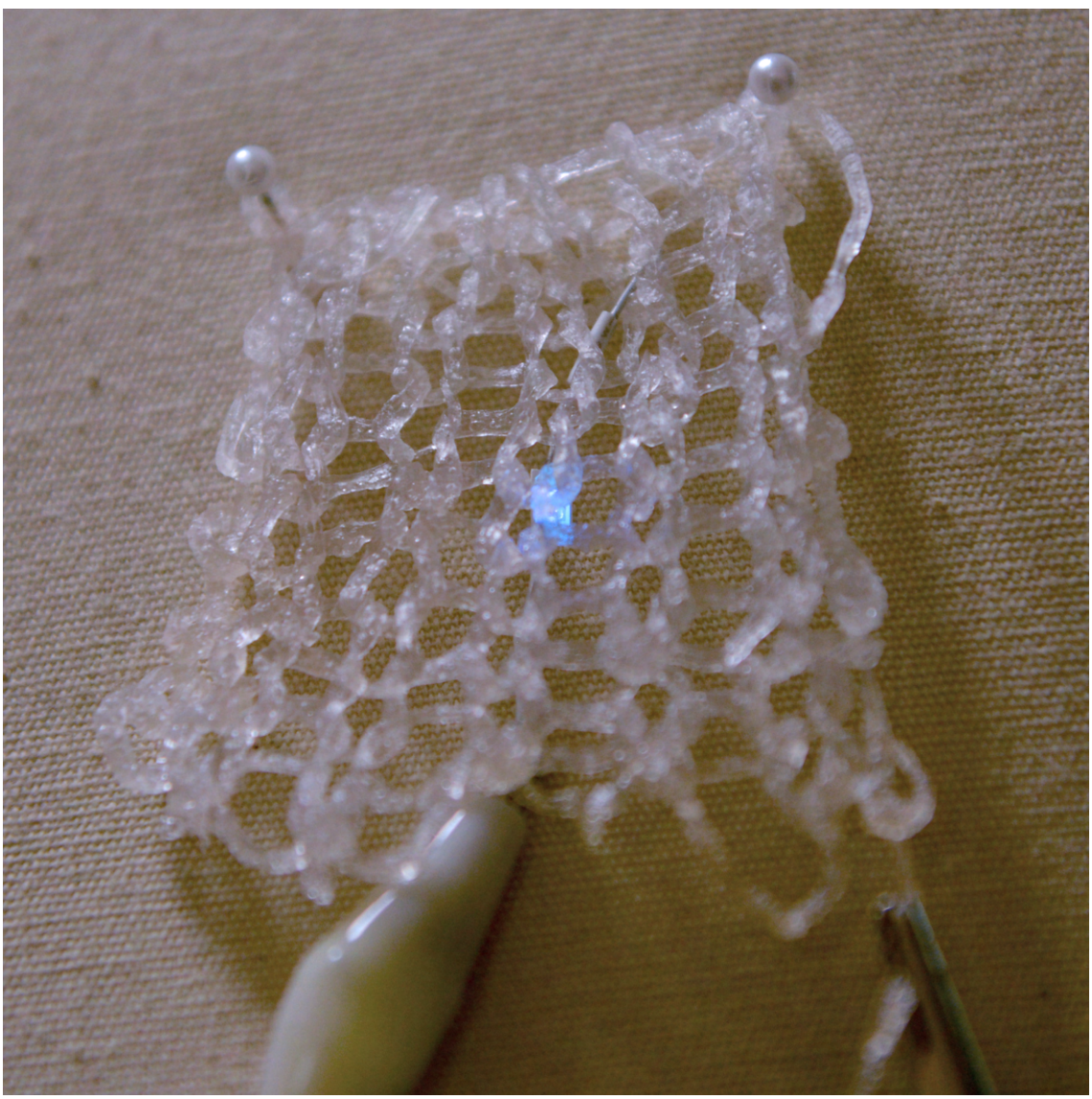
Exploration: Conductive Bioplastic Yarn

Statement of purpose:
I wanted to explore conductivities in bioplastic yarn. After some preliminary research and advised by Professor Heard, I decided to make colored conductive bioplastic yarn. I found a recipe of making bioplastic yarn using sodium alginate. I also saw some tutorials on making conductive bioplastic by adding carbon powder. I planned to combine the techniques.

I had some **expectations** before starting the experiments:

- From the images in the sodium alginate conductive yarn material, the yarn looked very thick and flexible, so I thought that making thin yarns would be a challenge.
- From the conductive bioplastic tutorial, the conductivity seemed really good, so I thought adding conductive powders would allow making conductive bioplastic easily.



Week 1.

3.30.21 preliminary material research

Stage 3

Colored

??? Mixing colored powder with conductive powder?

Most conductive powder is black/copper/silver.

Stage 2

Conductive

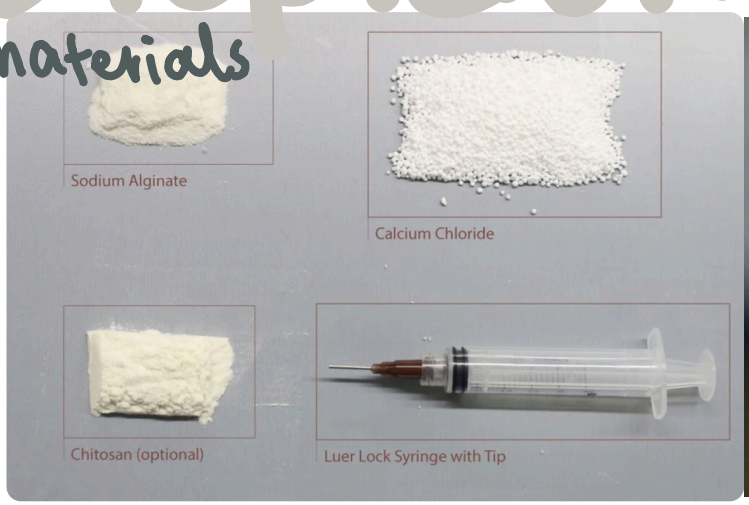
Conductive metal powder.

Most metallic powder used for paint & makeup is not conductive. Copper powder seems to be the first material to try from

Stage 1

Bioplastic Yarn

materials



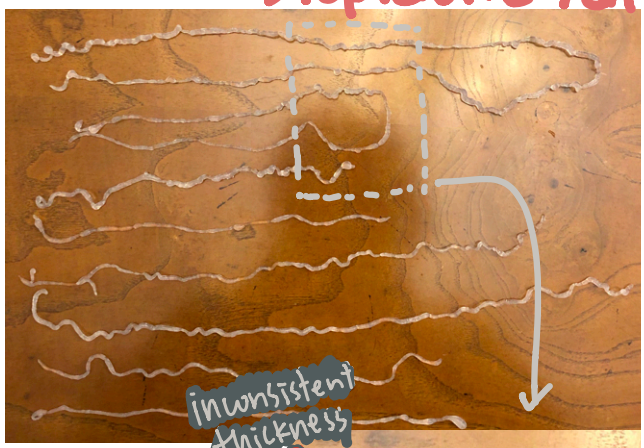
recipe found at instructables.com/Create-Bio-yarn

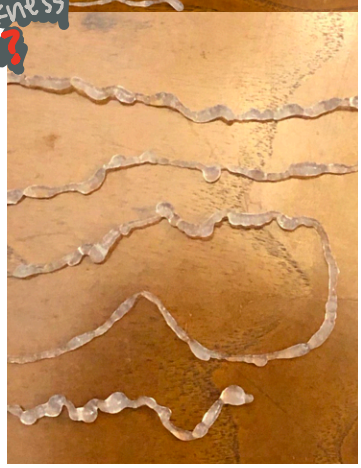
Week 2

4.6.21 first batch of bioplastic yarn

Colored Conductive Bioplastic Yarn

15% Calcium chloride bath →





knitted using a toy knitting machine ↓

← knitted piece

shrinked after dried →

Next week objective:

Try chitosan and different percentage of sodium alginate.

Try producing yarn with more consistent width.

Week 3

4.13.21 bioplastic yarns of different compositions

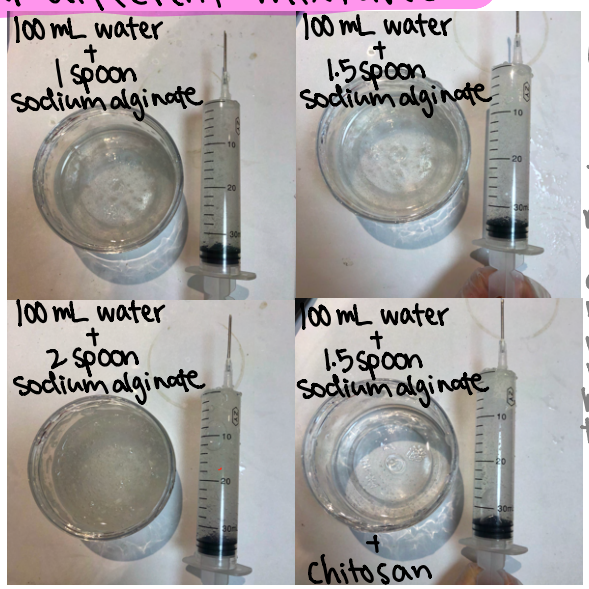
Colored Conductive

Bioplastic Yarn

Extruding methods:

- tip above water
- stationary while extruding
- tip underwater
- move while extruding

Experimented with four different mixtures:

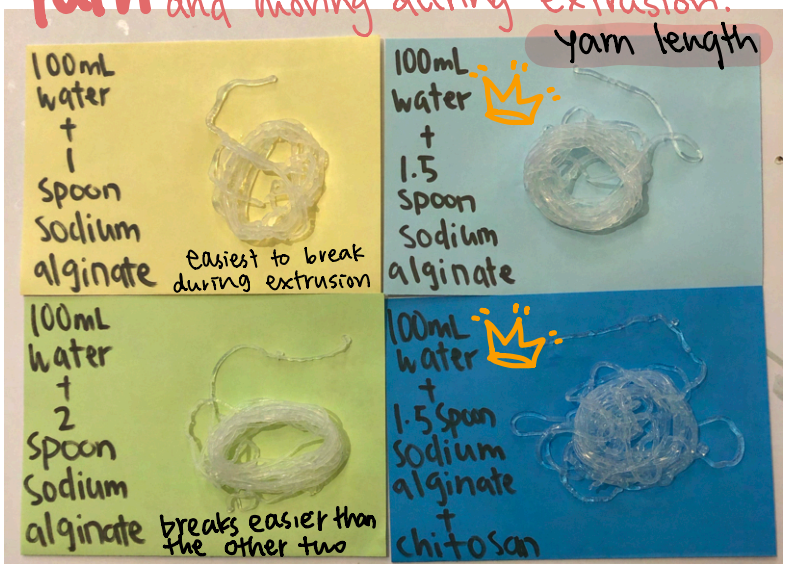


these two mixtures look clearer because warmer water has used to dilute

Results:

Yarn

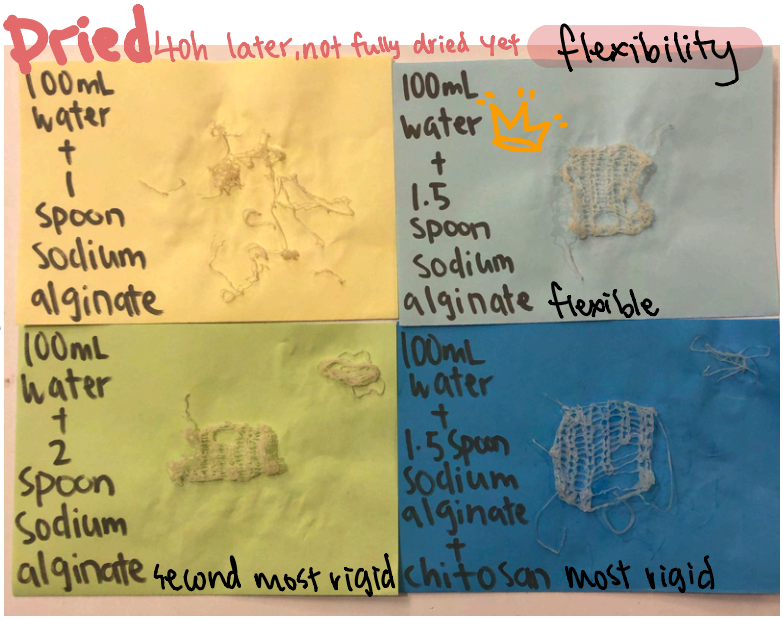
All created with tip underwater and moving during extrusion.



Knitted

Dried

40h later, not fully dried yet



Conclusion:

We rank the importance of the three properties for the purpose:

flexibility > endurance > yarn length

Thus, 100mL water + 1.5 spoon sodium alginate has the best performance. To address the endurance issue, start knitting later and let it dry for a longer period of time should make improvements.

Next week Objective:

Conductive!

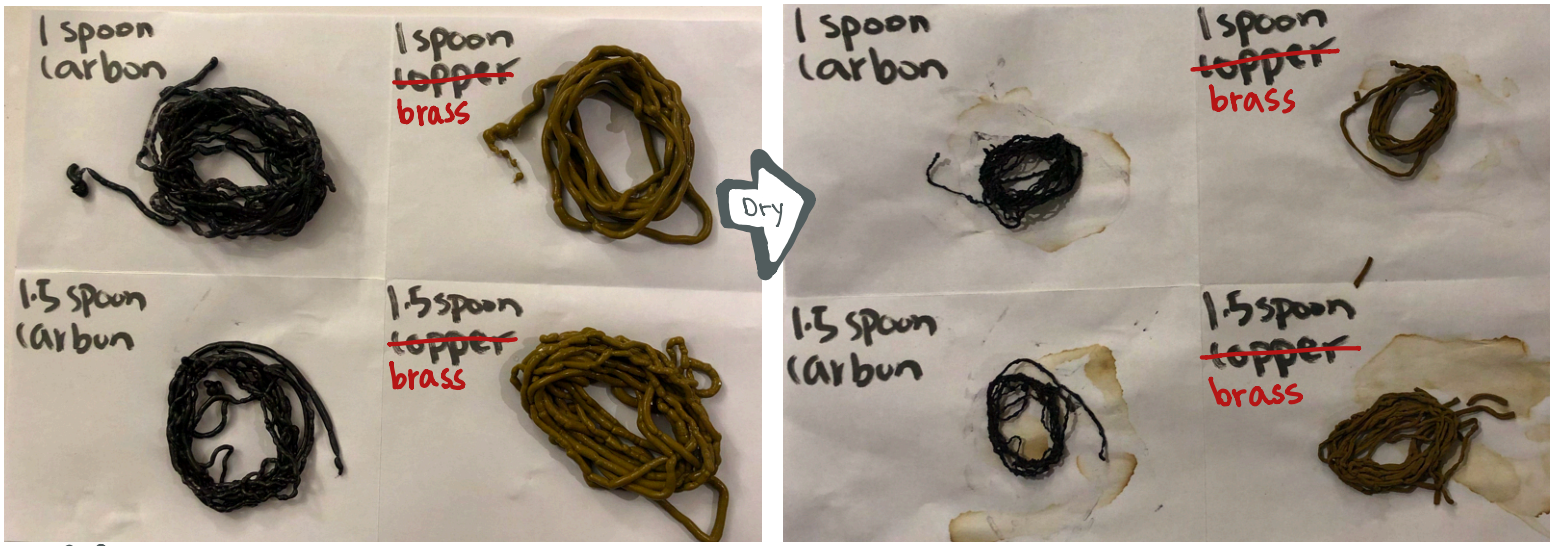
Week 4

4.24.21 bioplastic yarns of different compositions

Colored Conductive Bioplastic Yarn

Recipe:
100mL water
+ Sodium alginate
+ conductive powder

! What I realized after the experiments: I bought brass powder instead of copper powder.



Differences in making:

* Carbon yarn **thinner** than brass yarn. Brass yarn is **thicker** than pure sodium alginate yarn.
  - carbon particles are smaller. carbon can be used as lubricants.
* Carbon yarn **floats** in water with similiar behavior as pure sodium alginate yarn. Brass yarn **sinks**.
  - brass is heavier than carbon.

Differences after dried:

* Carbon yarn is more **elastic** than brass yarn. Brass yarn breaks easily.
  - Was not able to compare with pure sodium alginate yarn. But carbon powder has a clear advantage!
* Carbon yarn is more **conductive** with the same volume added as brass yarn.
  - Concerned with the **large resistance** value. Maybe make resistive yarn instead of conductive yarn? Copper powder instead of brass powder could improve conductivity. Also considering that glycerin might be added for better elasticity, it might also worsen the conductivity.

Resistance

suspect this is caused by not having enough carbon powder added

carbon powder	1.5 spoon carbon	1spoon carbon
0.006MΩ/cm	1.36MΩ/cm	NA
brass powder	1.5 spoon brass	1spoon brass
NA	3.2 MΩ/cm	6.6MΩ/cm

not sure why I couldn't get a resistance value

Next week objective:

* try higher carbon powder composition
* try glycerin for elasticity

Week 5

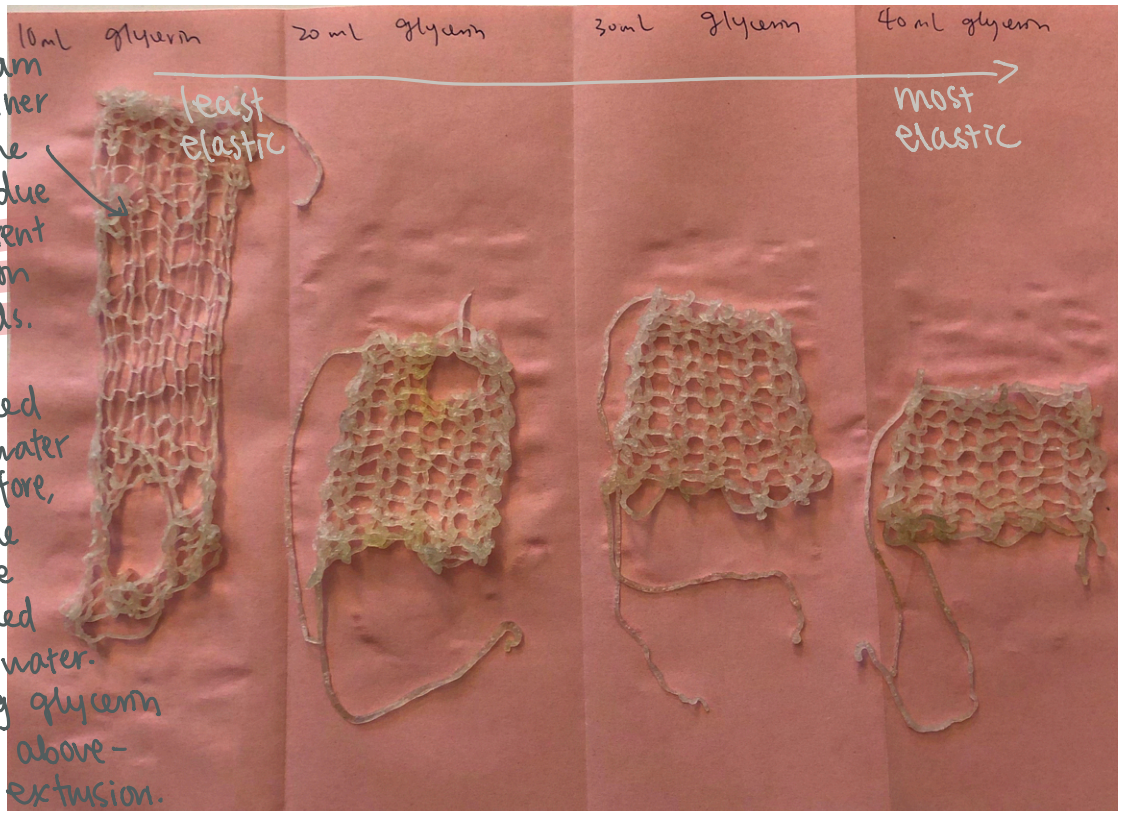
4.30.21 | bioplastic carbon yarn

Colored Conductive Bioplastic Yarn

Added glycerin for elasticity

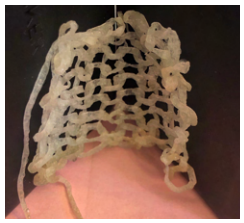
Success!

100mL water + 1.5 spoon of sodium alginate + glycerin specified



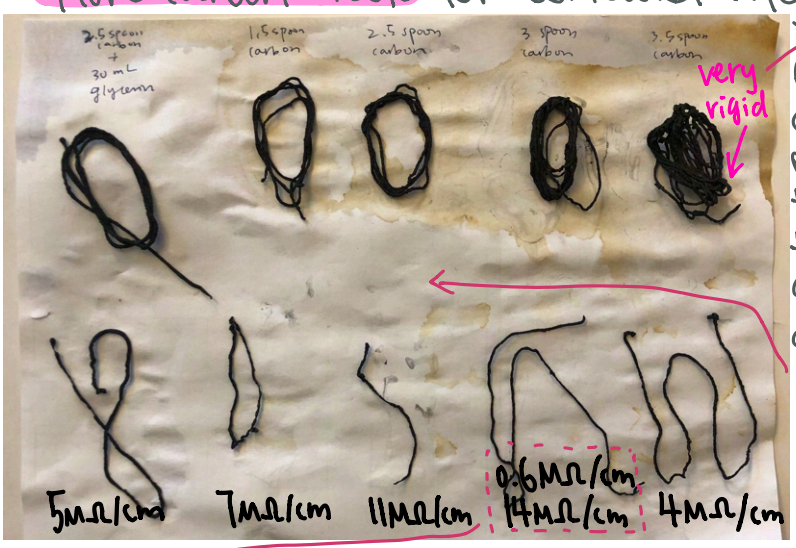
This yarn is thinner than the others due to different extrusion methods. This is extruded underwater like before, and the rest are extruded above water. Adding glycerin allows above-water extrusion.

All samples were able to fold.



Observation As little as adding only 10mL glycerin, the yarn becomes so much more elastic. It still breaks when pulled really hard but the behavior is getting much closer to normal yarn. Without glycerin, the knitting must be done before fully dried, but with glycerin, I think manipulations can be done even after dried.

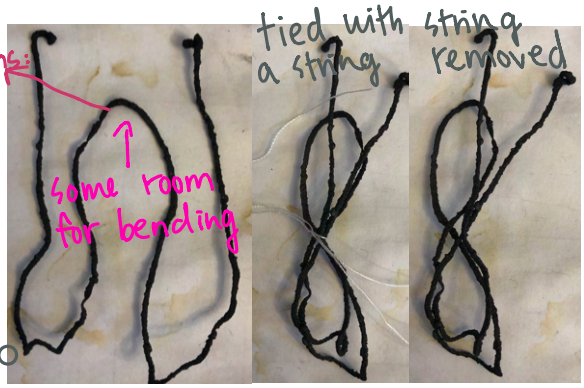
More carbon tests for conductivity



observations:

very rigid

Carbon does add some elasticity to the yarn that has good plastic deformation.



observations: Adding more carbon powder does increase conductivity.

Observations: Resistance values along the yarn are far from consistent because the liquid was not perfectly mixed before extrusion.

Next Week Objectives:

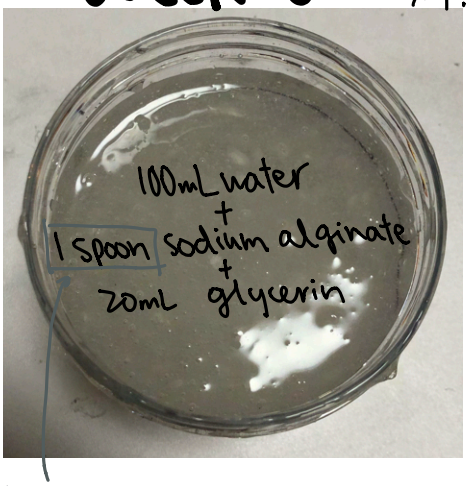
- Light up an LED!
- Remeasure carbon powder resistance
- Try making more uniformly conductive yarn

Week 6

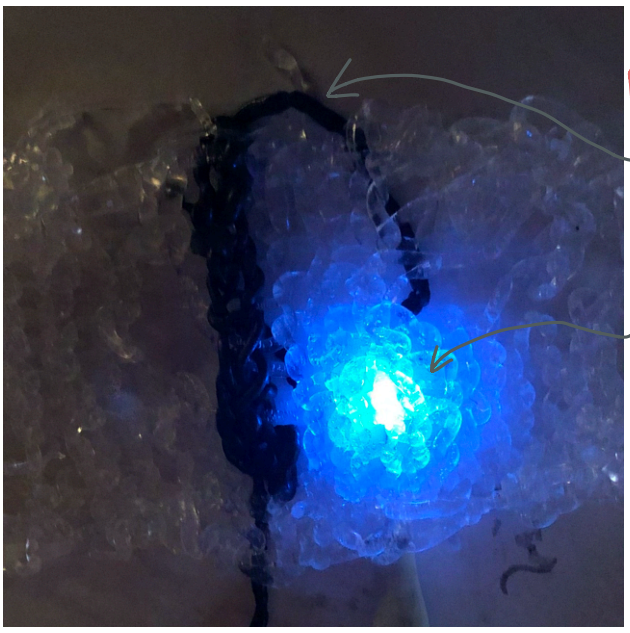
5.4.21

Light up an LED!

Colored Conductive Bioplastic Yarn

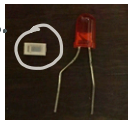


1 spoon instead of the usual 1.5 spoon to try if conductivity could be improved. This was a mistake because although yarn diameter increased, it broke too easily during the knitting process.



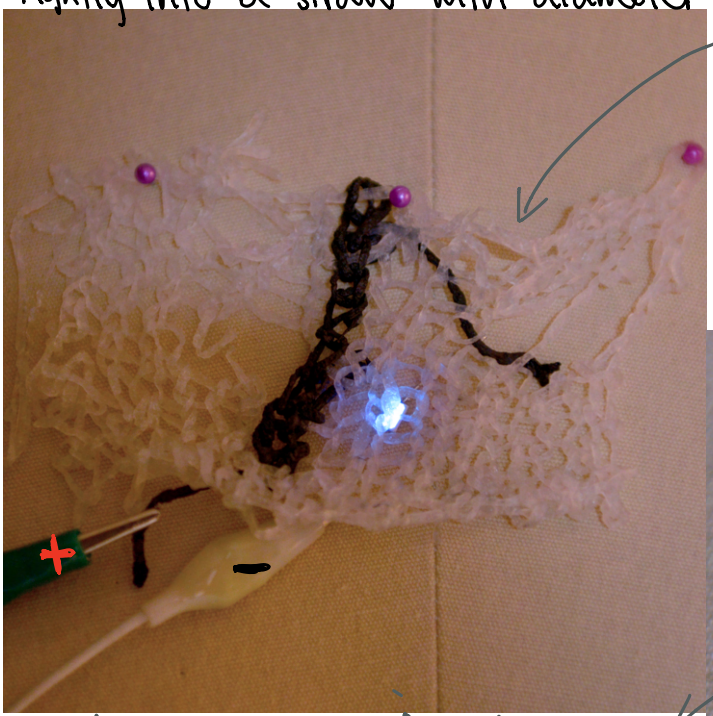
'conductive yarn' has 5 spoons of carbon powder.

0.2W 60MA 2.0-2.2V LED used instead of the more commonly used 1.8-2.2V 20mA LEDs for brighter lights.

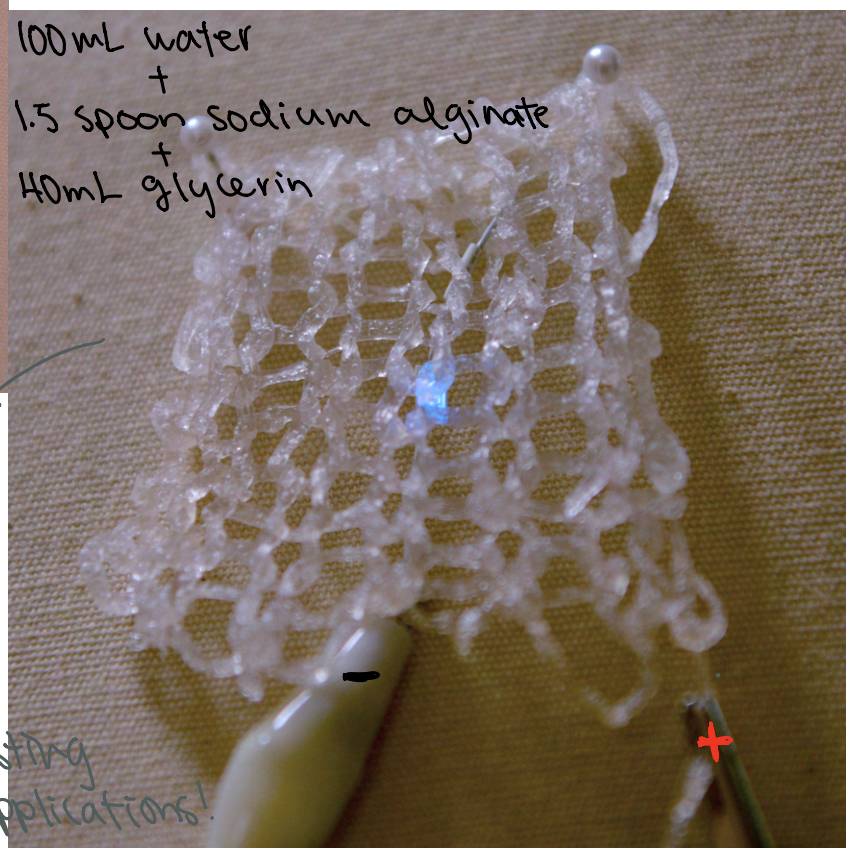


I took this photo before drying. Water was the main factor for conductivity, which means better conductivity can be achieved with more conductive powder.

I also measured resistance of carbon powder alone. I put the carbon powder tightly into a straw with diameter of 5mm, the resistance was ~150kΩ/cm.



To speed up drying, I baked the knitted fabric with fan on at 50°C for a few hours and left it at room temperature over night. BUT it was not actually dried because the entire piece of fabric is conductive.

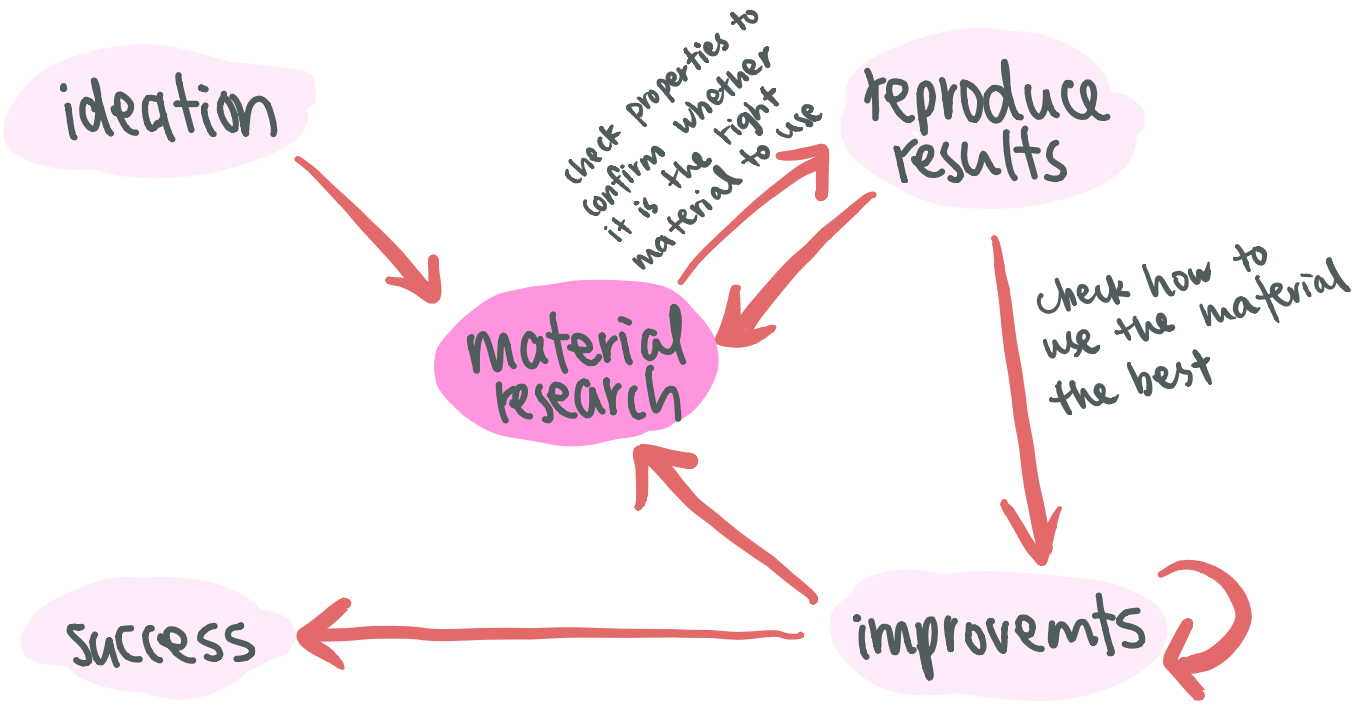


Inspired by the result found, I took the piece from last week. Surprisingly, after over a week at room temperature, it still remains conductive!

Question: Is the conductivity caused by remained water or other particles?

Nevertheless, this is a very interesting finding that could have useful applications!

Selection Methodology



Things Learned

- The conductive yarn is really thin after it is dried.
- After drying, sodium alginate conductive yarn becomes very rigid and breaks easily. Adding glycerin makes it flexible.
- The metallic powder I purchased is not conductive.
- Conductive bioplastic sheet is much easier to fabricate than conductive bioplastic yarn, because uneven compositions drastically reduce conductivity.
- Air dried yarn at room temperature is not fully dried.
- The remaining water in 'dried' yarn still allows the yarn to be conductive, though the resistance is very large.
- We can make conductive bioplastic yarn without conductive powders, but further experiments would be needed to see how long the conductivity will last.