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Title: Applying Permanent, Robust Stenciled Patterns of Fine Particles to Elastomeric Surfaces

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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? **No**

3. **Filming location:** Will the filming need to take place in multiple locations? **Yes**

Current Protocol Length
Number of Steps: 17
Number of Shots: 41

Introduction

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

1.1. **Chelsea Davis:** Our research focuses on understanding large deformations in magneto-rheological elastomers under combined mechanical and magnetic field loading. To quantitatively visualize these deformations in our experiments, we use optical tracking techniques, like DIC that requires permanent markings on the surface of our silicone samples.

1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 2.2.1* **Videographer's NOTE**: Verbally miscalled this as shot 1.3

What technologies are currently used to advance research in your field?

1.2. **Paul Mitalski:** To compare simulations and experimental results, we use DIC, along with customized universal testing machines capable of applying both mechanical and magnetic loads to specimens. The specimen surfaces are marked with patterns to give the software something to track.

1.2.1. *B-roll: 2.3.1* **NOTE**: ALL OF Paul Mitalskski's statements were done as voice over without video. So use the B-rolls only

What are the current experimental challenges?

1.3. **Chelsea Davis:** Without permanent surface markings, deformation tracking is impossible. Silicones are inherently non-adhesive and highly extensible. This means that most paints and common marking methods for plastics don't work because they won't stick or crack and flake off when the strains get really high.

1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 3.2.2*

What research gap are you addressing with your protocol?

1.4. **Paul Mitalski:** Our protocol addresses the need for a reliable method to mark elastomers undergoing large deformations, enabling accurate optical tracking through repeated mechanical cycles.

1.4.1. *B-roll: 3.5.1* **NOTE**: ALL OF Paul Mitalskski's statements were done as voice over without video. So use the B-rolls only

What advantage does your protocol offer compared to other techniques?

1.5. **Jacob McGough:** Unlike most marking methods that fade or flake off with time or high strains, our approach allows specimens to be marked and stored without degradation. This ensures consistent tracking and repeatability in experiments, particularly for aging and fatigue studies.

1.5.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 5.2.1*

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

Testimonial Questions (OPTIONAL):

Videographer: Please capture all testimonial shots in a wide-angle format with sufficient headspace, as the final videos will be rendered in a 1:1 aspect ratio. Testimonial statements will be presented live by the authors, sharing their spontaneous perspectives.

How do you think publishing with JoVE will enhance the visibility and impact of your research?

1.6. **Chelsea Davis, Associate Professor of Mechanical Engineering at the University of Delaware**: We are hoping publishing our protocol in JoVE will provide an alternative method to help experimentalists who utilize optical tracking techniques like digital image correlation.

1.6.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera. *Suggested B-roll: 3.6.2*

Protocol

2. Stenciled and DIC Speckle Mold Preparation

Demonstrators: Jacob McGough, Paul Mitalski

2.1. To begin, attach the air compressor to the air brush **[1]**. Plug the air compressor into an appropriate electrical outlet and turn it on **[2]**. Inside a fume hood while wearing the appropriate personal protective equipment, fill the air brush with isopropyl alcohol **[3]** and clean it multiple times **[4]**.

2.1.1. WIDE: Talent attaching the air compressor hose to the air brush.

2.1.2. Talent plugging the compressor into the socket and switching it on.

2.1.3. Talent pouring isopropyl alcohol into the air brush reservoir inside a fume hood, while wearing PPE.

2.1.4. Talent pressing the trigger of the air brush and spraying alcohol through the nozzle into a container.

2.2. Now, place the stencil on a paper towel inside a fume hood **[1-TXT].** Keep the spray nozzle approximately 30 centimeters away from the stencil **[2]** and spray in a smooth, continuous motion **[3]**. Wait 30 to 60 seconds until the stencil becomes tacky but is no longer wet **[4]**.

2.2.1. Talent placing the stencil flat on a paper towel inside the fume hood. **TXT: Wear appropriate PPE throughout the procedure**

2.2.2. Close-up of the nozzle being held at a 30-centimeter distance.

2.2.3. Talent spraying the adhesive in a smooth motion.

2.2.4. Shot of stencil becoming tacky.

2.3. Then, place the mold on a paper towel inside a fume hood **[1]** and use clean nonlatex gloves to carefully pick up the stencil without disturbing the adhesive **[2]**. Place the adhesive side of the stencil onto the mold **[3]** and run one finger firmly across the stencil to flatten it, ensuring uniform contact with the mold **[4]**.

2.3.1. Talent positioning the mold on a paper towel inside the fume hood.

2.3.2. Talent lifting the stencil gently using gloved hands.

2.3.3. Talent aligning and placing the stencil adhesive-side down onto the mold.

2.3.4. Talent pressing along the stencil with a finger to smooth it down.

2.4. Next, using painter's tape, tape the edges of the stencil to the mold **[1]**.

2.4.1. Talent applying painter's tape along the stencil edges, securing it onto the mold.

2.5. For digital image correlation or DIC *(D-I-C)* speckle mold, place the mold on a paper towel inside a fume hood with the mold cavity surface facing up **[1-TXT].** Keep the spray nozzle approximately 30 centimeters away from the mold **[2]** and apply one coat of mold release to the mold in a smooth continuous motion **[3]**.

2.5.1. Talent placing the mold cavity side up on a paper towel inside the fume hood. **TXT: DIC: Digital Image Correlation**

2.5.2. Close-up of spray nozzle held 30 centimeters above the mold.

2.5.3. Talent spraying mold release over the mold in a smooth motion.

3. Airbrush Preparation and Spray the Mold with the Stencil
Demonstrator: Jacob McGough

3.1. Inside a fume hood, use a funnel or a small spoon to transfer approximately 10 milliliters of fine powder into a test tube **[1-TXT]**. Add isopropyl alcohol to the test tube to bring the total volume to 45 milliliters **[2]**. Seal the test tube **[3]** and shake it vigorously to mix the suspension **[4]**.

3.1.1. Talent scooping graphite or colored pigment using a small spoon and adding it to a test tube inside the fume hood. **TXT: Add graphite or colored pigment**

3.1.2. Talent pouring isopropyl alcohol into the test tube until it reaches the 45 milliliter mark.

3.1.3. Talent capping the test tube.

3.1.4. Talent shaking the tube vigorously to create a uniform suspension.

3.2. Now, re-shake the prepared suspension to re-homogenize the contents **[1]** and fill the air brush container until it is 75 percent full with the suspension **[2]**.

3.2.1. Talent shaking the test tube to remix the suspension.

3.2.2. Talent pouring the suspension into the air brush container, stopping at three-quarters full.

3.3. Turn on the air compressor and confirm the air pressure is set between 1.38 and 1.72 bar, or 20 to 25 pounds per square inch **[1]**.

3.3.1. ~~Talent switching on the compressor~~. **NOTE**: Not filmed, VO merged

3.3.2. Talent adjusting the pressure settings.

3.4. Inside the fume hood, position the mold with the adhered stencil at a slightly off-vertical angle **[1]** and aim the air brush slightly off to the side of the mold to ensure the spray initiates before reaching the mold **[2]**.

3.4.1. Talent propping up the mold with stencil in a tilted orientation inside the fume hood.

3.4.2. Talent aiming the air brush away from the mold to establish the spray trajectory.

3.5. Then, pull the air brush trigger back gently to begin spraying **[1]**. Smoothly apply the first coat of the suspension, keeping the nozzle approximately 30 centimeters from the surface and moving in a continuous motion **[2]**.

3.5.1. Talent pressing the trigger and initiating spray.

3.5.2. Close-up of the air brush nozzle spraying at a steady distance with an even coating over the stencil and mold. **Videographer's NOTE**: Was called as 3.5.2 BY MISTAKE

3.6. After the first coat, release the air brush trigger **[1]** and observe the surface for uniform distribution of the fine particle suspension **[2]**. If needed, apply additional layers across the stencil and mold surface **[3]**.

3.6.1. Talent releasing the trigger.

3.6.2. Shot of the mold surface after spraying.

3.6.3. Shot of spraying again lightly after the first coat.

3.7. Wait until the fine particles are visibly dry before removing the stencil and ensure a minimum drying time of 180 to 300 seconds **[1]**.

3.7.1. Shot of mold resting undisturbed with the stencil.

3.8. Then, remove the painter's tape from the top shorter edge of the mold **[1]** and slowly pull the tape upward **[2]** to detach the stencil from the mold in one smooth motion **[3]**.
NOTE: VO added for the extra shot

3.8.1. Talent peeling the painter's tape from the top edge of the mold.

3.8.2. Talent pulling the tape gently, lifting off the stencil along with it.

Added shot: 3.8.3 - close up of mold once stencil was peeled off

4. Spray the Mold Without a Stencil and Mold Assembly

4.1. After turning on the air compressor **[1-TXT]**, position the mold without any stencil at a slightly off-vertical angle for a perpendicular spray application inside the fume hood **[2]**.

4.1.1. Shot of the air compressor display after turning on. **TXT: Air pressure: 0.34 - 0.69 bar (5 - 10 psi)**

4.1.2. Talent angling the mold (without stencil) upright at a slight tilt inside the fume hood.

4.2. To test the air brush, compress the trigger briefly while spraying onto a spare sheet of paper **[1]**. Confirm that the resulting speckle pattern is spatially random and of suitable size for the experimental imaging setup **[2]**.

4.2.1. Talent pressing the air brush trigger to spray on a test paper.

4.2.2. Close-up of speckle dots on paper, displaying appropriate density and size.

4.3. Now, flick the trigger over the mold to apply the speckle pattern on its surface **[1]** and wait for at least 180 to 300 seconds until the fine particles are visibly dry **[2]**.

4.3.1. Talent spraying short bursts across the mold surface to form a speckled pattern.

4.3.2. Shot of the mold resting and dried up.

4.4. Finally, assemble the mold in preparation for the injection molding process **[1]** or store them for a few days prior to injection molding **[2]**.

4.4.1. Talent aligning the mold to complete assembly.

Added shots: 4.5. Shot of a several molds side by side or as a collage. Do include the cuboid mold with JoVE logo

NOTE: Series of shots showing finished samples using the process/molds were filmed. Please make a collage of the molds and display here, focusing on the JoVE mold as the authors want to show them. Contact me if there are any questions (poornima.g@jove.com)

Results

5. Results

5.1. Specimens created for mechanical testing included various geometries such as plates, cylinders, and cubes with contrasting grid and speckle patterns on opposite surfaces **[1]**, including white plates with black grids **[2]**, black plates with white grids **[3]**, and plates with blue grids **[4]**.

5.1.1. LAB MEDIA: Figure 7.

5.1.2. LAB MEDIA: Figure 7. Video editor: Highlight A.

5.1.3. LAB MEDIA: Figure 7. Video editor: Highlight B.

5.1.4. LAB MEDIA: Figure 7. Video editor: Highlight E.

5.2. Optical tracking design patterns included grid patterns **[1]**, sparse DIC speckle patterns **[2]**, and dense speckle patterns for varying strain measurement needs **[3]**.

5.2.1. LAB MEDIA: Figure 9A.

5.2.2. LAB MEDIA: Figure 9B.

5.2.3. LAB MEDIA: Figure 9C.

5.3. Digital image correlation analysis under increasing global strain displayed progressive local displacement in the vertical direction, visualized by a heat map with colors ranging from red to blue **[1]**.

5.3.1. LAB MEDIA: Figure 10. *Video editor: Highlight the six images sequentially (strain $\varepsilon = 0.00$ to $\varepsilon = 0.55$)*.

1. isopropyl alcohol

Pronunciation link:
https://www.merriam-webster.com/dictionary/isopropyl
https://www.merriam-webster.com/dictionary/alcohol
IPA: /ˌaɪsoʊˈproʊpəl ˈælkəˌhɑl/
Phonetic spelling: eye-soh-PROH-puhl AL-kuh-hawl

2. fume hood

Pronunciation link:
https://www.merriam-webster.com/dictionary/fume
https://www.merriam-webster.com/dictionary/hood
IPA: /fjuːm hʊd/
Phonetic spelling: fyoohm hood

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3. nonlatex

(This splits into "non-latex")
Pronunciation link:
https://www.merriam-webster.com/dictionary/latex (used with prefix non-)
IPA: /ˌnɑnˈleɪtɛks/
Phonetic spelling: non-LAY-teks

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4. Digital Image Correlation (DIC)

Pronunciation link:
https://www.merriam-webster.com/dictionary/digital
https://www.merriam-webster.com/dictionary/correlation
IPA: /ˈdɪdʒɪtəl ˈɪmɪdʒ ˌkɔrəˈleɪʃən/
Phonetic spelling: DIJ-ih-tuhl IM-ij kaw-ruh-LAY-shuhn

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5. graphite

Pronunciation link:
https://www.merriam-webster.com/dictionary/graphite
IPA: /ˈɡræfaɪt/ or /ˈɡræfˌaɪt/
Phonetic spelling: GRAF-ite

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6. suspension

Pronunciation link:
https://www.merriam-webster.com/dictionary/suspension
IPA: /səˈspɛnʃən/
Phonetic spelling: suh-SPEN-shuhn

7. bar

(Context: unit of pressure)
Pronunciation link:
https://www.merriam-webster.com/dictionary/bar
IPA: /bɑr/
Phonetic spelling: bar (like "bar")

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8. centimeters

Pronunciation link:
https://www.merriam-webster.com/dictionary/centimeter
IPA: /ˈsɛntəˌmitərz/
Phonetic spelling: SEN-tuh-mee-terz

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9. speckle

Pronunciation link:
https://www.merriam-webster.com/dictionary/speckle
IPA: /ˈspɛkəl/
Phonetic spelling: SPEK-uhl

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10. perpendicular

Pronunciation link:
https://www.merriam-webster.com/dictionary/perpendicular
IPA: /ˌpɜrpənˈdɪkjələr/
Phonetic spelling: per-puhn-DIK-yuh-luhr

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11. mechanical

Pronunciation link:
https://www.merriam-webster.com/dictionary/mechanical
IPA: /məˈkænɪkəl/
Phonetic spelling: muh-KAN-ih-kuhl