FINAL SCRIPT: APPROVED FOR FILMING

Submission ID #: 69040
Scriptwriter Name: Pallavi Sharma
Project Page Link: https://review.jove.com/files_upload.php?src=21057248

Title: Adapting Taylor Dispersion to Measure the Dispersion Coefficient of Electrolyte Solutions via an Accessible Microfluidic Setup

Authors and Affiliations:
James M. Teague[1], Lingyun Ding[2], Francesca Bernardi[1*]

[1]Worcester Polytechnic Institute. Worcester
[2]University of California Los Angeles

Corresponding Authors:
Francesca Bernardi (fbernardi@wpi.edu)

Email Addresses for All Authors:
Francesca Bernardi (fbernardi@wpi.edu)
James M. Teague (jmteague@wpi.edu)
Lingyun Ding (dingly@g.ucla.edu)

Author Questionnaire

1. **Microscopy**: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

2. **Software:** Does the part of your protocol being filmed include step-by-step descriptions of software usage? **Yes, all done**

3. **Filming location:** Will the filming need to take place in multiple locations? **No**

Current Protocol Length
Number of Steps: 27
Number of Shots: 56

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

1.1. **Francesca Bernardi**: The scope of our work is to design and implement an accessible microfluidic experimental platform suitable to answer a broad range of fundamental fluids questions.

1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

What are the current experimental challenges?

1.2. **Francesca Bernardi:** The biggest challenge is to develop a reproducible and yet flexible manufacturing process for microchannels with sufficient precision utilizing low-cost equipment.

1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

What research gap are you addressing with your protocol?

1.3. **James Teague:** Our research seeks to address the current lack of easily accessible and accurate experimental setups and protocols to measure the enhanced diffusivity of an electrolyte species. Our platform also allows for visualization of multispecies ion interactions.

1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera.

What advantage does your protocol offer compared to other techniques?

1.4. **James Teague:** Our experimental setup and protocol are inexpensive, easily accessible, and accurate. The low-cost microchannel manufacturing technique employed allows the production of custom designed chips in minutes.

1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B roll: 2.3*

Videographer: Obtain headshots for all authors available at the filming location.

Protocol

2. Assembly of the Experimental Setup

Demonstrator: James Teague

2.1. To begin, launch the craft cutter design software on the connected computer **[1]**. Design the microchannel top directly in the software or import a compatible design from external software **[2]**.

2.1.1. WIDE: Talent seated at a workstation launching the craft cutter software on the computer.

2.1.2. SCREEN: 69040_screenshot_1.mp4

2.2. Then, attach a 21-centimeter by 5-centimeter polyester rectangle to the sticky side of the cutting mat **[1]**. Using masking tape, tape all four perimeter edges to secure the rectangle **[2]**.

2.2.1. Talent placing the polyester rectangle onto the adhesive side of the cutting mat.

2.2.2. Talent carefully applying masking tape along all four sides of the polyester sheet.

2.3. Next, load the cutting mat into the craft cutter by aligning the marked edges with the arrow indicators on the device **[1]**. Insert the blade into the carriage slot of the craft cutter **[2]**.

2.3.1. Talent aligning and inserting the taped cutting mat into the craft cutter.

2.3.2. Close-up of talent inserting the cutting blade into the carriage slot of the cutter.

2.4. Click on **Send** located at the top right of the design page on the monitor to proceed to the review screen. Then, set the **blade depth** to 9, **force** to 33, **passes** to 1, and **speed** to **1 [1].**

2.4.1. SCREEN: 69040_screenshot_2.mp4: 00:00-00:03, 00:08-00:11, 00:18-00:34.

2.5. Now, click on **Submit** to send the job to the craft cutter **[1]** and initiate the cutting process **[2]**. After removing the cutting mat from the cutter use tweezers to remove the negative polyester material from the cut sheet **[3]**. NOTE: The VO is edited for the additional shot

2.5.1. SCREEN: 69040_screenshot_2.mp4: 00:34-00:38

Added shot: 2.5.1.B Recording of craft cutter in action performing the cut submitted in

2.5.2. Talent using tweezers to remove the negative polyester material from the cutting mat carefully.

2.6. Next, design donut-shaped polyimide gaskets using the craft cutter design software or import the gasket design from compatible software **[1]**. Attach a 21-centimeter long piece of polyimide tape with the sticky side facing up onto the cutting mat and secure it with masking tape along all four edges **[3]**.

2.6.1. SCREEN: 69040_screenshot_3.mp4: 00:00-00:10

2.6.2. Talent placing the polyimide tape sticky side up onto the cutting mat and applying masking tape along the four edges of the polyimide tape.

2.7. Enter the cut settings for the polyimide tape with a blade depth of 9, force of 1, passes of 1, and speed of 1 **[1]**. Click on **Submit** to send the gasket cutting job to the craft cutter **[2-TXT]**.

2.7.1. SCREEN: 69040_screenshot_3.mp4: 00:10-00:16

2.7.2. SCREEN: 69040_screenshot_3.mp4: 00:16-00:19 **TXT: Use separate blades for polyester and polyimide to maintain sharpness**

2.8. Then, place the cut polyester sheet on a clean, flat surface with the protrusions facing upward **[1]**.

2.8.1. Talent placing the finished polyester sheet on a flat workstation, ensuring the protrusions are oriented upward.

2.9. Using tweezers, peel off one gasket from the cut polyimide tape and place it onto the flat underside of a 3D-printed port **[1]**. Align the port with the flow inlet hole and using the gasket, attach it to the flat-laid polyester sheet **[2].**

2.9.1. Talent using tweezers to lift a single polyimide gasket from the cutting mat and placing it onto the underside of a 3D printed port.

2.9.2. Talent attaches the port with gasket to the polyester sheet.

2.10. Now, under a fume hood, apply a small amount of superglue along the perimeter of the port while pressing it downward to create a watertight seal **[1-TXT]**.

2.10.1. Talent applies superglue around the edge of the attached port while pressing it down. **TXT: Leave 2–3 h or use activator spray, wait 10 min for seal**

2.11. For the fabrication of the polyimide microchannel body, design the microchannel body using the craft cutter design software or by importing a compatible external design **[1]**. Attach the 21-centimeter-long strip of polyimide tape with the sticky side up onto the cutting mat **[2]**. Then, load the cutting mat into the craft cutter by aligning the marked edges with the arrow indicators on the device **[3-TXT]**.

2.11.1. SCREEN: 69040_screenshot_4.mp4: 00:00-00:08

2.11.2. Talent attaching the polyimide tape onto the cutting mat with the adhesive side facing up.

2.11.3. Talent inserting the taped cutting mat into the craft cutter, aligning it accurately. **TXT: Keep the same blade used to cut the gaskets**

2.12. Click on **Send** at the top right of the design page to review the material and cut settings. Use the same cutting parameters as used for the gaskets. Click **Submit** to send the cutting job to the craft cutter **[1]**. Then, remove the cutting mat from the cutter **[2]** and using tweezers, remove the negative polyimide material from the channel design **[3]**.

2.12.1. SCREEN: 69040_screenshot_4.mp4: 00:08-00:00:15

2.12.2. Talent removing the cutting mat from the cutter.

2.12.3. Talent using tweezers to peel off the negative material from the cut polyimide channel.

2.13. Now, place the polyimide tape with the sticky side facing upward on a flat, clean surface **[1]**. Carefully position the polyester rectangle onto the exposed polyimide tape, centering the polyimide strip across the width of the polyester **[2]**. Using a roller, apply even downward pressure to eliminate large air bubbles and visually inspect for any debris or warping **[3]**.

2.13.1. Talent laying the polyimide tape sticky side up on a flat workspace. NOTE: 2.13.1 and 2.13.2 were filmed in a single shot

2.13.2. Talent aligning and placing the solid polyester rectangle on top of the polyimide tape.

2.13.3. Talent rolling over the assembly with a hand roller and visually inspecting the surface for imperfections.

2.14. Afterward, flip the polyimide tape assembly and remove the protective cover from the adhesive side **[1]**. Align the top polyester sheet mounted with the 3D-printed port to the inlet and outlet of the polyimide tape, then carefully lay the polyester sheet over the polyimide layer **[2-TXT]**.

2.14.1. Talent flipping over the layered polyimide and polyester assembly and peeling away the protective adhesive liner.

2.14.2. Talent aligning the top polyester sheet with the port precisely over the polyimide inlets and outlets and gently pressing it down. **TXT: Eliminate air bubble and inspect for debris**

2.15. For the syringe pump setup, fill a 0.5-milliliter glass syringe with deionized water **[1]**. Mount the syringe onto a programmable syringe pump and press the **fast-forward** button until water begins to emerge from the syringe tip **[2]**.

2.15.1. Talent drawing deionized water into a 0.5 milliliter glass syringe. NOTE: 2.15.1 and 2.15.2 were filmed in a single shot.

2.15.2. Talent mounting the filled syringe onto the programmable syringe pump and activating the fast-forward mode until water is visible at the tip.

2.16. Then, cut a 50-centimeter-long piece of polytetrafluoroethylene tubing **[1]**. Using tweezers, connect the two ends of the tubing to 27-gauge syringe tips by inserting the tubing over the tips and pulling it downward **[2-TXT]**.

2.16.1. Talent measuring and cutting the PTFE tubing to 50 centimeters.

2.16.2. CLOSE-UP: Talent using tweezers to fit the tubing securely over the 27-gauge syringe tip. **TXT: Length: 1.27 cm, OD: 0.4064 mm**

2.17. Fill the connected syringe tip and tubing with deionized water until a convex meniscus forms at the tip opening **[1]**. Attach the tip to the pre-mounted glass syringe on the pump, ensuring there are no air bubbles present in either the syringe or the tip **[2]**.

2.17.1. Talent filling the syringe tip and tubing with deionized water and showing the formation of a convex meniscus.

2.17.2. Talent connecting the water-filled tip to the syringe on the pump and carefully inspecting for the absence of air bubbles.

2.18. Set the syringe pump to Infuse mode only. Input the syringe type and size as 0.5 milliliters into the pump's interface **[1]**. Using 2.54-centimeter-wide masking tape, tape the fully assembled microfluidic chip to the light panel **[2]**.

2.18.1. Show selection of the Infuse mode on the syringe pump display. Demonstrate inputting the syringe type and selecting 0.5 milliliter as the syringe size.

2.18.2. Talent carefully positioning and taping down the microfluidic chip onto the light panel.

2.19. Next, mount a 20-millimeter f/2 *(F-Two)* macro lens onto the camera and connect it to a remote trigger **[1]**. Set up a tripod and mount the camera above the light panel, angled downward to face the experiment **[2]**. Center the view on the capture point cut in the polyimide tape **[3-TXT]**. Program the camera via the remote trigger to take images every 1 second **[4]**.

2.19.1. Talent attaching a 20 millimeter f/2 macro lens to the camera and connecting the remote trigger cable.

2.19.2. Talent setting up the tripod, mounting the camera, and adjusting its position directly above the chip.

2.19.3. Camera viewfinder showing the capture point centered, with channel edges also visible in frame. **TXT: Position camera ≥1 cm above panel to capture cut + channel view**

2.19.4. Display the remote trigger interface and show the interval set to 1 second for automated image capture.

3. Experimental Run to Compute the Diffusion Coefficient of Passive Tracers

3.1. Apply a layer of transparent tape over the tracer inlet hole to prevent liquid from escaping, ensuring one edge of the tape is folded over to form a small tab for easy removal **[1]**. Connect and run the programmable syringe pump to gently flood the microchannel with deionized water at a very low flow rate **[2]**.

3.1.1. Talent placing transparent tape over the tracer inlet hole, folding one edge for removal.

3.1.2. Talent connecting and activating the syringe pump at a low flow rate.

3.2. Then, fill a 0.5-microliter micropipette tip with the prepared tracer solution **[1]**. Using the folded tab, peel back the tape covering the tracer inlet hole **[2]**. Using the corner of a low-lint wipe, lightly wick away any excess deionized water from the inlet hole and wait 30 seconds for the water fronts to stabilize **[3]**.

3.2.1. Talent pipetting the tracer solution into a 0.5 microliter pipette tip.

3.2.2. Talent lifting the folded tab to peel off the tape from the tracer inlet.

3.2.3. CU: Talent using a low-lint wipe corner to gently remove water from the tracer inlet and timing a 30-second wait.

3.3. After 30 seconds, dispense the tracer solution into the inlet hole using the pipette **[1]**. Immediately smooth the tape back over the hole using minimal pressure and a continuous motion to reseal the inlet **[2-TXT]**.

3.3.1. Talent discharging the tracer from the micropipette into the inlet.

3.3.2. Talent resealing the inlet by pressing the tape back over it smoothly and gently.

TXT: Allow tracer to diffuse fully across the channel

3.4. After ensuring that the syringe pump is programmed to the target volumetric flow rate, start the syringe pump and trigger the remote camera simultaneously to begin imaging **[1]**.

3.4.1. Talent pressing the pump start and activating the remote trigger at the same time.

4. Data Processing for the Measurement of Dispersion Coefficient

4.1. If the horizontal edges of the rectangle overlay are not aligned with the microchannel walls, hover the cursor over a rectangle corner, click, and rotate the image until the horizontal walls align parallel to the channel walls **[1]**. Press any key to proceed. The image pop-up will close and reopen with the corrected orientation **[2]**. Click and drag to select a square region with sides equal to the channel width, centered at the capture point **[3]**. Press any key to continue, and the image pop-up will close **[4]**.

4.1.1. SCREEN: 69040_screenshot_5.mp4: 00:00-00:04

4.1.2. SCREEN: 69040_screenshot_5.mp4: 00:04-00:05

4.1.3. SCREEN: 69040_screenshot_5.mp4: 00:05-00:12

4.1.4. SCREEN: 69040_screenshot_5.mp4: 00:12-00:13

4.2. Then, extract the blue channel intensity at each pixel within the selected crop region from the RGB image. Invert the values by subtracting each from 255, the maximum blue channel value **[1]**.

4.2.1. SCREEN: 69040_screenshot_6.mp4: 00:00-00:05

.

4.3. Compute the mean intensity value of the inverted blue channel across all pixels in the cropped region **[1]**. Save each computed value to generate a time series of average inverted blue channel intensity at the capture point **[2]**.

4.3.1. SCREEN: . 69040_screenshot_7.mp4: 00:00-00:02

4.3.2. SCREEN: 69040_screenshot_7.mp4: 00:02-00:04

4.4. Use the nonlinear **curveFitter** *(Curve-Fitter)* toolbox in the code to input the full time series of average inverted blue channel intensities **[1]**.

4.4.1. SCREEN: 69040_screenshot_8.mp4: 00:00-00:08

Results

5. Results

5.1. The averaged inverted blue channel intensities over time were plotted and showed close agreement between experimental data and the theoretical Taylor dispersion fit **[1],** with time points at 140 seconds **[2],** 150 seconds **[3],** and 200 seconds clearly shown **[4].**

5.1.1. LAB MEDIA: Figure 6. *Video editor: Highlight both the dashed (experimental) and solid (fit) lines on the plot.*

5.1.2. LAB MEDIA: Figure 6. *Video editor: Zoom in on the dark blue dot at around 140 seconds and its corresponding image preview.*

5.1.3. LAB MEDIA: Figure 6. *Video editor: Zoom in on the orange dot at around 150 seconds and its corresponding image preview.*

5.1.4. LAB MEDIA: Figure 6. *Video editor: Zoom in on the green dot at around 200 seconds and its corresponding image preview.*

5.2. Dispersion factor results from experiments at three different aspect ratios showed good agreement with theoretical predictions **[1].**

5.2.1. LAB MEDIA: Figure 7.

---

1. **Polyimide**
Pronunciation link: https://www.merriam-webster.com/dictionary/polyimide
IPA: /ˌpɑːliˈaɪˌmaɪd/
Phonetic Spelling: pah-lee-EYE-myde

2. **Microchannel**
Pronunciation link: (HowToSay "microchannel")
https://www.howtosay.co.in/pronounce/microchannel-in-english/
IPA: /ˌmaɪkroʊˈkænəl/
Phonetic Spelling: my-kroh-KAN-uhl

3. **Dispersion**
Pronunciation link: https://dictionary.cambridge.org/pronunciation/english/dispersion
IPA (US): /dɪˈspɝːʒən/
Phonetic Spelling: di-SPUR-zhuhn

4. **Taylor** (as in “Taylor dispersion”)
   Pronunciation link: https://www.howtopronounce.com/taylor
   IPA: /ˈteɪlər/
   Phonetic Spelling: TAY-lur
5. **Gasket**
   (Not always highly “technical” but may be mispronounced)
   Pronunciation link: https://www.merriam-webster.com/dictionary/gasket
   IPA: /ˈgæskɪt/
   Phonetic Spelling: GAS-kit
6. **Polyester**
   Pronunciation link: https://www.merriam-webster.com/dictionary/polyester
   IPA: /ˌpɑːliˈɛstər/
   Phonetic Spelling: pah-lee-ES-ter
7. **Carriage** (in “blade carriage slot”)
   Pronunciation link: https://www.merriam-webster.com/dictionary/carriage
   IPA: /ˈkærɪdʒ/
   Phonetic Spelling: KAIR-ij
8. **Meniscus**
   (Appears in “convex meniscus”)
   Pronunciation link: https://www.merriam-webster.com/dictionary/meniscus
   IPA: /məˈnɪskəs/
   Phonetic Spelling: muh-NIS-kus