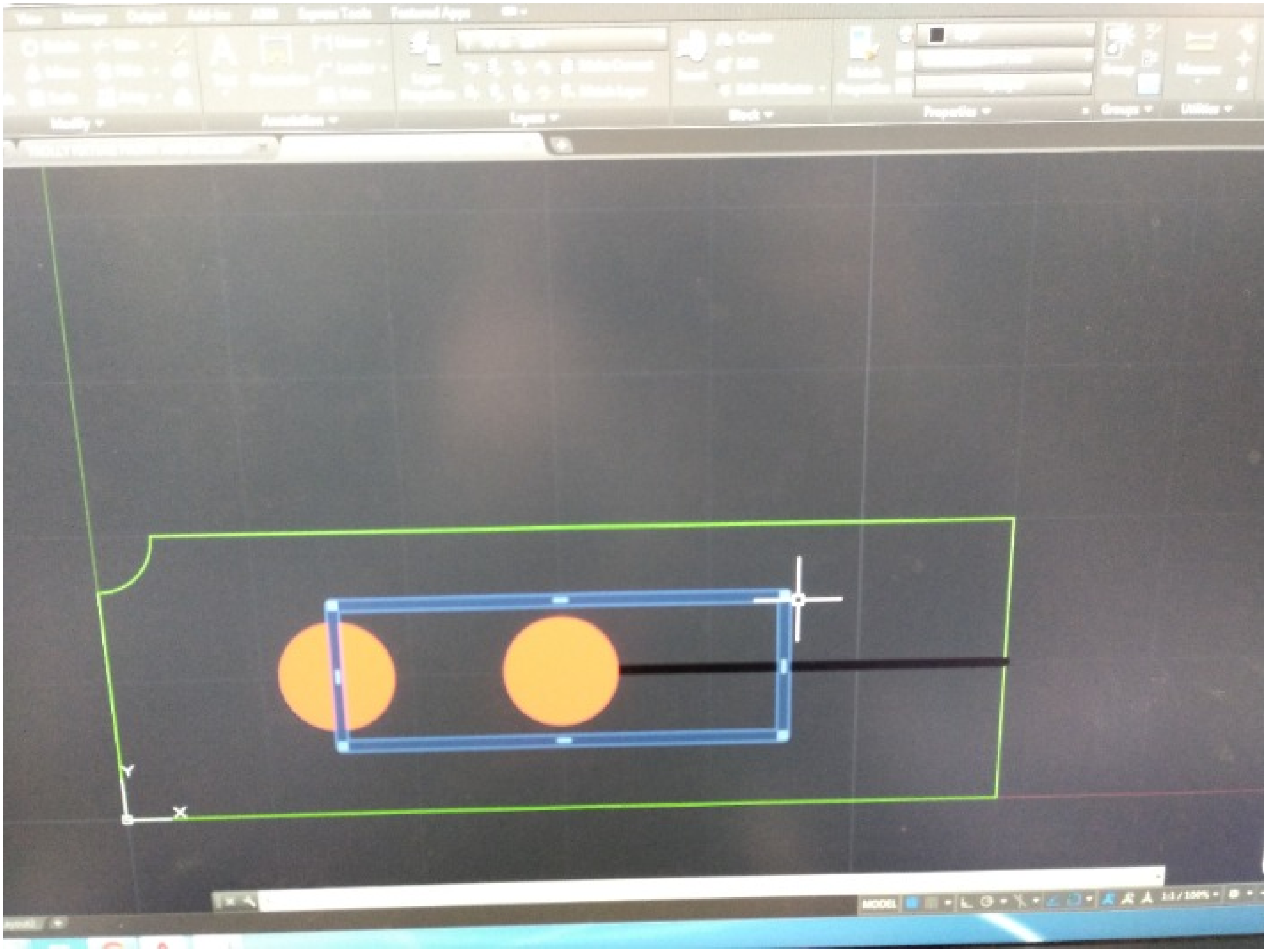
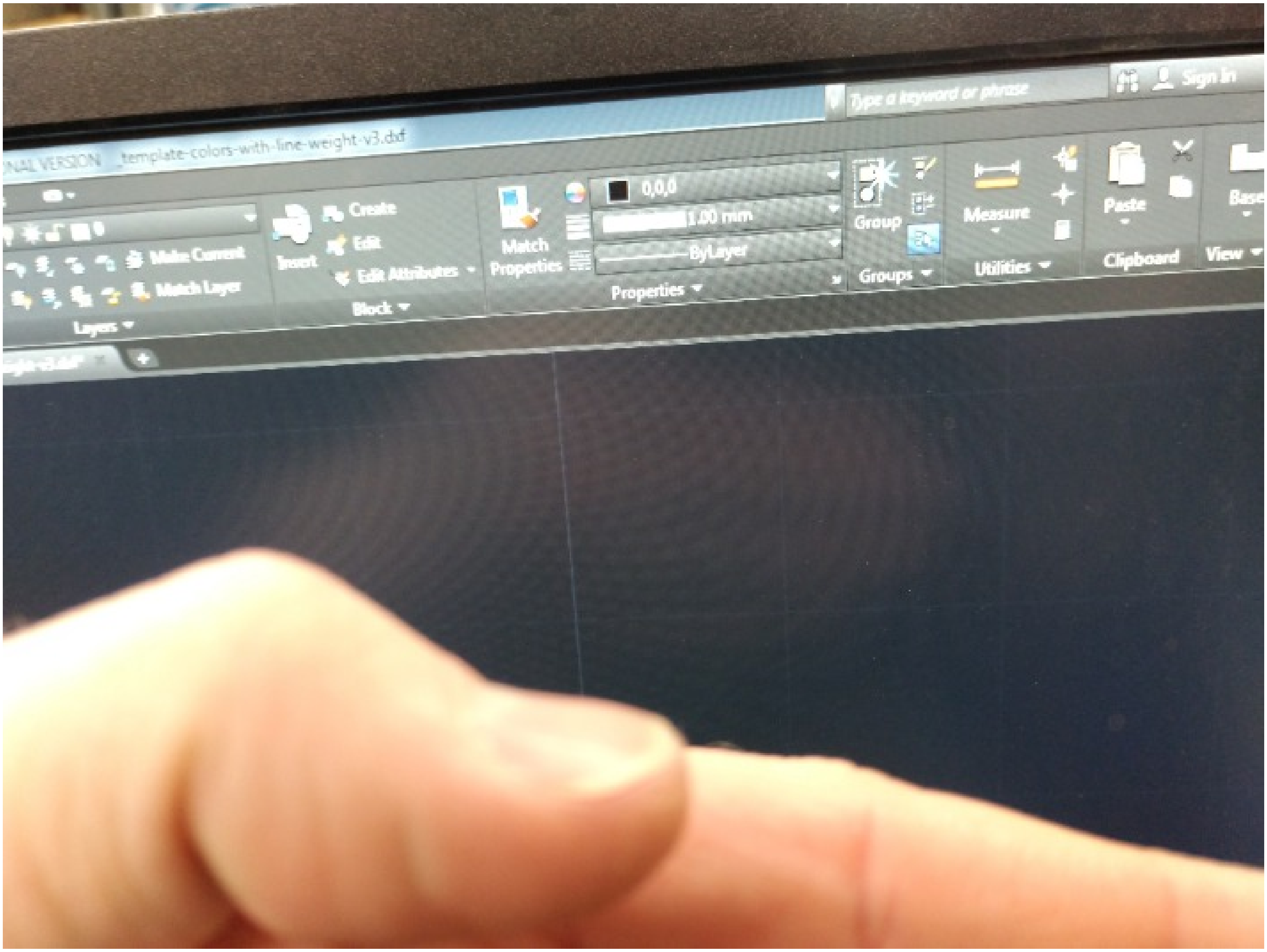
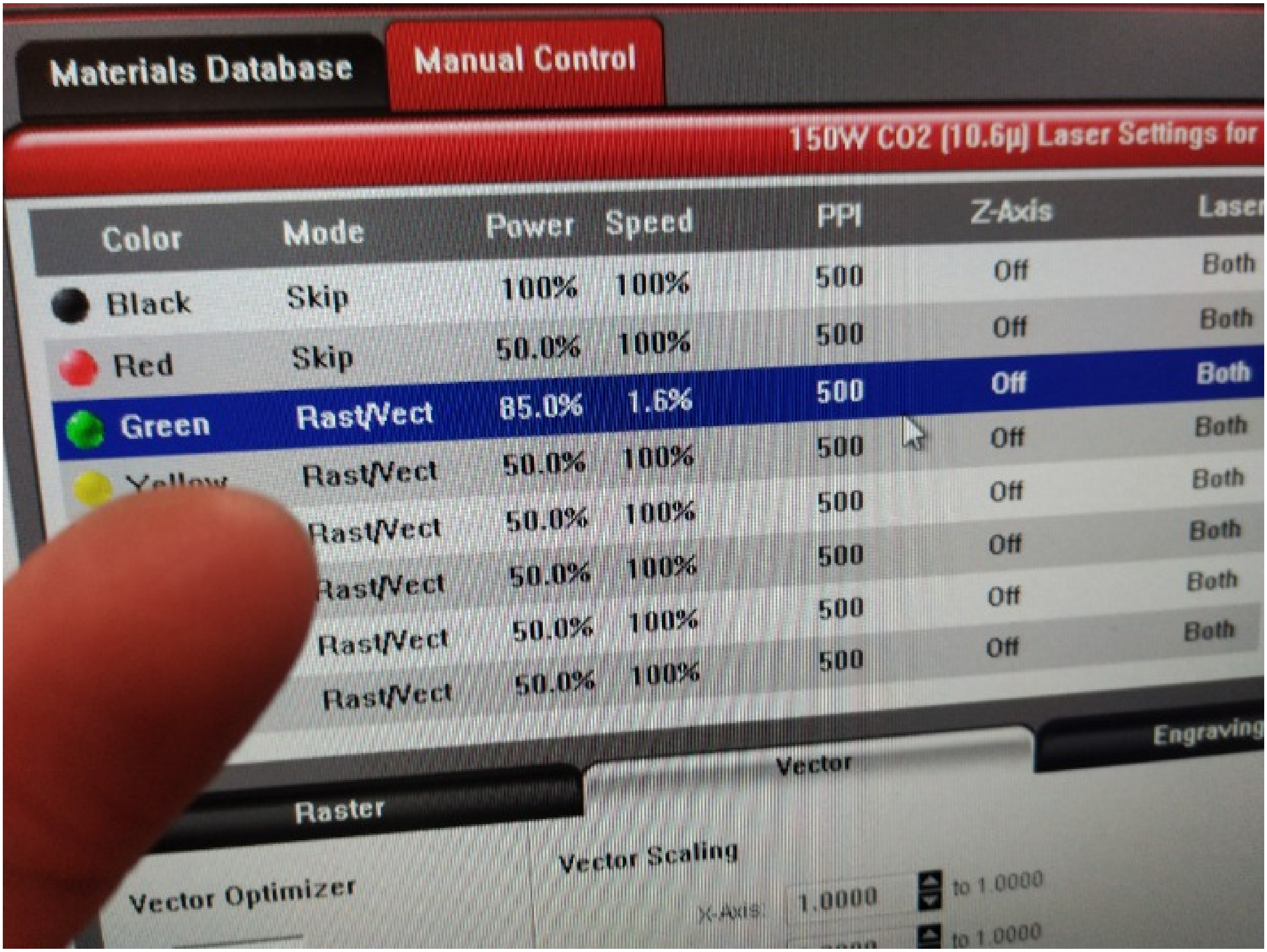
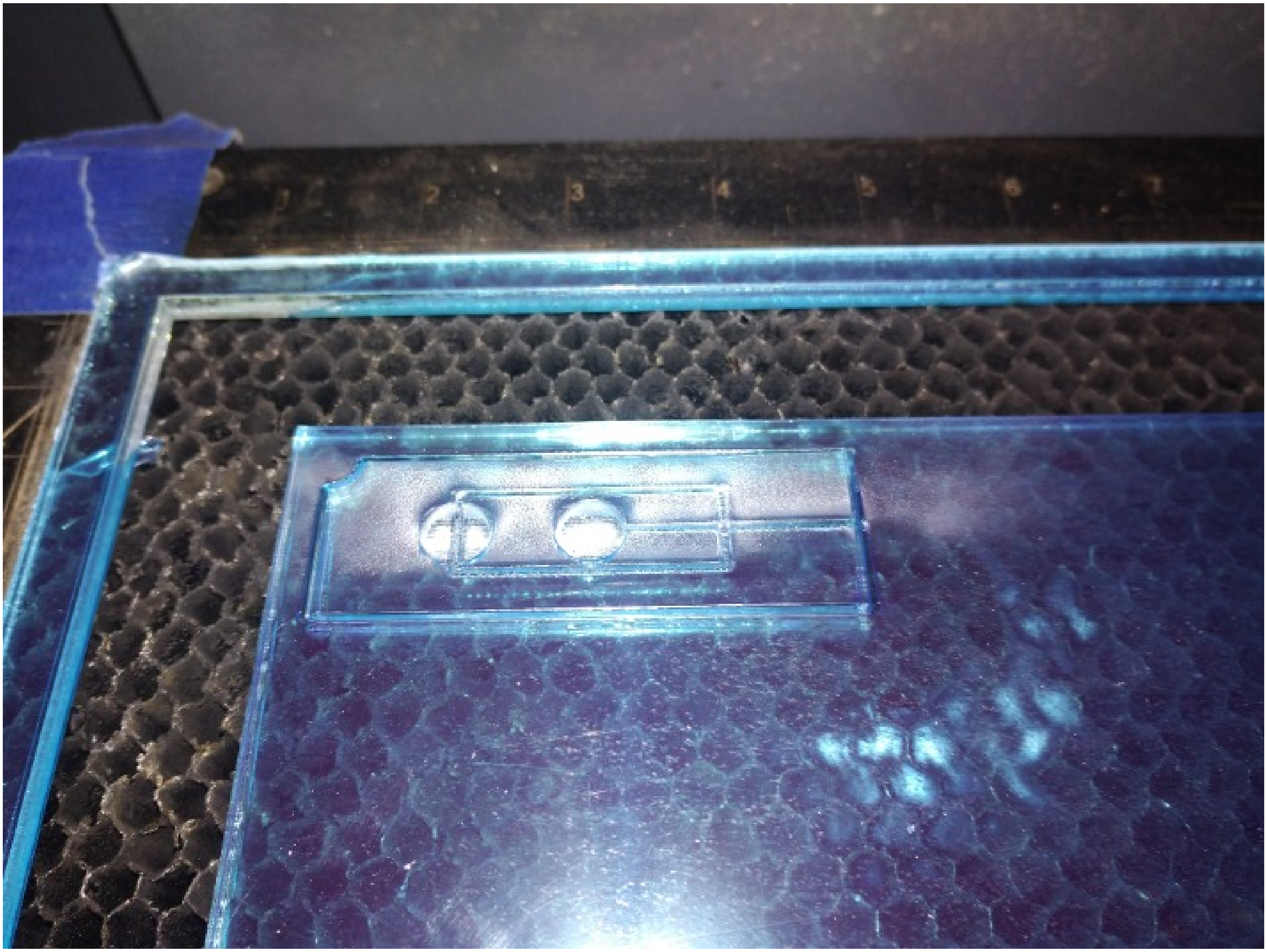
6

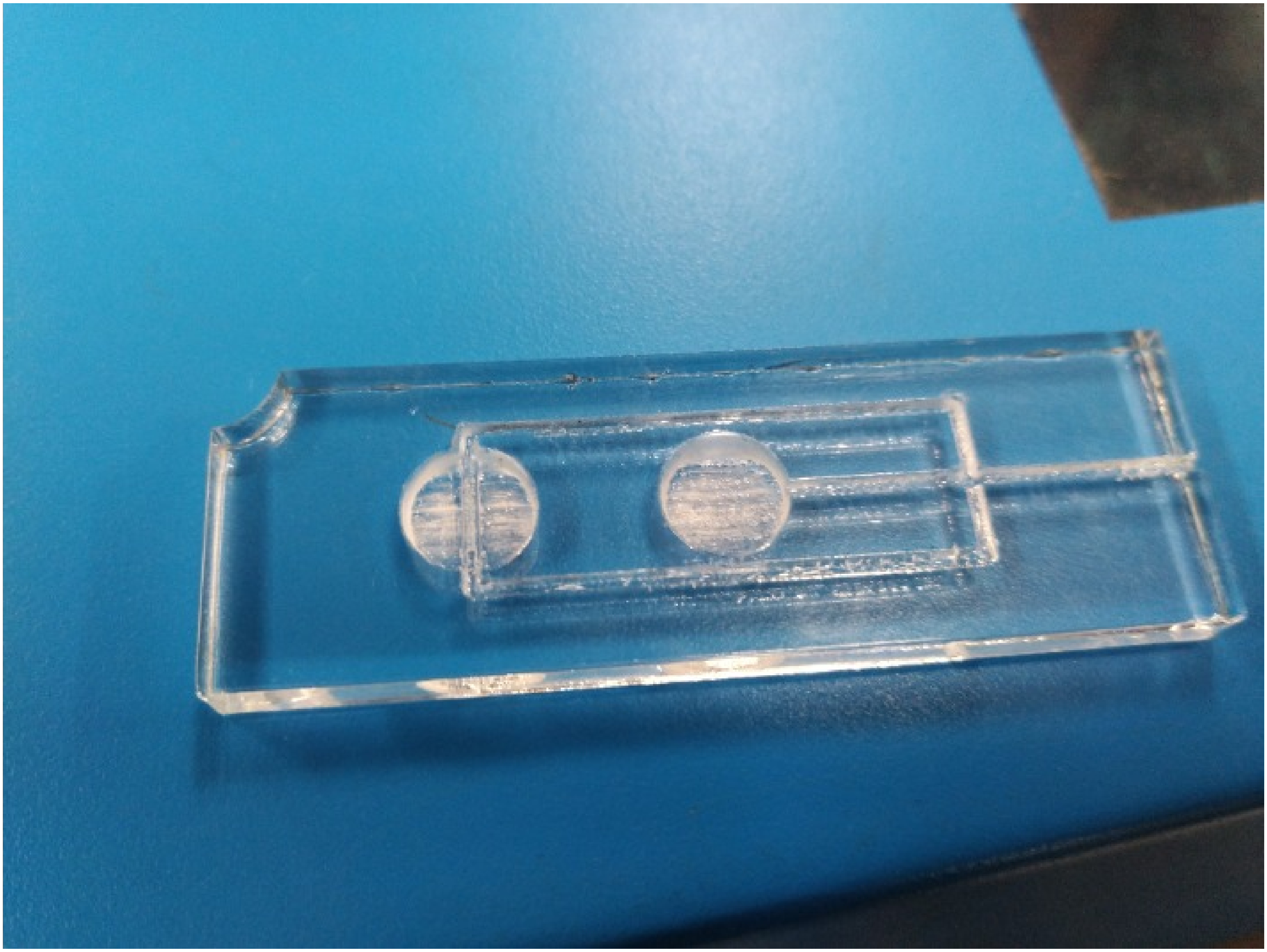


Y
X
MODEL

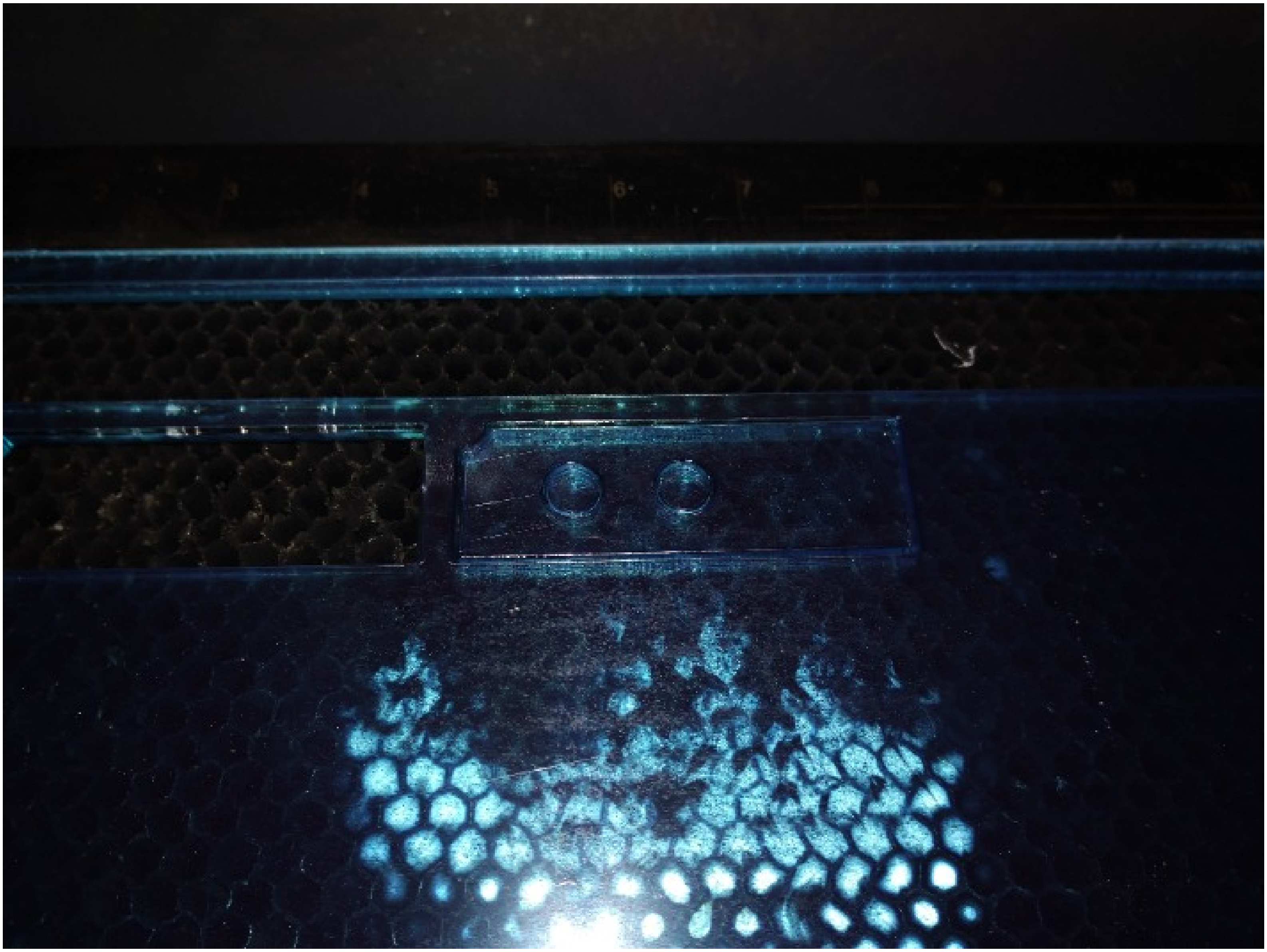

_template-colors-with-line-weight-v3.dxf
Type a keyword or phrase
Sign In
Make Current
Match Layer
Layers
Insert
Create
Edit
Edit Attributes
Block
Match Properties
0,0,0
1.00 mm
ByLayer
Properties
Group
Groups
Measure
Utilities
Paste
Clipboard
View

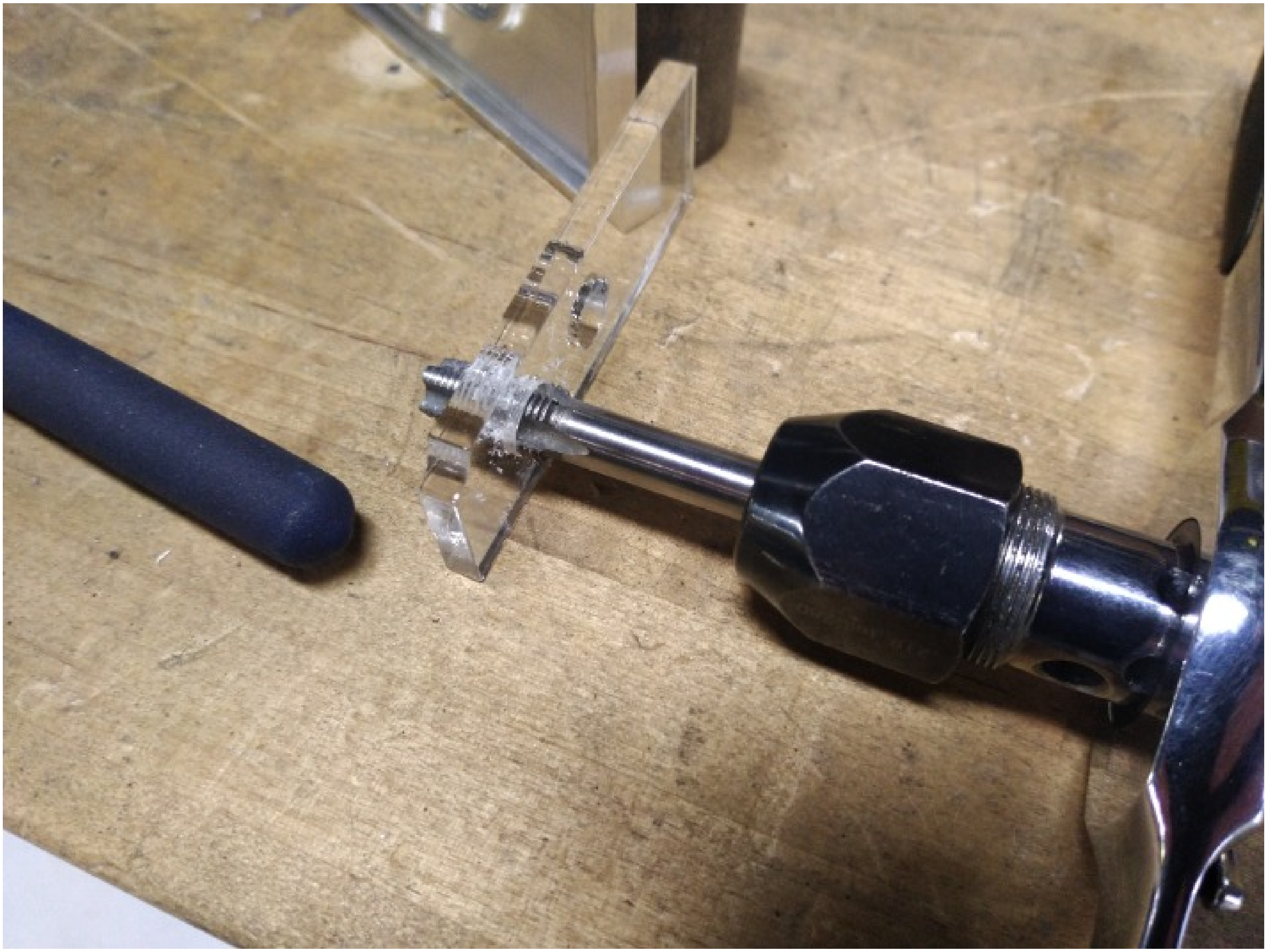

Materials Database
Manual Control
150W CO2 (10.6µ) Laser Settings for
Color
Mode
Power
Speed
PPI
Z-Axis
Black
Skip
100%
100%
500
Off
Both
Red
Skip
50.0%
100%
Green
Rast/Vect
85.0%
1.6%
Rast/Vect
50.0%
Raster
Vector
Engraving
Vector Scaling
Vector Optimizer
X-Axis:
1.0000
to 1.0000

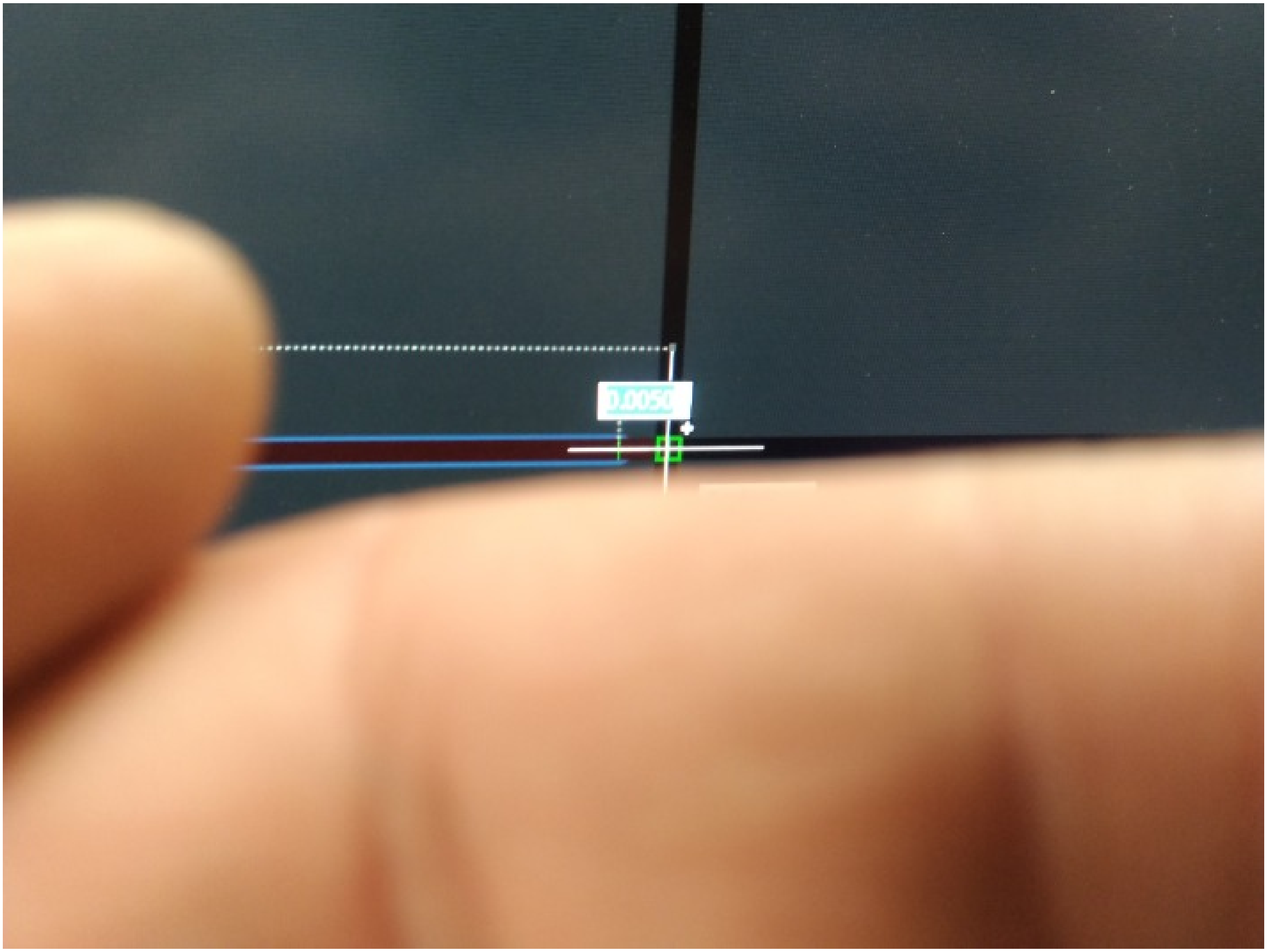





#3



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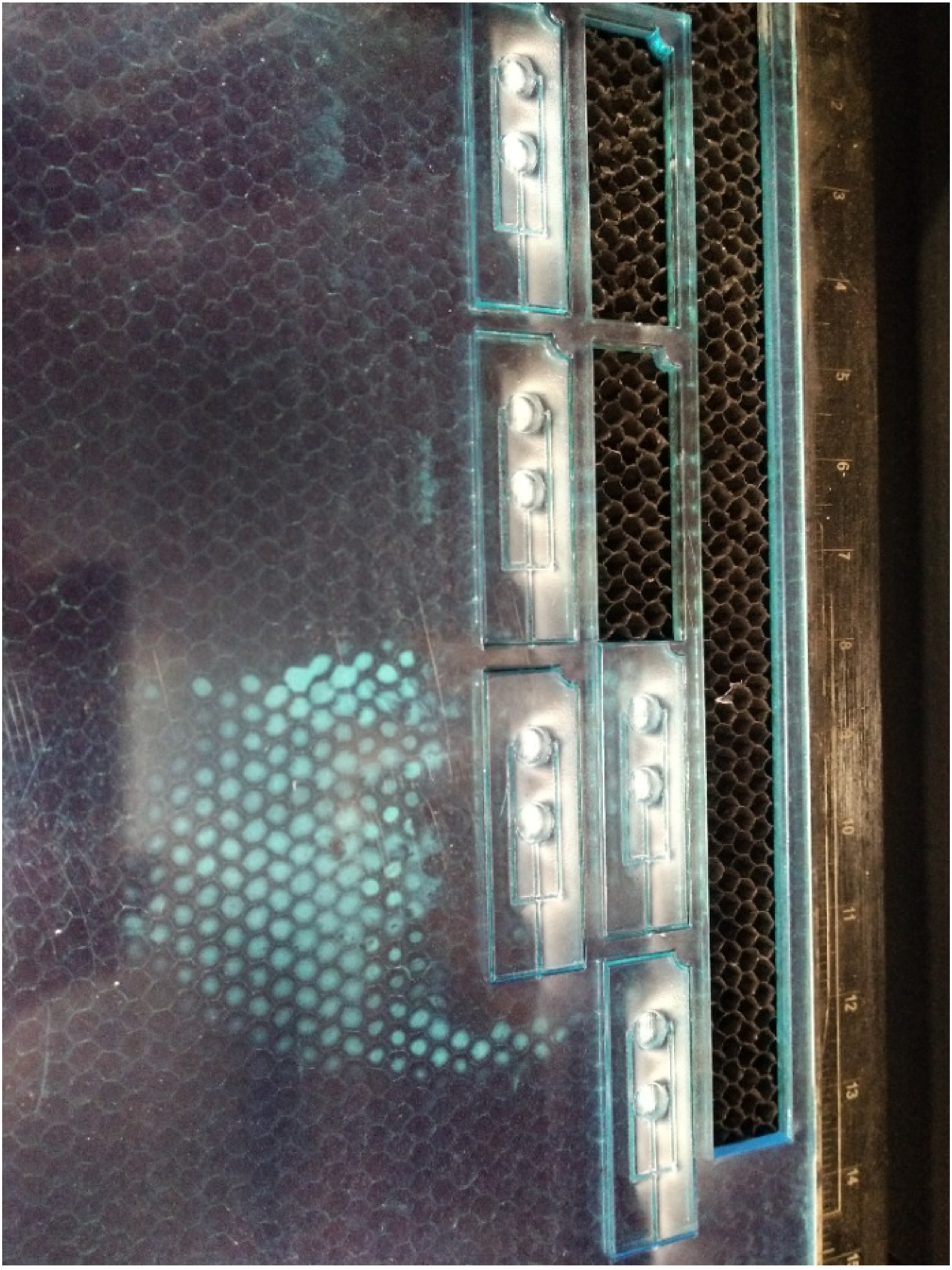
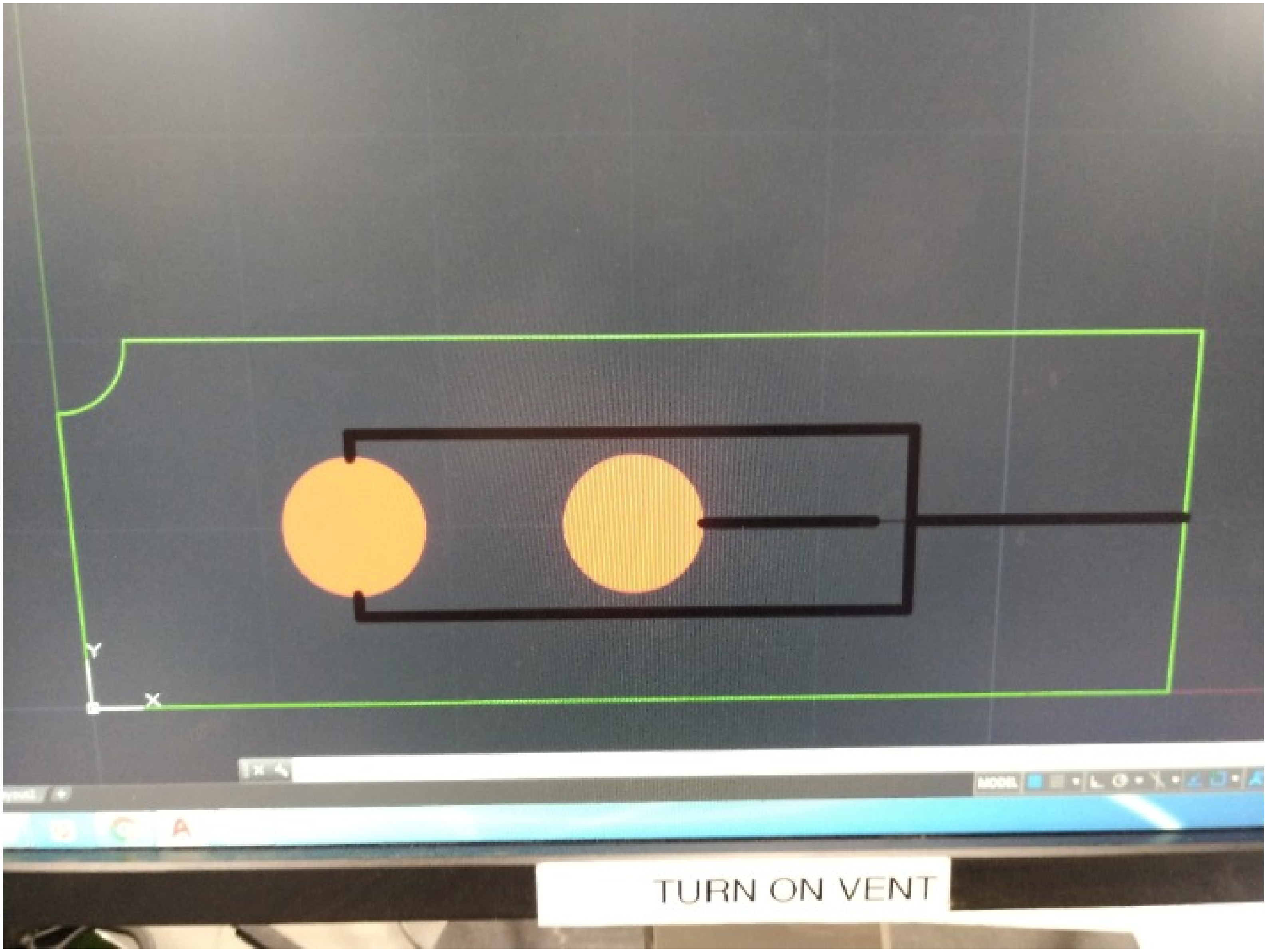
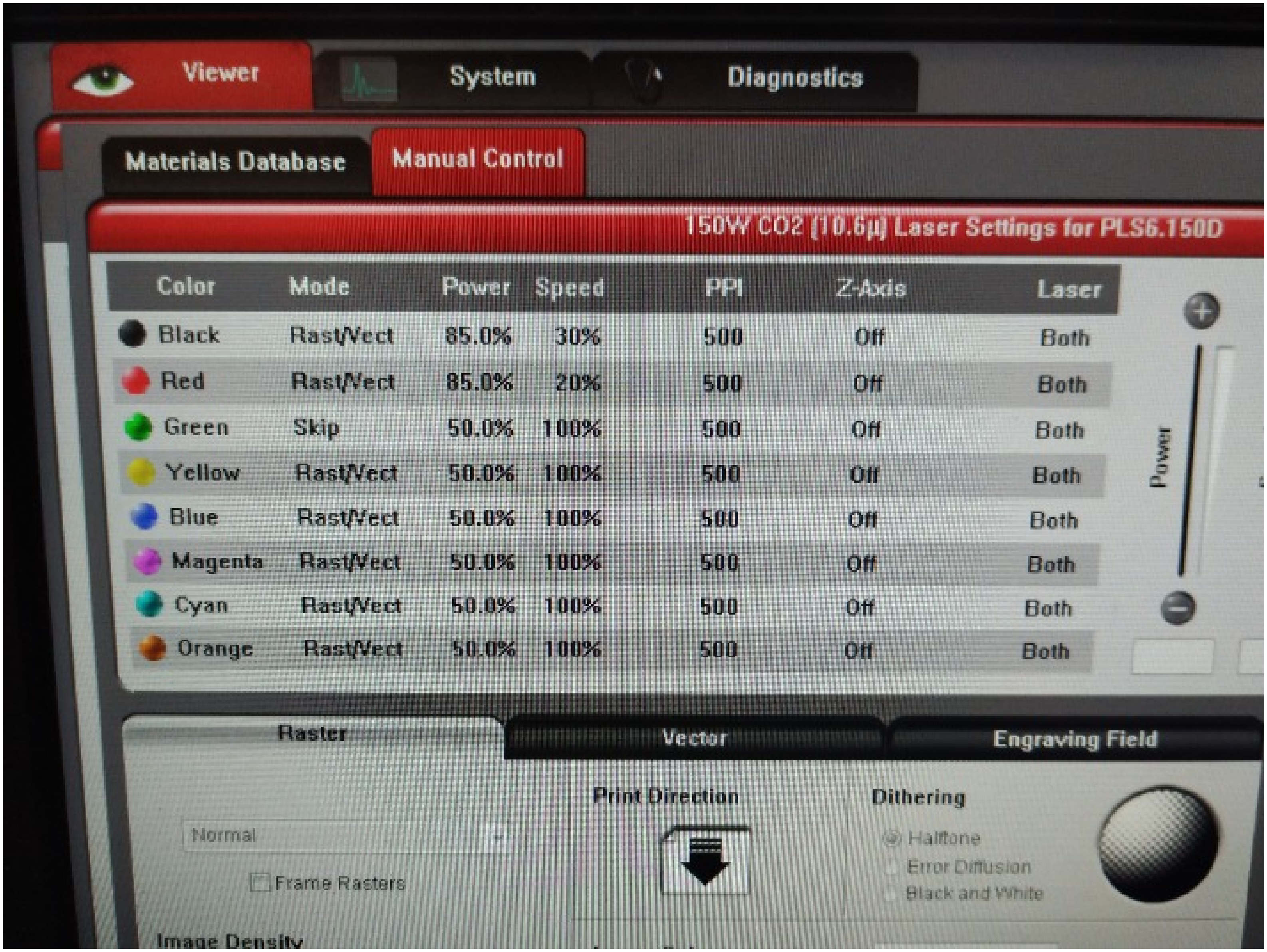
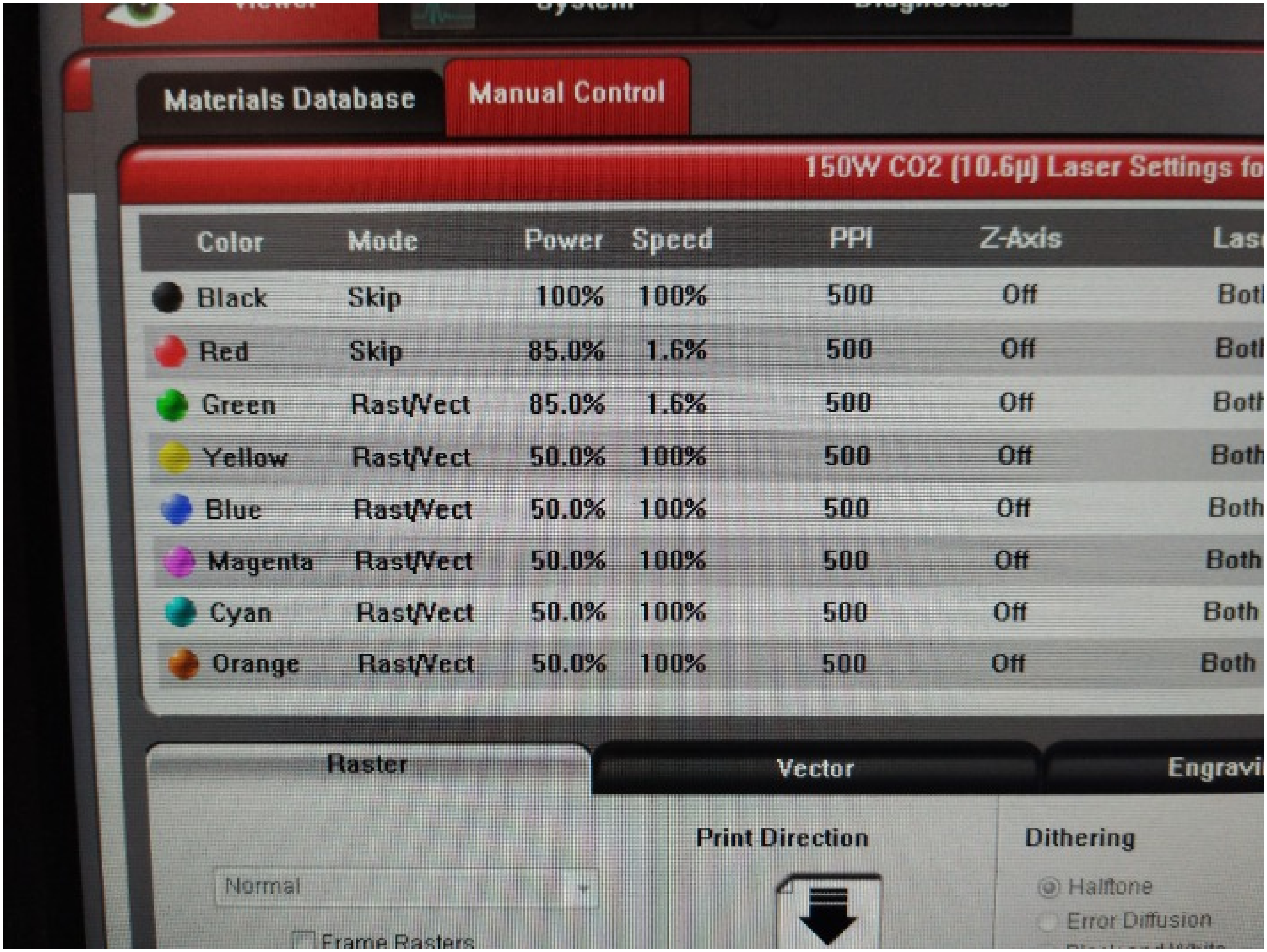
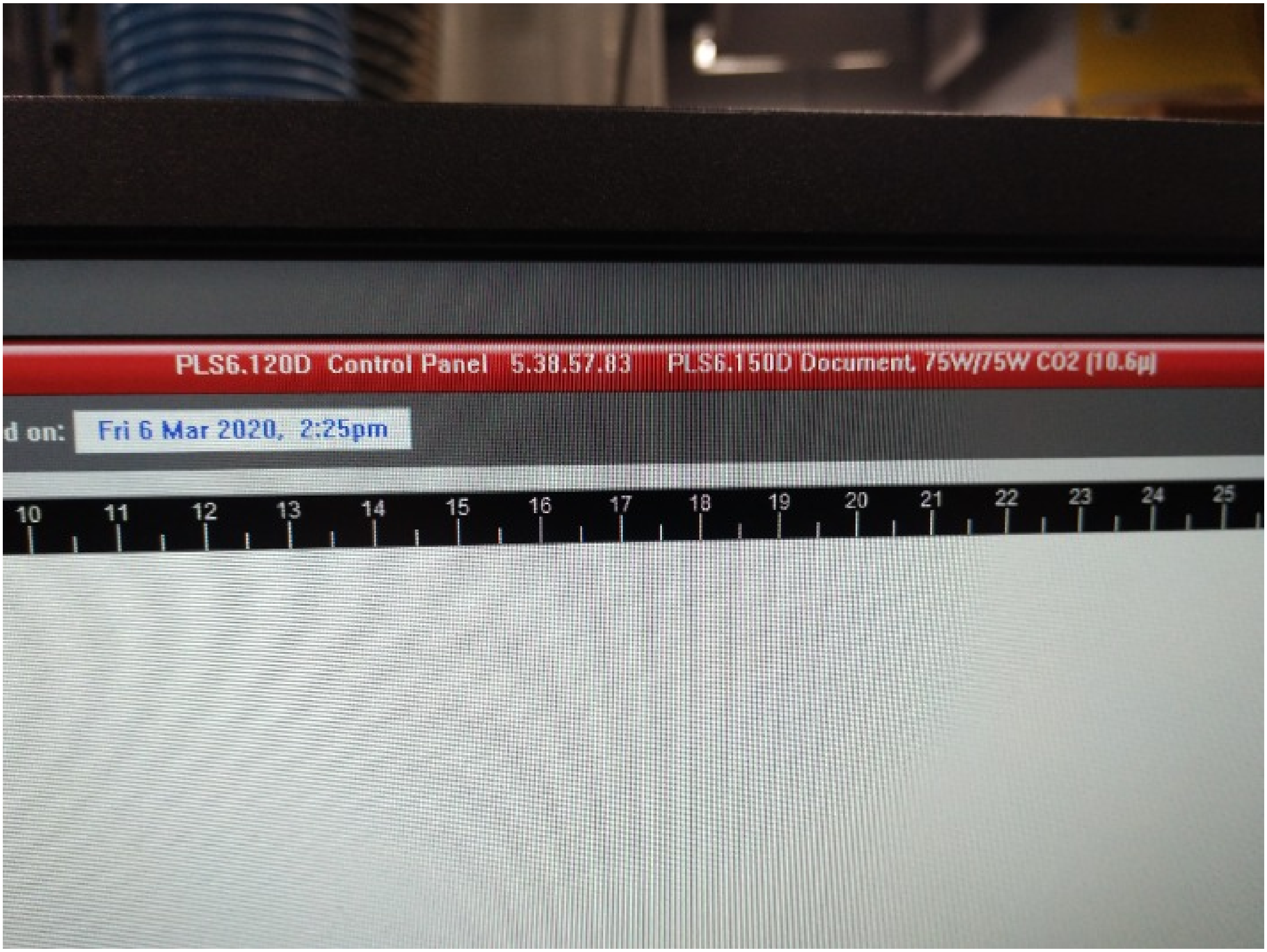


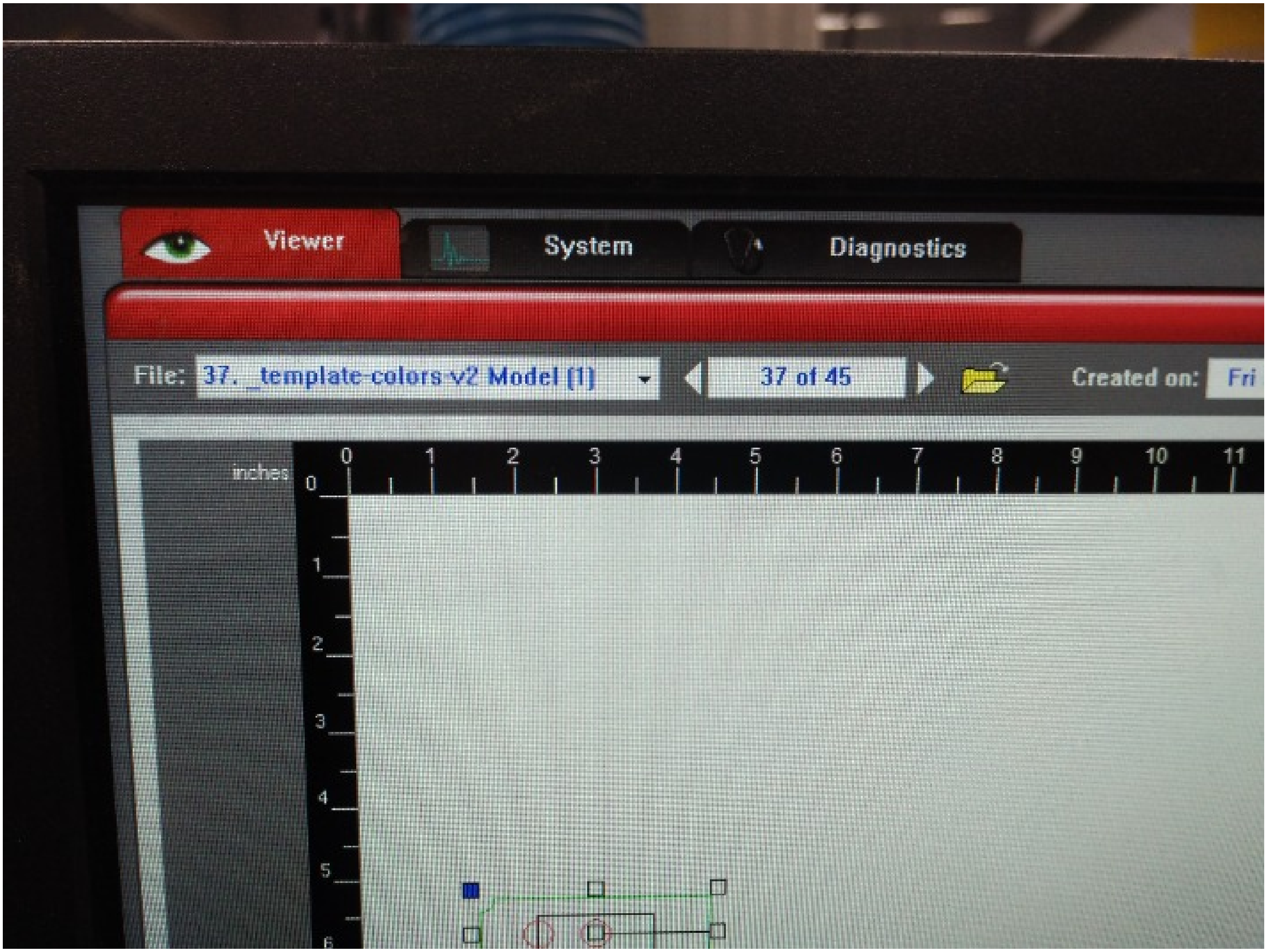

Y
X
MODEL
TURN ON VENT

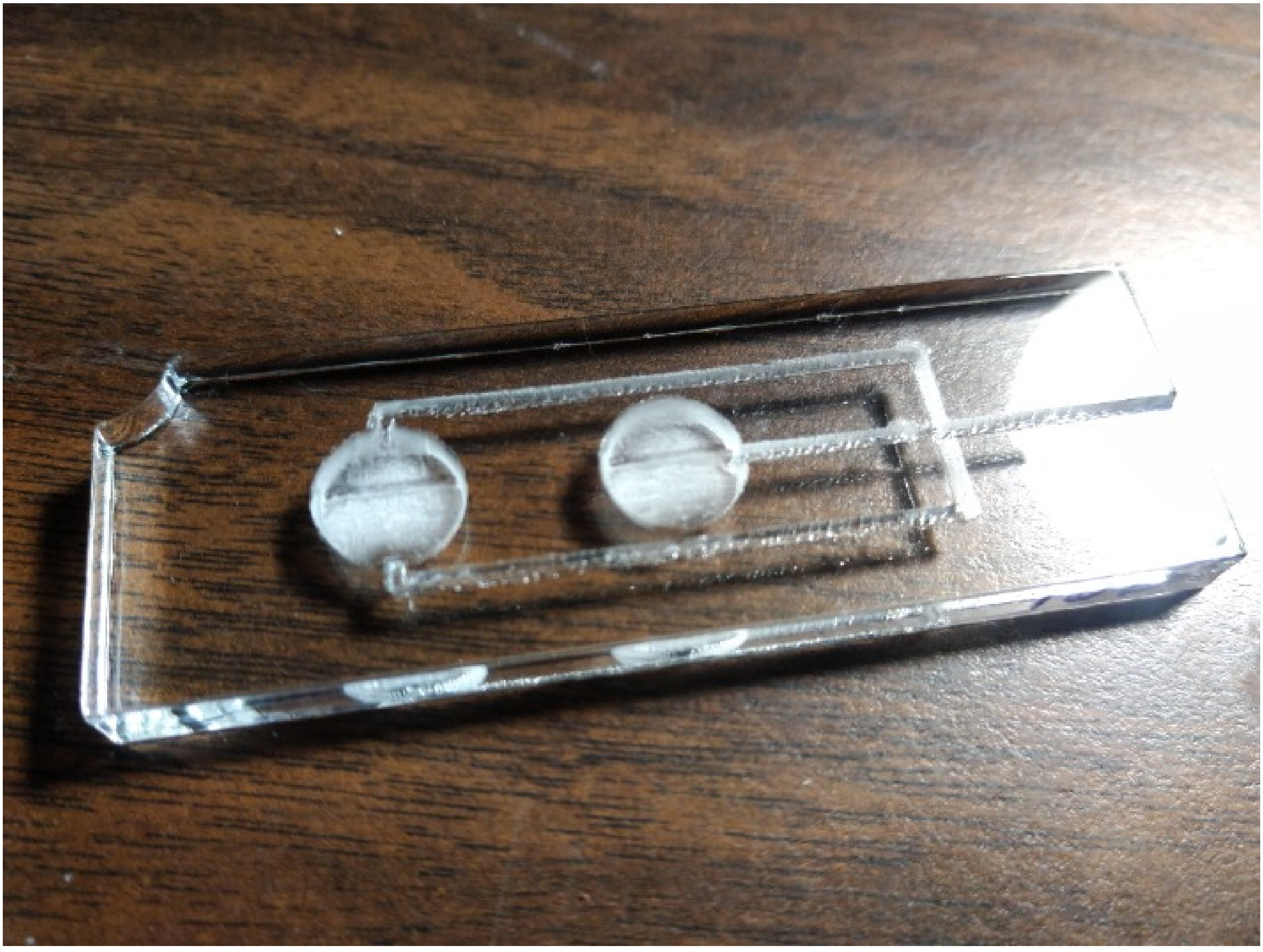

Viewer
System
Diagnostics
Materials Database
Manual Control
150W CO2 (10.6µ) Laser Settings for PLS6.150D
Color Mode Power Speed PPI Z-Axis Laser
Black Rast/Vect 85.0% 30% 500 Off Both
Red Rast/Vect 85.0% 20% 500 Off Both
Green Skip 50.0% 100% 500 Off Both
Yellow Rast/Vect 50.0% 100% 500 Off Both
Blue Rast/Vect 50.0% 100% 500 Off Both
Magenta Rast/Vect 50.0% 100% 500 Off Both
Cyan Rast/Vect 50.0% 100% 500 Off Both
Orange Rast/Vect 50.0% 100% 500 Off Both
Power
Raster
Vector
Engraving Field
Print Direction
Dithering
Normal
Frame Rasters
Halftone
Error Diffusion
Black and White
Image Density

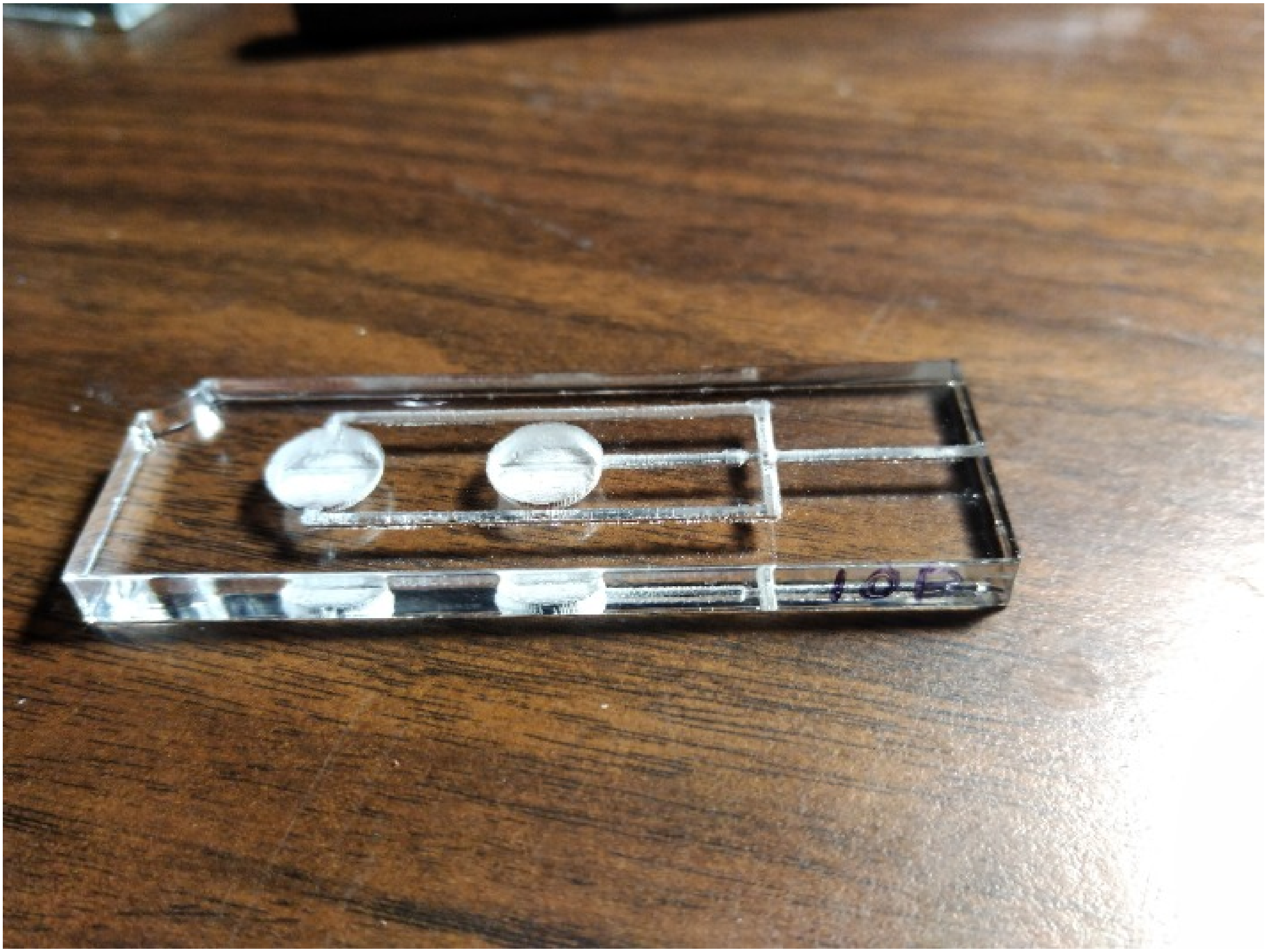


Color	Mode	Power	Speed	PPI	Z-Axis	Las
Black	Skip	100%	100%	500	Off	Bot
Red	Skip	85.0%	1.6%	500	Off	Bot
Green	Rast/Vect	85.0%	1.6%	500	Off	Bot
Yellow	Rast/Vect	50.0%	100%	500	Off	Both
Blue	Rast/Vect	50.0%	100%	500	Off	Both
Magenta	Rast/Vect	50.0%	100%	500	Off	Both
Cyan	Rast/Vect	50.0%	100%	500	Off	Both
Orange	Rast/Vect	50.0%	100%	500	Off	Both

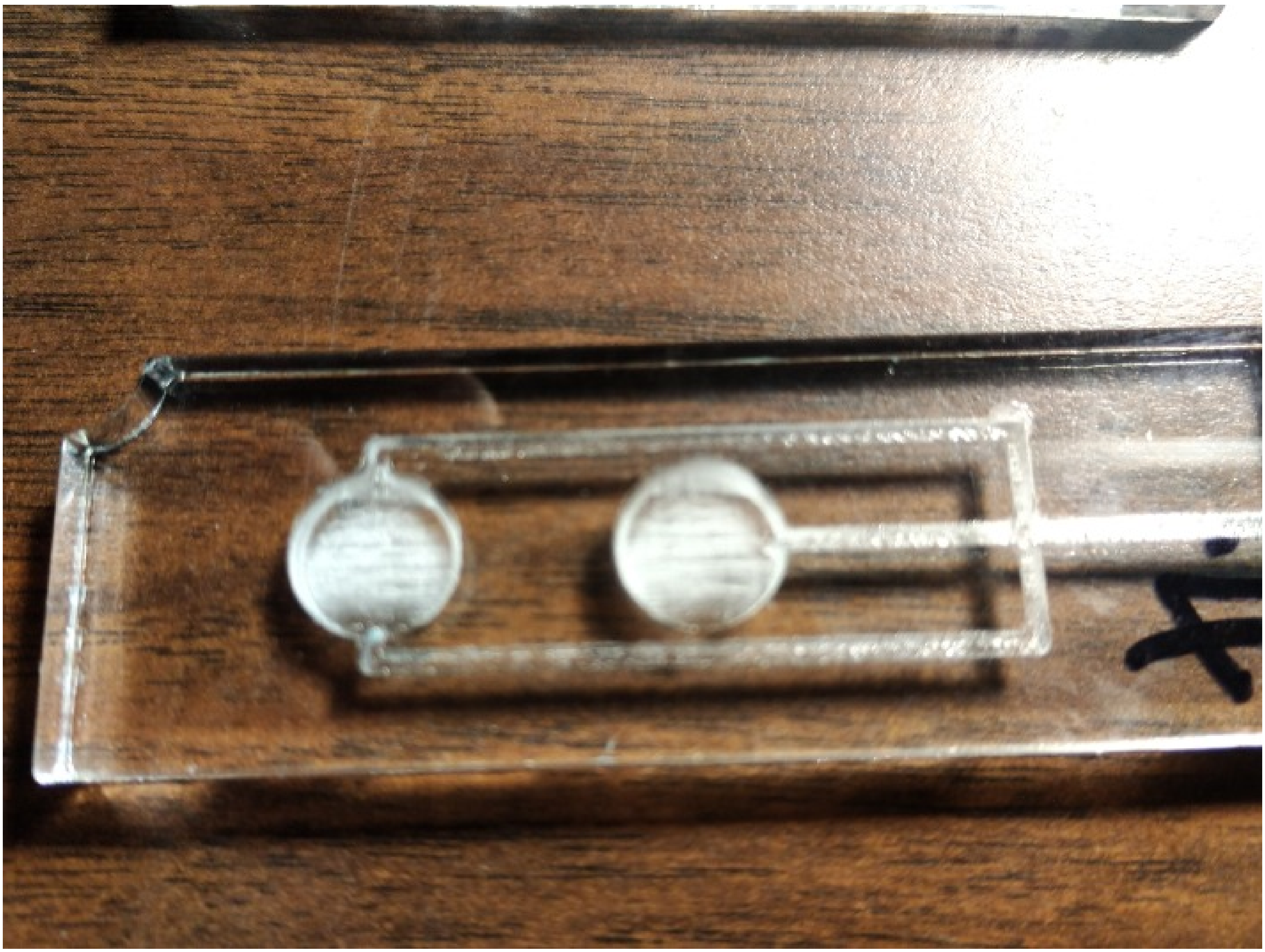

PLS6.120D Control Panel 5.38.57.83 PLS6.150D Document, 75W/75W CO2 (10.6μ)
d on: Fri 6 Mar 2020, 2:25pm
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


Viewer
System
Diagnostics
File: 37. _template-colors v2 Model (1)
37 of 45
Created on: Fri
inches






alcohol
skin cleanser
swabs




4 PACK
Nutrition Facts
370


1960
CHICKEN AND BEEF
5
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15
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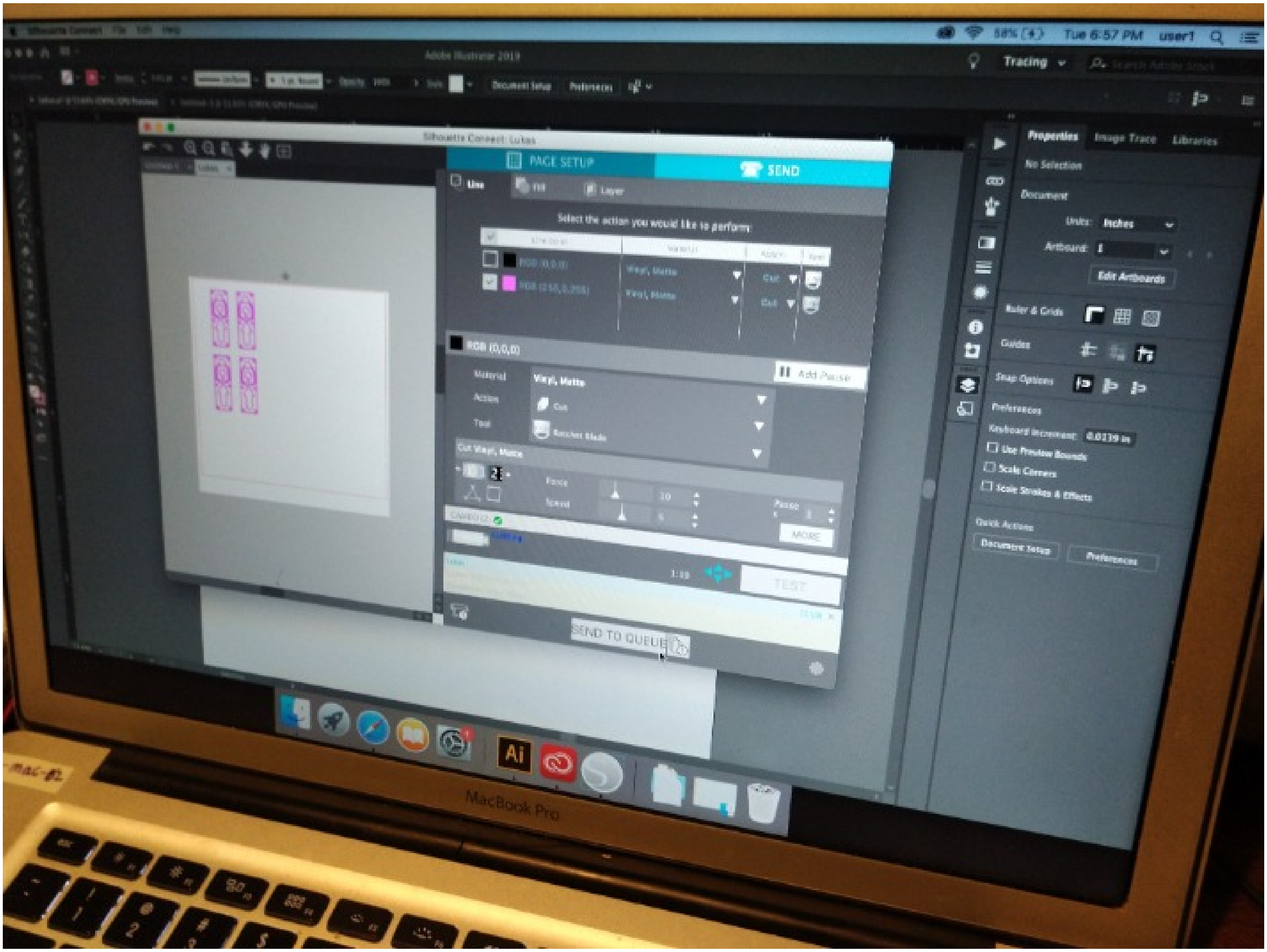
25

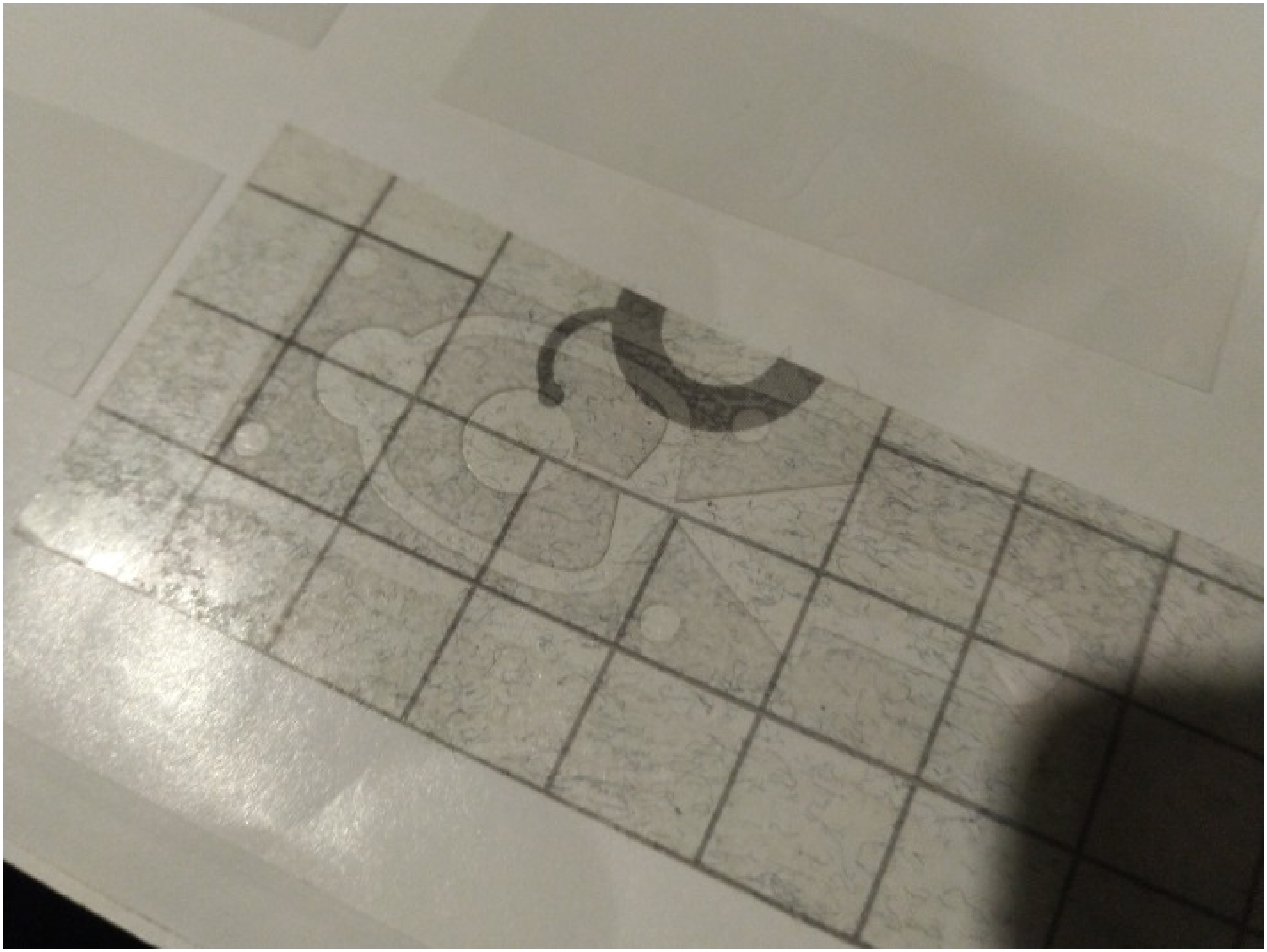

P

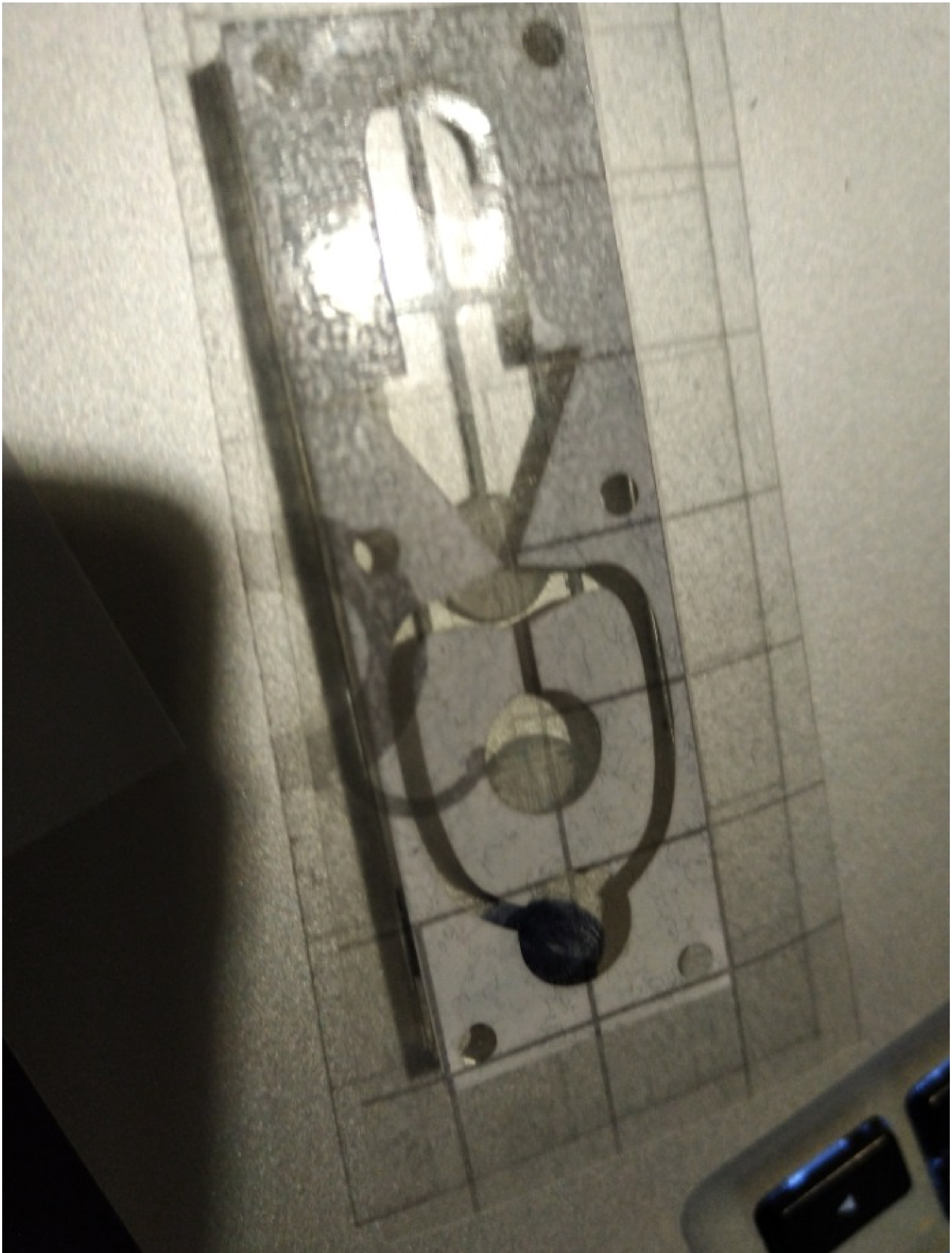

air stone
Lee's
AQ2
Super Pump
MARINA
PYTHON
Air Pump
Whisper
Air Pump
Tetra

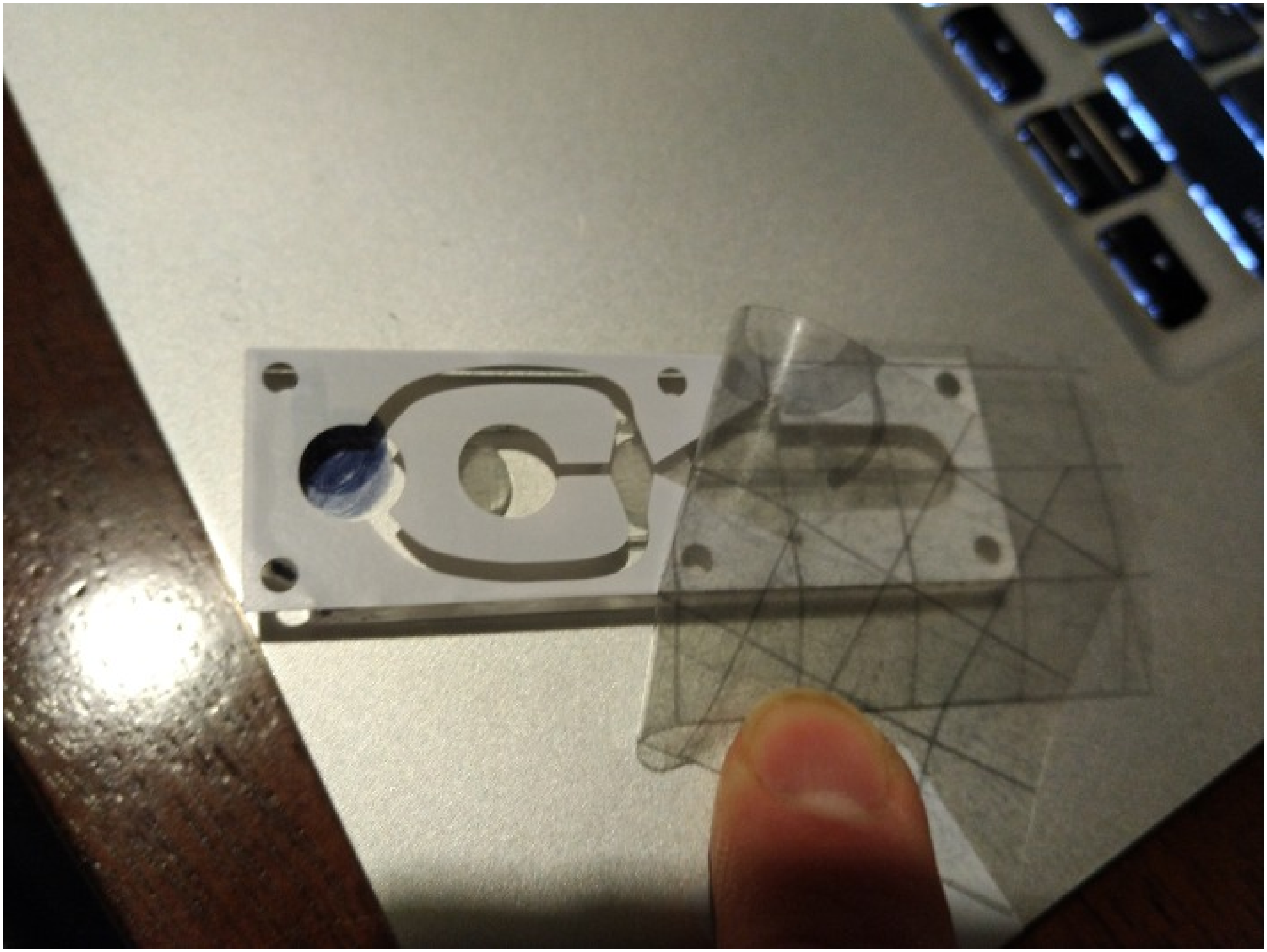

9pk LEE 2 WAY VALVE
Item # 48020
2.49
9pk LEE DISCARD-A-STONE COARSE
Item # 18875
5.99
2-Way Plastic Valve
Discard-A-Stone
Piedra desechable
1.99
LEE CHECK VALVE
3.99
9.99

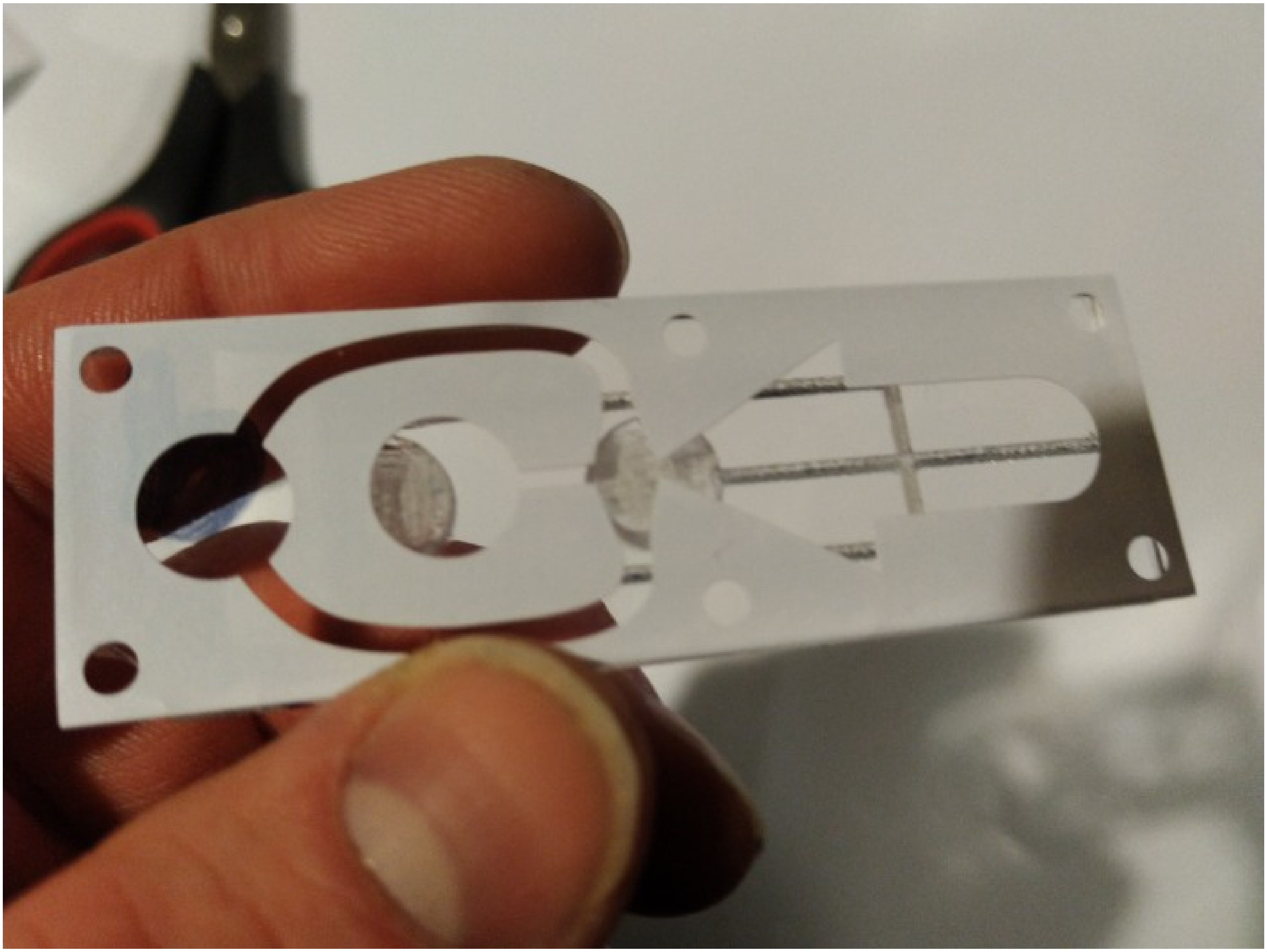

Air Stone
Pierre à air
Ausströmerstein
Piedra difusora
Luchtsteen
8' LEE STANDARD AIRLINE TUBING
Item # 32953
2.99
Lee's
14505
AIRLINE TUBING
TUYAU À AIR
TUBO DE AIRE
FLEXIBLE
6pk LEE AIRLINE HOLDERS
Item # 23264
3.99
de aire
MARINELA
BLUE LED BUBB
WAND
Item # 42152
23.99
MARINA
Bubble Disk
Disque à air
Discard-A-Stone
12520

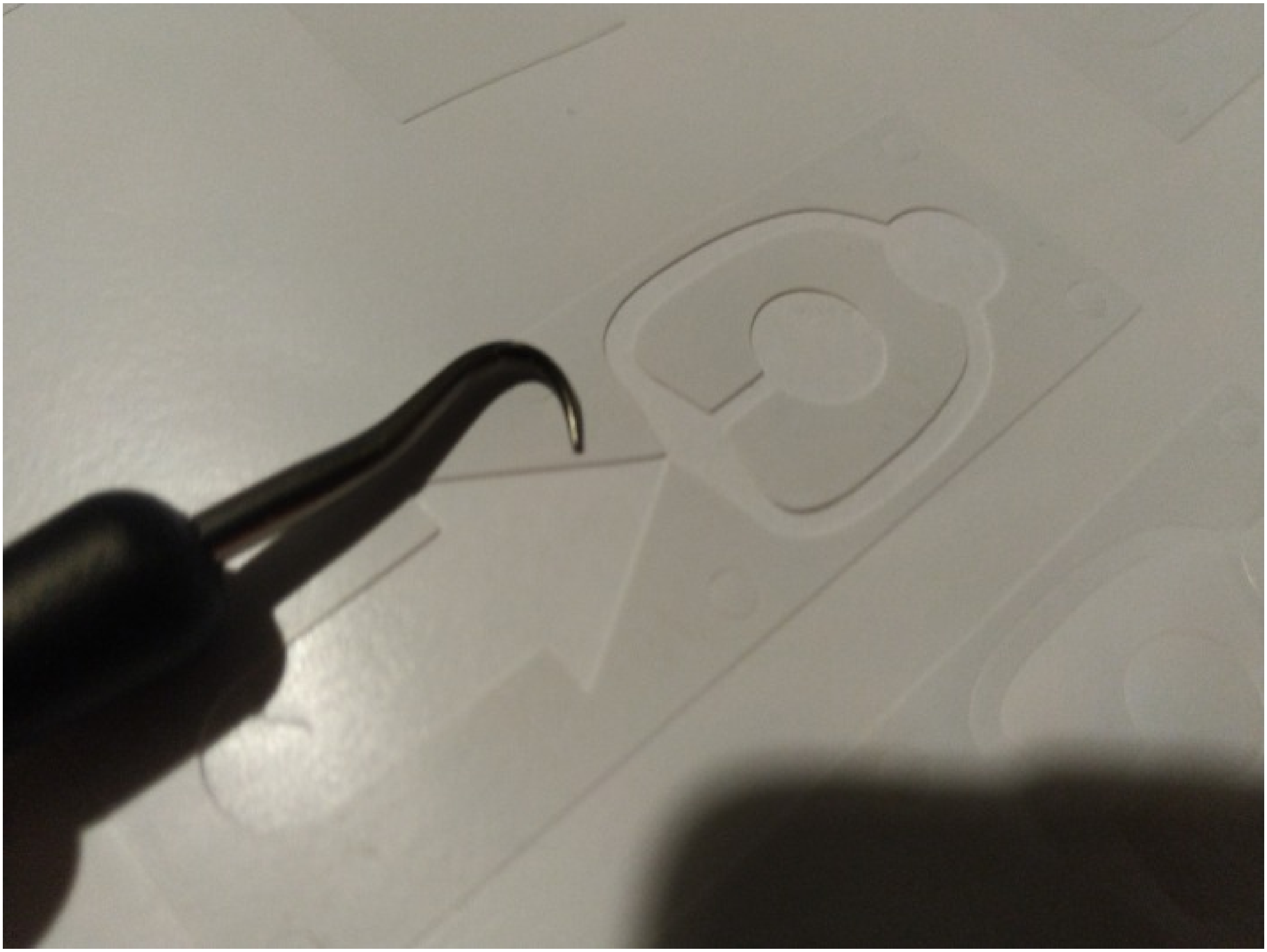

Tue 6:57 PM
user1
Tracing
Silhouette Connect: Lulas
PAGE SETUP
SEND
Select the action you would like to perform:
Add Pause
SEND TO QUEUE
TEST
MORE
Properties
Image Trace
Libraries
No Selection
Document
Units:
Inches
Artboard:
Edit Artboards
Ruler & Grids
Guides
Snap Options
Preferences
Keyboard Increment:
Use Preview Bounds
Scale Corners
Scale Strokes & Effects
Quick Actions
Document Setup
Preferences
MacBook Pro

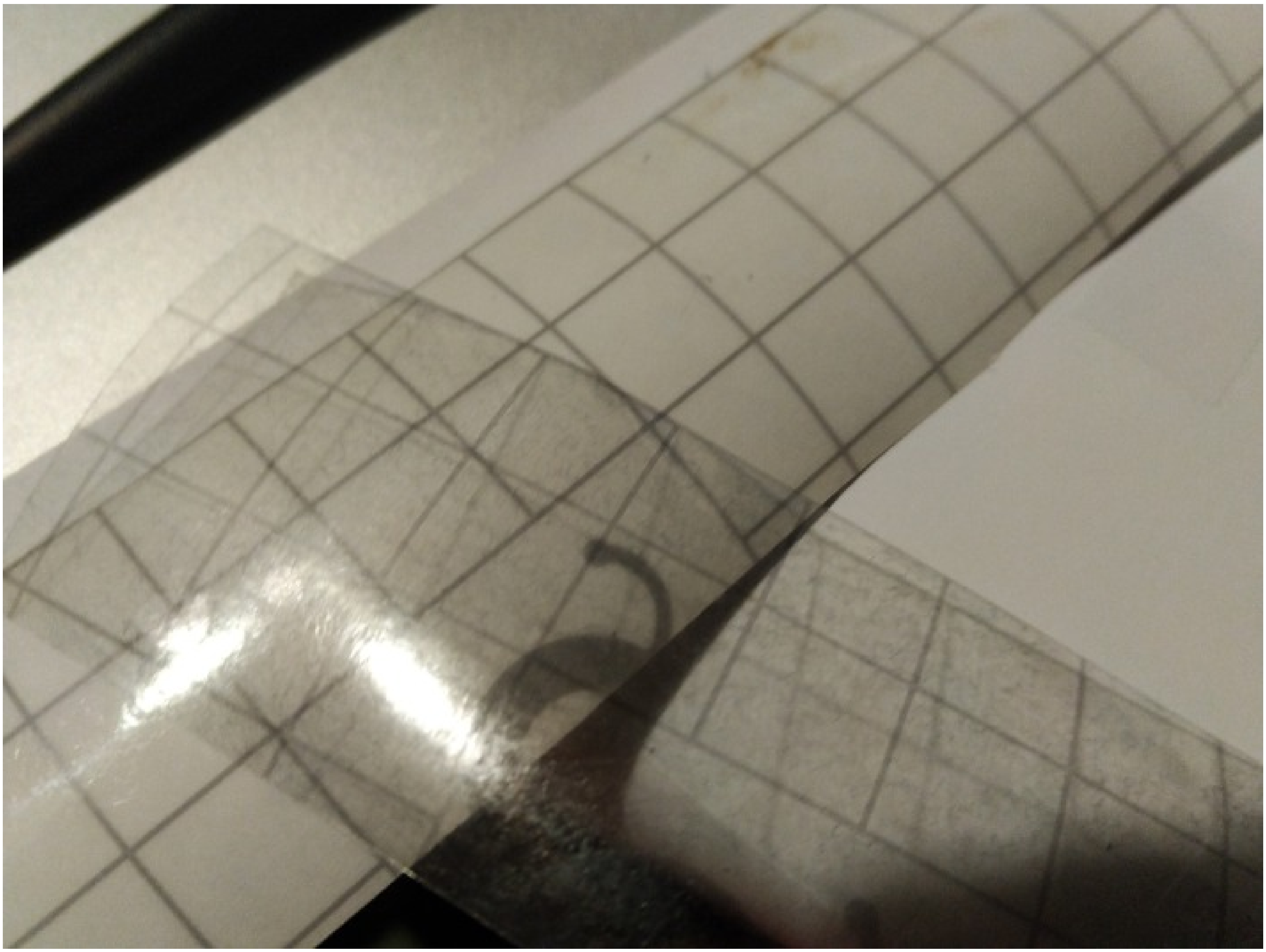


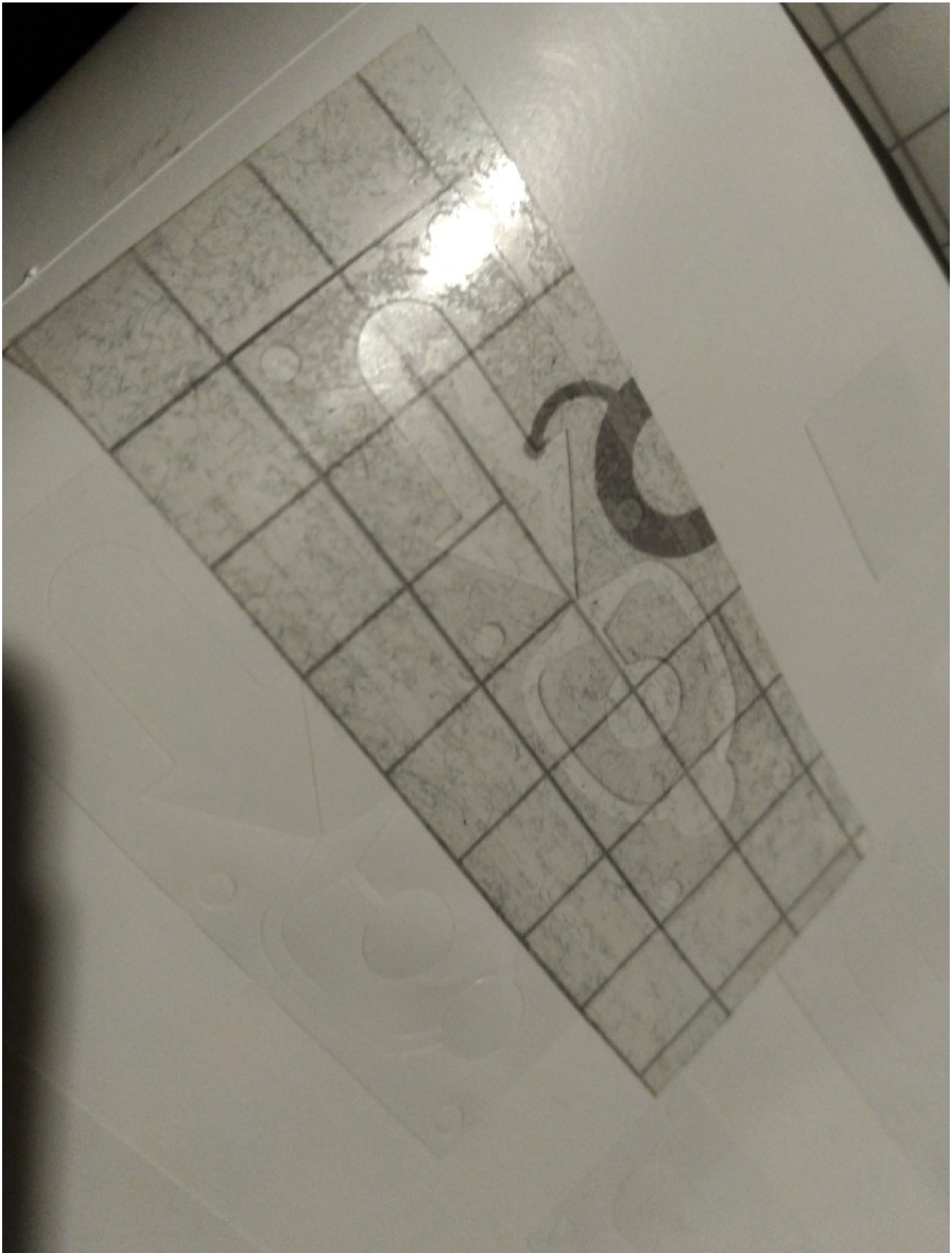


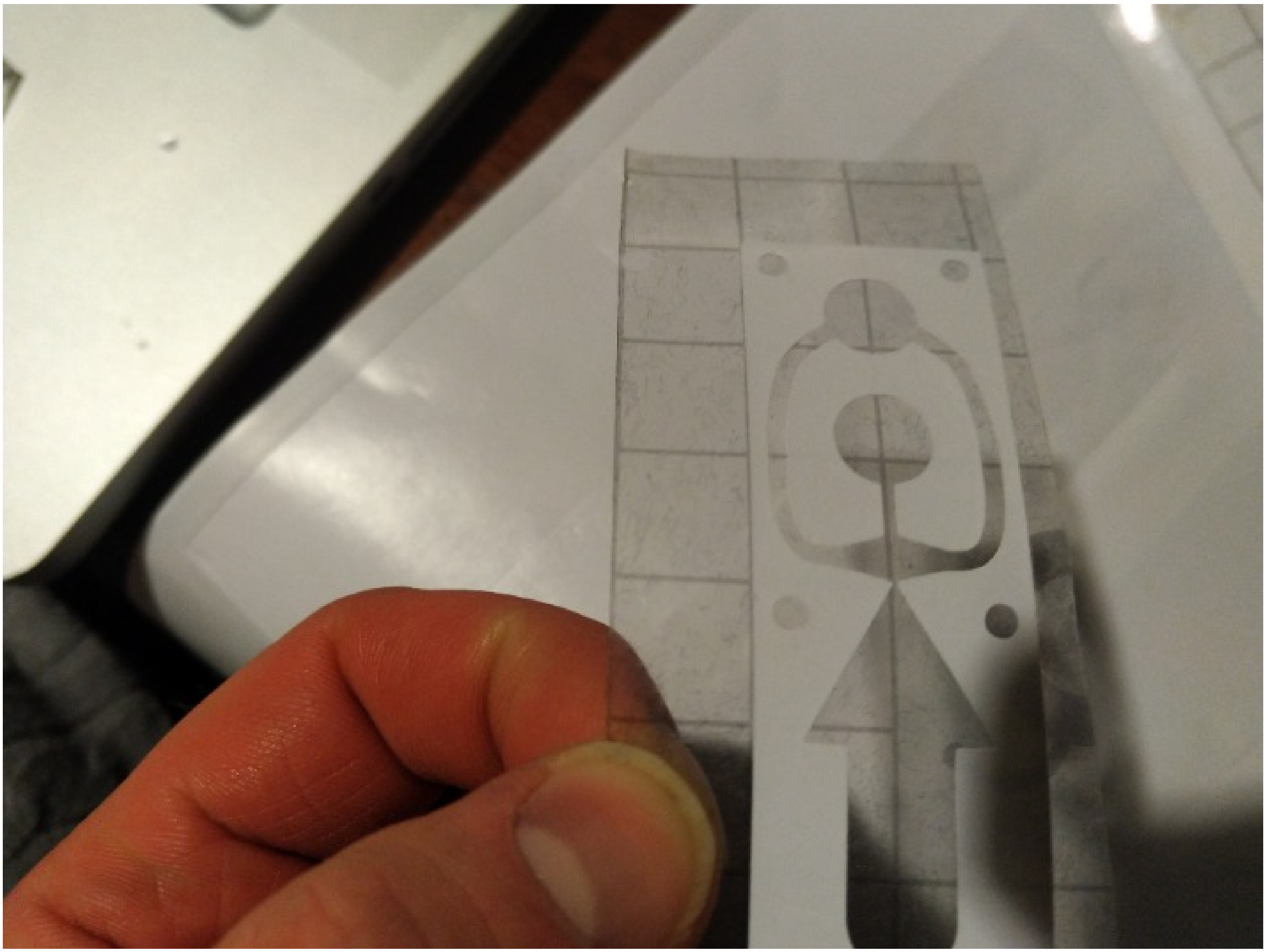


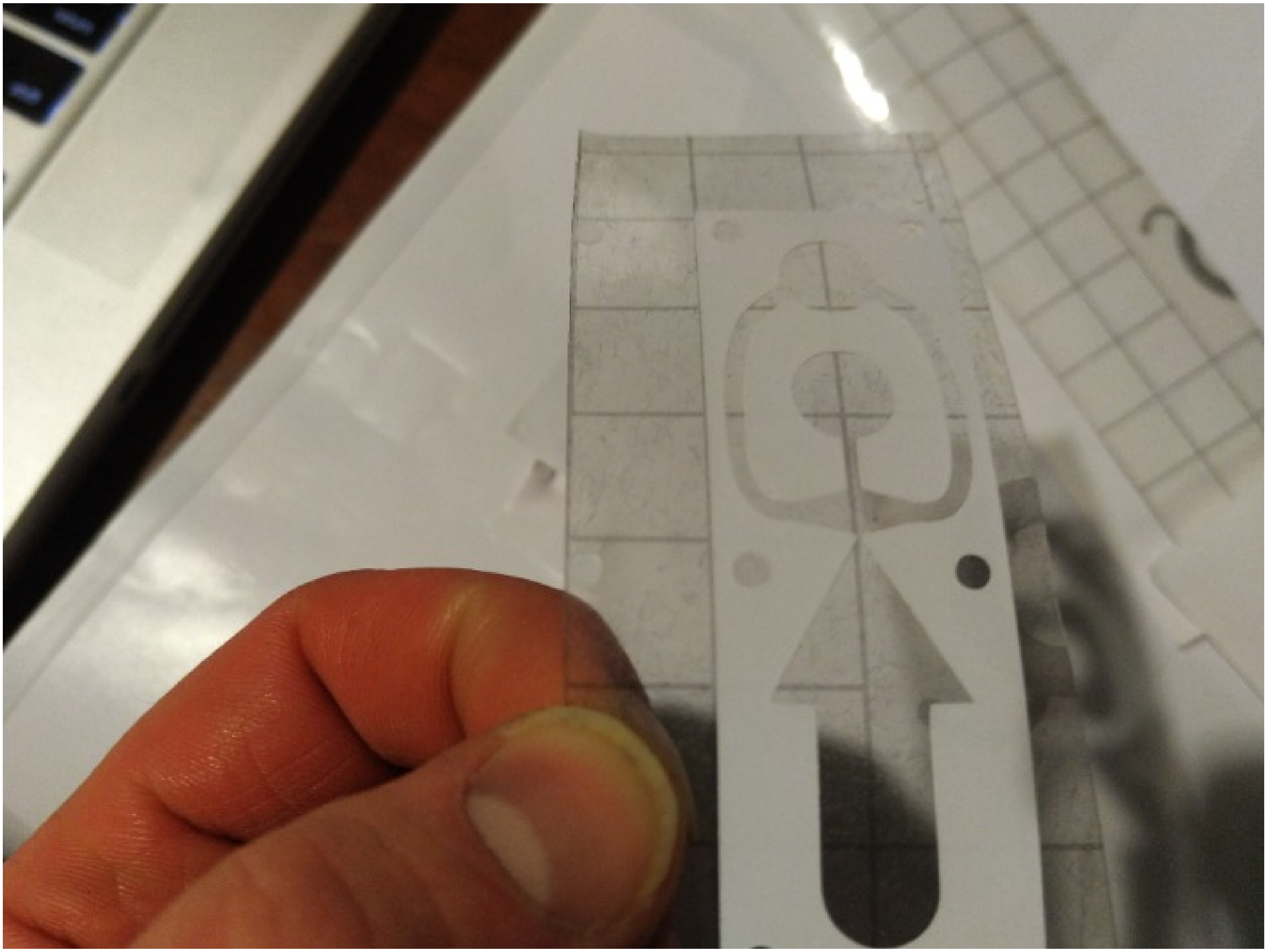


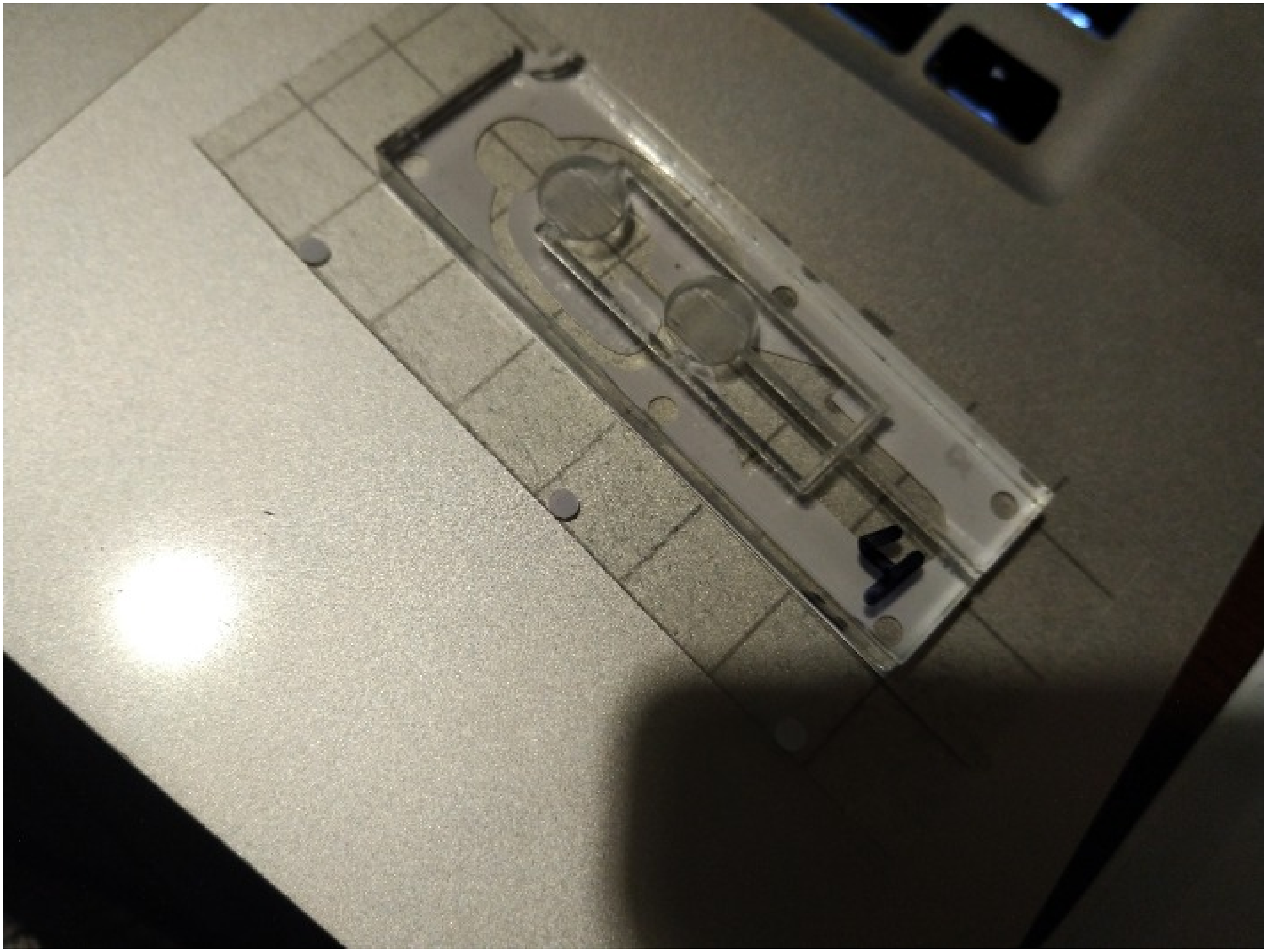


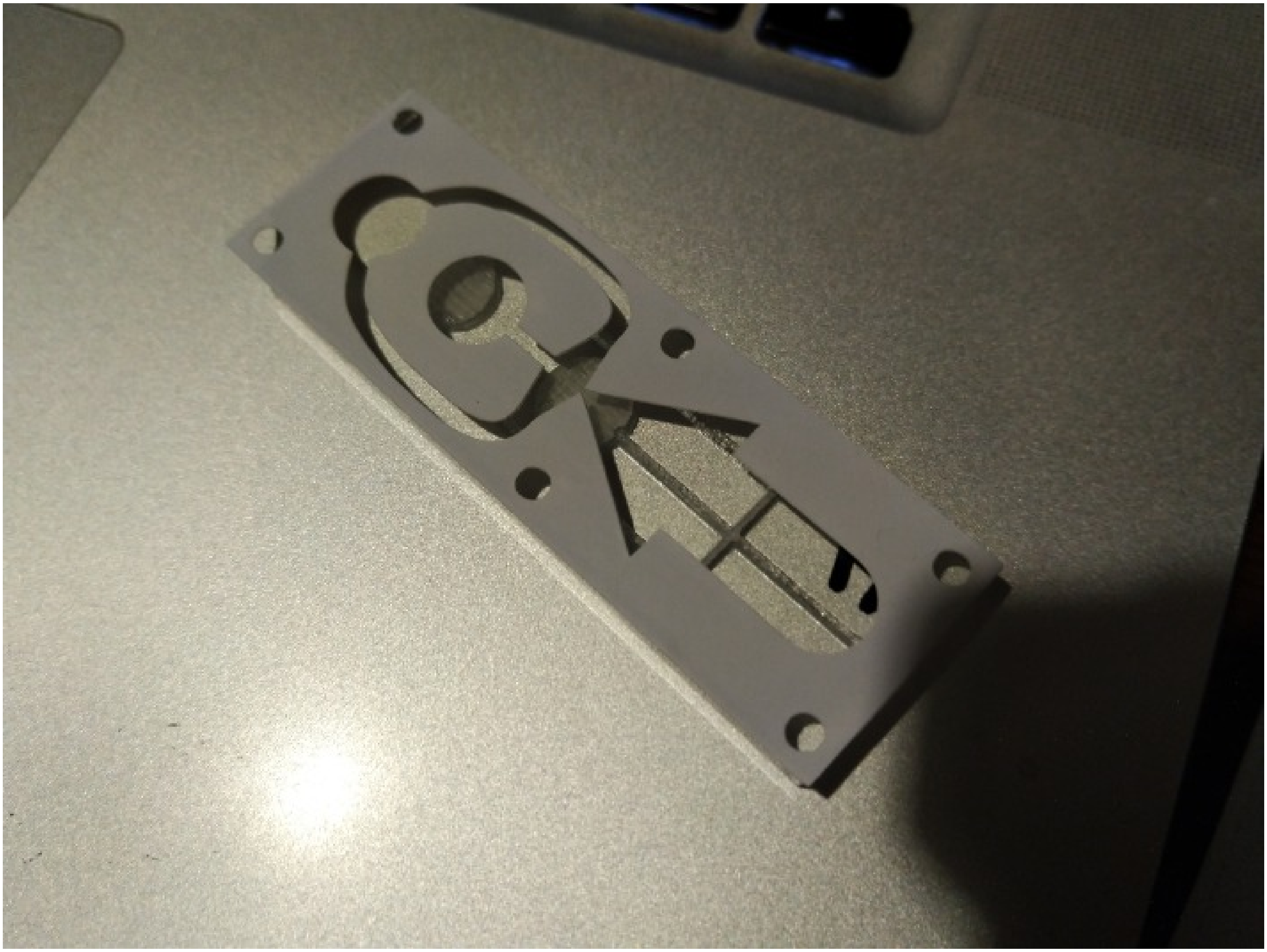




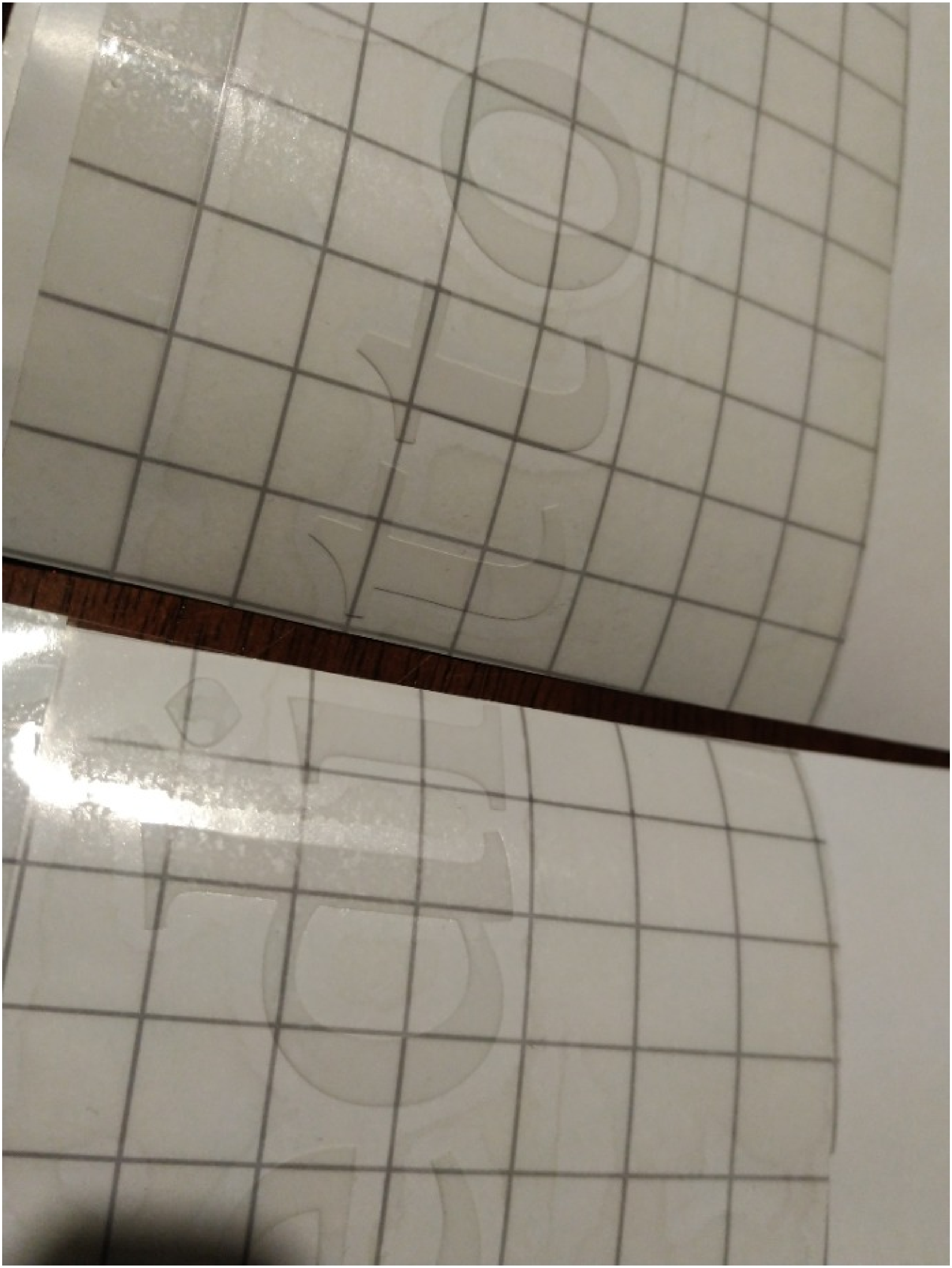


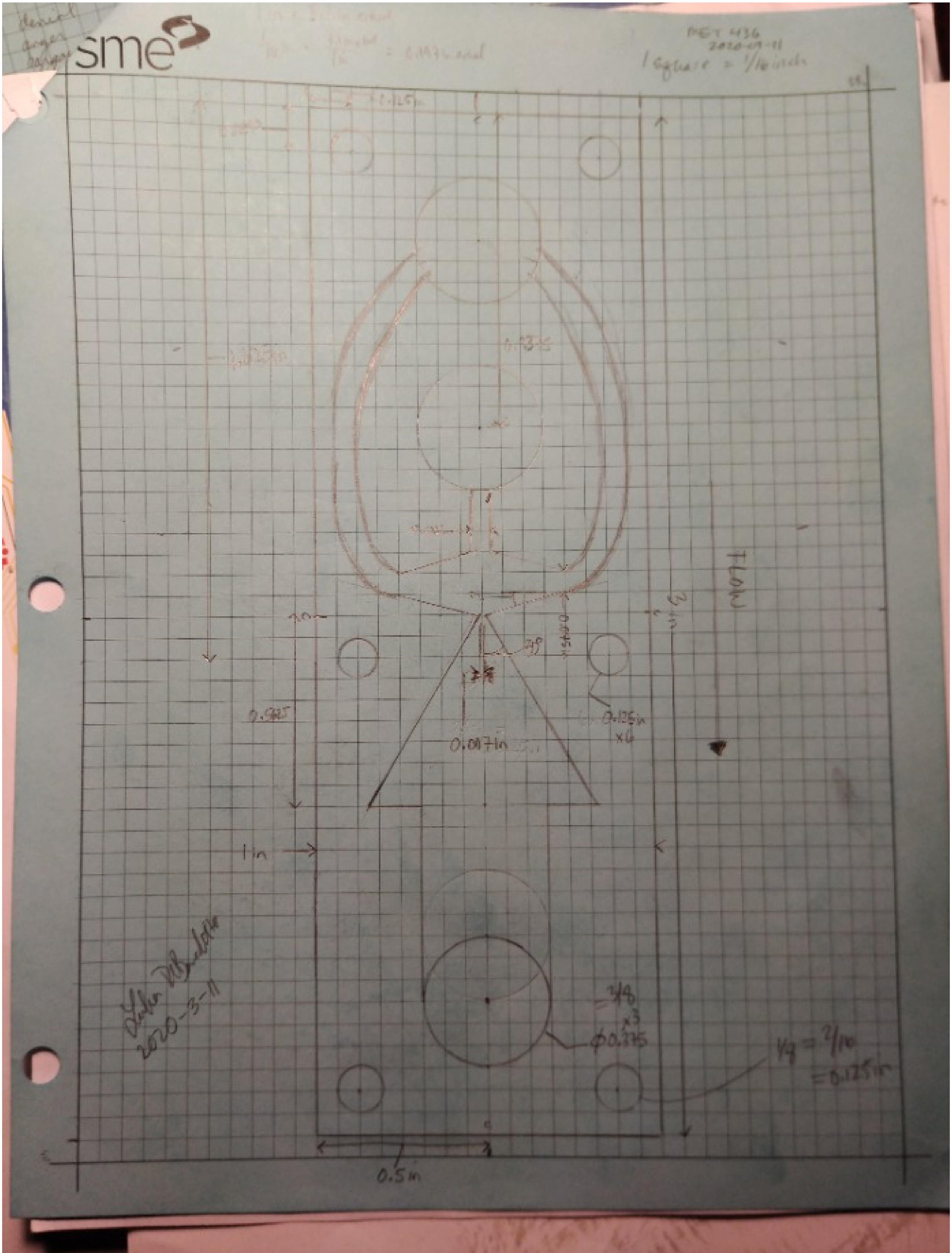



4

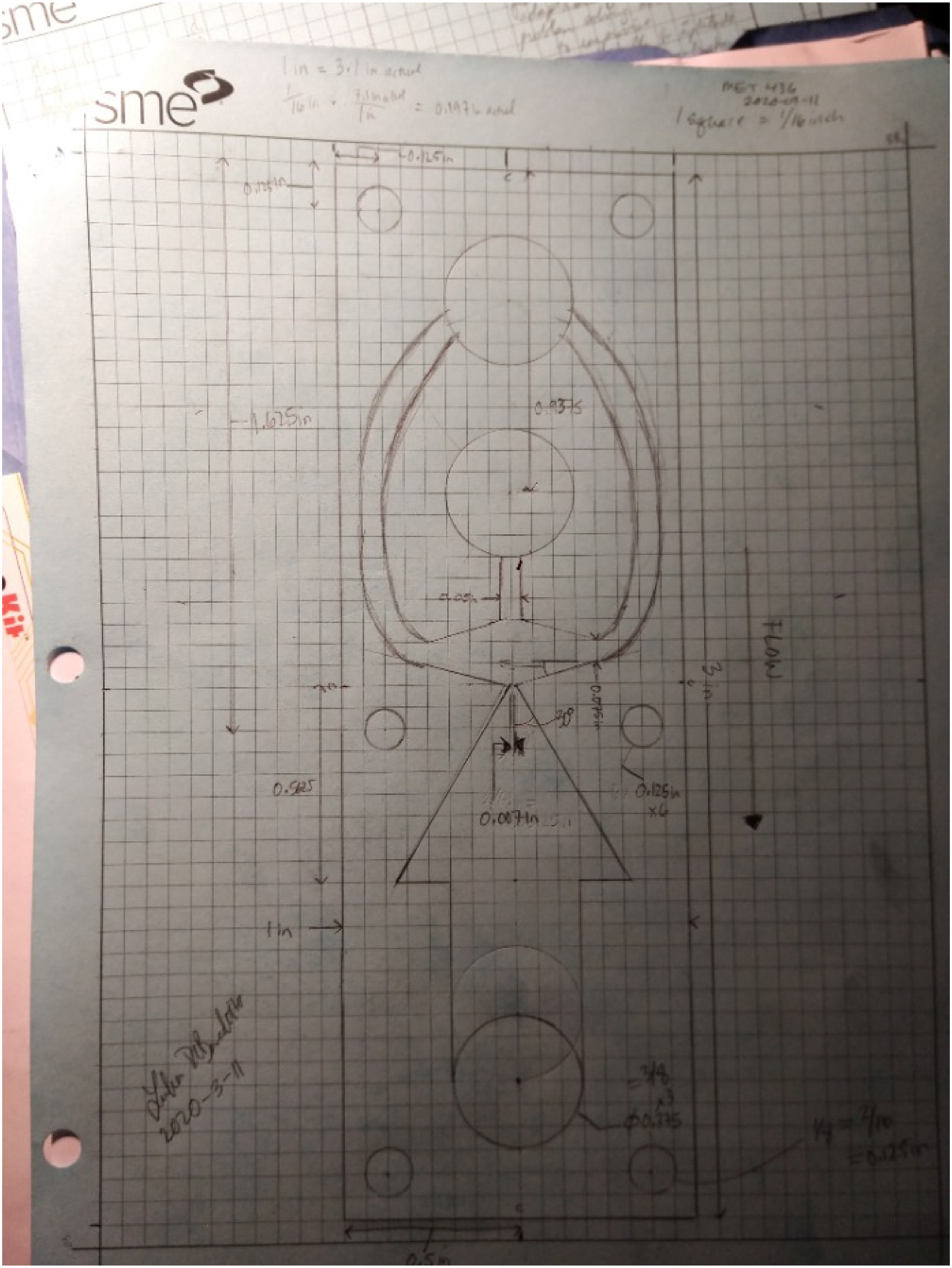



silhouette
CAMEO
ENTER

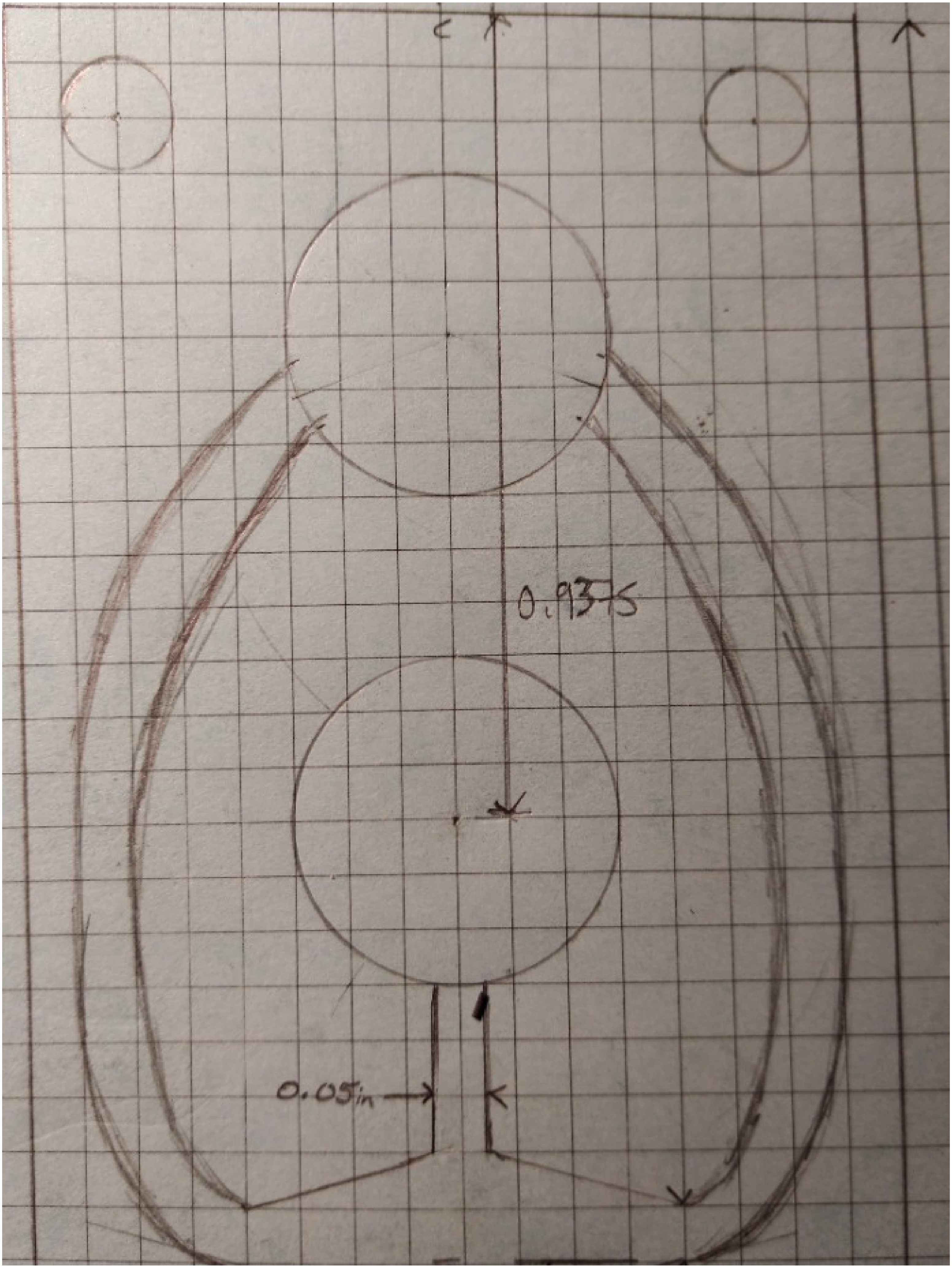




MET 436
1 square = 1/16 inch
FLOW
3 in
1 in
0.125 in
x6
3/8
x3
φ0.375
1/8 = 2/16
= 0.125 in
0.5 in
2020-3-11

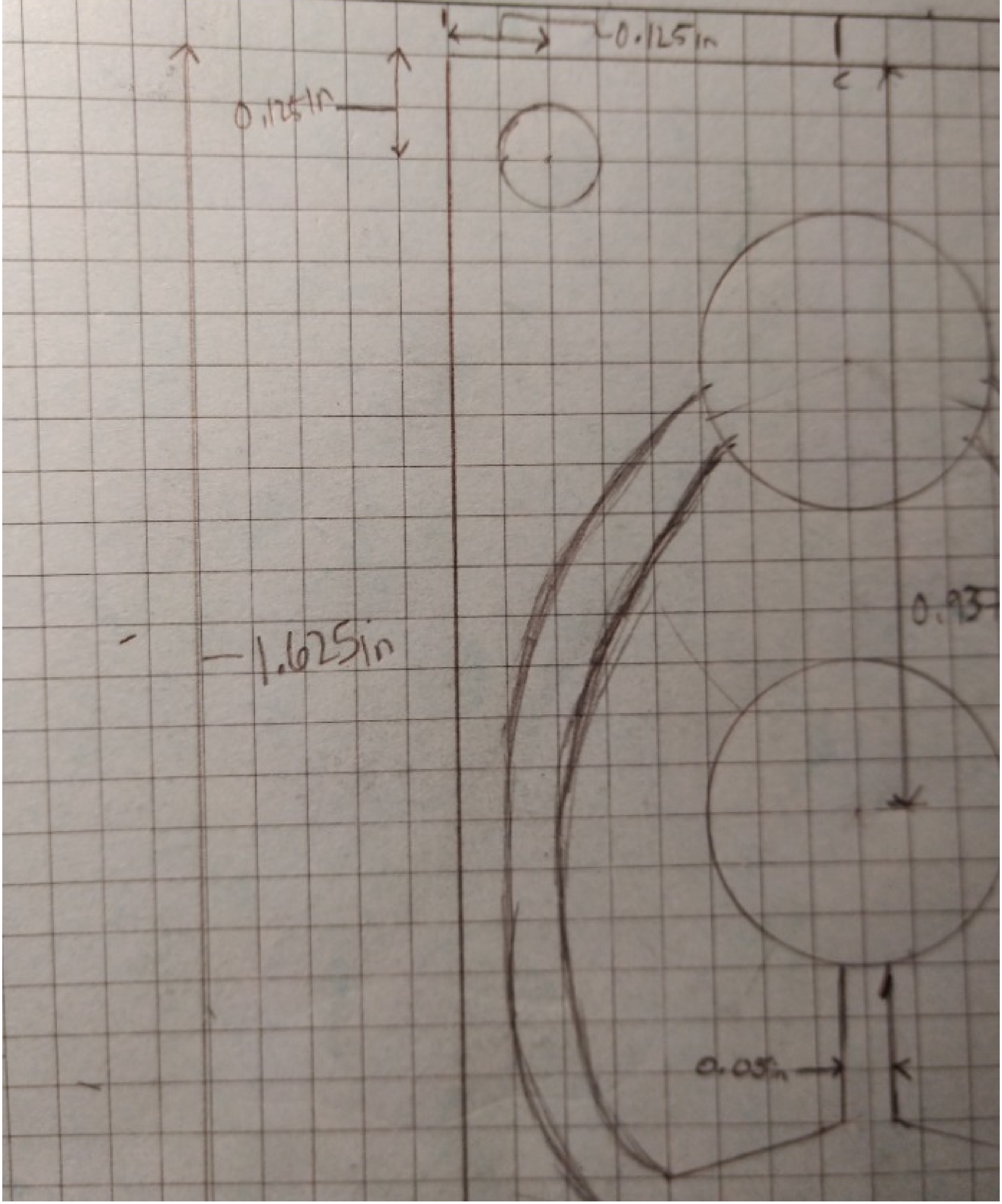


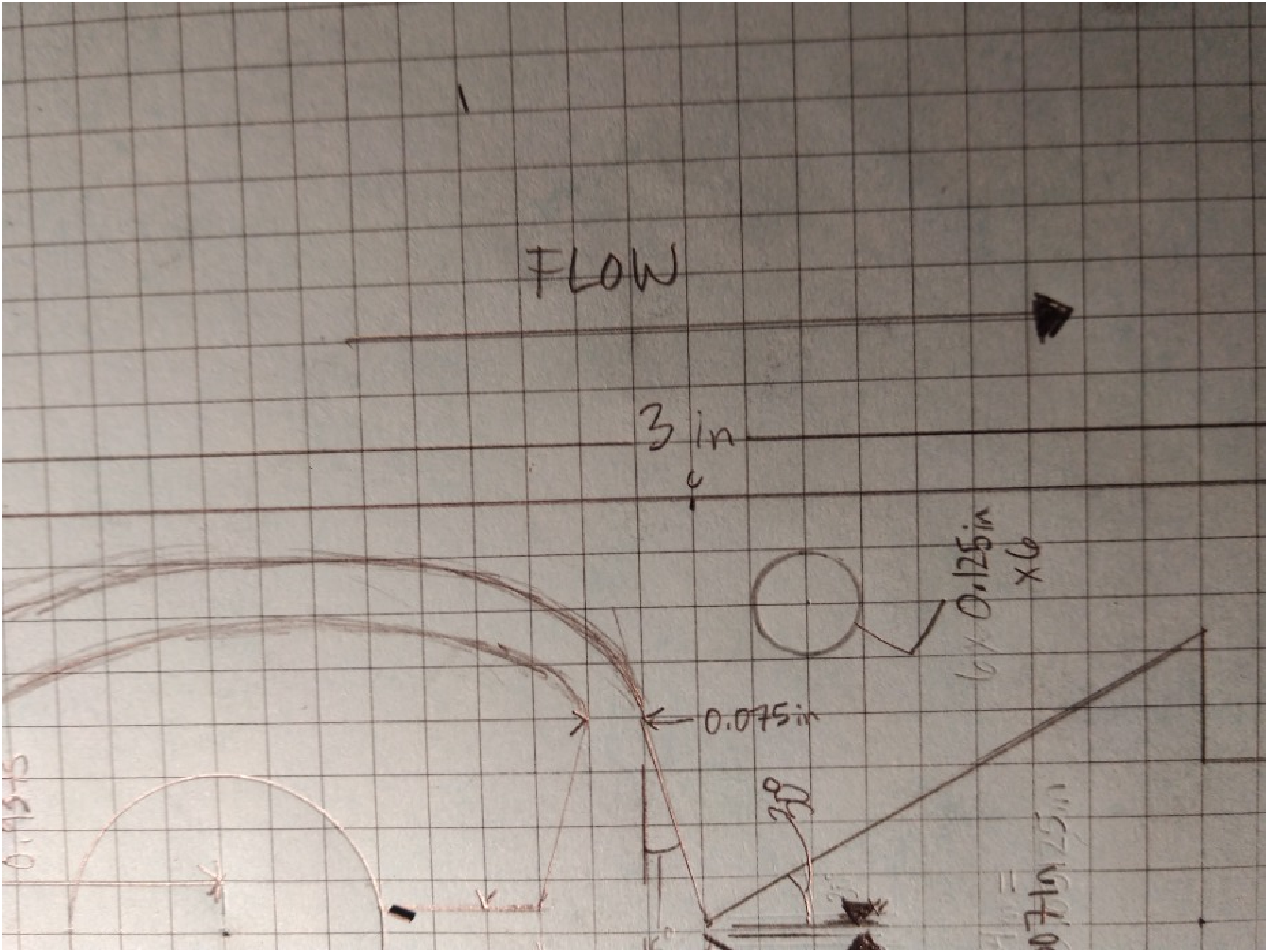
1 in = 3.1 in actual
MET 436
1 square = 1/16 inch
0.125in
1.625in
0.9375
0.05in
FLOW
3 in
0.075in
30
0.525
0.125in
x6
0.007in
1in
x3
Ø0.375
0.5in
2020-3-11



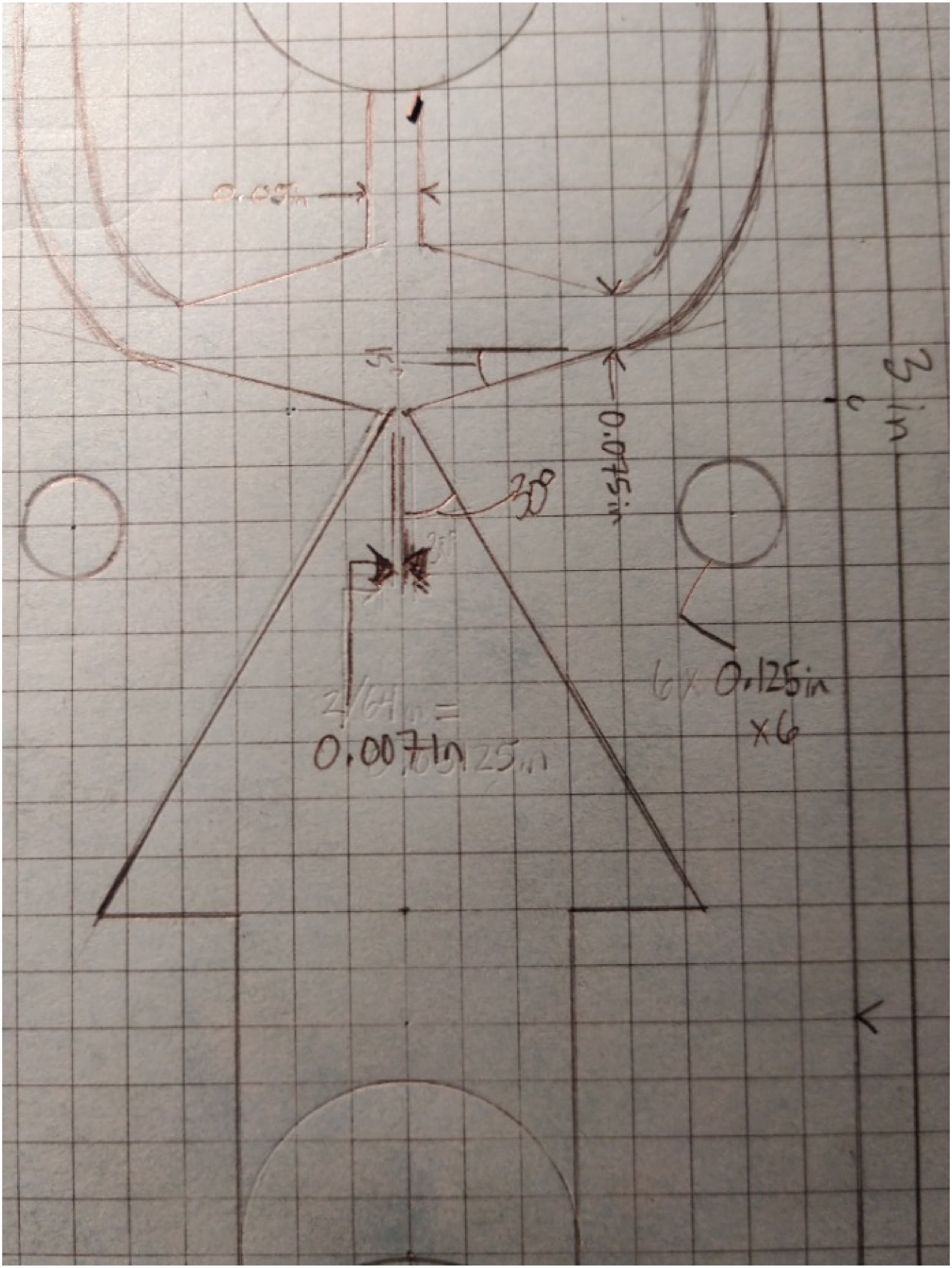
0.9375
0.05in

$\frac{1}{16 \text{ in}} \cdot \frac{3.1 \text{ in actual}}{1 \text{ in}} = 0.197 \text{ in actual}$

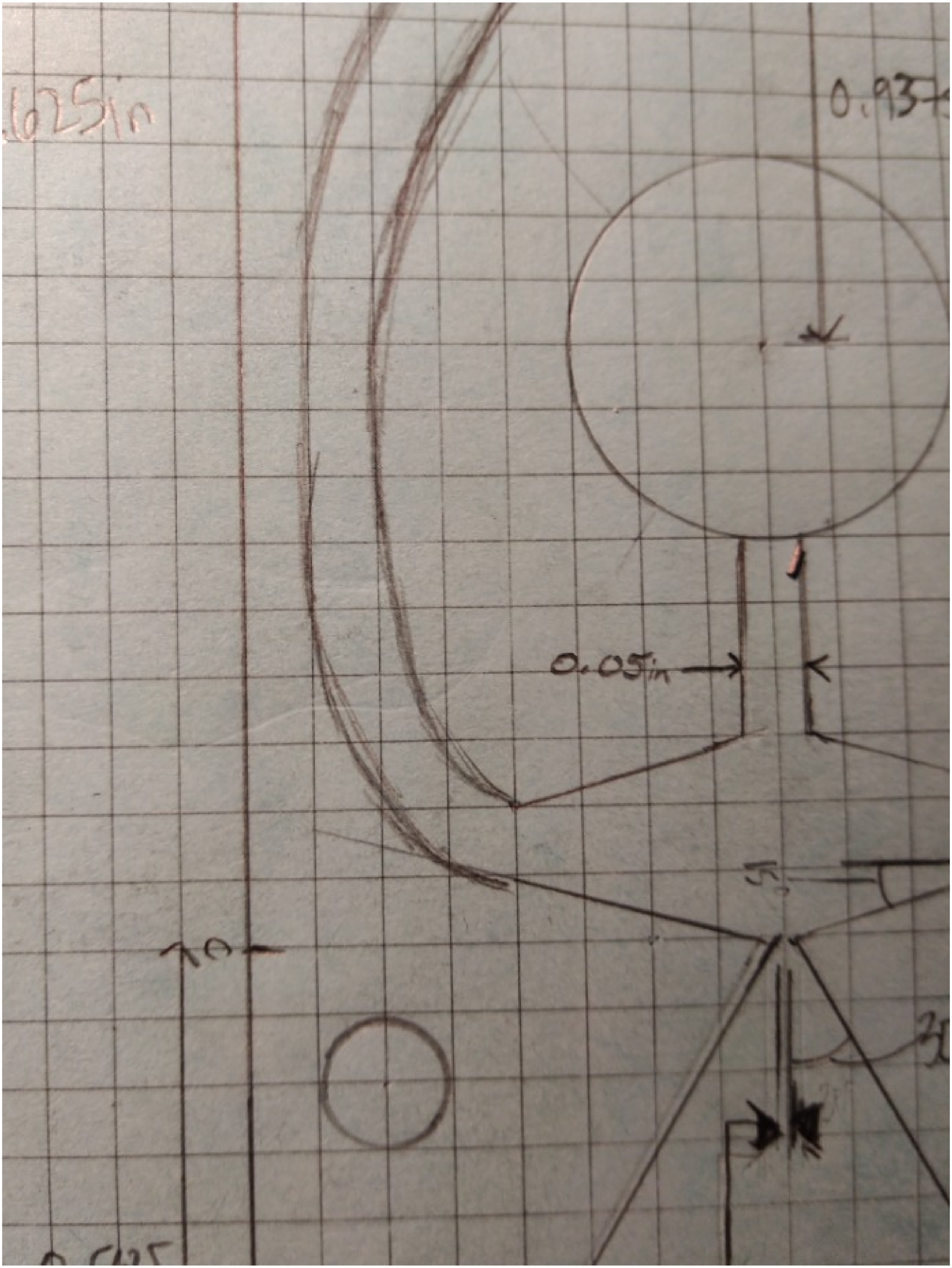


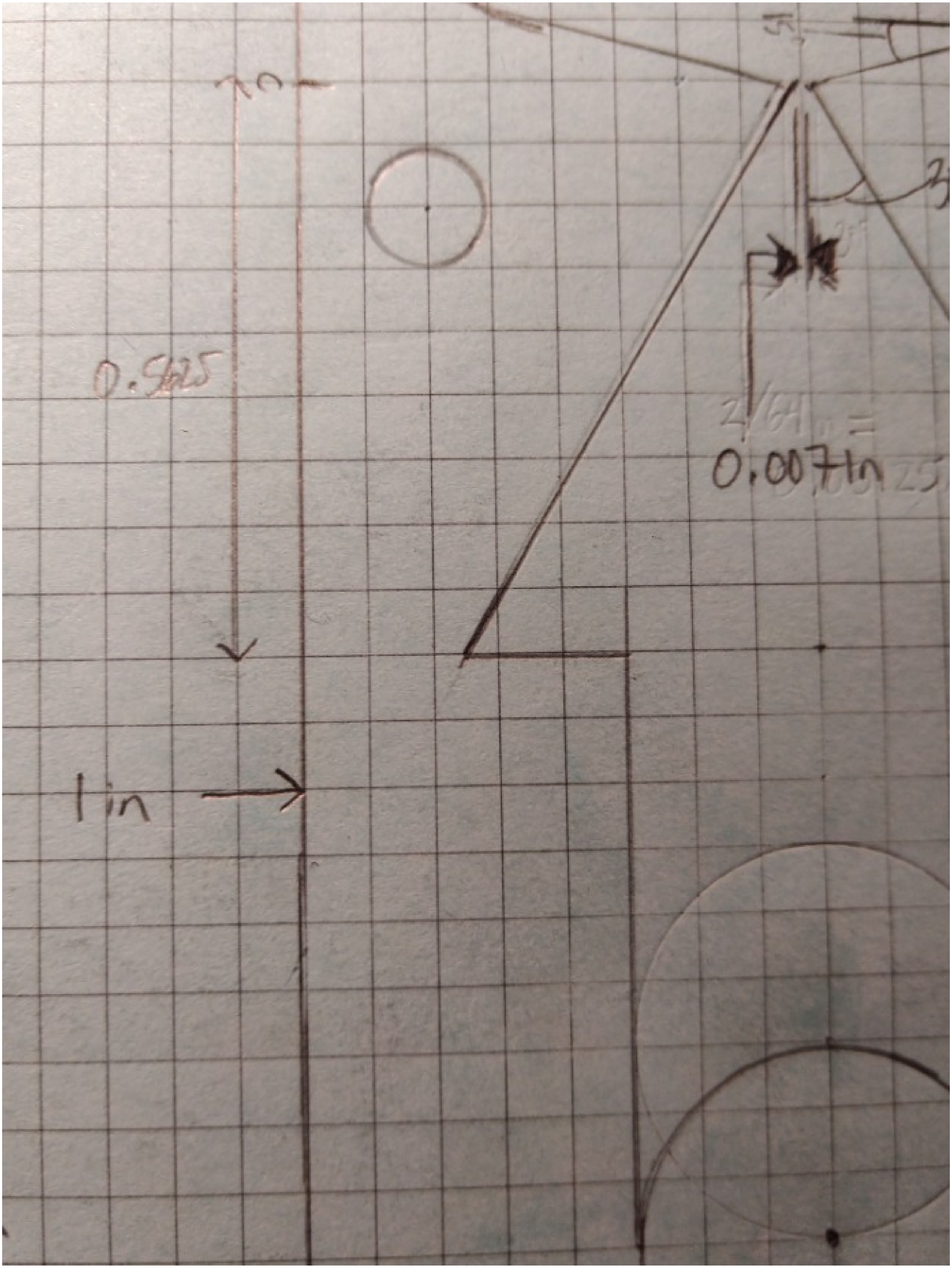


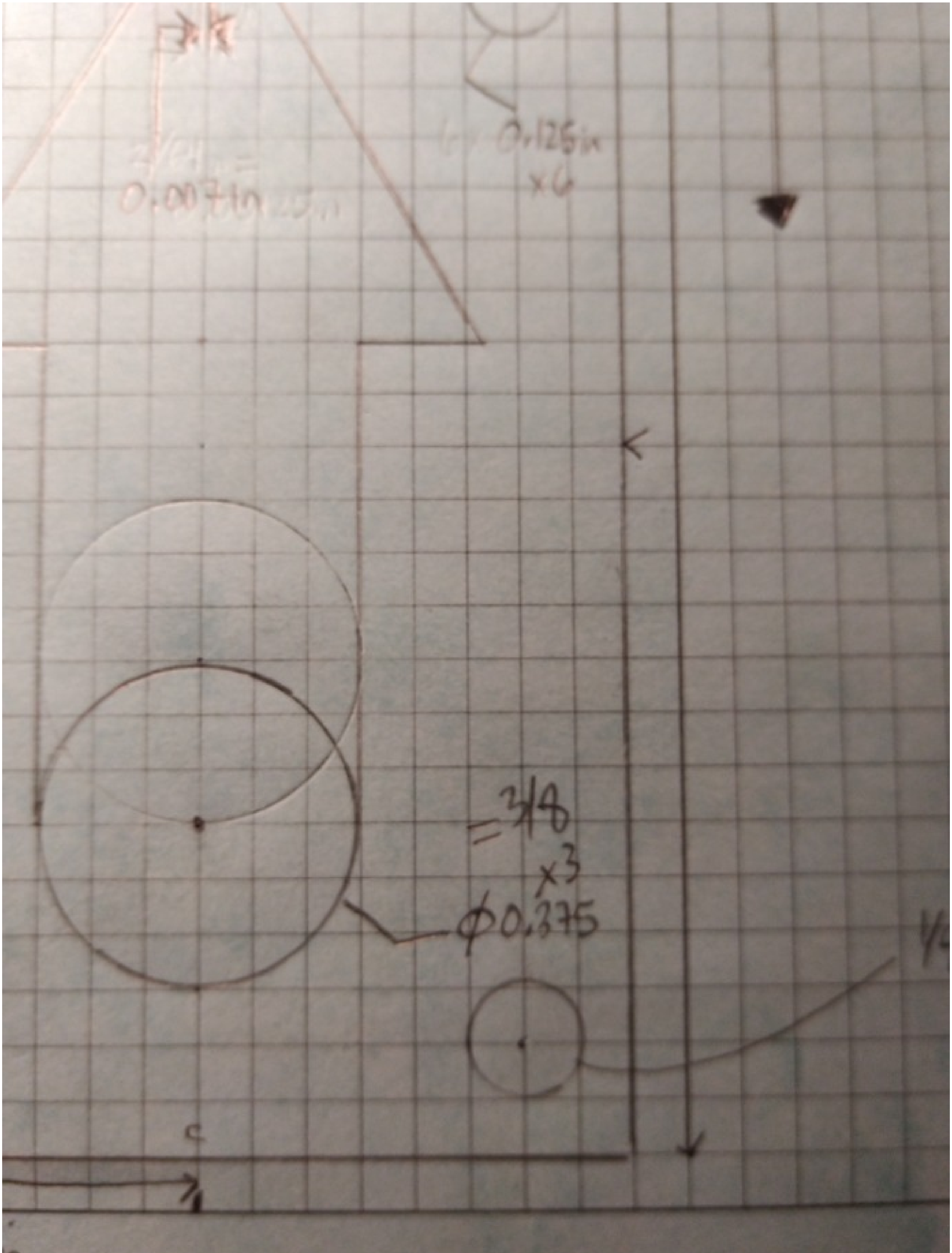
FLOW
3 in
0.075 in
0.125 in
x6
30°



0.07in
5°
0.075in
30°
3 in
2/64 in =
0.007in
0.03125in
6x 0.125in
x6


0.05in


0.5625
1 in
0.007in


0.125in
x6
=3/8
x3
ϕ0.375

6x Ø0.125in
×6

= 3/8
×3
Ø0.375

1/8 = 2/16
= 0.125in


Transparent 3D Printing
on the Desktop
CLEAR RESIN
Form 3 • 100 µm
Form 3
Flawless Prints,
Every Time.
formlabs

Lukas DiBeneditto
Professor Tim Cooley
MET 436 Pneumatic Motion Control Systems
Purdue University, Purdue Polytechnic New Albany
15 March 2020

NOTE: This document represents the raw unedited digital notes and research for the MET 436 Project 3 Microfluidics, excluding hand written notes. It may contain quotes that have not yet been attributed to their author, and as such are excluded from proper citation requirements.

DIY Magnetic Digital Microfluidic/Ferrofluid Biocomputer - YouTube
https://www.youtube.com/watch?v=TeB56b0Mj8s

magnetic fluid controlled by electronics

--

DIY Magnetic Digital Microfluidic/Ferrofluid Biocomputer - YouTube
https://www.youtube.com/watch?v=TeB56b0Mj8s

software with music controlling microfluidics

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Bioprinting 101: How to make Microfluidic Chips - YouTube
https://www.youtube.com/watch?v=dxz10In1774

Student In STEM Ria Bhatia demonstrates how you can create a pH gradient generator chip using microfluidics. Through this experiment, you will familiarize yourself with TinkerCad, a widely used 3D modelling software. Additionally, you will learn about microfluidics, which deal with the flow of liquids inside micrometer-sized channels, and receive an introduction to flow concepts, such as laminar flow. Throughout this project, you will also learn about acid-base reactions, which are indicators of pH value, and technical skills, such as ImageJ and Excel analysis.

ph gradient microfludic chip

mixing of fluids by ph

PDMS
Pluronic F-127
HCL & NaOH
pH Indicator

r3bEL mini bioprinter

biopsy punch

5 ml plastic syringes with lure? locks
22-guage blunt tipe 1/2 inch needles
14-guage blunt tip 1/2 inch needles
petri dishes

pdms curing 24 hours

--

From CES 2020: MEMS Microfluidic Precision Dispensing - YouTube
https://www.youtube.com/watch?v=CWhrDKcF8_8

perfume dispensing using mems and microfluidics

1 droplet to millions of droplets

STMicroelectronics
23.9K subscribers
Find out more information: http://bit.ly/CES20-microfludics

AIRIA Scent Dispenser and Precision Skincare Device from P&G®.
• High-precision dispensing of fragrances and cosmetics enable by ST MEMS microfluidic technology
• Microfluidic technology allows release of lightweight microdroplets and tight control of dispensing
• Fully mature technology, available in commercial products

--

What's Inside: Inkjet Cartridges-WIRED - YouTube
https://www.youtube.com/watch?v=YMjY-aiG1zo

surface tension is a big issue

Inkjet cartridges are comprised of 95 percent water, but what's inside the other 5 percent? We break apart the compact containers to find out what's inside the mostly liquid assets.

--

Stanford engineers build a water-droplet based computer that runs like clockwork - YouTube
https://www.youtube.com/watch?v=m5WodTppevo

microfluidics using ferro fluid and magnetics

Manu Prakash, an assistant professor of bioengineering at Stanford, and his students have developed a synchronous computer that operates using the unique physics of moving water droplets. Their goal is to design a new class of computers that can precisely control and manipulate physical matter. For more info: http://news.stanford.edu/news/2015/ju...

https://news.stanford.edu/news/2015/june/computer-water-drops-060815.html

--

The Thought Emporium
400K subscribers
Microfluidics is the study and construction of collections of tiny fluid channels that can accomplish an incredible array of tasks; from simple mixing, to math and computer logic. But making the flow cells that make use of the principles of microfluidics is normally expensive due to material and equipment costs.

In this video we explore a dirt cheap method for making very high quality microfluidic low cells, including one of the worlds smallest tesla valves, and a device meant to isolate cancer cells from a blood sample.

SVGs: https://github.com/FOULAB/microfluidic-shrinky-dinks

Papers:

Shrinky dink 1:
https://www.researchgate.net/publication/5753844_Shrinky-Dink_microfluidics_Rapid_generation_of_deep_and_rounded_patterns

Shrinky dink 2: https://www.ncbi.nlm.nih.gov/pubmed/18094775

Blood spiral: https://www.ncbi.nlm.nih.gov/pubmed/26678083

Images from papers:
PCR lab on a chip: https://advances.sciencemag.org/content/advances/3/3/e1501645.full.pdf

Octobot: https://www.youtube.com/watch?v=CDohWwEXQ68

Microfluidic cell separation:
https://www.researchgate.net/figure/Microfluidic-cell-separation-and-processing-methods-a-Microfilter-designs-of-Weir-type_fig13_313874117

Review of microfluidic separation and filtration:
https://sci-hub.tw/10.1007/978-981-10-5394-8_3

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Website: http://thethoughtemporium.com/

--

Geraldine Hamilton: Body parts on a chip - YouTube
https://www.youtube.com/watch?v=CpkXmtJOH84

TED
16.2M subscribers

It's relatively easy to imagine a new medicine, a better cure for some disease. The hard part, though, is testing it, and that can delay promising new cures for years. In this well-explained talk, Geraldine Hamilton shows how her lab creates organs and body parts on a chip, simple structures with all the pieces essential to testing new medications -- even custom cures for one specific person. (Filmed at TEDxBoston)

--

3D print your brain, timelapse, high-res microfluidics, custom colors... - YouTube https://www.youtube.com/watch?v=7Z8uPHL52Q0

formlabs 3d printer 500-600 micron holes
sand with 600 then 1000 grit sand paper

Applied Science
610K subscribers

The new Form Labs printer prints my brain and a bunch of other highly detailed stuff.

Download my brain: https://www.thingiverse.com/thing:290...
Complete instructions to print your own brain: https://github.com/miykael/3dprintyou...
Using the above tool on Windows: http://nuclear-imaging.info/site_cont...

Formlabs: https://formlabs.com/

Tesla valve: https://grabcad.com/library/tesla-one...

Vortex tube: https://grabcad.com/library/vortex-tube

https://www.patreon.com/AppliedScience
Category

--

Skillbuilder: Seven Tips for Working With Acrylic - YouTube
https://www.youtube.com/watch?v=TWAMdmJPdhg

flame edge

step bit for holes in think acrlyic

masking tape for large holes let the drill bit do the work

Make:
1.67M subscribers

Acrylic is a wonderful plastic that can be used for all sorts of different projects. It comes in both transparent and colored options, and can be machined, laser cut, or heated and bent into almost any shape.

--

DIY Flow Chemistry with Arduino. - YouTube
https://www.youtube.com/watch?v=R4Ohwhk47tg

Michael Brandon
49 subscribers
This video serves to accompany my poster presented at the 2017 world chemistry congress in São Paulo, Brazil.
For more information about the event visit http://www.iupac2017.org.

Croatt Research Group | Flow Chemistry https://chem.uncg.edu/croatt/flow-chemistry/

--

Arduino Peristaltic Pump - YouTube
https://www.youtube.com/watch?v=GdTUIwj5ros

Fahmi Ghani
308 subscribers
Code: http://pastebin.com/dXgLJcWq
I cannot reply to some comment here. Please make sure your google plus account set to public.

Testing 12V peristaltic pump using Arduino.
Volume increment 1ml.
Stated flow rate100 ml/min
Actual flow rate around 60ml/min

I have test few more peristaltic pump of same model.
Every pump has different flow rate, must do calibration to get correct fluid volume.

--

What is a Peristaltic Pump and How Does it Work? - YouTube
https://www.youtube.com/watch?v=_9IjMMoAFdA

pump so that fluids don't touch the pump

Fresh Water Systems
3.4K subscribers
A peristaltic pump transfers chemicals sealed inside a tube to prevent cross-contamination. This pump is the best choice for medical, agricultural, and water treatment purposes that require precise dosages of liquid. Here's what you need to know about how a peristaltic pump works and where you should use one.

Check out our peristaltic pumps here:
https://www.freshwatersystems.com/col...

For more information on water treatment, check out our blog!
https://www.freshwatersystems.com/blo...

--

3D Printed Mini Peristaltic Pump - YouTube
https://www.youtube.com/watch?v=J2KLq7485kM

Off Grid Crafts
1.47K subscribers

INSTAGRAM: https://www.instagram.com/off_grid_cr...
FACEBOOK: https://www.facebook.com/Offgrid-Craf...
** Making of a 3d printed peristaltic pump with a small geared stepper motor.

the size without the motor is 31 x 31 x 11 mm .. this tube is 3.2mm with 1.6mm hole. the motor is from air condition's flaps. the bearings are from a gpu fan olso you can find them from cpu fan the outer diammeter is 8mm , the inside diammeter is 3mm and the height is 4mm

thingiverse file: https://www.thingiverse.com/thing:3445927

--

Diabetics Are Hacking Their Own Insulin Pumps - YouTube
https://www.youtube.com/watch?v=bouYRMItWnI

CNBC
1.39M subscribers
There is a revolution in the Type 1 diabetes community and thousands of people are now hacking their insulin pumps for better blood sugar management. CNBC's Erin Black, who was diagnosed with Type 1 diabetes 20 years ago, decided to try out the hacked system. Here's what happened.

Type 1 diabetes is a disease that affects more than 1.2 million Americans. I'm one of them.

It's a disease that impairs the body's ability to produce the hormone insulin, which normally comes from the pancreas. So insulin has to be injected.

Managing blood sugars can be very difficult, and patients use a pump to help mimic the activity of the pancreas. However, pumps don't automatically adjust insulin levels for diabetics. And the manual process is tedious and can be dangerous.

But a few years ago, people figured out how to hack their insulin pumps to make them automatically adjust insulin levels more precisely.

--

An affordable, refreshable Braille tablet that relies on microfluidics - YouTube
https://www.youtube.com/watch?v=0fIg4rI4cDw

University of Michigan Engineering
26.5K subscribers
Instead of showing one line at a time, a new Braille tablet being designed at the University of Michigan can display a page of information and is significantly cheaper than the current Braille displays. Read the article: https://www.technologyreview.com/s/54...

Watch more videos from Michigan Engineering and subscribe:
https://www.youtube.com/user/michigan...

The University of Michigan College of Engineering is one of the world's top engineering schools. Michigan Engineering is home to 12 highly-ranked departments for both undergraduate and graduate studies, with over 80,000 alumni around the globe.
http://engin.umich.edu

Current technologies for the blind like one-line Braille displays and text-to-speech are slow and hold back literacy. By using microfluidics, researchers are able to keep the cost at around $1,000, compared to the $5,000 cost of the one-line displays.

Follow Michigan Engineering:
Twitter: https://twitter.com/umengineering
Facebook: https://facebook.com/michigan.enginee...
Instagram: https://instagram.com/michiganenginee...

Contact Michigan Engineering:
https://engin.umich.edu/about/contact/

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In Pursuit of an Affordable Tablet for the Blind - MIT Technology Review
https://www.technologyreview.com/s/545301/in-pursuit-of-an-affordable-tablet-for-the-blind/

Connectivity
In Pursuit of an Affordable Tablet for the Blind
By borrowing from microfluidics, a team of University of Michigan researchers are reinventing the Braille display to be cheaper and more useful.
by Signe Brewster
Jan 11, 2016
An inexpensive, full-page Braille tablet could make topics like science and math more easily accessible to the blind, according to a team of researchers who have built a prototype device.

A prototype of the tablet, which uses air or fluid to raise the dots that create braille letters.
The device, which is under development at the University of Michigan, uses liquid or air to fill tiny bubbles, which then pop up and create the blocks of raised dots that make up Braille. Each

bubble has what is essentially a logic gate that opens or remains closed to control the flow of liquid after each command, according to Sile O'Modhrain, a professor of performing arts technology who collaborated on the tablet.

Existing refreshable Braille displays tend to max out at one line of text and cost several thousand dollars. They use plastic pins pushed up and down by a motor. The Michigan team found it impossible to pack the pins in densely enough to create a reasonably sized full-page display, and as a result started from scratch with the microfluidic option. The switch could help them make the final product tablet-sized instead of laptop-sized, like existing refreshable displays.

The tablet borrows manufacturing techniques from the silicon industry, where chips are laid down in layers instead of having many small parts to assemble. As a result, the Michigan team is aiming to offer a Braille tablet for less than $1,000.

"My observation is that, currently, even many of us who read Braille well find reading it with single-line Braille displays slower and more tiring than using text-to-speech or audio materials," says Chris Danielsen, a spokesperson for the National Federation of the Blind. "I think this would dramatically change with a larger display, especially one at a reasonable price point."

As access to text-to-speech software has grown, pressure to learn Braille has dropped. A 2009 report from the National Federation of the Blind stated that less than 10 percent of blind children were learning Braille at the time, compared with 50 to 60 percent at Braille's height in the 1960s.

But that doesn't mean there is no longer a need for the 200-year-old writing system. Braille books, for example, have long been used to show the blind textured images. Text-to-speech software can't convey the same visual information. However, if there isn't a book available, people with visual impairments have to turn to another person to prepare them materials, which can be expensive.

"Anything where you want to be able to see stuff written down, like coding or music or even just mathematics, you really have to work in Braille," says O'Modhrain, who is visually impaired. "That just means for a lot of people these things are not accessible or not available."

O'Modhrain believes the team is about a year and a half away from commercializing the technology, which may be used for an application other than Braille at first. That would drive the cost down for its later adoption by the blind.

“It would be great to see these getting into school so children can learn to read math and science materials,” O’Modhrain says.

--

Electrowetting - Digital Microfluidics on Printed Circuit Board - Prototype - YouTube
https://www.youtube.com/watch?v=C677yPYXWIs

GaudiLabs
1.89K subscribers
Demonstration of a prototype of a Digital Microfluidics Device based on Electrowetting (EWOD) technology, built with printed circuit board fast prototyping method. Open Science.

GaudiLabs, Open Source Lab Equipement and Open Culture Technology: http://www.gaudi.ch

Elektrowetting - Hackteria Wiki
http://hackteria.org/wiki/Elektrowetting

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Micro and Nanofabrication (MEMS) | EPFLx on edX - YouTube
https://www.youtube.com/watch?v=5fqRX9WMr0s

edX
231K subscribers
Take this course for free on edx.org:
https://www.edx.org/course/micro-and-nanofabrication-mems

Learn the fundamentals of microfabrication and nanofabrication by using the most effective techniques in a cleanroom environment.

About this course

Microfabrication and nanofabrication are the basis of manufacturing for nearly all modern miniaturized systems that are ubiquitously used in our daily life. Examples include; computer chips and integrated sensors for monitoring our environment, cars, mobile phones, medical devices and more.

Micro- and nanofabrication can be taught to students and professionals by textbooks and ex-cathedra lectures, but the real learning comes from seeing the manufacturing steps as they happen.

In this engineering course, we will go a step beyond classroom teaching to not only explain the basics of each fabrication step but also show you how it’s done through video sequences and zooming into the equipment.

What you'll learn
How to select the correct fabrication process for a specific micro-device or microsystem
Establish the workflow for the cleanroom processes
Identify how physical and chemical phenomena govern miniaturized systems for various applications
Resource planning for a given microsystem fabrication

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The next step in nanotechnology | George Tulevski - YouTube
https://www.youtube.com/watch?v=Ds_rzoyyfF0

TED
16.2M subscribers

Nearly every other year the transistors that power silicon computer chip shrink in size by half and double in performance, enabling our devices to become more mobile and accessible. But what happens when these components can't get any smaller? George Tulevski researches the unseen and untapped world of nanomaterials. His current work: developing chemical processes to compel billions of carbon nanotubes to assemble themselves into the patterns needed to build circuits, much the same way natural organisms build intricate, diverse and elegant structures. Could they hold the secret to the next generation of computing?

TEDTalks is a daily video podcast of the best talks and performances from the TED Conference, where the world's leading thinkers and doers give the talk of their lives in 18 minutes (or less).

Look for talks on Technology, Entertainment and Design -- plus science, business, global issues, the arts and much more.
Find closed captions and translated subtitles in many languages at http://www.ted.com/translate

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Like TED on Facebook: https://www.facebook.com/TED

Subscribe to our channel: http://www.youtube.com/user/TEDtalksD...

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Digital Microfluidics for Automated Proteomic Processing. - YouTube
https://www.youtube.com/watch?v=tHOvxvL83cw

how to use lab chemicals to make a microfluidics device

including photo etching

Sudip Roy
80 subscribers
Prof. A. Wheeler, Wheeler Lab, University of Toronto, Canada.

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Sand and polish clear resin using wax turtle ||| Manual Technique - YouTube
https://www.youtube.com/watch?v=Ur74MgEGGSM

Cre_Arth
54.2K subscribers
Finishing the clear resin using wax turtle.

Other video :
Resin cast figure https://youtu.be/X8s7AGOmXOc

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Multiple drops on OpenDrop digital microfluidic device. - YouTube
https://www.youtube.com/watch?v=t9vGEFjMJ7o

GaudiLabs
1.89K subscribers
Demonstration of moving and merging of multiple drops on the open source digital microfluidics platform OpenDrop.

For more information see GaudiLabs here:
http://www.gaudi.ch/GaudiLabs/?page_id=392

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OpenDrop – Desktop Digital Biology Laboratory
http://www.gaudi.ch/OpenDrop/

Desktop Digital Biology Laboratory

OpenDrop is a development part of a bigger ecosystem around digital biology with the aim of making personal lab-automation accessible to more people.

Being a community project grown out of the hackteria.org network and the DIYBio movement we are building on trustful co-operation with all people interested in the project. We also welcome collaboration with existing initiatives and research projects.

The project is developed in parallel on different aspects and disciplines. Technical developments are paralleled by biological application research and community management. Workshops on the technology, on the use of the device as well as on the biological and chemical protocols are planed.

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Programmable Droplets | Udayan Umapathi | TEDxBeaconStreet - YouTube
https://www.youtube.com/watch?v=onDTXSEo_Ig

TEDx Talks
23.2M subscribers
Water is ubiquitous. Can we program water droplets to make art and perform biology? Udayan is a designer, artist, an experimental physicist, researcher at MIT, and CEO of Droplet.IO Inc. His work is underlined by the idea that "computation is a way of understanding the universe". He asks, "if the universe is a computer, then how do we program it?". His most recent work showed how to bring programmability to water droplets. What started out as experiments to create computer interfaces with liquid matter, has resulted in a new paradigm in programmable materials which he calls "Programmable Droplets". Trained as an engineer at RVCE, artist and scientist at MIT he seeks to blur the boundary between the natural and synthetic computation through Droplet.IO Inc. a Boston based start-up that he co-founded. Through the start-up he is creating tools to "program biology", the ultimate form of programmable material.

Udayan has worked with Prof.Hiroshi Ishii and Prof.Neil Gershenfeld while at the MIT Media Lab. In the past he has also worked at various research labs, in the industry and he has also co-founded a couple of start-ups. His work has been showcased at international venues such as ACM UIST, ACM CHI, MRS, and exhibited at various art galleries including ARS Electronica. This talk was given at a TEDx event using the TED conference format but independently organized by a local community. Learn more at https://www.ted.com/tedx

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Research Advances in Microfluidic Biochips - YouTube
https://www.youtube.com/playlist?list=PLwYzDeSMOcCy7L28F1sO1yj4hhClsUjTa

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Easy, Quick Method for Making a Microfluidic Device - YouTube
https://www.youtube.com/watch?v=mjsFOSBFSG8

low cost 2 part epoxy syringe and and fluids
acrylic and slide

cutter cuts adhesive
then microscope slide heated

SteinbockGroup
80 subscribers
Using simple tools and a membrane cutter, we build a Y-shaped microfluidic device. The assembly takes about 10 minutes plus the drying time for epoxy glue. The channel volume in this example is about 22 uL. The device layout can be readily changed to fit your project.

Detailed Publication with link:
Q. Wang, M. R. Bentley, O. Steinbock, "Self-organization of Layered Inorganic Membranes in Microfluidic Devices", J. Phys. Chem. C 121, 14120, 2017
https://doi.org/10.1021/acs.jpcc.7b02778

Link to Silhouette Portrait 2 membrane cutter (~ $135):
https://www.amazon.com/gp/product/B009GZUPFA

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Sandia Digital Microfluidic Hub - YouTube
https://www.youtube.com/watch?v=9GInRQYzSJg

Sandia National Labs
28.3K subscribers
The Sandia Digital Microfluidic Hub — a droplet-handling router — enables the interconnection of diverse processing and analysis modules to automate complex microliter-scale molecular biology sample-preparation protocols.

2012-2890P

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Microfluidics Adventures #1: Physics at the microscale - YouTube
https://www.youtube.com/watch?v=b8zE2i755-k

The Lutetium Project

3.62K subscribers
The Microfluidics Adventures of the Lutetium Project, part one! In this first video, we'll tackle the physics of the microscopic world. You'll know why the laws of physics seem so weird at the microscale...

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Simple fabrication of complex microfluidic devices (ESCARGOT) - YouTube
https://www.youtube.com/watch?v=7z8I7awRYY4

Vittorio Saggiomo
583 subscribers
How to make complex, 3D microfluidic devices in a easy way?
How to incorporate external components in the microfluidic device?

That's pretty easy: ESCARGOT (Embedded SCAffold RemovinG Open Technology)
https://onlinelibrary.wiley.com/doi/full/10.1002/advs.201500125
(open access)

Patent pending.

Music: Dvorak, Serenade for Strings, Op.22, II. (Groberg)
Creative Commons Attribution-NonCommercial-NoDerivs 3.0
https://imslp.org/wiki/Serenade_for_Strings,_Op.22_(Dvo%C5%99%C3%A1k,_Anton%C3%ADn

--

Drug Testing Shake Up with Organs-on-a-Chip - YouTube
https://www.youtube.com/watch?v=rI8piLXJawQ

stretchy organ on a chip

key is the ability for the material to stretch back and forth

Bloomberg
2.09M subscribers

July 28 -- Our latest BWest series: Bioengineering the Senses. We take a closer look at tech on the frontiers of medical science. Today, we take a look at organs-on-a-chip under development at the Wyss Institute of Harvard University. Could this device speed up and improve the way new medicines are developed?

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Precizioned® Water Soluble Injection Wax - YouTube
https://www.youtube.com/watch?v=AylqrzOQVKs

Rio Grande
78K subscribers
Check out the products used in this video:
Precizioned Water Soluble Injection Wax - 700498, http://ow.ly/VJMN30oCkYm
Riace Intuitive Wax Injector System - 700917, http://ow.ly/3f6630oCl0a
Magnetic Stirring System with Heated Stand - 335210, http://ow.ly/JxtC30oCl2G

In this video from Rio Grande, our senior jewelry designer, Scott Patrick discusses the features and benefits of a water soluble injection wax from Precizioned®, the same company that makes Fire & Frost injection waxes.

Learn about the special characteristics of this water soluble wax and how it can be a great choice for certain hollow core designs. Scott shows the basic steps needed to make a hollow bead—he mentions that either hand-carved or CAD designs can be used. He follows all the steps, resulting in a detailed, hollow wax bead that is ready to cast.

Rio Grande stands for makers who create with their hands and their hearts and who are courageous enough to make jewelry their livelihood.

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GRN CASTİNG GOLD CASTİNG COMPANY - YouTube
https://www.youtube.com/watch?v=NvCtbouQClg

fractcal casting of water soluable wax?

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3D printing human tissue: where engineering meets biology | Tamer Mohamed | TEDxStanleyPark - YouTube
https://www.youtube.com/watch?v=nbtz8fhhMhE

TEDx Talks
23.2M subscribers
A record amount of money is spent developing new drugs, but drug approval rates are declining and many fatal diseases are left untreated. A big reason behind this is often times current drug testing methods including animal testing don't accurately predict the human response to drugs. What if we can 3D print living human tissue to test new drugs and study disease?

Tamer Mohamed talks about how 3D printing human tissue will allow us to develop better, safer, and cheaper drugs while reducing our reliance on animal testing. Beyond drug development, Tamer imagines a future where replacement organs are 3D printed using a patient's own cells, avoiding organ wait lists and the risk of rejection.

Tamer Mohamed is a biomedical engineer, innovator, and entrepreneur. He is President and CEO of Aspect Biosystems Ltd., a biotechnology company operating at the leading edge of 3D bioprinting and tissue engineering - www.aspectbiosystems.com. Tamer can be reached at tamer@aspectbiosystems.com

developing safe and effective drug is very difficult

your body is unique

cells are the building blocks of the body

3d bioprinter

cells in ink cartridge

lab on a printer

3d bioprinting

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Homemade Bioprinter
473 subscribers
Links to particular components
Syringe Mount gcode file:
https://drive.google.com/file/d/1nLUcHdqFBRLwX6xg0847WoLRSoje9x2_/view
EFD Model 1500XL Dispenser (can be found for cheap on auction sites)
Creality CR10S: https://us.gearbest.com/3d-printers-3...
Air Compressor:
https://www.aircompressorsdirect.com/Hitachi-EC28M-Air-Compressor/p85544.html

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Hitachi EC28M Ultra Quiet (59 DB) Oil-Free Portable 1 gallon Air Compressor - - Amazon.com
https://www.amazon.com/gp/product/B077ZQYXZ1/

quiet air compressor

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New Hitachi EC28M Ultra-Quiet 1 Gallon Air Compressor Review and Comparison - YouTube
https://www.youtube.com/watch?v=eO_WL0Vx4BA

WorkshopAddict
120K subscribers
Price the Hitachi EC28M Ultra-Quiet 1 Gallon Air Compressor on Amazon:
http://amzn.to/2F9nHme
Quiet Trim Compressor - Hitachi states that the EC28M is a quiet compressor. We feel that is an understatement! Hitachi uses an industrial oil-free pump for high durability with a maintenance-free operation. The air compressor is very portable with a nice rubber carry handle and weighing 25.2 lbs. The steel roll cage protects the gauges and the front of the air compressor well. It does leave the rear drain valve wide open to an accident.

In our testing, this air compressor would start from zero and pressurize to 125 psi in one minute and nine seconds. Recovery time was 21 seconds going from 97 psi to 125 psi. Those times are without a hose connected. depending on the size and length of hose, that could increase those times. But the reality of this air compressor is that it would not matter if it ran all the time, it is that quiet that with it in the same room, it would not matter. The YouTube video makes it sound louder than it is.

Hitachi EC28M Air Compressor Specs
Power supply: 120V/60Hz
Rated Amps 2.8 Amps
Motor Type: Induction
Running HP: 0.5 HP
Tank type: Hotdog
Tank capacity: 1 gallon
Max pressure: 125 PSI
Air delivery @ 40 PSI: 1.3 CFM
Air deliver @ 90 PSI: 0.8 CFM
Weight: 25.2 pounds
Dimensions: 14 in. x 14 in. x 13.5 in
Coupling socket: ¼” x 1”
Gauges: regulated pressure gauge and tank pressure gauge
Small Quiet Compressor
If you are looking for a very small and very quiet air compressor, Hitachi makes it! This air compressor will most likely be used as a trim carpentry air compressor. In our shop, we will use it to run the safety mechanisms on the Bendpak automotive lifts. When our current small compressors turn on, they are loud and you cannot talk. With this Hitachi, it could be running and it would not interrupt the conversation or even make us talk louder.

It is hard to compare how quiet this air compressor is. In the YouTube video, we show it with our phone decibel meter and compare it to the DEWALT FlexVolt, Ridgid 18-volt, and Hitachi 4 gallon air compressors. There is no one even close to the quietness of this small compressor. If you have a use for this compressor, it is priced right and has great performance.

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Biomedical Engineering Students Design 3D Bioprinter - YouTube
https://www.youtube.com/watch?v=N6dVMMIqToA

Florida Tech
2.94K subscribers

Cameron Hume, Rahmatul Mahmoud, Prabhuti Kharel, Daniela Friere and Pamela Forero are a team of mechanical engineering and biomedical engineering students that built a 3D bioprinter, known as Caracal, for their student design project. Caracal recently won the President's Cup Award at the 2017 Northrop Grumman Engineering & Science Student Design Showcase.

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DIY Syringe Pump (Food 3D Printer - Part 1) - YouTube
https://www.youtube.com/watch?v=UHa-OKb_CiM

Dr. D-Flo
18K subscribers
For more information: https://www.drdflo.com/pages/Projects/Syringe-Pump.html

The lab Dr. D-Flo works in needed two syringe pumps for biological experiments. Commercial syringe pumps can cost upwards of $3,000! Dr. D-Flo built two of Naroom's open source syringe pumps for $200 each. While building Dr. D-Flo realized that these pumps could be used for a food 3D Printer. What exactly does that mean? Subscribe to his youtube channel to find out!

nema 17 motor

radial to stepper motor

syringe is steady flow as opposed to peristaltic flow

arduino motorshield library

--

OpenSCAD - The Programmers Solid 3D CAD Modeller
https://www.openscad.org/

allows manipulation of parameters of the 3d model in text based format

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Building a Bioprinter Part 2 - YouTube
https://www.youtube.com/watch?v=x9Dv4mSWczM

cellulose acetate and acetone

commonly used bio ink

Homemade Bioprinter
473 subscribers
Cellulose Acetate:
https://www.sigmaaldrich.com/catalog/product/aldrich/180955?lang=en&region=US

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Turning paper into plastic - YouTube
https://www.youtube.com/watch?v=yMG0yfGFJ00

NileRed
1.29M subscribers
NOTE: I made a mistake in the diagrams for cellulose, all of the glucose units are missing an oxygen atom!

Paper is made of cellulose, and in this video, I'll be converting it into a plastic called cellulose acetate. I'll be making two forms of it, known as cellulose diacetate and cellulose triacetate.

--

3-D printing with Cellulose | QPT - YouTube
https://www.youtube.com/watch?v=AsN6Y_SxdC0

cellulose acetate and acetone

cellulose is from wood binder

acetone quicly evaporates and plastic hardes

Rajamanickam Antonimuthu

57.3K subscribers
Cellulose is the most abundant organic polymer in the world.
For centuries, Celluose is used for creating Paper.
Now MIT's new research is giving hope for using this Celluse as 3D printing material also.
i-e This new research is potentially providing a renewable, biodegradable alternative to the polymers currently used in 3-D printing materials.

Cellulose is the most important component in giving wood its mechanical properties. It's inexpensive, biorenewable, biodegradable, and also very chemically versatile. So it's used in a lot of products. Cellulose and its derivatives are used in pharmaceuticals, medical devices, as food additives, building materials, clothing. And a lot of these kinds of products would benefit from the kind of customization that additive manufacturing i-e 3D printing enables.

Meanwhile, 3-D printing technology is rapidly growing. Among other benefits, it allows you to individually customize each product you make.

Using cellulose as a material for additive manufacturing is not a new idea, and many researchers have attempted this but faced major obstacles. When heated, cellulose thermally decomposes before it becomes flowable, partly because of the hydrogen bonds that exist between the cellulose molecules. The intermolecular bonding also makes high-concentration cellulose solutions too viscous to easily extrude.

Instead, the MIT team chose to work with cellulose acetate — a material that is easily made from cellulose and is already widely produced and readily available. Essentially, the number of hydrogen bonds in this material has been reduced by the acetate groups. Cellulose acetate can be dissolved in acetone and extruded through a nozzle. As the acetone quickly evaporates, the cellulose acetate solidifies in place. A subsequent optional treatment replaces the acetate groups and increases the strength of the printed parts.

Cellulose acetate is already widely available as a commodity product. In bulk, the material is comparable in price to that of thermoplastics used for injection molding, and it's much less expensive than the typical filament materials used for 3-D printing. This, combined with the room-temperature conditions of the process and the ability to functionalize cellulose in a variety of ways, could make it commercially attractive.

News Source: http://news.mit.edu/2017/3-d-printing-cellulose-0303

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How does a cotton candy floss machine work? - YouTube
https://www.youtube.com/watch?v=5mytgt4-468

bigclivedotcom
594K subscribers
A look inside two different cotton candy floss machine heads.

Cotton candy, or candy floss as we say in the UK is made by spinning ordinary sugar in a drum with a source of heat. The sugar crystals cant escape from the spinning drum until they are in a molten state, and then the drops of molten sugar are thrown from the drum centrufugally, making long thin strands of sugar floss in the process.

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Polydimethylsiloxane - Wikipedia
https://en.wikipedia.org/wiki/Polydimethylsiloxane

Polydimethylsiloxane (PDMS), also known as dimethylpolysiloxane or dimethicone, belongs to a group of polymeric organosilicon compounds that are commonly referred to as silicones.[1] PDMS is the most widely used silicon-based organic polymer, and is particularly known for its unusual rheological (or flow) properties. PDMS is optically clear, and, in general, inert, non-toxic, and non-flammable. It is one of several types of silicone oil (polymerized siloxane). Its applications range from contact lenses and medical devices to elastomers; it is also present in shampoos (as dimethicone makes hair shiny and slippery), food (antifoaming agent), caulking, lubricants and heat-resistant tiles.

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IMPORTANT

Lab 6A: PDMS Microfluidics: O2 Plasma Treatment - YouTube https://www.youtube.com/watch?v=fMUemBZ0k5Q

aluminum foil in glass jar with atmosphere evacuated

glass microscope slide
cured pdms placed on slide

plasma treatment

15 seconds 100 C = 212 F

the glass slide will act as a buffer from the aluminum foil

evacuate the jar to 6 Torr = 0.116021 psi with vacuum pump

place a mug of water to protect the microwave

the soot will cause the pdms to very hydrophobic

MIT OpenCourseWare
2.32M subscribers
MIT 6.S079 Nanomaker, Spring 2013
View the complete course: http://ocw.mit.edu/6-S079S13
Instructors: Dr. Katey Lo, Dr. Joseph Summers, Prof. Vladimir Bulovic

This video is a tutorial on performing O2 plasma treatment of PDMS using a microwave oven. The demonstration includes how to set up the treatment, as well as testing the hydrophobicity of the treated PDMS.

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Videos | Nanomaker | Electrical Engineering and Computer Science | MIT OpenCourseWare
https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-s079-nanomaker-spring-2013/videos/

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Ultimaker PVA Explained - Water-soluble support material - YouTube https://www.youtube.com/watch?v=0ENgGkPP94w

Ultimaker
25K subscribers
This video explains how water-soluble PVA support material is 3D printed in dual extrusion with the Ultimaker 3.
Learn more about the Ultimaker 3 here: http://ultim.kr/2eof06C

Model: Gyro the Dodo by Virtox

« About Ultimaker »
From the very beginning we've nurtured an environment for open source collaboration and sharing. Through our industry-leading products such as Ultimaker 3D printers and Cura software, all realized through open source, people who joined our 3D printing community now have a way of expressing ideas and creating products with ease that just wasn't there before.

Our innovative Cura software makes 3D printing so easy. It's a free to download 3D slicer which prepares your 3D models quickly and easily. For newbies it'll do everything for you, and for experts there's a world of advanced settings to tinker with. Cura has been engineered to make the very most of the Ultimaker family. And vice versa. Born from open source community collaboration, together they create a stable, reliable and seamless 3D printing experience. The Ultimaker community of 3D printing experts is great for useful tips & tricks, inspiring prints, immediate help and new connections. Start exploring today.

« About 3D printing »
3D printing is often called additive manufacturing as well. It's a rapid prototyping technology which uses plastic filaments that are extruded under high temperatures. Layer by layer it 3D prints the physical object. Professionals and makers all around the world use Ultimaker 3D printers for rapid prototyping, engineering, product design, 3D printed art, jewelry, and in fashion, medicine and education. With several aftermarket or 3D printed add-ons you can even turn an Ultimaker into a food 3D printer.

« Links »
Ultimaker: http://ultim.kr/1RwV8tR
How does 3D printing work?: http://ultim.kr/1RP0Zx8
Ultimaker 3D printers: http://ultim.kr/1X7lExO
Ultimaker 3D printing filament: http://ultim.kr/1QGsdDO
Ultimaker Cura software: http://ultim.kr/1YnEJNv
Ultimaker 3D Printing Community: http://ultim.kr/1Qy5WKx

Ultimaker Facebook: https://facebook.com/ultimaker
Ultimaker Twitter: https://twitter.com/ultimaker
Ultimaker Instagram: https://instagram.com/ultimaker
Ultimaker Google+: https://google.com/+ultimaker

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Microfluidics 101: How to Make PDMS - YouTube
https://www.youtube.com/watch?v=6zG4utI40Kw

BU iGEM
291 subscribers
This is one of four M101 tutorial videos produced by the 2017 BostonU_HW iGEM Team. This video goes step-by-step through the process of making PDMS in the lab.

To see a written protocol of this process, please click the link below:
http://2017.igem.org/wiki/images/3/3b/UF101_PDMS_Protocol.pdf

Video Produced by Sarah Nemsick & Dinithi Samarasekera

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http://2017.igem.org/wiki/images/3/3b/UF101_PDMS_Protocol.pdf

PDMS Production Protocol
Chemical Components Required:
● Silicone elastomer curing agent ● Silicone elastomer base
Materials Required:
● Stirring tool
● Plastic weighing dish
● Digital scale
● Glass plate
● Desiccator
● Oven
● Indoor mounting tape
● Exacto knife
● Compressed air
● Ruler

● Cutting board
● Chip of the desired size
● Rubbing alcohol
● Kim wipes

Instructions:

Preparing the Elastomer mix:

1. Turn the digital scale on, place the plastic weighing dish on it and tare
2. Pour 28g of elastomer base into the weighing dish followed by 4g of elastomer curing agent

If you would like to adjust the thickness or size of PDMS made, ensure you use a ratio of 1:7 of the elastomer base and curing agent. As long as this ratio is used, you can scale the volume of PDMS made up or down as needed.

3. Mix the base and curing agent together for 10 minutes using your stirring tool
4. Use a pipette tip to burst the largest bubbles in the mixture
5. To burst the remaining bubbles, place the plastic dish inside your desiccator and desiccate for 5 minutes
6. After 5 minutes, open and close the valve suddenly - this will pop the bubbles left in the mixture
7. Repeat this process at least three times until all bubbles have burst
8. Release pressure in your dessicator and remove the weighing tray
9. If bubbles remain in the PDMS repeat steps 5-6 until they have all popped

Preparing your glass plate:

1. Spray your glass plate with rubbing alcohol and wipe it down with a kim wipe to clean it, if necessary use a soft toothbrush to scrub away any persistent debris
2. Place the plate on a baking tray and ensure it is resting in a flat position to ensure the PDMS spreads out uniformly thick
3. Cut two pieces of indoor mounting tape and paste along the widest part of your glass plate as illustrated in the image below
4. Pour the elastomer mix onto the center of the glass plate leaving a border along the edges of the plate
5. If any bubbles form while pouring, use a pipette tip to burst them
6. Dispose of your weighing dish with the remaining PDMS mixture
7. Leave the mix to sit for one hour, in this time the elastomer mix should spread evenly across the glass plate
8. Pre-heat your oven while waiting for the elastomer mix to spread over the glass plate, it should have come to temperature by the end of the hour

Cooking and Cutting to Size:

1. Once the oven has come to temperature, place the baking tray with the glass plate on it inside

2. Set a timer and cook the PDMS for one hour
3. After one hour, take the PDMS out of the oven and leave to cool for at least 45 minutes, or until cool to the touch
4. Using a ruler and exacto knife cut off the indoor mounting tape from the edges of the PDMS as illustrated in the image below
5. Peel the PDMS off the glass plate carefully, avoiding tears
6. Place this on the cutting mat
7. If there is any excess PDMS left on the glass plate, remove and discard of this.
8. Place your piece of PDMS on a cutting board.
9. Place a chip of the desired dimensions on the PDMS avoiding areas with bubbles or embedded debris
10. Using the exacto knife, cut around the perimeter of your chip. PDMS can easily tear, so do so slowly and carefully.
11. Depending on the size of your remaining PDMS, you may want to save this for another chip, discard any pieces too small to use.
12. You now have a layer of PDMS that is the correct size for your chip

Cleaning the Glass Plate:
1. Spray the glass plate with rubbing alcohol and wipe with a Kim wipe to remove any debris
2. Use compressed air to dry the plate

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Super Water-Repellent Cellulose Acetate Mats | Scientific Reports
https://www.nature.com/articles/s41598-018-30693-2

Article
Open Access
Published: 20 August 2018

Super Water-Repellent Cellulose Acetate Mats

Fateh Mikaeili & Pelagia I. Gouma

Scientific Reports volume 8, Article number: 12472 (2018) Cite this article

Abstract

A single-step synthesis of super-water-repellent oil sorbents based on cellulose acetate (CA) mats is reported in this paper. Key phenomenological mechanisms involving roughness and changes in chemistry are used to describe the change in hydrophobic behavior of the CA mats. Contact angle calculations followed by Cassie's model apparent contact angle prediction have shown roughness alone is not capable of producing the super-hydrophobicity exhibited by as-spun mats. Fourier transform infrared spectroscopy of spin coated and electrospun mats shows a significant difference in the stretching of the hydroxyl bonds of the two materials. As it is this hydroxyl group which adds to the overall polarity of surface thus hydrophilicity of the material, we propose that the electrospinning process not only creates a rougher surface but also alters the chemistry of the electrospun cellulose acetate mats which ultimately gives rise to the reported hydrophobicity. Finally, due to their water repellent nature, and oleophilicity of the as-spun mats were tested as oil sorbent mats. The as-spun mats were capable of absorbing thirty times their weight in oil demonstrating their application for oil-water remediation.

Introduction

Introduction
For a material to be considered super hydrophobic, it must display an apparent water contact angle of more than 150° and low contact angle hysteresis1. To find materials which exhibit this, one does not need to look very hard; a number of excellent examples of super hydrophobic surfaces can be found by simply examining nature. Numerous plant's leaves across the globe exhibit hydrophobicity2,3 the tarsus of a strider4, the palm of a gecko5 and even the shell of some desert beetles6 all make use of hydrophobicity. Biomimicry and other attempts to make non-natural super hydrophobic surfaces7,8 have concluded that surface roughness and surface energy are the key characteristics that affect the hydrophobicity of a material9,10,11,12. Many attempts have been made to develop super hydrophobic materials by manipulating these two characteristics13.

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"Small Blood Vessels: Big Health Problems?": Scientific Recommendations of the National Institutes of Health Workshop | Journal of the American Heart Association
https://www.ahajournals.org/doi/10.1161/JAHA.116.004389

Small blood vessels (generally <100 μm in internal diameter) contribute to fundamental physiological processes and pathological events, but may not necessarily garner the attention associated with macrovascular physiology and disease. Major reasons for the bench‐to‐bedside research gap is the complexity and the size of small vessels throughout the body. Small vessels contain diverse cellular components and interact with a large variety of nonvascular parenchymal cell populations that differ among various organs. Depending on their location, the overlapping effect of environmental, epigenetic, and developmental factors adds to this complexity, challenging the translation of fundamental discoveries to the bedside. A better understanding of the specific structural and functional signatures of small vessels throughout the body and how their local perturbations can contribute to systemic pathophysiological conditions has the potential to transform diagnostic and therapeutic approaches.

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Adhesives and Mountants for Materials Science & Metrology
https://www.emsdiasum.com/microscopy/products/materials/adhesives.aspx

Adhesives and Mountants for Materials Science & Metrology
tdsCrystalbondarrow11Crystalbond™ Adhesives
A temporary adhesive. These wash away adhesives are used as a temporary bond for holding delicate crystals, metallurgical specimens, glass components, and ceramic substrates for dicing, slicing, drilling and polishing. These materials adhere readily to metals, glass, ceramic and then can be washed after machining away using various solvents.

Applications
Machining or slicing single crystal metal specimens
Grinding and polishing sapphire, ceramic, optical garnets, ferrites, and LCD glass
Dicing and slicing germanium and silicon wafers in semiconductor production
Dicing and slicing alumina and beryllia substrates for IC and microelectronic production
Holding beam leads in IC devices for pull-off tests
Dicing subminiature chip capacitors and microwave IC substrates
Crystalbond™ Properties

Crystalbond™ Properties

	509	555	590
Description	Thermo polymer*	Thermo polymer*	Thermo polymer*
Form	⅞" Dia. x 7" stick	Lump	Rectangle stick
Softening	160°F (71°C)	125°F (52°C)	257°F (125°C)
Flow Point	250°F (121°C)	130°F (54°C)	302°F (150°C)
Viscosity at Flow Point	6,000 cps	500 cps	9,000 cps
Color	Clear Amber	White	Brown
Solvent	Acetone or 509 Stripper	Water	Methanol or 590-S Stripper

*Thermoplastic polymer

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MET 314 Application of Machine Elements
MET 320 Applied Thermodynamics
MET 436 Pneumatic Motion Control Systems Capstone 2

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Precizioned® Water Soluble Injection Wax - YouTube
https://www.youtube.com/watch?v=AylqrzOQVKs

Rio Grande
78.1K subscribers
Check out the products used in this video:
Precizioned Water Soluble Injection Wax - 700498, http://ow.ly/VJMN30oCkYm
Riace Intuitive Wax Injector System - 700917, http://ow.ly/3f6630oCl0a
Magnetic Stirring System with Heated Stand - 335210, http://ow.ly/JxtC30oCl2G

In this video from Rio Grande, our senior jewelry designer, Scott Patrick discusses the features and benefits of a water soluble injection wax from Precizioned®, the same company that makes Fire & Frost injection waxes.

Learn about the special characteristics of this water soluble wax and how it can be a great choice for certain hollow core designs. Scott shows the basic steps needed to make a hollow bead—he mentions that either hand-carved or CAD designs can be used. He follows all the steps, resulting in a detailed, hollow wax bead that is ready to cast.

Rio Grande stands for makers who create with their hands and their hearts and who are courageous enough to make jewelry their livelihood.

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The emergence of "4D printing" | Skylar Tibbits - YouTube
https://www.youtube.com/watch?v=0gMCZFHv9v8

placing shapes in water causes them to actuate and assembly automatically stratasys printers and autodesk autocad

TED
16.2M subscribers

3D printing has grown in sophistication since the late 1970s; TED Fellow Skylar Tibbits is shaping the next development, which he calls 4D printing, where the fourth dimension is time. This emerging technology will allow us to print objects that then reshape themselves or self-assemble over time. Think: a printed cube that folds before your eyes, or a printed pipe able to sense the need to expand or contract.

TEDTalks is a daily video podcast of the best talks and performances from the TED Conference, where the world's leading thinkers and doers give the talk of their lives in 18 minutes (or less). Look for talks on Technology, Entertainment and Design -- plus science, business, global issues, the arts and much more.
Find closed captions and translated subtitles in many languages at http://www.ted.com/translate

Follow TED news on Twitter: http://www.twitter.com/tednews
Like TED on Facebook: https://www.facebook.com/TED

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Introduction to Organs-on-Chips - YouTube
https://www.youtube.com/watch?v=Mg2fJ0UBj_0

Wyss Institute
3.86K subscribers
What if we could test drugs without animal models?

For more information, please visit our technology page:
wyss.harvard.edu/technology/human-organs-on-chips/

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Human Organs on a Chip - YouTube
https://www.youtube.com/watch?v=fA_M9AMtM5g

National Instruments

15.1K subscribers
Dave Trumper from MIT and Jared Kirschner, Senior Software and Electrical Engineer from demonstrate their preclinical research platform for predicting safety, efficacy, and movement of drugs and vaccines in the body.

IMPORTANT

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Here's How Scientists Replicate Mysterious Organs...on a Chip - YouTube
https://www.youtube.com/watch?v=HVEfi-iNpvM

Lawrence Livermore National Laboratory
51.7K subscribers
LLNL has been working on simulating different parts of the human body on a CHIP! Including one of the most mysterious parts of the human brain. But how? And why?

Here are the other places you can find us on the internet:

Facebook: https://www.facebook.com/livermore.lab/
Twitter: https://twitter.com/Livermore_Lab
Instagram: https://www.instagram.com/livermore_lab/

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What is Tissue Engineering? - YouTube
https://www.youtube.com/watch?v=7Q3S6q97FiU

NIBIB gov
10.3K subscribers
NIBIB's 60 Seconds of Science explains what tissue engineering is and how it works.

Music by longzijun 'Chillvolution.'

For more information on Tissue Engineering:
https://www.nibib.nih.gov/science-education/science-topics/tissue-engineering-and-regenerative-medicine

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13. Tissue Engineering Scaffolds: Processing and Properties - YouTube
https://www.youtube.com/watch?v=Txidu-5VYfU

when you have time

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induced pluripotent stem stells

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Nina Tandon: Could tissue engineering mean personalized medicine? - YouTube
https://www.youtube.com/watch?v=r6nSmSTKHGc

TED
16.2M subscribers

Each of our bodies is utterly unique, which is a lovely thought until it comes to treating an illness -- when every body reacts differently, often unpredictably, to standard treatment. Tissue engineer Nina Tandon talks about a possible solution: Using pluripotent stem cells to make personalized models of organs on which to test new drugs and treatments, and storing them on computer chips. (Call it extremely personalized medicine.)

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Tissue Engineering for Regenerative Medicine | Warren Grayson | TEDxBaltimore - YouTube
https://www.youtube.com/watch?v=PlEb50m7v_k

bio degradable polymer

TEDx Talks
23.2M subscribers
Facial bone loss impacts the physical, social, and emotional well-being of patients. This talk describes the process for regenerating new, customized, facial bones using tissue engineering.

Recorded at TEDxBaltimore 2016

Warren is Assistant Professor in Biomedical Engineering at Johns Hopkins University. His lab seeks to address the challenges associated with engineering functional craniofacial and orthopaedic constructs for use in therapeutic applications.

This talk was given at a TEDx event using the TED conference format but independently organized by a local community. Learn more at http://ted.com/tedx

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Recent concepts in biodegradable polymers for tissue engineering paradigms: a critical review: International Materials Reviews: Vol 64, No 2
https://www.tandfonline.com/doi/abs/10.1080/09506608.2018.1460943?journalCode=yimr20

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Biomaterials: Crash Course Engineering #24 - YouTube
https://www.youtube.com/watch?v=-jw8osY5QJM

biomaterials
biocompatible

polyuretheane

hydrogels
hydrophylic structures
phema hydrogel

gel polycarbonate dihydroxyacetone (MPGE-PDHA) and polyethylene gylycol

CrashCourse
10.4M subscribers

We've talked about different materials engineers use to build things in the world, but there's a special category of materials they turn to when building things to go inside our bodies. In this episode we'll explore the world biomaterials like titanium and their coatings, the special chemistry of polyurethane, and the cross-linked structure of hydrogels. We'll also look at the importance of safety & research, as well as the enormous future potential of biomaterials.

Crash Course Engineering is produced in association with PBS Digital Studios

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Manufacturing acetate for high quality eyewear - YouTube
https://www.youtube.com/watch?v=n2B6EC75sOo

Niall O'Kane Optometrists
A short documentary on how Mazzucchelli makes his incredible acetate's sheets, a glimpse about a family business that shaped the eyewear industry, a story about an industrial process which is still "handmade" in all its aspects.

Entirely shot at Mazzucchelli's facility in Castiglione Olona, Varese, Italy.

Learn more about all of our products and services at www.nokopticians.co.uk

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Make your own bioplastic - YouTube
https://www.youtube.com/watch?v=5M_eDLyfzp8

Green Plastics
8.53K subscribers
Please visit http://www.green-plastics.net/ for questions and answers about this video and making bioplastics at home!

This video shows you how to make starch-based plastic (bioplastic) in your own kitchen, from household ingredients. Visit the Green Plastics website to submit questions and see other questions and answers from students and hobbyists who have made their own home-made bioplastic projects.

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chemical etching on acrylic?

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Photo Chemical Machining Process - Northwest Etch - YouTube
https://www.youtube.com/watch?v=NDp3OPI6dgo

NW Etch
80 subscribers
Website: https://www.nwetch.com
The Photo Chemical Machining process has 9 essential steps to achieve simple or complex thin-metal components of one to one million parts. This is a very economical option for research and development or prototype phase of a project when quick turnaround is vital. Our PCM process is used to etch through metal thicknesses between .0005″ to .060″ and between .060″ to .250″ for depth etching on metal only.

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Optical finish for acrylic -- vapor polishing and other techniques - YouTube
https://www.youtube.com/watch?v=7na8kQ78vkQ

I needed to polish two acrylic lenses that were made on a CNC lathe to the best possible finish (hopefully, optical quality). I made some test coupons and tried three different polishing techniques on three different surfaces to see which combination of techniques would yield the best results. The winner was clearly 2000 grit sandpaper followed by Novus No.2 polish. Vapor polishing: http://www.youtube.com/watch?v=bduno3...

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IMPORTANT

test this:

1. laser cut channels and ports, same piece or flat piece?
2. tap ports?
3. scrape of channel ridges with razor blade

4. fill channel with water soluable wax
5. prep second flat piece and channel piece for acrylic solvent weld
6. place pieces in jig (may need metal jig, because of solvent)
7. solvent weld acrylic with needle
8. allow to dry 5 min set, 30 min 80%? strength cure
9. install ports
9. attach hose to ports
10. test with syringes water and food coloring

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IMPORTANT

google search "acrylic microfluidics"

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Reconfigurable Acrylic-tape Hybrid Microfluidics | Scientific Reports
https://www.nature.com/articles/s41598-019-41208-y

In the abovementioned experiment, hydrophobic patterns can be created by selectively replacing hydrophilic glue with a hydrophobic coating on desired areas of the tape. The detailed experiment steps are explained below and shown in Fig. 5(g). First, a plastic film was laser cut to expose the desired patterns of the final hydrophobic areas. The cut film is applied on the sticky side of the hydrophilic tape, serving as a mask. The exposed hydrophilic glue on the tape was removed by rubbing a cotton swab soaked with IPA on the surface. Commercially available hydrophobic fluid (GRF135, Granger) was sprayed onto the masked tape to make the exposed area hydrophobic. With the plastic film mask removed, the hydrophilic tape can be applied to seal the acrylic channels with the hydrophobic patterns at the desired locations.

We note that acrylic-tape microfludics can be sterilized, especially before the devices are reconfigured. Commercially available pre-sterilized tapes (ARcare 8311, Adhesive Research) can be used. By removing the tape, channels in the used acrylic microfluidic devices are fully exposed and can be thoroughly cleaned or sterilized by solvents. We immersed the acrylic substrates with laser ablated channels in IPA and ethanol over 48 hours, and there was no crack observed, proving the solvent cleaning is safe to sterilize our acrylic substrates. We also note that the application of reconfigurable functional tapes is not limited to flow pattern controls. Other functional materials can be patterned onto the tapes for interdisciplinary process control, such as the chemical catalyst for multi-step reactions and biomarkers for immunoassays. Furthermore, the tape coating process is suitable for mass production in industry, which is important for translating laboratory research to real-world applications.

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Introducing the Form 3 and Form 3L: Powered by Low Force Stereolithography - YouTube
https://www.youtube.com/watch?v=vZW1fOIgcWU

Formlabs is proud to announce two new advanced Low Force Stereolithography (LFS) 3D printers that will help usher in a new era for industrial 3D printing: the Form 3, the latest in our line of professional printers for the desktop, is available to order now, and the Form 3L, the first affordable large format resin 3D printer, is available for pre-order. Learn more at http://bit.ly/2Yx2zNz More information on Form 3: http://bit.ly/2CK2gFR More information on Form 3L: http://bit.ly/2THmZjk

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Request a Free Sample 3D Printed Part | Formlabs
https://formlabs.com/request-sample-part/?part=clear-microfluidics-model

Millifluidics Model

IMPORTANT

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Customizable 3D Printed ‘Plug and Play’ Millifluidic Devices for Programmable Fluidics
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0141640#pone.0141640.ref021

Customizable 3D Printed ‘Plug and Play’ Millifluidic Devices for Programmable Fluidics
Soichiro Tsuda,Hussain Jaffery,David Doran,Mohammad Hezwani,Phillip J. Robbins,Mari Yoshida,Leroy Cronin
Published: November 11, 2015https://doi.org/10.1371/journal.pone.0141640

Abstract
Three dimensional (3D) printing is actively sought after in recent years as a promising novel technology to construct complex objects, which scope spans from nano- to over millimeter scale.

Previously we utilized Fused deposition modeling (FDM)-based 3D printer to construct complex 3D chemical fluidic systems, and here we demonstrate the construction of 3D milli-fluidic structures for programmable liquid handling and control of biological samples.

BASIC FLUIDIC OPERATION DEVICES, SUCH AS WATER-IN-OIL (W/O) DROPLET GENERATORS FOR PRODUCING COMPARTMENTALIZED MONO-DISPERSE DROPLETS, SENSOR-INTEGRATED CHAMBER FOR ONLINE MONITORING OF CELLULAR GROWTH, ARE PRESENTED.

In addition, chemical surface treatment techniques are used to construct valve-based flow selector for liquid flow control and inter-connectable modular devices for networking fluidic parts. As such this work paves the way for complex operations, such as mixing, flow control, and monitoring of reaction / cell culture progress can be carried out by constructing both passive and active components in 3D printed structures, which designs can be shared online so that anyone with 3D printers can reproduce them by themselves.

IMPORTANT

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3D Printed Reactionware
3D printed reactionware gallery. Click on the image to download the STL files and associated images (in zip format)
Tsuda et. al., PLoS One, 2015
http://www.chem.gla.ac.uk/cronin/media/files/STL.zip

IMPORTANT

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IMPORTANT
PURCHASE

Purdue University - Department of Chemistry - Body Cover Safety and Lab Coats
https://www.chem.purdue.edu/chemsafety/PPE/body_cover_safety_and_lab_coats.html

The FR coat appears to be pale blue and VWR picure is here:

89426-898 FR LABCOAT M SF 5XL 1EA 72.89 USD

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CellConcentrationTurbidimeter - Open Source Ecology
https://wiki.opensourceecology.org/wiki/CellConcentrationTurbidimeter

IMPORTANT

The OSE sensor uses a collimated LED light source with a spectral bandwidth approx. 20nm FWHM centered near 610nm, such as Kingbright WP7113SEC/J4 (available from DigiKey). At the opposite side of a flow cell, a collimated silicon PIN photodiode such as Osram SFH213 (also available from DigiKey) receives the light beam. The flow cell is constructed of two parallel glass windows sealed to spacers with silicone adhesive.

http://www.kingbrightusa.com/images/catalog/SPEC/WP7113SEC-J4.pdf

WP7113SEC/J4 Kingbright | Optoelectronics | DigiKey
https://www.digikey.com/products/en?WT.z_se_ps=1&keywords=WP7113SEC%2FJ4

SFH 213 OSRAM Opto Semiconductors Inc. | Sensors, Transducers | DigiKey
https://www.digikey.com/product-detail/en/osram-opto-semiconductors-inc/SFH-213/475-1077-ND/607286

https://www.osram.com/os/

Continuous turbidometric measurements of microbial cell density in bioreactors using a light emitting diod and photodiode
http://starch.dk/isi/papers/JMM%2010%20EB.pdf

1989

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turbididy

the quality of being cloudy, opaque, or thick with suspended matter.

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We've Got A New Toy! - Analog Turbidity Sensor (SEN0189) - Mar2016 - YouTube
https://www.youtube.com/watch?v=POsJc-tM2ZI

The turbidity sensor is able to detect suspended particles in water by measuring the light transmittance and scattering rate which changes with the amount of total suspended solids in water. As the TTS increases, the liquid turbidity level increases. This sensor has both analog and digital signal output modes. You can select the mode according to the MCU as the threshold is adjustable in digital signal mode. Turbidity Sensor For Arduino:
https://www.dfrobot.com/product-1394.... More Sensors:
https://www.dfrobot.com/category-36.h...

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Raspberry Pi to Arduino Shields Connection Bridge - Compatible with the new Raspberry Pi (Model B+)
https://www.cooking-hacks.com/raspberry-pi-to-arduino-shield-connection-bridge

Raspberry Pi to Arduino Shields Connection Bridge
The Raspberry Pi to Arduino shields connection bridge allows to use any shield, board or module designed for Arduino in Raspberry Pi.
Additionally, we have developed the arduPi library to use the Arduino code in Raspberry Pi.

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Geiger Counter - Radiation Sensor Board for Arduino and Raspberry Pi
https://www.cooking-hacks.com/documentation/tutorials/geiger-counter-radiation-sensor-board-arduino-raspberry-pi-tutorial

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"microfluidics" 3D Models to Print - yeggi
https://www.yeggi.com/q/microfluidics/

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IMPORTANT

3D Printing Microfluidic Models – 5 Most Interesting Projects | All3DP
https://all3dp.com/2/3d-printing-microfluidic-models-most-interesting-projects/

3D PRINTING MICROFLUIDIC DEVICES
Sphere Maker

Liquid microspheres can be created with ease using a 3D printed fluidic devices.
Liquid microspheres can be created with ease using a 3D printed fluidic devices. Source: Ultimaker
One of the advantages of microfluidics is its ability to separate and create small countable units of fluid. Researchers from Cardiff University used Ultimaker 3D printers to do just that.

But why would we need to make spheres using microfluidics? As they mention in the video, spheres are made for biomedical applications as well as nuclear energy applications. Furthermore, the simple ability to "count" small volumes of fluid can be helpful. Exact volumes of fluid can be deposited in a digital manner based upon the number of counted spheres, for example.

Advantages:

Produces relatively consistent spheres at a rapid and continual rate
Disadvantages:

Requires a secondary sheath fluid to form the sample into spheres

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IMPORTANT

Cardiff University: Accessible 3D printed microfluidic devices
https://ultimaker.com/learn/cardiff-university-accessible-3d-printed-microfluidic-devices

Alex Morgan, Research Associate at Cardiff University, points out that other researchers previously discounted the use of 3D printing to create microfluidic devices as they were non-transparent and often leaked. By optimizing the print settings, however, Alex found that by printing in 50-micron layers and at a print speed of 30mm a second, devices can be printed that are both transparent and water-tight. The research group's recent publication explains how to do this.

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3D Printing Microfluidic Models – 5 Most Interesting Projects | All3DP
https://all3dp.com/2/3d-printing-microfluidic-models-most-interesting-projects/

3D PRINTING MICROFLUIDIC DEVICES
ESCARGOT Method (Multilayer Complex Microfluidic Geometries)
With the ESCARGOT method, very complex structures, such as this hilbert cube can easily be created in PDMS.
With the ESCARGOT method, very complex structures, such as this hilbert cube can easily be created in PDMS. Source: labsolutely.org
Multilayer or complex microfluidic geometries, including components like mixers and valves, are oftentimes difficult to create. Thankfully, researchers at Wageningen University and the University of Castilla-La Mancha developed the ESCARGOT method, which allows for complex three-dimensional microfluidic forms to be created along with embedded non-3D-printed materials, if desired.

This method involves printing an ABS template that is encapsulated in PDMS. After curing, the template is removed using solvent extraction. The process has many uses, including an embedded heating element for selective heating of fluid across a particular area of the microfluidic device.

Advantages:

Can quickly create complex 3D templates for PDMS-based microfluidic flow cells
Can embed non-3D-printed components directly into the microfluidic device
Disadvantages:

Template removal process involves the use of acetone (which is highly flammable)
May take a long time to dissolve extremely fine and complex geometries

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Simple and Versatile 3D Printed Microfluidics Using Fused Filament Fabrication
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0152023

Simple and Versatile 3D Printed Microfluidics Using Fused Filament Fabrication
Alex J. L. Morgan ,Lorena Hidalgo San Jose,William D. Jamieson,Jennifer M. Wymant,Bing Song,Phil Stephens,David A. Barrow ,Oliver K. Castell
Published: April 6, 2016https://doi.org/10.1371/journal.pone.0152023

Fig 2. Extrusion 3D printed flow focusing junctions.

A) Water in oil droplets formed in a PLA module that has a glass observation window embedded within it. B) Alginate solution droplets in sunflower oil generated in a semi-transparent PLA module. Oil flow rate: 3ml/hr, alginate flow rate: 1ml/hr C) Mineral oil droplets in water and 10mM oleic acid carrier phase. Generated on a semi transparent PLA device. Water flow rate: 4ml/hr, oil flow rate: 1.5ml/hr. Junctions A and C have inlet channel widths of 1mm with a 1.4mm wide outlet. Junction B has 600μm wide channels with a 900μm wide outlet.

https://doi.org/10.1371/journal.pone.0152023.g002

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Accelerating Millifluidic Research with 3D Printing | Formlabs
https://formlabs.com/blog/accelerating-millifluidic-research-with-3d-printing/

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Formlabs Research: Microfluidics - YouTube
https://www.youtube.com/watch?v=0m6XJUU-4VM

Mark Scott is a research scientist at Harvard University. Mark is fascinated with 3D printing as a research & educational tool, and in the Form 1+ video demonstrates a series of microfluidics and millifluidic devices designed by Yoav Reches and Will Patrick, a research assistant in Neri Oxman's Mediated Matter group at the MIT Media Lab.

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DIY Syringe Pump (Food 3D Printer - Part 1) - YouTube https://www.youtube.com/watch?v=UHa-OKb_CiM

For more information: https://www.drdflo.com/pages/Projects... The lab Dr. D-Flo works in needed two syringe pumps for biological experiments. Commercial syringe pumps can cost upwards of $3,000! Dr. D-Flo built two of Naroom's open source syringe pumps for $200 each. While building Dr. D-Flo realized that these pumps could be used for a food 3D Printer. What exactly does that mean? Subscribe to his youtube channel to find out!

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Metafluidics – Open Repository for Fluidic Systems
https://metafluidics.org/

ON THE BLOG
Welcome to Metafluidics!
by dkong
Thank you for visiting Metafluidics! We hope you will join our community of microfluidic makers, practitioners, and enthusiasts.

Metafluidics was built to provide a home for digital design files and all of the other information necessary to reproduce or remix a microfluidic device. Please create a profile for yourself and peruse the repository!

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Enabling Microfluidics: from Clean Rooms to Makerspaces - ScienceDirect
https://www.sciencedirect.com/science/article/pii/S016777991730001X

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IMPORTANT

COOLEY LINKS

Final Project Microfluidics – Lukas DiBeneditto https://en.wikipedia.org/wiki/Microfluidics

http://2014.igem.org/Tracks/Microfluidics

http://news.mit.edu/2017/open-source-microfluidics-0613
https://2011.igem.org/Team:EPF-Lausanne/Tools/Microfluidics/HowTo2
https://sites.google.com/site/rafaelsmicrofluidicspage/valve-controllers/solenoid-valves?tmpl=%2Fsystem%2Fapp%2Ftemplates%2Fprint%2F&showPrintDialog=1
https://softroboticstoolkit.com/book/control-board
https://www.intechopen.com/books/advances-in-microfluidics-new-applications-in-biology-energy-and-materials-sciences/integrated-control-of-microfluidics-application-in-fluid-routing-sensor-synchronization-and-real-tim
https://www.elveflow.com/microfluidic-tutorials/microfluidic-reviews-and-tutorials/microfluidics/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2998071/
https://www.youtube.com/watch?v=TuKcFtKfyrY
https://www.youtube.com/watch?v=rD-9oBYG9rc

Fabrication methods –
https://www.youtube.com/watch?v=oo5FT5Ij7KE watched
https://www.youtube.com/watch?v=Xj1rk5xv8RE watched
https://www.youtube.com/watch?v=S-_KKiR_eYk watched some
https://www.youtube.com/watch?v=mjsFOSBFSG8 watched
https://www.youtube.com/watch?v=dxz10In1774 watched
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https://www.youtube.com/watch?v=cM10uk1EPEA watched
https://www.youtube.com/watch?v=ji32urfesZg watched
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https://www.youtube.com/watch?v=7z8I7awRYY4
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https://www.youtube.com/watch?v=Uw4-qmj7P0A
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https://www.youtube.com/watch?v=o9nnWV37nP8
https://www.youtube.com/watch?v=J5LwNGm0tbw
https://www.youtube.com/watch?v=fE3W4G2DZW4

Microfluidics 101 –
https://www.youtube.com/watch?v=1H-CFTPg498
https://www.youtube.com/watch?v=6zG4utI40Kw
https://www.youtube.com/watch?v=YSDMbnLvCQo
https://www.youtube.com/watch?v=DHf6j5r6RNo

Other vids –
https://www.youtube.com/watch?v=b8zE2i755-k
https://www.youtube.com/watch?v=68p3qAm4i7U
https://www.youtube.com/watch?v=EYuyRUjnTgc

Microfluidic 3D printer – SE3D https://www.se3d.com/

Microfluidic applications – https://www.youtube.com/

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IMPORTANT

Microfluidics - Wikipedia
https://en.wikipedia.org/wiki/Microfluidics

Microfluidics
From Wikipedia, the free encyclopedia
Jump to navigationJump to search
Microfluidics refers to the behaviour, precise control, and manipulation of fluids that are geometrically constrained to a small scale (typically sub-millimeter) at which capillary penetration governs mass transport. It is a multidisciplinary field that involves engineering, physics, chemistry, biochemistry, nanotechnology, and biotechnology. It has practical applications in the design of systems that process low volumes of fluids to achieve multiplexing, automation, and high-throughput screening. Microfluidics emerged in the beginning of the 1980s

and is used in the development of inkjet printheads, DNA chips, lab-on-a-chip technology, micro-propulsion, and micro-thermal technologies.

Typically, micro means one of the following features:

Small volumes (µL, nL, pL, fL)
Small size
Low energy consumption
Microdomain effects
Typically microfluidic systems transport, mix, separate, or otherwise process fluids. Various applications rely on passive fluid control using capillary forces, in the form of capillary flow modifying elements, akin to flow resistors and flow accelerators. In some applications, external actuation means are additionally used for a directed transport of the media. Examples are rotary drives applying centrifugal forces for the fluid transport on the passive chips. Active microfluidics refers to the defined manipulation of the working fluid by active (micro) components such as micropumps or microvalves. Micropumps supply fluids in a continuous manner or are used for dosing. Microvalves determine the flow direction or the mode of movement of pumped liquids. Often, processes normally carried out in a lab are miniaturised on a single chip, which enhances efficiency and mobility, and reduces sample and reagent volumes.

Contents

Microscale behaviour of fluids

Silicone rubber and glass microfluidic devices. Top: a photograph of the devices. Bottom: Phase contrast micrographs of a serpentine channel ~15 µm wide.
The behaviour of fluids at the microscale can differ from "macrofluidic" behaviour in that factors such as surface tension, energy dissipation, and fluidic resistance start to dominate the system. Microfluidics studies how these behaviours change, and how they can be worked around, or exploited for new uses.[1][2][3][4][5]

At small scales (channel size of around 100 nanometers to 500 micrometers) some interesting and sometimes unintuitive properties appear. In particular, the Reynolds number (which compares the effect of the momentum of a fluid to the effect of viscosity) can become very low. A key consequence is co-flowing fluids do not necessarily mix in the traditional sense, as flow becomes laminar rather than turbulent; molecular transport between them must often be through diffusion.[6]

High specificity of chemical and physical properties (concentration, pH, temperature, shear force, etc.) can also be ensured resulting in more uniform reaction conditions and higher grade products in single and multi-step reactions.[7][8]

Key application areas
Microfluidic structures include micropneumatic systems, i.e. microsystems for the handling of off-chip fluids (liquid pumps, gas valves, etc.), and microfluidic structures for the on-chip handling of nanoliter (nl) and picoliter (pl) volumes.[9] To date, the most successful commercial application of microfluidics is the inkjet printhead.[10] Additionally, microfluidic manufacturing advances mean that makers can produce the devices in low-cost plastics[11] and automatically verify part quality[12].

Advances in microfluidics technology are revolutionizing molecular biology procedures for enzymatic analysis (e.g., glucose and lactate assays), DNA analysis (e.g., polymerase chain reaction and high-throughput sequencing), proteomics, and in chemical synthesis.[13][14] The basic idea of microfluidic biochips is to integrate assay operations such as detection, as well as sample pre-treatment and sample preparation on one chip.[15][16]

An emerging application area for biochips is clinical pathology, especially the immediate point-of-care diagnosis of diseases[17]. In addition, microfluidics-based devices, capable of continuous sampling and real-time testing of air/water samples for biochemical toxins and other dangerous pathogens, can serve as an always-on "bio-smoke alarm" for early warning.

Microfluidic technology has led to the creation of powerful tools for biologists to control the complete cellular environment, leading to new questions and discoveries. Many diverse advantages of this technology for microbiology are listed below:

General single cell studies including growth [18][19]
Cellular aging: microfluidic devices such as the "mother machine" allow tracking of thousands of individual cells for many generations until they die.[18]
Microenvironmental control: ranging from mechanical environment [20] to chemical environment [21] [22]
Precise spatiotemporal concentration gradients by incorporating multiple chemical inputs to a single device [23]
Force measurements of adherent cells or confined chromosomes: objects trapped in a microfluidic device can be directly manipulated using optical tweezers or other force-generating methods [24]
Confining cells and exerting controlled forces by coupling with external force-generation methods such as Stokes flow, optical tweezer, or controlled deformation of the PDMS (Polydimethylsiloxane) device [24][25][26]
Electric field integration [26]
Plant on a chip and plant tissue culture [27]
Antibiotic resistance: microfluidic devices can be used as heterogeneous environments for microorganisms. In a heterogeneous environment, it is easier for a microorganism to evolve. This can be useful for testing the acceleration of evolution of a microorganism / for testing the development of antibiotic resistance.
Some of these areas are further elaborated in the sections below.

Open microfluidics
In open microfluidics, at least one boundary of the system is removed, exposing the fluid to air or another interface (i.e. liquid).[28][29][30] Advantages of open microfluidics include accessibility to the flowing liquid for intervention, larger liquid-gas surface area, and minimized bubble formation.[28][30][31] Another advantage of open microfluidics is the ability to integrate open systems with surface-tension driven fluid flow, which eliminates the need for external pumping methods such as peristaltic or syringe pumps.[32] Open microfluidic devices are also easy and inexpensive to fabricate by milling, thermoforming, and hot

embossing.[33][34][35][36] In addition, open microfluidics eliminates the need to glue or bond a cover for devices, which could be detrimental to capillary flows. Examples of open microfluidics include open-channel microfluidics, rail-based microfluidics, paper-based, and thread-based microfluidics.[28][32][37] Disadvantages to open systems include susceptibility to evaporation,[38] contamination,[39] and limited flow rate.[30]

Continuous-flow microfluidics

Continuous flow microfluidics rely on the control of a steady state liquid flow through narrow channels or porous media predominantly by accelerating or hindering fluid flow in capillary elements. In paper based microfluidics, capillary elements can be achieved through the simple variation of section geometry. In general, the actuation of liquid flow is implemented either by external pressure sources, external mechanical pumps, integrated mechanical micropumps, or by combinations of capillary forces and electrokinetic mechanisms.[40][41] Continuous-flow microfluidic operation is the mainstream approach because it is easy to implement and less sensitive to protein fouling problems. Continuous-flow devices are adequate for many well-defined and simple biochemical applications, and for certain tasks such as chemical separation, but they are less suitable for tasks requiring a high degree of flexibility or fluid manipulations. These closed-channel systems are inherently difficult to integrate and scale because the parameters that govern flow field vary along the flow path making the fluid flow at any one location dependent on the properties of the entire system. Permanently etched microstructures also lead to limited reconfigurability and poor fault tolerance capability. Computer-aided design automation approaches for continuous-flow microfluidics have been proposed in recent years to alleviate the design effort and to solve the scalability problems.[42]

Process monitoring capabilities in continuous-flow systems can be achieved with highly sensitive microfluidic flow sensors based on MEMS technology, which offers resolutions down to the nanoliter range.

Droplet-based microfluidics

File:Gas4psi LONDs26uLmin-1 50kfps x10lens.webm

High frame rate video showing microbubble pinch-off formation in a flow-focusing microfluidic device [43]

Main article: Droplet-based microfluidics

Droplet-based microfluidics is a subcategory of microfluidics in contrast with continuous microfluidics; droplet-based microfluidics manipulates discrete volumes of fluids in immiscible phases with low Reynolds number and laminar flow regimes. Interest in droplet-based microfluidics systems has been growing substantially in past decades. Microdroplets allow for handling miniature volumes (μl to fl) of fluids conveniently, provide better mixing, encapsulation, sorting, and sensing, and suit high throughput experiments.[19] Exploiting the benefits of droplet-based microfluidics efficiently requires a deep understanding of droplet generation [44] to perform various logical operations[45][46] such as droplet motion, droplet sorting, droplet merging, and droplet breakup.[47]

Digital microfluidics

Alternatives to the above closed-channel continuous-flow systems include novel open structures, where discrete, independently controllable droplets are manipulated on a substrate using electrowetting. Following the analogy of digital microelectronics, this approach is referred to as digital microfluidics. Le Pesant et al. pioneered the use of electrocapillary forces to move droplets on a digital track.[48] The "fluid transistor" pioneered by Cytonix[49] also played a role. The technology was subsequently commercialised by Duke University. By using discrete unit-volume droplets,[44] a microfluidic function can be reduced to a set of repeated basic operations, i.e., moving one unit of fluid over one unit of distance. This "digitisation" method facilitates the use of a hierarchical and cell-based approach for microfluidic biochip design. Therefore, digital microfluidics offers a flexible and scalable system architecture as well as high fault-tolerance capability. Moreover, because each droplet can be controlled independently, these systems also have dynamic reconfigurability, whereby groups of unit cells in a microfluidic array can be reconfigured to change their functionality during the concurrent execution of a set of bioassays. Although droplets are manipulated in confined microfluidic channels, since the control on droplets is not independent, it should not be confused as "digital microfluidics". One common actuation method for digital microfluidics is electrowetting-on-dielectric (EWOD). Many lab-on-a-chip applications have been demonstrated within the digital microfluidics paradigm using electrowetting. However, recently other techniques for droplet manipulation have also been demonstrated using magnetic force,[50] surface acoustic waves, optoelectrowetting, mechanical actuation,[51] etc.

Paper-based microfluidics

Main article: Paper-based microfluidics

Paper-based microfluidic devices fill a growing niche for portable, cheap, and user-friendly medical diagnostic systems.[52] Paper based microfluidics rely on the phenomenon of capillary penetration in porous media.[53] To tune fluid penetration in porous substrates such as paper in two and three dimensions, the pore structure, wettability and geometry of the microfluidic devices can be controlled while the viscosity and evaporation rate of the liquid play a further significant role. Many such devices feature hydrophobic barriers on hydrophilic paper that passively transport aqueous solutions to outlets where biological reactions take place.[54] Current applications include portable glucose detection[55] and environmental testing,[56] with hopes of reaching areas that lack advanced medical diagnostic tools.

DNA chips (microarrays)

Early biochips were based on the idea of a DNA microarray, e.g., the GeneChip DNAarray from Affymetrix, which is a piece of glass, plastic or silicon substrate, on which pieces of DNA (probes) are affixed in a microscopic array. Similar to a DNA microarray, a protein array is a miniature array where a multitude of different capture agents, most frequently monoclonal antibodies, are deposited on a chip surface; they are used to determine the presence and/or amount of proteins in biological samples, e.g., blood. A drawback of DNA and protein arrays is that they are neither reconfigurable nor scalable after manufacture. Digital microfluidics has been described as a means for carrying out Digital PCR.

Molecular biology

In addition to microarrays, biochips have been designed for two-dimensional electrophoresis,[57] transcriptome analysis,[58] and PCR amplification.[59] Other applications include various electrophoresis and liquid chromatography applications for proteins and DNA, cell separation, in particular, blood cell separation, protein analysis, cell manipulation and analysis including cell viability analysis [19] and microorganism capturing.[16]

Evolutionary biology

By combining microfluidics with landscape ecology and nanofluidics, a nano/micro fabricated fluidic landscape can be constructed by building local patches of bacterial habitat and connecting them by dispersal corridors. The resulting landscapes can be used as physical implementations of an adaptive landscape,[60] by generating a spatial mosaic of patches of opportunity distributed in space and time. The patchy nature of these fluidic landscapes allows for the study of adapting bacterial cells in a metapopulation system. The evolutionary ecology of these bacterial systems in these synthetic ecosystems allows for using biophysics to address questions in evolutionary biology.

Cell behavior

Main article: Microfluidic cell culture

The ability to create precise and carefully controlled chemoattractant gradients makes microfluidics the ideal tool to study motility [61], chemotaxis and the ability to evolve / develop resistance to antibiotics in small populations of microorganisms and in a short period of time. These microorganisms including bacteria [62] and the broad range of organisms that form the marine microbial loop,[63] responsible for regulating much of the oceans' biogeochemistry.

Microfluidics has also greatly aided the study of durotaxis by facilitating the creation of durotactic (stiffness) gradients.

Cellular biophysics

By rectifying the motion of individual swimming bacteria,[64] microfluidic structures can be used to extract mechanical motion from a population of motile bacterial cells.[65] This way, bacteria-powered rotors can be built.[66][67]

Optics

The merger of microfluidics and optics is typical known as optofluidics. Examples of optofluidic devices are tunable microlens arrays[68][69] and optofluidic microscopes.

Microfluidic flow enables fast sample throughput, automated imaging of large sample populations, as well as 3D capabilities.[70][71] or superresolution.[72]

Acoustic droplet ejection (ADE)

Acoustic droplet ejection uses a pulse of ultrasound to move low volumes of fluids (typically nanoliters or picoliters) without any physical contact. This technology focuses acoustic energy into a fluid sample to eject droplets as small as a millionth of a millionth of a litre (picoliter = 10−12 litre). ADE technology is a very gentle process, and it can be used to transfer proteins, high molecular weight DNA and live cells without damage or loss of viability. This feature makes the technology suitable for a wide variety of applications including proteomics and cell-based assays.

Fuel cells

Further information: Electroosmotic pump

Microfluidic fuel cells can use laminar flow to separate the fuel and its oxidant to control the interaction of the two fluids without the physical barrier that conventional fuel cells require.[73][74][75]

Astrobiology

To understand the prospects for life to exist elsewhere in the universe, astrobiologists are interested in measuring the chemical composition of extraplanetary bodies.[76] Because of their small size and wide-ranging functionality, microfluidic devices are uniquely suited for these remote sample analyses.[77][78][79] From an extraterrestrial sample, the organic content can be assessed using microchip capillary electrophoresis and selective fluorescent dyes.[80] These devices are capable of detecting amino acids,[81] peptides,[82] fatty acids,[83] and simple aldehydes, ketones,[84] and thiols.[85] These analyses coupled together could allow powerful detection of the key components of life, and hopefully inform our search for functioning extraterrestrial life.[86]

Future directions

Microfluidic drug assays:[87]

On-chip characterization:[88]
Microfluidics in the classroom: On-chip acid-base titrations[89]
Sepsis detection in minutes not days.
Unlocking multi-angle imaging for microfluidic devices [90]
See also
icon Biology portal
Technology portal
Advanced Simulation Library
Droplet-based microfluidics
Fluidics
Microphysiometry
Micropumps
Microvalves
Induced-charge electrokinetics
Lab-on-a-chip
μFluids@Home
Paper-based microfluidics
Microfluidic cell culture
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Education

Wikibooks has a book on the topic of: Microfluidics

M.Sc. Microfluidics : Concepts, Application and Innovation : http://microfluidics-master.fr in Paris (France)

Scholia has a topic profile for Microfluidics.

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Advanced Simulation Library - Wikipedia
https://en.wikipedia.org/wiki/Advanced_Simulation_Library

Advanced Simulation Library (ASL) is free and open-source hardware-accelerated multiphysics simulation platform. It enables users to write customized numerical solvers in C++ and deploy them on a variety of massively parallel architectures, ranging from inexpensive FPGAs, DSPs and GPUs[1] up to heterogeneous clusters and supercomputers. Its internal computational engine is written in OpenCL and utilizes matrix-free solution techniques.

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ASL - Download
http://asl.org.il/download/

Debian: libasl

Ubuntu – Package Search Results -- libasl-dev
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Tracks/Microfluidics - 2014.igem.org
http://2014.igem.org/Tracks/Microfluidics

Introduction to Microfluidics
Microfluidic, or “lab-on-a-chip” technology, is a maturing field of research involving miniaturized systems where fluids are manipulated on the scale of nanoliters and picoliters. With

microfluidics it is possible to perform high-throughput biological experiments integrating multiple functions in devices no larger than a postage stamp. Researchers have successfully miniaturized oligo synthesis1, gene2 and genetic circuit assembly3, along with cell culture4.

In this track, each team will receive an 8-channel, open-source microfluidic controller (Figure 1, right) along with silicon molds for fabricating a polydimethylsiloxane (PDMS)-based ring-mixer device for genetic circuit assembly (Figure 1, left). PDMS microfluidic devices, fabricated by multilayer soft lithography, enable thousands of flexible valves to be integrated into cm2 devices and allow users to carry out complex fluid operations such as the parallel compartmentalization of thousands of picoliter-scale volumes, pumping, and mixing5,6.

Microfluidics chip and schematic Microfluidics setup images
Figure 1 (left) A ring-mixer microfluidic device for genetic circuit assembly showing four device operations. Scale-bar represents 10 mm. (right) A 32-channel Arduino-based microfluidic controller. Students will receive an 8-channel version.
The controller can execute pneumatically-driven device operations comprising a full microfluidic genetic circuit assembly protocol (Figure 1, left) with the push of a button and does not require tethering with a computer for function. Solenoids for pneumatic manipulation are controlled by an open-source Arduino Mega microcontroller, and device operations, written in open-source software, Arduino Sketch, are customizable. A protocol for genetic circuit assembly will be pre-loaded into each controller.

Representatives from each team will be expected to attend a Tutorial Weekend at iGEM headquarters in April (exact date TBD) where instructors will show students how to fabricate their own devices, program the controller, and ultimately operate the devices and perform a genetic circuit assembly reaction.

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Droplet Generator - YouTube
https://www.youtube.com/watch?v=43k43kT5o4Y

Using air to create gaps between each sample.

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Microfluidics for the masses | MIT News
http://news.mit.edu/2017/open-source-microfluidics-0613

Microfluidics for the masses
New open-source website features blueprints for lab-on-a-chip devices.

Jennifer Chu | MIT News Office
June 13, 2017

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A new MIT-designed open-source website might well be the Pinterest of microfluidics. The site, Metafluidics.org, is a free repository of designs for lab-on-a-chip devices, submitted by all sorts of inventors, including trained scientists and engineers, hobbyists, students, and amateur makers. Users can browse the site for devices ranging from simple cell sorters and fluid mixers, to more complex chips that analyze ocular fluid and synthesize gene sequences.

The site also serves as a social platform for the microfluidics community: Any user can log in to submit a design; they can also like, comment on, and download design files to reproduce a featured device or improve on it.

David S. Kong, director of the MIT Media Lab's new Community Biotechnology Initiative, says the new site is designed to accelerate innovation in microfluidic design, which until now has followed a conventional, academically peer-reviewed route.

"There's a familiar experience for people in microfluidics: You see a really amazing paper that shows you a design, but if you want to try to copy the design, the actual design files that are a critical part of reproducing or remixing a device are not shared in any systematic way," Kong says. "As a result, researchers around the world are in parallel reinventing the wheel. It's one of the reasons why open-source in general is a very powerful set of principles. It can really accelerate the diffusion of technology."

Kong and his colleagues outlined the open-source platform in a paper published last week in the journal Nature Biotechnology. His co-authors are Todd Thorsen, Peter Carr, and Scott Wick of MIT's Lincoln Laboratory; Jonathan Babb and Jeremy Gam in the Department of Biological Engineering; and Ron Weiss, professor of biological engineering and of electrical engineering and computer science.

An open ecosystem

The researchers modeled their Metafluidics site after popular open-source repositories such as GitHub — a free site that hosts open-source software projects — and Thingiverse, a website that features hardware design files for user-created toys, gadgets, and robots.

Kong came up with the idea for Metafluidics as a synthetic biologist at Lincoln Laboratory, where he worked to combine DNA fragments to reprogram new functions into living cells. To do so, he regularly made use of DNA repositories such as the National Institutes of Health's GenBank — a publically available database through which scientists can share and access genetic sequences and their associated functions.

"There's been quite a bit of sharing of different types of information around synthetic biology," Kong observes. "So this kind of larger open-source movement in biotech is important, and we're hoping to fill this key part of the ecosystem that's specifically related to hardware."

Curating chips

The team worked with Bocoup, an open-source software consulting company, to design an open-source platform to share microfluidic designs. To access the free site, users fill out a brief profile to log in, after which they can browse through featured devices or search the site for specific microfluidic functions.

Each device uploaded to the site includes a brief description, along with a list of materials used to fabricate the chip, and its associated design files, such as computer-aided-design (CAD) drawings.

"Paper microfluidics, 3-D-printed and soft lithography chips, all these techniques require that digital design file," Kong says. "That's the key thing we're making available for the first time to the larger community."

The site is currently populated with designs submitted by students and hobbyists along with leading experts in the field such as Thorsen, who has contributed several previously published, highly cited devices and the blueprints to reproduce them.

"We're reaching out to major pioneers and leaders in the broader field and curating collections of their design files," Kong says. "Hopefully this will inspire people to make the next generation of [microfluidics] parts."

The site is managed by an editorial team, including Nina Wang, a rising sophomore in biological engineering at MIT, and Kong, who is working to build awareness of the site within the microfluidics community. Eventually, as people upload more devices, the team plans to highlight certain designs as, for example, a “Part of the Week.”

“Over time we also want to initiate challenges: Who can make the fastest particle sorter? Who can make devices that can culture a certain type of gut microbe?” Kong says. “My opinion is that innovation as a whole benefits when you have diverse communities involved and there’s a tremendous amount of openness.”

A microfluidics democracy

The researchers submitted a novel device to the site to demonstrate the open-source platform’s potential for use in synthetic biology. Using common microfluidic parts and an open-source controller, or valving system, the team designed a genetic circuit assembly device — a chip that automatically combines DNA fragments to form a new genetic sequence capable of performing a new function when embedded in a living cell.

“Our hope is, by demonstrating an application like DNA assembly with our open-source system, this will encourage others to reproduce our system and remix it for applications that are foundational to synthetic biology,” Kong says.

In the long view, he envisions the site will “democratize” microfluidics and illuminate new ideas from unexpected sources.

“We have a great mixture of parts, from the most advanced pioneers in the field, to students who are making microfluidics for the very first time,” Kong says. “There’s the potential for some obscure student from some other part of the world to develop a following, if the microfluidics community finds their part is interesting or cool.”

This research was supported, in part, by the Assistant Secretary of Defense for Research and Engineering, the National Institutes of Health, and the National Science Foundation.

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Team:EPF-Lausanne/Tools/Microfluidics/HowTo2 - 2011.igem.org
https://2011.igem.org/Team:EPF-Lausanne/Tools/Microfluidics/HowTo2

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Team:EPF-Lausanne/Tools/Microfluidics/HowTo2

Microfluidics How-To Part II: Building Your Setup

Microfluidics Main | How-To Part I | How-To Part II | Tamagotchip

A basic computer-controlled microfluidics setup. Note the compressed air input split into two sides, both fed through a pressure regulator. The left side is the low-pressure manifold for the flow layer. The right side is the high-pressure solenoid array for the control layer.
Microfludic chips are nothing but a piece of moulded rubber. To actually get something out of them, an external setup of tubing, compressed air, and valves is needed to flow in fluids and actuate the on-chip valves. To see what's happening, you'll also need some form of microscope. No matter the application of the chip, whether it is designed to study fluid mechanics, to characterise protein-DNA interaction, or even cultivate bacteria and nematodes, the external setup remains essentially the same.

Contents [hide]

A basic microfluidics control setup

Building the setup is relatively straightforward, once you have determined which components are needed and their purpose, and once you have collected the parts. Connecting the components is basic plumbing: just remember to wrap plumber's tape around all metallic screw threads, and then connect the pressure regulators in the correct orientation. With this in mind, we'll go through the parts of a microfluidics setup one by one, and from there you should be able to build your own.

Injecting fluids: compressed air and tubing, pressure regulators

Close-up of the flow-layer tube: connected to a manifold, and plugged into the chip using a tubular pin

A microfluidic chip is a network of small channels for fluids. To inject fluid in, a small (.02" inner diameter) tube is filled, then plugged into the chip through one of the punched holes (connecting them with a tubular metal pin). On the other end, the tubes are plugged into a manifold, in turn supplied with air at about 0.2 bar (3 psi), as set by a pressure regulator. The fluid is thus forced into the channels by the compressed air. A syringe can also be used to fill the chip, but it is hard to keep an even pressure (plus you quickly run out of hands).

Controlling flow: on-chip valves and 3-way valves.

Our chips have a second control layer above or below the main flow layer. The layers are separated by a thin membrane of PDMS, and their channels overlap in specific locations. When channels of the control layer are pressurized, the membrane bends into the flow layer and blocks it. This creates a microfluidic 'on-chip' valve.

Our array of solenoid valves, on a manifold. These allow individual pressurisation of on-chip valves of the control layer.
The channels of the control layer are filled in the same way as the flow layer, but require much higher pressure to bend the membrane. We typically used about 2 bar or 30 psi. Each independant valve in the control layer is pressurised by a different tube, regulated by a three-way valve. These switch between high pressure (from mains pressure, and the pressure regulator) to low pressure (atmospheric pressure), and hence allow quick toggling of the microfluidic valve between the open (unpressurised) and closed (pressurised) state. Three way valves come in manually- or electrically-controlled flavours. The manual kind is simpler and more reliable; we use them for the MITOMI chips. The electric kind (more specifically solenoid valves) we use for the web-controlled setup.

Watching what's going on: the microscope

Our toy microscope and light-table
In our experience, the best tool to look at a microfluidic chip is a low-magnification rear-illuminated binocular microscope. However, we needed a cheap way of viewing the chip on a computer, to then stream the image through internet. We used a toy webcam microscope ($50), and bought a toy light table for rear-illumination ($25). To improve stability and focusing, we fixed the microscope to a chemist's stand and placed the light table on a scissor jack.

Webcam microscope: Celestron Deluxe Handheld Digital Microscope
Light table: Artograph GLOBOX
Hooking it all up: preparing tubes and priming the chip
The presence of bubbles in a channel increases its fluidic resistance, and therefore perturbates or even blocks flow. To avoid this, the first step in running a chip is priming: filling all the channels with fluid, then closing all the micro-valves and keeping pressure applied, until any air remaining in the chip diffuses through the chip walls and disappears.

Once all the channels are filled, the experiments can begin. For the worm chip, we would prime the device with buffer, then introduce the worm after the chip is filled. For the MITOMI chip, we would flow in various biomolecules (neutravidin, bovine serum albumin, antibodies, cell-free extracts) and DNA.

Details of connections

Below are four images detailing how the tubing and electronics in our setup are connected, and the role of each component.

A printed circuit board (PCB) is used to connect the solenoid valves to the relays on the easyDAQ, and power them. The solenoids are connected to the PCB via two flat cables, one soldered to the red wires, one soldered to the black wires (they are 14-wire cables, with two wires removed). The other end of each cable is fitted with a 14-pin connector. The PCB is powered by a 24 V power supply, and distributes the power to each solenoid through the relays on the EasyDAQ. Therefore, when a relay is open, a 24 V load is applied to the corresponding solenoid (wich opens it). When the relay is closed, both leads of the solenoid are grounded (which closes it).

Annotated picture of the fluidics setup. The role of each component is explained. Not shown: since the picture was taken, manometers were added to the pressure regulators.

Close-up of the PCB that connects the valves to the EasyDAQ.

How the solenoids are switched between ground and 24 V by the relays. Only shown for four relays; our setup has twelve connected identically.

The EasyDAQ: 24 USB-controlled relays. The relays are connected to the PCB just by wires fixed in the screw-in headers.

Complete parts list

All the parts used for the pneumatics, with approximate cost in Swiss francs, are listed below. The microscope is an additional cost, but most labs would have one already. The Mac Pro is a lone from EPFL's Biomedical Imaging Group, and the Thinkpad is an oldie that was lying around.

Savings could be made on the pressure regulators, on the valves, and on the EasyDAQ - most setups are better off with manual valves anyway.

Part	Supplier	Qty	Unit cost [CHF]	Subtotal [CHF]
Pressure Regulator	Bellofram	2	186.00	372.00
Manometer 0 - 4.5 bar	Mosch	2	11.20	22.40
EasyDAQ USB24mx	EasyDAQ	1	230.00	230.00
12-Solenoid manifold (part S08-1557)	Pneumadyne	1	245.00	245.00
Luer barbed adapter, 1/16" (part EW-45503-00)	Cole-Parmer	1	9.20	9.20
Luer valve manifold (part EW-06464-87)	Cole-Parmer	1	10.30	10.30
Luer lock needles .6 mm ID, 12.7 mm length	Dosieren.net	100	0.28	28.00
Tygon .02" tubing, 100 ft	Cole-Parmer	1	50	50.00
PE Tubing (6 mm x 4 mm ODxID), 100 m	Serto	1	30	30.00
Push-to-connect fittings, for 6 mm OD (various)	Riegler	~10	[varies]	~15.00
Teflon tape, 6 mm	Serto	1	10.92	10.92
Total		1007.82		

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COOLEY's Manifold

Solenoid Valves - Rafael's Microfluidics Site
https://sites.google.com/site/rafaelsmicrofluidicspage/valve-controllers/solenoid-valves

Automated Valve Controllers >
Solenoid Valves
Disclaimer
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General Info
There are many different brands and models of solenoid valves to choose from, but here we list two kinds that have worked well for us. All the valves listed in this page operate at 24V DC.

At the end of this page, there is a section that explains how to connect any of the valve manifolds to the microfluidic chips.

3-Way or 2-Way?

For operating on-chip microfluidic valves, it is imperative that you always use 3-way solenoid valves that switch the on-chip valve between two pressures: Quake-style PDMS chips need the valves to switch between high pressure and atmospheric pressure, while other types of microfluidic valves (such as those developed by Prof. Mathies at UC Berkeley) might require high pressure and vacuum, or atmospheric pressure and vacuum. All the valves listed in this page are 3-way. Do NOT use 2-way valves for these types of microfluidic devices.

Normally Open of Normally Closed?

Normally open means that the valve has its output connected to the pressure line when the electrical power is off

Normally closed means that the valve has its output connected to the vent line when the electrical power is off

Selecting between normally open and normally closed solenoid valves depends on how you will use the chip.

If during an experiment the valves on the chip are closed most of the time, you should get the normally open solenoid valves

If during an experiment, the valves on the chip are open most of the time, you should get the normally closed solenoid valves

We always use normally open solenoid valves, regardless of the operation of the chips, because they automatically set the chip to a very safe all-valves-closed state if electrical power to the solenoids fails for some reason. And our experience is that most experiments will run with most on-chip valves closed most of the time.

Festo Valves

This is now our standard brand of valve, used for all experiments, in conjuction with the Wago controllers, because it has the following advantages over the Pneumadyne brand (see below), although it is a little bit more expensive:

Valves come with individual connectors even when they don't have a diode. This is very convenient when one wants to change a defective valve, since it doesn't require disconnecting any wires from the controller

Manifolds can be ordered fully assembled, including connectors for all ports

Valves have a nominal switching time of 4ms, so they can be operated at fairly high speeds

WARNING: These Festo valves can only be used with the high speed version of the USB-Based Controller or with the WAGO Controller. Do NOT use these valves with the regular speed USB Controller.

The standard 8-valve manifolds have the following part numbers, and can be bought from www.festo.com for approximately $490.00 each (as of August 2011).
Normally open: part# 197334, type MH1-A-24VDC-N-HC-8V-PR-K01-QM-AP-BP-CX-DX
Normally closed: part# 197334, type MH1-A-24VDC-C-HC-8V-PR-K01-QM-AP-BP-CX-DX
These part numbers correspond to manifolds that come with 1m long cables, 1/4" push-in connectors for the supply and exhaust ports, and 5/32" push-in connectors for the output ports ("working" ports in Festo's terminology), as shown in the following images. Each one of these solenoid valves consumes 0.042A.

These valves can be connected to the high speed USB-Based Controller using the same 10-pin, 0.1", female connector housing and female connector terminals listed in the parts lists for Pneumadyne Valves shown below. The assembly of this 10-pin connector can be seen in the USB-Based Controller page.
Pneumadyne Valves
We used this brand at the Quake Lab for a long time and it works very well, but they don't sell a model with a connector and no diode, so the diode-less valves would require disconnecting at the controller when changing a defective or damaged valve (a difficult thing to do with the USB controller, unless you manually put a connector on each valve). Additionally, they have switching times that are double that of the Festo valves (~8ms).

The following spreadsheet contains a list of the part numbers needed to build manifolds with Pneumadyne valves. If you will use these valves with the USB-Based Controller, you must select the type of valve corresponding to the controller you are building (low or high speed), and whether you want normally open or normally closed valves (all prices as of July 2011). The USB-Based Controller page explains how to wire the valves to connect them to the USB Controller using the 10-pin female connector listed below.

SMC Valves
In some countries it will be difficult to find the Festo or Pneumadyne valves, so an alternative supplier is SMC Corp. We have never used this brand of valves, but they should work fine. The SMC valve type most similar to the Festo or Penumadyne ones belongs to the SY100 series. The part numbers that would seem to work well are as follows:
Valves (base mounted, normally open, 24Vdc, plug connector with lead wire, with light/surge suppressor for use with the low speed USB controller): SY124-5MZ

Valves (base mounted, normally open, 24Vdc, NO light or surge suppressor for use with the high speed USB or WAGO controllers): SY124-5M
NOTE: For normally closed valves, change the SY124 to SY114 in the part number
8-valve manifold: SS3Y1-S41-08-M3
WARNING: We have never used these valves, so the part numbers above might not be totally accurate. We created the part numbers by looking at the SY100 series catalog. If you intend to buy these types of valves, please double check the part numbers in the catalog, which is available on-line.

You will need fittings with metric threads to connect these manifold to the chips (M3x0.5) and to the pressure source (M5x0.8). You can easily find metric fittings that are equivalent to those on the parts list for the Pneumadyne valves.

Connecting the Solenoid Valves to the Chips

The following parts are needed to connect the valve manifolds to the chips (the 1/4" tube is for connecting the manifold to the pressure source). All prices as of July 2011.

These part are used together as shown in the following picture (click on the image to enlarge):

Comments
You do not have permission to add comments.

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IMPORTANT

Fluidic Control Board | Soft Robotics Toolkit
https://softroboticstoolkit.com/book/control-board

Fluidic Control Board

The Soft Robotics Toolkit Control Board is an open source hardware platform that can be used to operate and control fluidic soft actuators, such as the PneuNets Bending Actuator or the Fiber-Reinforced Actuators described on this site. The purpose of the control board is to act as a prototyping and testing tool, and to provide students with a hands-on understanding of how to control fluid-operated soft robots. It also enables designers to quickly test the behavior of pneumatic soft actuators.

The board consists of a pump (which provides pressurized fluid to the system) and a set of solenoid valves (which can open and close to direct the flow of fluid in the system). The pressure in the system is regulated by Pulse-Width Modulation (PWM), which involves the controlled timing of the opening and closing of the valves. Pressure sensors provide feedback on the behavior of the system. The board can be controlled manually (by adjusting switches and knobs) or automated via software running on the included Arduino microcontroller.

This section of the website contains the files and instructions required to build your own control board for use with your own fluid-operated soft robots. To build the board all that is needed is some basic electronics skills (such as soldering two wires together). The bill of materials section provides the list of required components. Operating the board is relatively straightforward. We provide some example code that can be used to control the system, and provide guidelines on how to modify this code to suit your projects.

Bill of Materials | Soft Robotics Toolkit
https://softroboticstoolkit.com/book/controlboard-bom

Miniature Diaphragm Pneumatic Pump

Vendor link
Data sheet
Principle of operation (video)

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Diaphragm Pump Animation - YouTube
https://www.youtube.com/watch?v=Ljb7R09f-8k

How does a Diaphragm Pump work? View our animation to gain a better understanding of the Diaphragm Pump. Some facts about this pump: Gas transfer roughing pump Low to medium vacuum Want more vacuum? Visit us at www.precisionplus.com!

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Peristaltic Liquid Pump with Silicone Tubing - 5V to 6V DC Power ID: 3910 - $24.95 : Adafruit Industries, Unique & fun DIY electronics and kits
https://www.adafruit.com/product/3910

DESCRIPTION
Move fluid safely from here to there with this very nice Peristaltic Pump that works with 5V or 6V power. Unlike most liquid pumps, this is a peristaltic type - the pump squishes the silicone tubing that contains the liquid instead of impelling it directly. The upshot? The pump never touches the fluid which makes this an excellent choice for any food/drink/sterile-based pumping such as for making drink-bots or gardening robots!

The pump is basically a geared down DC motor, so it has a lot of torque. Inside the pump is a 'clover' pattern of rollers. As the motor turns, the clover presses on the tube to press the fluid though. The pump does not need to be primed and in fact can self-prime itself with water a half meter with ease. You can PWM the motor to speed up or slow down the flow rate and if you connect the motor the other way it will move fluid the other direction. Works great with either a power transistor (basic on/off) or a motor driver chip such as the L293D.

Also works with our Crickit for Circuit Playground Express! Use the crickit run motor blocks on Microsoft MakeCode, and you're off to a great start!

We've also got a version that works well with 12V DC power.

Please note: The pump comes with a bit of silicone tubing already installed with two half-meter tubes attached on with barbed connectors. However, the silicone tubing is not sterile and might be dirty on its way to you. Before using, the tubing must be sterilized! The included tubing is also not rated FDA or USDA compliant and is only meant for basic testing of the pump. If you need to purchase FDA/USDA compliant tubing for use with your food-hacking project, check out McMaster-Carr. They have many types of silicone tubing available by the foot! We also have a meter of silicone tubing you can pick up right now!

Wikipedia has a great article on peristaltic pumps. Please check it out for more details on how these devices work!

This embedded content is from a site (www.youtube.com) that does not comply with the Do Not Track (DNT) setting now enabled on your browser.

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TECHNICAL DETAILS
Working Temperature: 0℃ - 40℃
Motor voltage: 5 to 6 VDC
Motor current: 500mA
Flow rate: up to 100 mL/min
Weight: 104 grams
Dimensions: 27.8mm diameter motor, 66.8mm total length
Mounting holes: 3.7mm diameter, 50mm center-to-center distance
Tube length: approx 530mm / 20.8"
Tube diameters: inner diameter 3.5mm, outer diameter 5mm

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Guy uses K40 laser, then micro paint tubes

More on laser cutting microfluidics with K40 cutter - YouTube
https://www.youtube.com/watch?v=oo5FT5Ij7KE

Allen Lab Vlog #48 3/8/217 I'm still working on laser cutting microfluidics with the Chinese K40 laser cutter. We're getting closer.

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possible use of a shop sabre to cut small channels with tiny router bit and milling bit, mostly 2d

Acrylic Microfluidics Plate Milled on DATRON M8Cube - YouTube
https://www.youtube.com/watch?v=Xj1rk5xv8RE

Visit www.datron.com for more info. This is the seventh in our Short Video Series which is intended to give a good look at a machining application in under a minute or two. This video shows an acrylic microfluidics plate for the medical industry being machined on a DATRON M8Cube equipped with a vacuum chuck as workholding. The finished part is shown at the end. As will be the case with all of our Short Videos, the Application Notes for this exact part (milling strategies, feeds, speeds, and tools) are available on our website here:
https://bit.ly/2za59Ol

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COOLEY

Various microfluidics manufacturing method mainly from micro electronics manufacturing industry, such as chemical etching, photolithography, use of chemicals

Mod-01 Lec-24 Microfabrication Techniques - YouTube
https://www.youtube.com/watch?v=S-_KKiR_eYk

Microfluidics by Dr. Ashis Kumar Sen, Department of Mechanical Engineering, IITMadras. For more details on NPTEL visit http://nptel.iitm.ac.in

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COOLEY

drill press
epoxy
needle tip droppers

Easy, Quick Method for Making a Microfluidic Device - YouTube
https://www.youtube.com/watch?v=mjsFOSBFSG8

Using simple tools and a membrane cutter, we build a Y-shaped microfluidic device. The assembly takes about 10 minutes plus the drying time for epoxy glue. The channel volume in this example is about 22 uL. The device layout can be readily changed to fit your project. Detailed Publication with link: Q. Wang, M. R. Bentley, O. Steinbock, "Self-organization of Layered Inorganic Membranes in Microfluidic Devices", J. Phys. Chem. C 121, 14120, 2017 https://doi.org/10.1021/acs.jpcc.7b02778 Link to Silhouette Portrait 2 membrane cutter (~ $135):

Amazon.com: Silhouette Portrait 2 Electronic Cutting Tool
https://www.amazon.com/gp/product/B009GZUPFA

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Project Management
- Planning
- Meetings
- Administration

Project Requirements
- Plan Document
- Risk Matrix
- Severity vs. Likelihood
- Work Breakdown Structure (WBS)
- GANTT Chart

Process Selection
- Research
- Select 2

Process Testing
- Process 1 Testing
- Process 2 Testing

Machine
- Platform
- Hardware Selection
- Liquid Selection
- 3d Printing
- Electronics and Power
- Arduino Programming

Manufacturing Process
- Repeat-ability
- Reliability

Closure

Final Presentation
Manufacturing Process PFD
Drawing Package

3/8 All thread
3/8 Nuts
3/8 Smooth rod
3D Printer
3D Printer Filiment
80/20 T-slot Aluminum Building System
Acrylic of Various Sizes
Arduino Uno
Brass threaded connectors
B|Braun Extension Set with Female Luer Lock Connector and Spin-Lock Connector Length 21
Priming Volume 3 mL
CJ-B Weld Clear Weld 5 Min Professional Grade Epoxy
Calipers
FormLabs Clear Resin for Transparent Applications Clear Resin 1 L RS-F2-GPCL-04
Jumpers
Laptop
Laser Cutting Machine
LongRunner CNC Shield
Needle Tip Squeeze Bottle
NIPRO Disposable Syringe 30 mL
Nitrile Gloves
Safety Goggles
SCIGRIP Acrylic Solvent No. 3 Very Fast Set
Stepper Drivers
Tape Measure
USB Cord
USB Video Microscope
Wiring

Severity
Symptoms
Triggers

Responses

Risk Matrix

	Severity	Symptoms	Triggers	Responses
5 Certain				
4 Likely				
3 Possible				
2 Unlikely				
1 Rare				

Severity Risk Matrix

Symptom	Severity	Likelihood	Likelihood x Severity Rating
4 Catastrophic			
3 Critical			
2 Marginal			
1 Negligible			

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DIY Inline straight connector for aquarium air tube - YouTube
https://www.youtube.com/watch?v=9EdjmSJk1Vs

I've been using Whisper 10 1.5 watt air pump designed for aquariums up to 10 gallons. It worked well for many years. The ends of connected tubes wear out noticeably over time. Usually I cut off the loose part. It's an easy fix that can be repeated until you run out of tube to cut. An inline straight connector comes to mind. And you may find one amongst used pens and mechanical pencils. Look for a conical tipped pen with a smooth surface. The tube should fit tightly inside of the tip from the wide side of it. The tip of the pen should fit tightly inside of the tube. Keep in mind - it is not the most reliable connector! Nevertheless, it works in a pinch for low air pressure, when you are in rush to add air to your aquarium! It even works with a number of connectors on one tubing line. Here is an example where I use a straight connector on a tubing line between an air pressure valve and an air stone, Works like a charm. Have fun and happy aquarium :) Blog: http://rndmbits.blogspot.com/2017/01/... More fun on my website www.fewdoit.com Views as Money: https://www.youtube.com/watch?v=03hgI...

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#174: How to Save Money on Aquarium Airline Connectors - Tank Tip - YouTube
https://www.youtube.com/watch?v=sxglF6QZdzY

1/4 Drip Line Fittings found in your lawn and garden department work just as well on your 1/4 standard airline hose for your aquarium. They take a little more effort to get on, but at 1/3 the cost, I hope you agree it's a sweet little tip to save some money! Also, Petco is running it's $1/gallon sale, so go grab a tank or two before July 27th if you've been waiting. Do you own an aquarium? Would you like to help support this channel? Subscribe to My Aquarium Box to get the world's first subscription box for aquarium hobbyists delivered to your door once per month: http://www.myaquariumbox.com

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Top Ten Plumbing Fittings for Your Saltwater Aquarium Setup - YouTube
https://www.youtube.com/watch?v=wVFZtmXX6ck

http://www.bulkreefsupply.com/plumbin... BRStv's top ten plumbing fittings to help create a saltwater aquarium setup that is easy to maintain and clean. Here we go, starting with number 10 of our favorite plumbing fittings. 10. Uniseals are a cool product that allow you to add pipe to curved surfaces like the side of a 5 gallon bucket. Bulkheads are great for connecting fittings to flat surfaces but not great for curved surfaces. Drill a hole for the Uniseal's rubber fitting and insert your pipe. Then glue on your desired fitting or valve. 9. Loc-Line is a popular solution for returns because it is flexible and easy to attach to bulkheads on the back of the tank. Loc-line has a variety of nozzles, ball valves and check valves. 8. Silicone tubing is fairly expensive but when used for specific assemblies like connecting pumps and piping to hard surfaces - you can greatly reduce the noise and vibration transfer. 7. Street 45s and 90s. Street fittings fit directly into other fittings and valves and can reduce cutting a connecting piece. This helps you save on materials and the costs associated as well as the space from not using extra pieces. Additionally street fittings are more compact than standard elbow fittings. 6. Wye Check Valves prevent water from siphoning down the return line and overflowing your sump. They are more reliable than regular check valves because they are easily disassembled for cleaning and maintenance. 5. Diamond Coated Glass Drill Bits can make drilling a whole in your tank simple and worry free. Remember as long as the tank isn't too small, thin or made of tempered glass - anyone can do it. 4. Braided Vinyl Tubing differs from standard vinyl tubing in that it is stiffer and much harder to kink. By soaking the tubing in hot water, you can shape it to meet your needs. 3. Weld-On Solvents and Primers are great for folks who haven't had much experience with plumbing projects - it gives a little buffer. It is also a low volatile organice compound or VOC solvent which makes it safer to use. 2. High Quality Ball Valves like the true union Cepex ball valve are a great addition to your plumbing setup. The valves found at big box stores are impossible to turn. Cepex valves are easy to turn, remove or replace and you can tighten the seal on the ball which extends the life of the valve and reduces the need to cut it out or replace it. 1. Unions, Unions, Unions. We have been preaching for years the benefits of using as many unions in your aquarium plumbing setup as possible. Unions are a small fitting that allow you to easily unscrew and attach any fitting, valve or pump. Seriously, we recommend using unions wherever you can. So do you have experience with all these plumbing fittings? What plumbing fittings have worked well for you and your reef tank? Do you think you'll try something new from our list? *Legal Stuff* The purpose and content of this video is to provide general information regarding the products and their applications as presented in the video. Aquatic sales solutions, inc. And its officers, directors, employees and agents disclaim all express or implied warranties, in any way, related to the products and their application as presented in this video, make no representation or warranty regarding the products and the application as presented in this video and shall not be liable for any direct or indirect losses or damages of any type, including but not limited to punitive damages, or from personal injury or death resulting from or in any manner related to the video, and the products in and contents of the video. The viewer expressly agrees that aquatic sales solutions, inc. And its officers, directors, employees and agents shall not be liable for any damages or losses related to the products in and content of the video and hereby agrees to hold the foregoing harmless from any such losses or damages.

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Luer Fittings | Nordson MEDICAL
https://www.nordsonmedical.com/Components-and-Technologies/Fluid-Management-Components/Luer-Fittings/

Nordson MEDICAL offers designers worldwide the broadest selection of male luer and female luer fittings and connectors, luer adapters and luer accessories. Over 120 separate configurations are offered in nylon, polypropylene, polycarbonate and PVDF, with many color and special material options available from stock or upon special order. Our male and female luers are available with tubing connections that fit many tubing materials ranging from 1/16" (1.6 mm) to 1/4" (6.4 mm) IDs, with threaded ends and panel mount versions also available.

Nordson MEDICAL's luer fittings are part of a standardized system of small-scale tubing connectors used to make secure leak-proof unions in medical devices and laboratory instruments. The special 6% of a luer fitting provides a unique secure friction seal appropriate for gas and fluid connections. The Nordson MEDICAL barb (on luer fittings featuring a barbed tubing connection) has no parting lines on the barb to ensure a leak-free tubing union.

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What’s a Luer Lock? - Intertronics
https://www.intertronics.co.uk/2011/01/whats-a-luer-lock/

What’s a Luer Lock?
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adhere academyMost industrial dispensing systems rely on the Luer to fit dispensing needles, dispensing tips and other small fittings together. The Luer taper is a standardised (ISO 594) system for making leak-free connections between a male-taper fitting and its mating female part in the laboratory, industrial and medical world. Luer Slip fittings are simply held together by a friction fit; this is usually not recommended for industrial dispensing because it is not secure under pressure. Luer Lock fittings are more securely held because the hub of the female fitting (i.e. dispensing needle) has tabs or threads which screw into threads in a sleeve on the male part (dispensing barrel, dispensing syringe or dispensing valve).

All of our dispensing components rely on standard Luer Lock fittings, both for interchangeability and standardisation, and dispensing integrity and quality. Luer Slip and Luer Lock components are reasonably interchangeable. Some of our dispensing tips have more complex threads to keep them in place even when dispensing slippery customers like silicone oils.

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Micropump - Wikipedia
https://en.wikipedia.org/wiki/Micropump

Micropump
From Wikipedia, the free encyclopedia

Jump to navigationJump to search
File:TiCrPt micropump3.webm
A Ti-Cr-Pt tube (~40 μm long) releases oxygen bubbles when immersed in hydrogen peroxide (catalytic decomposition). Polystyrene spheres (1 μm diameter) were added to study the flow kinetics.[1]
File:Blood micropump.webm
Electrochemical micropump activating the flow of human blood through a 50×100 μm pipe.[2]
Micropumps are devices that can control and manipulate small fluid volumes.[3] Although any kind of small pump is often referred to as micropump, a more accurate definition restricts this term to pumps with functional dimensions in the micrometer range. Such pumps are of special interest in microfluidic research, and have become available for industrial product integration in recent years. Their miniaturized overall size, potential cost and improved dosing accuracy compared to existing miniature pumps fuel the growing interest for this innovative kind of pump.

Note that the below text is very incomplete in terms of providing a good overview of the different micropump types and applications, and therefore please refer to good review articles on the topic.[4][5][6]

Contents

Introduction and History

First true micropumps were reported in the mid-1970s,[7] but attracted interest only in the 1980s, when Jan Smits and Harald Van Lintel developed MEMS micropumps.[8] Most of the fundamental MEMS micropump work was done in the 1990s. More recently, efforts have been made to design non-mechanical micropumps that are functional in remote locations due to their non-dependence on external power.

A diagram showing how three microvalves in series can be used to displace fluid. In step (A), fluid is pulled from the inlet into the first valve. Steps (B) - (E) move the fluid to the final valve, before the fluid is expelled towards the outlet in step (F).

Types and Technology

Within the microfluidic world, physical laws change their appearance.[9] As an example, volumetric forces, such as weight or inertia, often become negligible, whereas surface forces can dominate fluidical behaviour, especially when gas inclusion in liquids is present. With only a few exceptions, micropumps rely on micro-actuation principles, which can reasonably be scaled up only to a certain size.

Micropumps can be grouped into mechanical and non-mechanical devices.[10] Mechanical systems contain moving parts, which are usually actuation and microvalve membranes or flaps. The driving force can be generated by utilizing piezoelectric, electrostatic, thermo-pneumatic, pneumatic or magnetic effects. Non-mechanical pumps function with electro-hydrodynamic, electro-osmotic, electrochemical [11] or ultrasonic flow generation, just to name a few of the actuation mechanisms that are currently studied.

Mechanical Micropumps

Diaphragm Micropumps

A diaphragm micropump uses the repeated actuation of a diaphragm to drive a fluid. The membrane is positioned above a main pump valve, which is centered between inlet and outlet microvalves. When the membrane is deflected upwards through some driving force, fluid is pulled into the inlet valve into the main pump valve. The membrane is then lowered, expelling the fluid through the outlet valve. This process is repeated to pump fluid continuously.[5]

Piezoelectric Micropumps

Piezoelectric micropump is one of the most common type of displacement reciprocating diaphragm pumps. Piezoelectric driven micropumps rely on electromechanical property of piezo ceramic to deform in response to applied voltage. Piezoelectric disk attached to the membrane causes diaphragm deflection driven by the external axial electric field thus expanding and contracting the chamber of the micropump[12]. This mechanical strain results in pressure variation in the chamber, which causes inflow and outflow of the fluid. The flow rate is controlled by the polarization limit of the material and the voltage applied on the piezo[13]. In comparison with other actuation principles piezoelectric actuation enables high stroke volume, high actuation force and fast mechanical response, though requiring comparatively high actuation voltage and complex mounting procedure of the piezo ceramic[8].

The smallest piezoelectric micropump with dimensions of 3.5x3.5x0.6 mm3 was developed by Fraunhofer EMFT[14] the world-renowned research organization with focus on MEMS and Microsystem technologies. The micropump consists of three silicon layers, one of which as a pump diaphragm confines the pump chamber from above, while two others represent middle valve chip and bottom valve chip. Openings of the passive flap valves at the inlet and outlet are oriented according to the flow direction. The pump diaphragm expands with application of a negative voltage to the piezo thus creating negative pressure to suck the fluid into the pump chamber. While positive voltage vice versa drives the diaphragm down, which results in overpressure opening outlet valve and forcing the fluid out of the chamber.

Openings of the passive flap valves at the inlet and outlet are oriented according to the flow direction. The pump diaphragm expands with application of a negative voltage to the piezo thus creating negative pressure to suck the fluid into the pump chamber in supply mode. While positive voltage drives the diaphragm down, which results in opening outlet valve due to overpressure in pump mode
Currently mechanical micropump technology extensively uses Silicon and Glass based micromachining processes for fabrication. Among the common microfabrication processes, the following techniques can be named: photolithography, anisotropic etching, surface micromachining and bulk micromachining of silicon[13]. Silicon micromachining has numerous advantages that facilitate the technology widespread in high performance applications as, for example, in drug delivery[8]. Thus, silicon micromachining allows high geometric precision and long-term stability, since mechanically moving parts, e.g. valve flaps, do not exhibit wear and fatigue. As an alternative to silicon polymer-based materials like PDMS, PMMA, PLLA, etc. can be used due to the superior strength, enhanced structural properties, stability and inexpensiveness. Silicon micropumps at Fraunhofer EMFT are manufactured by silicon micromachining technology[15]. Three monocrystalline silicon wafers (100 oriented) are structured by doublesided lithography and etched by silicon wet etching (using potassium hydroxide solution KOH). The connection between the structured wafer layers is realized by silicon fusion bond. This bonding technology needs very smooth surfaces (roughness lower than 0:3 nm) and very high temperatures (up to 1100o C) to perform a direct silicon–silicon bond between the wafer layers. Absence of the bonding layer allows definition of the vertical pump design parameters. Additionally, the bonding layer might be affected by the pumped medium.

The compression ratio of the micropump as one of the critical performance indicator is defined as the ratio between the stroke volume, i.e. fluid volume displaced by the pump membrane over the course of the pump cycle, and the dead volume, i.e. the minimum fluid volume remaining in the pump chamber in pumping mode [12].

{\textstyle \varepsilon =\bigtriangleup V/V_{0}}{\textstyle \varepsilon =\bigtriangleup V/V_{0}}

The compression ratio defines the bubble tolerance and the counter pressure capability of the micropumps. Gas bubbles within chamber hinder micropump operation as due to the damping properties of the gas bubbles the pressure peaks (ΔP) in the pump chamber decreases, while due to the surface properties the critical pressure (ΔPcrit) that opens passive valves increases[16]. The compression ratio of Fraunhofer EMFT micropumps reaches the value of 1, which implies self-priming capability and bubble tolerance even at challenging outlet pressure conditions. Large compression ratio is achieved thanks to special patented technique of piezo mounting, when electrical voltage is applied on the electrodes on the top and bottom of the piezoelectric ceramic during the curing process of the adhesive used for the piezo mounting. Considerable reduction of the dead volume resulted from predeflected actuators along with shallow fabricated pump chamber heights increases the compression ratio.

Peristaltic Micropumps

A peristaltic micropump is a micropump composed of at least three microvalves in series. These three valves are opened and closed sequentially in order to pull fluid from the inlet to the outlet in a process known as peristalsis.[17]

Non-Mechanical Micropumps

Valveless Micropumps

Static valves are defined as valves which have fixed geometry without any moving parts. These valves provide flow rectification through addition of energy (active) or inducing desired flow behavior by fluid inertia (passive). Two most common types of static geometry passive valves are Diffuser-Nozzle Elements [18][19] and Tesla valves. Micropumps having nozzle-diffuser elements as flow rectification device are commonly known as Valveless Micropumps.

Capillary Pumps

In microfluidics, capillary pumping plays an important role because the pumping action does not require external actuation power. Glass capillaries and porous media, including nitrocellulose paper and synthetic paper,[20] can be integrated into microfluidic chips. Capillary pumping is widely used in lateral flow testing. Recently, novel capillary pumps, with a constant pumping flow rate independent of the liquid viscosity and surface energy,[21][22][23][24] were developed, which have a significant advantage over the traditional capillary pump (of which the flow behaviour is Washburn behaviour, namely the flow rate is not constant) because their performance does not depend on the sample viscosity.

Chemically Powered Pumps

Chemically powered non-mechanical pumps have been fabricated by affixing nanomotors to surfaces, driving fluid flow through chemical reactions. A wide variety of pumping systems exist including biological enzyme based pumps,[25][26][27][28][29][30] organic photocatalyst pumps,[31] and metal catalyst pumps.[28][32] These pumps generate flow through a number of different mechanisms including self-diffusiophoresis, electrophoresis, bubble propulsion and the generation of density gradients.[26][29][33] Moreover, these chemically powered micropumps can be used as sensors for the detection of toxic agents.[27][34]

Light Powered Pumps

Another class of non-mechanical pumping is light-powered pumping.[35][36] Certain nanoparticles are able to convert light from a UV source to heat which generates convective pumping. These kinds of pumps are possible with titanium dioxide nanoparticles and the speed of pumping can be controlled by both the intensity of the light source and the concentration of particles.[37]

Applications

Micropumps have potential industrial applications, such as delivery of small amounts of glue during manufacturing processes, and biomedical applications, including portable or implanted drug delivery devices. Bio-inspired applications include a flexible electromagnetic micropump using magnetorheological elastomer to replace lymphatic vessels.[38] Chemically powered micropumps also demonstrate potential for applications in chemical sensing in terms of detecting chemical warfare agents and environmental hazards, such as mercury and cyanide.[27]

Considering contemporary state of air pollution one of the most promising applications for micropump lies in enhancement of gas and particulate matter sensors for monitoring personal air quality. Thanks to MEMS fabrication technology, gas sensors based on MOS, NDIR, electrochemical principles could be miniaturized to fit portable devices as well as smartphones and wearables. Application of the Fraunhofer EMFT piezoelectric micropump reduces reaction time of the sensor up to 2 seconds through fast sampling of the ambient air[39]. This is explained by the fast convection that takes place when micropump drives the air towards the sensor, while in absence of the micropump due to slow diffusion sensor response is delayed for several minutes. The current alternative to the micropump – the fan – has numerous drawbacks. Unable to achieve substantial negative pressure fan cannot overcome pressure drop at the filter diaphragm. Further, the gas molecules and particles can easily re-adhere to the sensor surface and its housing, which in time results in sensor drift.

Additionally inbuilt micropump facilitates sensor regeneration and thus resolves saturation issues by expelling gas molecules out of the sensor surface. Breath analysis is related field of use for the gas sensor that is empowered by micropump. Micropump can advance remote diagnostic and monitoring of gastrointestinal tract and pulmonary diseases, diabetes, cancer etc. by means of portable devices within telemedicine programs.

The promising application for MEMS micropumps lies in drug delivery systems for diabetes-, tumor-, hormone-, pain and ocular therapy in forms of ultra-thin patches, targeted delivery within implantable systems or intelligent pills. Piezoelectric MEMS micropumps can replace traditional peristaltic or syringe pumps for intravenous, subcutaneous, arterial, ocular drug injection. Drug delivery application does not require high flow rates, however, the micropumps are supposed to be precise in delivering small doses and demonstrate back pressure independent flow[40]. Due to biocompatibility and miniature size, silicon piezoelectric micropump can be implanted on the eyeball to treat glaucoma or phthisis. Since under these conditions the eye loses its ability to ensure outflow or production of aqueous humour, the implanted micropump developed by Fraunhofer EMFT with the flow rate of 30 μl/s facilitates proper flow of the fluid without restricting or creating any inconvenience to the patient[41]. Another health issue to be solved by micropump is bladder incontinence. Artificial sphincter technology based on the titanium micropump ensures continence by automatically adjusting the pressure during laughter or coughing. The urethra is opened and closed by means of a fluid-filled sleeve that is regulated by the micropump[42].

Micropump can facilitate scent scenario for consumer, medical, defense, first responder applications etc to enhance the effect of with ubiquitous picture scenarios (movies) and sound scenarios (music). Microdosing device with several scent reservoirs that are mounted near the nose can release 15 different scent impressions in 1 min[15]. Advantage of the micropump lies in the possibility to smell sequence of scents without different odors being mixed. The system ensures an appropriate dose of the scent to be detected by the user only as soon as scent molecules are delivered. Numerous applications are possible with micropump for scent-dosing: tasters training (wine, food), learning programs, psychotherapy, anosmia treatment, first responder training etc. to facilitate full immersion in the desired environment.

Within analytical systems, the micropump can be for lab-on-chip applications, HPLC and Gas Chromatography systems etc. For the latter micropumps are required to ensure accurate delivery and flow of gases. Since the compressibility of the gases is challenging, the micropump must possess high compression ratio[40].

Among other applications, the following fields can be named: dosage systems for small quantity of lubricants, fuel dosing systems, micro pneumatics, micro hydraulic systems and dosage systems in production processes, liquid handling (cushion pipettes, microliter plates)[43].

See also
Electroosmotic pump
Glossary of fuel cell terms
Impedance pump
microvalve
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Wikimedia Commons has media related to Micropumps.
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Integrated Control of Microfluidics – Application in Fluid Routing, Sensor Synchronization, and Real-Time Feedback Control | IntechOpen
https://www.intechopen.com/books/advances-in-microfluidics-new-applications-in-biology-energy-and-materials-sciences/integrated-control-of-microfluidics-application-in-fluid-routing-sensor-synchronization-and-real-tim

research summarizing various electronic control for microfluidics

microfluidics control technologies and propose a microprocessor-based unit that unifies them

3.1. Dropbot: Integrated control for digital microfluidics platforms
As was described above, a control of a digital-microfluidic device is based on activate/deactivate electrodes, which were patterned on the device for the direct manipulation of droplets with no need of actuating mechanical valves nor pressure sources and pumps. In 2013, Fobel and colleagues introduced the design of an open-source control and automation system termed DropBot, which enables manipulation of drop’s position and velocity by driving up to 320 independent electrodes [40]. The DropBot is based on an Arduino microcontroller board and is consists of a high-voltage amplifier, high-voltage driver boards, a webcam, and a PC. The system

continuously monitors the amplifier output and device impedance to maintain a stable actuation voltage and to track the position and velocity of drops.

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Microfluidics: A general overview of microfluidics - Elveflow
https://www.elveflow.com/microfluidic-reviews/general-microfluidics/a-general-overview-of-microfluidics/

Direct writing for microfluidics

Laser PHOTOABLATION in microfluidics
Photoablation for microfluidics allows to shape microfluidic channels by eliminating material from a thin layer of thermoplastic substrate with a forceful pulsed laser light.

In photoablation, tiny volumes of material absorb a pinnacle of laser energy. This assimilation initiates tough electronic transitions that induce a shock wave in the substrate which engenders bond breaking in the polymer chain. The decomposed molecular fragments then expand in a plasma plume that clears thermal energy away from the workpiece, forming a precise photoablated cavity. The depth and width of the channels are determined by the laser energy and by the repetition frequency of the pulse applied along the same channel.

Photoablation can be performed by exposing the substrate with a mask delineating the zone to be ablated, or by using a direct-write without mask.

Photoablation can be used with almost any material. It allow to produce very sharp features and creative patterns in a short time even though they can sometimes be hard to reproduce. However particles residues can be hard to remove, causing contamination and lack of reliability of the final device. Hence, photoablation cannot be exercised in any type of environment. Besides, the cost of the device can substantially vary depending on the type of laser used and the choice of the photoablating technique. Another drawback is that photoablation produces rather large channels and low resolution.

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Microfluidic tools for cell biological research
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2998071/

basic concepts and methodologies in designing microfluidic devices, and their diverse cell biological applications

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Microfluidic Fabrication - Y-Prize Tech Overview - YouTube
https://www.youtube.com/watch?v=TuKcFtKfyrY

need people to live on the microfabrication scale to encapsulate medicine in microdrops

Advanced medicine often depends on delivering a very precise dose of a drug to a very precise location in the body. The technology already exists for creating extremely small, precisely-sized nanoparticles of liquid, but to put these tiny droplets to any practical use, scientists have to be able to manufacture a lot of them efficiently. Penn researchers are now developing a new technique to expand the production of nanoparticles to an industrial scale. Although this technology is being developed for purposes of medical treatments, potential applications include agriculture, cosmetics, and more.

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3D Printed Microfluidics For Stem Cell Encapsulation - YouTube
https://www.youtube.com/watch?v=rD-9oBYG9rc

3d printing microfluidics devices

with paper

Simple and Versatile 3D Printed Microfluidics Using Fused Filament Fabrication
https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0152023

Simple 3D printing will open up microfluidics to a wider audience. Read the paper: http://journals.plos.org/plosone/arti... (open access) Microfluidics allows for the precise manipulation of fluids on the small scale. For many years it has been hailed as a technology capable of revolutionising research in the chemical and biological communities. High equipment costs and specialised skill requirements have created a fabrication barrier that has been a key factor in limiting the uptake of microfluidics in laboratories where it could be most beneficial. The use of relatively cheap and simple 3D printers to fabricate microfluidic devices using widely available materials could open up the possibilities of microfluidics to the wider scientific community allowing devices to be easily shared and created. Working in the laboratories of Prof David Barrow and Dr Oliver Castell at Cardiff University, Dr Alex Morgan (post-doctoral scientist in microfluidics and synthetic biology) has been able to print plug-and-play modules for the creation of reconfigurable microfluidic systems. Optimisation of printing conditions and materials enables the printing of transparent devices for visualisation of fluid flow or fluorescent imaging. Droplet microfluidics makes use of the difference in fluid behaviour on the small scale, where surface and viscous forces dominate. Many small droplets of water in oil can be produced at a rapid rate with great regularity. Microdroplets are useful for miniaturisation of chemical reaction and rapid, high-throughput experimentation. In collaboration with our colleagues Prof. Phil Stephens and Prof. Bing Song, we show the potential use of droplet microfluidics to encapsulate stem cells in droplet capsules. This technology enables scientists to culture cells in three-dimensional structures and create synthetic materials both supporting and protecting encapsulated cells. Such technology is expected to find use in regenerative medicine and tissue repair. Read more about this research: http://journals.plos.org/plosone/arti... (open access) Oliver Castell: https://www.cardiff.ac.uk/people/view... David Barrow: https://www.engin.cf.ac.uk/whoswho/pr... Phil Stephens: https://www.cardiff.ac.uk/people/view... Bing Song: http://www.cardiff.ac.uk/people/view/...

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https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0152023

ultimaker 2 3d printer peek pla oil water droplets red dye food coloring 800 um and 500 um with 50 um resolution

Microfluidics exploits the unique behaviour of fluids on the micro-scale where surface and viscous forces dominate over gravity and inertia, giving rise to laminar flow in single phase systems, and reproducible and programmable droplet flow in multiphase systems [5].

5.Sackmann EK, Fulton AL, Beebe DJ. The present and future role of microfluidics in biomedical research. Nature. 2014;507(7491):181–9. pmid:24622198

These advantageous fluid dynamics have been used in diverse fields with applications in cell encapsulation [6], DNA analysis [7, 8], drug prototyping [9], high throughput screening [10, 11], cell and droplet sorting and separation [12–15], chemical synthesis [16], chemical separations [17] radiopharmaceutical production [18], proteomics [19] and diagnostic technologies [20] amongst others.

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Bioprinting 101: How to make Microfluidic Chips - YouTube
https://www.youtube.com/watch?v=dxz10In1774

special bio printer, syringe squirts water soluable material, then cast in pdms, mold removed then mounted, with ports

Order your biokits: se3d.com/biokits Sign up for our free webinars: se3d.com/webinars Follow us on Linkedin for news and resources in bioprinting https://www.linkedin.com/company/se3d/ -- Student In STEM Ria Bhatia demonstrates how you can create a pH gradient generator chip using microfluidics. Through this experiment, you will familiarize yourself with TinkerCad, a widely used 3D modelling software. Additionally, you will learn about microfluidics, which deal with the flow of liquids inside micrometer-sized channels, and receive an introduction to flow concepts, such as laminar flow. Throughout this project, you will also learn about acid-base reactions, which are indicators of pH value, and technical skills, such as ImageJ and Excel analysis.

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Lab 6B: PDMS Microfluidics: Preparing a Test Pattern - YouTube
https://www.youtube.com/watch?v=zKm3A6dIXpg

pdms slide corona

MIT 6.S079 Nanomaker, Spring 2013 View the complete course: http://ocw.mit.edu/6-S079S13 Instructors: Dr. Katey Lo, Dr. Joseph Summers, Prof. Vladimir Bulovic This video is a tutorial of preparing a test pattern through a process of curing the PDMS, opening the microfluidic inlet and outlet ports, cleaning the PDMS, bonding it to glass, and using corona treatment. License: Creative Commons BY-NC-SA More information at http://ocw.mit.edu/terms More courses at http://ocw.mit.edu

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Lab 6B: PDMS Microfluidics: Preparing a Test Pattern - YouTube https://www.youtube.com/watch?v=zKm3A6dIXpg

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Microfluidic systems materials and fabrication 2 - YouTube
https://www.youtube.com/watch?v=CC2oibyDGBk

teacher talking about course on different ways to make microfluidic devices, inkjet printing mold making

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Silicone Devices: DIY Fabrication of Self-Contained Multi-Layered Soft Circuits using Microfluidics - YouTube
https://www.youtube.com/watch?v=cM10uk1EPEA

stretcy silicon electronics microfluidics vinyl squeezed layer height laser cutter

Project page: http://www.raframakers.net/wiki/Main/... Silicone Devices are self-contained and thus embed components for input, output, processing, and power. Our approach scales to arbitrary complex devices as it supports techniques to make multi-layered stretchable circuits and buried VIAs. Additionally, high-frequency signals are supported as our circuits consist of liquid metal and are therefore highly conductive and durable. To enable makers and interaction designers to prototype a wide variety of Silicone Devices, we also contribute a stretchable sensor toolkit, consisting of touch, proximity, sliding, pressure, and strain sensors. We demonstrate the versatility and novel opportunities of our technique by prototyping various samples and exploring their use cases. Strain tests report on the reliability of our circuits and preliminary user feedback reports on the user-experience of our workflow by non-engineers.

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Fabrico™, A Division of EIS - Medical Microfluidic Laser Fabrication - YouTube https://www.youtube.com/watch?v=ji32urfesZg

laser cutting, unknown material

Fabrico™, A Division of EIS - Medical Microfluidic Laser Fabrication Fabrico Medical's advanced laser system accurately cuts very small features and intricate designs on a broad range of flexible materials. Fabrico Medical design engineers utilize our state-of-the-art digital laser technologies to build highly precise microfluidic devices. Fabrico™, A Division of EIS - http://www.fabrico.com/ Medical Applications - http://www.fabrico.com/resources/reso... Contact Us - http://www.fabrico.com/contact-us

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Rapid prototyping of microfluidics device using epoxy mold - YouTube
https://www.youtube.com/watch?v=DaisC0XNzWQ

transparency material hand cut pdms

This video is visual representation of my work during summer internship at Centre for Nanoscience and engineering(CeNSE),indian institute of science,Bangalore,India under the guidance of Dr. Manoj Verma and Mentor Praneet Prakash. This video describes rapid prototyping of microfluidic device using epoxy mold. These epoxy molds can be obtained from readily available material and require less time than preparing standard photo resist mold from photolithography. These molds are also durable and reusable. Channels can be obtained from these mold in PDMS as per widely known method with slight modification in curing conditions. Resolution up to 1 mm is possible with hand cutting and further resolution and elaborate design may be obtained from computerized cutting

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PDMS Isopropanol Microfluidics - YouTube
https://www.youtube.com/watch?v=HGpeCObiePI

pdms leaking

Full procedure can be found at: http://education.mrsec.wisc.edu/282.htm Microfluidics deals with the precise control of fluids on the microscale. Often at the microscale, less reagents are used resulting in faster and less expensive laboratories. In this experiment, a fluidic channel is created by casting the PDMS on a master made with puffy paint. PDMS is cured by an organometallic crosslinking reaction to give an optically transparent polymer. Different colored isopropanol is dispensed into the channels to observe fluid mixing.

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Kizoa Movie - Video - Slideshow Maker: Microfluidic device fabrication - YouTube
https://www.youtube.com/watch?v=0mYwT23Zei0

looked like was of somesort and pdms mold

Microfluidic device fabrication with ESCARGOT methodology from V. Saggiomo and A. H. Velders (“Simple 3D printed scaffold-removal method for the fabrication of intricate microfluidic devices,” Adv. Sci., vol. 2, p. 1500125, 2015). Kizoa Movie - Video - Slideshow Maker - http://www.kizoa.com

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3D Printed Microfluidic Channels - YouTube
https://www.youtube.com/watch?v=STa2C05va94

galium channels with cnc then pdms then heat up or use voltage to remove galium

Visit www.nano.gov/NanoFilmPublicVoting to view other movies from the Nano Film (www.nano.gov/VideoContest) contest and vote for your favorite. This work demonstrates a simple method to fabricate 3D microchannels and microvasculature at room temperature by direct-writing liquid metal as a sacrificial template. The printed structures can be embedded in a variety of soft (e.g. elastomeric) and rigid (e.g. thermoset) polymers. Whereas conventional fabrication procedures typically confine microchannels to 2D planes, the geometry of the printed microchannels can be varied from a simple 2D network to complex 3D architectures without using lithography. The method produces robust monolithic structures without the need for any bonding or assembling techniques that often limit the materials of construction of conventional microchannels. Removing select portions of the metal leaves behind 3D metal features that can be used as antennas, interconnects, or electrodes for interfacing with lab-on-a-chip devices. This mechanism allows the rapid prototyping and development of personalized healthcare sensors that can be embedded in consumer-targeted wearable bio-monitoring devices. Dishit Parekh Advisor: Michael D. Dickey Department of Chemical and Biomolecular Engineering North Carolina State University, Raleigh, NC Laboratory website: www.che.ncsu.edu/dickeygroup/index.php

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About the NNI | Nano
https://www.nano.gov/node/7

Nanotechnology-Inspired Grand Challenges | Nano
https://www.nano.gov/grandchallenges

A Nanotechnology-Inspired Grand Challenge for Future Computing:

Create a new type of computer that can proactively interpret and learn from data, solve unfamiliar problems using what it has learned, and operate with the energy efficiency of the human brain.

digital picture of 1's and 0's meant to represent computing architechture
This challenge will look beyond conventional computing based on the Von Neumann architecture.
While it continues to be a national priority to advance conventional digital computing—which has been the engine of the information technology revolution—current technology falls far short of the human brain in terms of both the brain's sensing and problem-solving abilities and its low power consumption. Many experts predict that fundamental physical limitations will prevent transistor technology from ever matching these twin characteristics. This grand challenge will bring together scientists and engineers from many disciplines to look beyond the decades-old approach to computing based on the Von Neumann architecture as implemented with transistor-based processors, and chart a new path that will continue the rapid pace of innovation beyond the next decade.

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Ultrafast PMMA cutting and bonding for Microfluidics application - YouTube
https://www.youtube.com/watch?v=JzdkNnLQzMU

Full article and details available: http://link.springer.com/article/10.1... Droplet chip: https://youtu.be/fCbCrNbyxWo

Safe and cost-effective rapid-prototyping of multilayer PMMA microfluidic devices | SpringerLink
https://link.springer.com/article/10.1007/s10404-016-1823-1

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#IMPORTANT

Bill Hammack
engineerguy

The Engineering of Droplets and their Formation in a Commercial Inkjet Printer - YouTube
https://www.youtube.com/watch?v=-DckWNwE7R4

Bill describes how the minimization of surface area and inertia compete to form droplets. He then shows how engineers use this knowledge to create precisely-sized droplets in a commercial inkjet printer -- the type used to print expiration dates on food packages.

To understand how engineer's control drop size let's start with this toy, which shows the essentials of drop formation.

0:34
In it a narrow stream of liquid, called a "jet" flows from the opening and then becomes circular as it flows toward the bottom of the toy.

0:39
As you can see here the droplets are typially the same size.

0:42
This toy motivates the key scientific question: Why does a droplet form at all?

0:48
Why doesn't a get go forever without breaking up?

0:51
To answer that question I've put a small hole in this cup and will fill it with a 50/50 mixture by volume of water and glycerol, dyed green.

1:01
Glycerol is highly viscous, meaning informally that it is a "thick" liquid, so it will slow the flow and the formation of drops.

1:08
You see a smooth jet exits, but as it travels farther from the cup, the stream gets fuzzy which you can see better in close up. Let's slow this to see what occurs.

1:17
You see the smooth jet at the top, then as the stream descends, droplets forming, the fuzziness earlier.

1:25
Notice that just as the liquid exists it forms a uniform cylinder, but as it descends the cylinder's sides "wobble", which increases in intensity so that bulges form and disappear until this instability, this wobble, slices the jet into drops.

3,000 frames per second

1:38
The instability is caused by a liquid's tendency to minimize it's surface area, a tendency toward the most thermodynamically stable state.

For this jetting liquid that would be a sphere rather than a cylinder.

The surface area to volue ratio of a sphere is doubled that of an optimized cylinder with the same radius.

Cylinder = r * 2r
Sphere = 2πr * 2r = 4πr^2

1:55
The instability forms quickly: Look at the liquid exiting the cup.

1:59
I said it was uniform, but you can now see that the "wobbling" begins soon after exiting.

2:05
The flickering is the wobble, seen better if I zoom in and add guidelines, why though, doesn't the cylindrical jet immediately become a sphere?

2:14

That's because the minimization of the surface area competes with another tendency: inertia.

2:20
To see that look at one of the bulges that forms and disappears: these are, of course, failed attempts by the liquid to form a sphere.

2:27
Notice what must happen for a sphere (a droplet) to form: some liquid must travel in the opposite direction of the stream's flow.

freeze frame

see 3:03

```
| | | <-- jet's direction of flow
|  v  |    high pressure at constriction
|     |
|  o  |
| oOo |
|oOOOo|
|OOOOO| <-- bulge here
| oOo |     low pressure, liquid flows from high to low
|     |    pressure
|     |
|  ^  | <-- to create a drop some liquid must flow up
| | |     high pressure at constriction
```

2:34
But this flow is opposed by interia, as defined by Newton's First Law: an object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted on by an unbalanced force.

Newton's First Law

Ab oject at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction, unless acted on by an unbalanced force.

2:49

So, the flowing liquid keeps flowing downward pulled by gravity, until the minimization of surface area forces some liquid to move up by creating these bulges: upward flow occurs because at the ends of the bulge, where the steam is constricted, the pressure is higher than in the iddle, so liquid flows toward the middle.

3:06
Although these bulges are large here, recall that "wobbling" near the top: each wobble moves a bit of liquid up, increases as the stream descends.

3:16
Until eventually, as we see at the bottom of the stream, the surface area wins and droplets form.

3:20
The "wobble" observed at the top of the stream suggests how engineers can create precisely sized drops.

3:26
To create a stream with uniform drops that appear immediately we need to vibrate the stream at a frequency near that of the "wobble".

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Cylinder = r * 2r
Sphere = 2πr * 2r = 4πr^2

But why is a sphere's surface area four times its shadow? - YouTube
https://www.youtube.com/watch?v=GNcFjFmqEc8

The formula is no mere coincidence. Store: http://3b1b.co/store Home page: https://www.3blue1brown.com Special thanks: http://3b1b.co/sphere-thanks Discussion on Reddit: https://www.reddit.com/r/3Blue1Brown/... The first proof goes back to Greek times, due to Archimedes, who was charmed by the fact that a sphere has 2/3 the volume of a cylinder encompassing it, and 2/3 the surface area as well (if you consider the caps). Check out this video for another beautiful animation of that first proof: https://youtu.be/KZJw0AYn6_k Calculus series: http://3b1b.co/calculus Thanks to these folks for letting me use their images at the end: https://www.youtube.com/user/vlogbrot... https://www.youtube.com/user/physicsw... https://www.youtube.com/user/Vsauce https://www.youtube.com/user/onemeeel... ------------------ These animations are largely made using manim, a scrappy open source python library: https://github.com/3b1b/manim If you want to check it out, I feel compelled to warn you that it's not the most well-documented tool, and it has many other quirks you might expect in a library someone wrote with only their own use in mind. Music by Vincent Rubinetti. Download the music on Bandcamp: https://vincerubinetti.bandcamp.com/a... Stream the music on Spotify: https://open.spotify.com/album/1dVyjw... If you want to contribute translated subtitles or to help review those that have already been made by others and need approval, you can click the gear icon in the video and go to subtitles/cc, then "add subtitles/cc". I really appreciate those who do this, as it helps make the lessons accessible to more people. ------------------ 3blue1brown is a channel about animating math, in all senses of the word animate. And you know the drill with YouTube, if you want to stay posted on new videos, subscribe: http://3b1b.co/subscribe Various social media stuffs: Website: https://www.3blue1brown.com Twitter: https://twitter.com/3blue1brown Reddit: https://www.reddit.com/r/3blue1brown Instagram: https://www.instagram.com/3blue1brown... Patreon: https://patreon.com/3blue1brown Facebook: https://www.facebook.com/3blue1brown

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#IMPORTANT

Shrinking microbubbles with microfluidics: mathematical modelling to control microbubble sizes - Soft Matter (RSC Publishing)
https://pubs.rsc.org/en/content/articlelanding/2017/sm/c7sm01418j#!divAbstract

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#IMPORTANT

Microfluidic Production of Microbubbles | University of Virginia School of Engineering and Applied Science
https://engineering.virginia.edu/hossack-lab/research/microfluidic-production-microbubbles

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#IMPORTANT

(PDF) Multi-Layer Microbubbles by Microfluidics
https://www.researchgate.net/publication/270780256_Multi-Layer_Microbubbles_by_Microfluidics

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electrostatic to control drops

Toyota Develops New Paint Atomizer with Over 95 percent Coating Efficiency, Highest in the World | Corporate | Global Newsroom | Toyota Motor Corporation Official Global Website https://global.toyota/en/newsroom/corporate/31587468.html