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Student Handout

For this Materials Engineering Design Challenge, you will create a procedure for optimized organic fiber production. You will then sell your idea to a venture capital firm in order to convince them to invest in your company. You will create a presentation in which you attempt to convince them that you have the *best* handle on the market and the most innovative process for making the *best* organic conductive fibers.

Information about the nascent wearables technology industry can be researched, here are some sources to get you started:

- http://www.slideshare.net/PSFK/psfk-future-of-wearable-tech-summary-presentation
- http://cutecircuit.com/wearable-technology/#after_full_slider_1
- http://phandroid.com/2015/05/29/project-jacquard-smart-clothes/

Objective

Primary Goal: To refine a procedure for the creation of organic, graphite-based fibers, to maximize resistivity while minimizing width (thickness).
(Optional) 2nd Goal: To document this procedure as part of a larger presentation to a venture capital firm in an attempt to gain funding for a new organic fiber manufacturing company.

Constraints

1. Your test fiber must be at least 3 cm in length.
2. Your fiber should be as thin as possible, with a uniform diameter.
3. Your fiber should have minimum resistivity.

Procedure

Prepare in advance:

- Pour 2 g powdered sodium alginate should be poured into blender for every 100 ml of warm water. Pouring slowly while blender is already on will yield best results.
- Food coloring can be added at this stage
- Refrigerate overnight to deter bacterial growth

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Making the fibers:

- Prepare the calcium bath with deionized water and 6 g $CaCl_2$ flakes. If lab grade is not available, road deicing pellets can be used.
- Mix the graphite into the sodium alginate, using a spoon or wooden spatula. Do not pour, and avoid any handling of graphite that will result in airborne particles.
- Draw alginate/graphite suspension into a plastic 5 ml pipette or a plastic syringe.
- Extrude alginate/graphite at a constant rate into the calcium solution.
- Use a clean spoon, glass stirring rod or other to draw the “fiber” out of the solution. Dry on a paper towel.

Testing the fibers

- To test the resistance, use a multimeter set on 200 kΩ and be sure the tips of the leads are inserted into (not on top of) the fiber at a predetermined or measured length.
- The measured length of the fiber, for use in calculating resistivity, will be the distance between the leads when measuring resistance.
- To measure the diameter of the fiber, use a millimeter ruler or a light microscope set on the lowest setting with a transparent ruler positioned on the stage.

Analysis & Optimization

Complete the table on the worksheet (below) and calculate resistivity for each fiber created and measured. Factors to be varied:

- fiber width
- graphite concentration
- calcium concentration (although the level of calcium ions in the bath will reduce after each fiber is created)
- viscosity (water content) of sodium alginate

The goal is to optimize for smallest resistivity. As you create and test fibers, determine what factor(s) are responsible for lowest resistivity and try to optimize them, given the constraints and the availability of your resources.

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Your engineering design will be completed when you:

a. Have produced a fiber with lowest resistivity, and

b. You can explain what factors lead to this optimal state

Deliverables – Option 1

1) Statement of Goal
   a) What is the design engineering problem that your team is solving?
   b) What are the design constraints?
   c) What will be observed? What will be measured? What will be held constant and what will be optimized?
2) Data Acquisition (Record data in the table provided.)
   a) Use a measuring tape or ruler to measure the length of the fibers produced.
   b) Photograph the fiber next to a ruler.
   c) Measure the resistance of each fiber. Photograph the measurement of the resistance, which is captured using a multimeter.
3) Calculate the resistivity for each fiber. Determine the fiber that presents the most ideal properties.
   a) Photograph the sheet used to make the calculations of cross-sectional area and the resistivity.
   b) Write the data in the data table provided.
   c) Photo of calculations page with data for at least five fibers.
4) Write a conclusion paragraph that includes the following components. Remember to use technical vocabulary learned as part of the lesson.
   a) State the resistivity of the fiber that presented the best values.
   b) State what processing techniques, parameters and quantities led to the ideal resistivity values. Use the date in your table to support the conclusions described in your paragraph.
   c) Explain why resistivity is not the same thing as resistance.
   d) Is important to have a low or high resistivity in fibers? Explain your answer.
   e) Explain why graphene and graphite fibers are called organic? Why can these materials be used to produce electronics?
   f) Finish the sentence: Graphene/graphite is used in the development of these fibers because it has the following properties…

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Deliverables – Option 2

You are a start-up companying seeking funding from a venture capitalist firm. In order to convince the firm to support your product, you create an informative slide presentation to describe the technology. You will create your slide presentation using Google Slides. Your company presentation will include the components listed below.

- Title slide - name of your manufacturing company

• Why you think wearable technology will be The Next Big Thing, supported by quotes, references, pictures. 2-3 slides
• Brief analysis of the current market. 1-2 slides
• Why organic? 1-2 slides
• Resistance, dimensions and resistivity chart. 1 slide
• Graph of resistance v. diameter and/or resistance v. length (5 data points at a minimum). 1-2 slides
• Statement of what makes your fibers the best (diameter, resistivity, properties of graphite). 1 slide
• Your production process documented in photos
• Who would your customers be? (other than Levi's and CuteCircuit)
• Closing statement

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Calculating Resistivity

Resistivity of a wire is represented by the letter rho, and can be calculated using the equation:

$$\rho = RA/l$$

Where:

R is the electrical resistance of a uniform specimen of the material (measured in ohms, Ω)

l is the length of the piece of material (measured in meters, m)

A is the cross-sectional area of the specimen (measured in square meters, m^2)

Unlike resistance, resistivity is a function of the material regardless of width or length.

Question: what should the units of resistivity be? _____

In measuring resistivity of your wires, follow this procedure:

1. Put the wire on a slide and view it under the microscope. Using the ruler stage, estimate the diameter of your wire in meters.
2. Calculate the cross-sectional area of your wire using the following: $A = \pi r^2$
3. Place fiber alongside a ruler, pull straight.
4. Insert the tips of the multimeter leads into the fiber, 3 cm apart, so that the tips puncture the wire and current can travel through the wire.
5. Record the resistance and length.
6. Calculate resistivity using R, l and A.

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Data Table

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Fiber Width						
Graphite concentration						
Calcium concentration						
Sodium alginate concentration						
Wire diameter (m)						
Cross-sectional area (m^2)						
Wire length (m)						
Resistance (Ω)						
Resistivity						