

# NEST 4 – Full Fabrication Protocol

Revision 1 (06 June 2023)

## 1 THIN FILM FABRICATION

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1. Follow the procedure in the thin film fabrication protocol to produce released thin film Parylene electrodes (in their flat configuration)

## 2 INSPECT AND TEST

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### 2.1 VISUAL INSPECTION

*Equipment:* Stereoscope

*Microscope with at least 10x magnification*

1. Using the stereoscope, inspect the device for any large mechanical failures, such as:
  - a. Folded Parylene
  - b. Torn Parylene
  - c. Metal delamination
  - d. Incorrect thermoformed shape
2. Using 5x and 10x magnification (or higher), inspect the device for microscopic mechanical failures, such as:
  - a. Parylene cracks
  - b. Torn Parylene
  - c. Metal cracks
  - d. Metal delamination
3. If any defects are found in functional device areas, the device should not be used  
*Note: defects such as Parylene cracks only in the tabs or metal cracks only in the label which do not impact the electrodes, traces, or bondpads are ok*

### 2.2 SHORTING AND IMPEDANCE CHECK

*Equipment:* LCR Meter

*Stereoscope*

*Materials:* Platinum wire electrode

*Small wire or probe (2)*

*PBS*

1. Set the LCR meter to measure impedance using a 10 kHz, 20 mV signal
2. Place the mounted device under a stereoscope with the bondpads in view
3. Using two small wires or probes, probe the two bondpads to check for electrical shorting between the two electrodes

- a. If impedance magnitude is less than 100 k $\Omega$  or impedance phase is greater than (i.e. closer to zero than)  $-65^\circ$ , the electrodes are shorted and the device should not be used
4. Drop PBS on the device to cover the electrodes only
5. Connect the platinum wire electrode to one of the LCR probes and place the platinum wire in contact with the PBS droplet
6. Probe each bondpad to test channel impedance
  - a. If impedance magnitude is greater than 100 k $\Omega$  or impedance phase is less than (i.e. farther from zero than)  $-65^\circ$ , the trace is broken and the device should not be used
7. Remove all probes and wires, gently rinse the device with DI water, and allow to air dry

### 3 THERMOFORM

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#### 3.1 FIXTURE

*Materials:*      *Mandrel of desired size\**  
                          *Oven safe tray*  
                          *Teflon film (0.001"/25  $\mu$ m thick or thinner)*  
                          *Kapton tape (0.0025"/64  $\mu$ m thick or thinner)*  
                          *Glass slides*

*\* 2 inch long dispensing tips are recommended for easier handling*

*\* Mandrel size is selected using the desired inner diameter of the cuff (0.5 or 0.7 mm), the thickness of the Teflon film, and the thickness of the Kapton tape:*

*Mandrel diameter = cuff diameter - 4 x Teflon thickness - 1 x Kapton thickness*

*For 0.5 mm cuffs: 0.34 mm mandrel (29 gauge needle)*

*For 0.7 mm cuffs: 0.54 mm mandrel (25 gauge needle)*

1. Prepare fixture(s) per the following procedure. If prepared fixtures are already available from prior thermoforming runs, this step may be skipped.
  - a. Cut a piece of Teflon film to 2 cm x 4 cm
  - b. Cut a piece of Kapton tape to 2 cm x 1 mm
  - c. Tape one of the 2 cm sides of the Teflon film along the length of the mandrel using the Kapton tape
2. Hold the mandrel horizontally with the Teflon film underneath the mandrel and pointed towards you
3. Hold the Teflon film tight and rotate the mandrel to wrap the film around the mandrel until the Kapton tape is covered with Teflon
4. Place the Parylene cuff electrode on the Teflon with the exposed electrodes facing up and the tail oriented towards you
5. Align the Parylene electrode such that the center trace is parallel to the mandrel and the top edge of the electrodes are touching the mandrel
6. While holding the Teflon film tight, roll the mandrel towards you, rolling the Parylene electrodes underneath the Teflon film around the mandrel

7. Continue rolling until the entire Parylene electrode is covered, maintaining tension on the Teflon film and watching to ensure the Parylene does not fold or kink
8. Roll the remainder of the Teflon film around the mandrel and hold in place using two small pieces of Kapton tape

### 3.2 BAKE

*Equipment:* Vacuum oven with N<sub>2</sub>

1. Place a stack of 4 glass slides on an oven safe tray and cover with a piece of Teflon film  
*Note: Glass slides are used to lift the mandrel above the surface of the tray so that the mandrel can sit flat on the surface and the plastic end of the dispensing tip does not lift it up – if a different mandrel without a bulky end piece or with a larger end piece is used, fewer or more slides can be used*
2. Place the fixtured device(s) on top of the glass slide so that the mandrel is in contact with the film
  - a. Multiple devices can be placed on top of a single glass slide, so long as there is enough space that the mandrels do not interfere with each other
3. Place a piece of Teflon film over the fixtured devices and place one glass slide on top of the device(s)  
*Note: This step is used to ensure the tape does not fail and allow the device to unravel under high heat*
4. Carefully place the tray in a vacuum oven, close, and evacuate chamber to 70 cmHg or greater vacuum
5. Purge chamber with N<sub>2</sub> to 20-30 cmHg, then re-evacuate to 70 cmHg or greater
6. Repeat step 5 twice (three total N<sub>2</sub> purges)
7. Bake wafers (under vacuum) for 12 hours at 100 °C
8. Remove tray from oven and unstack glass slides

### 3.3 REMOVE FROM FIXTURE

*Materials:* 1" x 3" Teflon sheet (thick enough to remain rigid, 1/16" recommended)  
Kapton tape

1. While holding the Teflon film in place, remove the tape holding it down
2. Slowly unroll the film from the mandrel, holding it tight as you unroll
3. Once the device is visible, continue slowly unrolling and make sure the Parylene is not sticking to the Teflon film by gently nudging it with tweezers as needed – Parylene should easily separate from the film and start to roll on itself
4. Once the device has been fully exposed, grab one of the electrode handling tabs with tweezers and remove it from the fixture
5. Place the device on the Teflon sheet and tape down the two electrode handling tabs using Kapton tape
6. Tape the bondpad end flat on the Teflon sheet (exposed metal side up) using the bondpad tabs

## 4 INSPECT AND TEST

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### 4.1 VISUAL INSPECTION

*Equipment: Stereoscope  
Microscope with at least 10x magnification*

4. Using the stereoscope, inspect the device for any large mechanical failures, such as:
  - a. Folded Parylene
  - b. Torn Parylene
  - c. Metal delamination
  - d. Incorrect thermoformed shape
5. Using 5x and 10x magnification (or higher), inspect the device for microscopic mechanical failures, such as:
  - a. Parylene cracks
  - b. Torn Parylene
  - c. Metal cracks
  - d. Metal delamination
6. If any defects are found in functional device areas, the device should not be used  
*Note: defects such as Parylene cracks only in the tabs or metal cracks only in the label which do not impact the electrodes, traces, or bondpads are ok*

### 4.2 SHORTING AND IMPEDANCE CHECK

*Equipment: LCR Meter  
Stereoscope*

*Materials: Platinum wire electrode  
Small wire or probe (2)  
PBS*

8. Set the LCR meter to measure impedance using a 10 kHz, 20 mV signal
9. Place the mounted device under a stereoscope with the bondpads in view
10. Using two small wires or probes, probe the two bondpads to check for electrical shorting between the two electrodes
  - a. If impedance magnitude is less than 100 k $\Omega$  or impedance phase is greater than (i.e. closer to zero than) -65°, the electrodes are shorted and the device should not be used
11. Drop PBS on the device to cover the electrodes only
12. Connect the platinum wire electrode to one of the LCR probes and place the platinum wire in contact with the PBS droplet
13. Probe each bondpad to test channel impedance
  - a. If impedance magnitude is greater than 100 k $\Omega$  or impedance phase is less than (i.e. farther from zero than) -65°, the trace is broken and the device should not be used
14. Remove all probes and wires, gently rinse the device with DI water, and allow to air dry

## 5 LEAD ATTACH

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*Note: This section currently describes the procedure for attaching wires for interim benchtop testing. This procedure will be updated after the development of the lead attach process by Med-Ally in Y2.*

### 5.1 CONNECT WIRES

*Materials:*      *Epo-TEK H20E Silver Epoxy*  
                      *Desired lead wire*  
                      *Kapton tape*

1. Mix Epo-TEK H20E silver epoxy per manufacturer recommendation
2. Cut lead wire to desired length
3. If lead wire is insulated, strip 1 mm of insulation off one end of each wire and 3-8 mm of insulation of the other end of each wire
4. Align one lead wire (1 mm exposed end) to each bondpad manually or using a vacuum tool and hold in place using Kapton tape
  - a. Kapton tape should not cover or interfere with the bondpad or the length of the lead wire which passes over the bondpad
  - b. Ensure the wire is flat against the bondpad to allow for a stronger connection
  - c. Add enough tape to the free end of the wire to prevent any movement during further processing steps
5. Using a toothpick, needle, or scrap wire, pick up a small volume of Epo-TEK H20E epoxy and dab it over each exposed wire and bondpad, ensuring the two wires/bondpads do not short to each other
  - a. If possible, prevent contact with the Teflon sheet – epoxy can be separated from the Teflon sheet if it comes in contact but it is difficult to do
6. Place the device(s) in a vacuum oven, close, and evacuate chamber to 70 cmHg or greater vacuum
7. Purge chamber with N<sub>2</sub> to 20-30 cmHg, then re-evacuate to 70 cmHg or greater
8. Repeat step 7 twice (three total N<sub>2</sub> purges)
9. Bake wafers (under vacuum) for 4 hours at 85 °C
10. Remove device(s) from oven

### 5.2 INSULATE CONNECTIONS

*Materials:*      *Loctite 4902 Epoxy*

1. Dispense a drop of Loctite 4902 epoxy onto a slide or weigh boat
2. Using a toothpick, needle, or scrap wire, pick up a small volume of Loctite 4902 and dab it over each exposed wire/bondpad/silver epoxy connection, ensuring all conductive areas are covered
  - a. If possible, prevent contact with the Teflon sheet – epoxy can be separated from the Teflon sheet if it comes in contact but it is difficult to do
3. Allow the epoxy to cure at room temperature for at least one hour
4. Repeat process if any areas exposed remain or a stronger connection is desired

## 6 INSPECT AND TEST

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### 6.1 VISUAL INSPECTION

*Equipment: Stereoscope*

*Microscope with at least 10x magnification*

1. Using the stereoscope, inspect the device for any large mechanical failures, such as:
  - a. Folded Parylene
  - b. Torn Parylene
  - c. Metal delamination
  - d. Incorrect thermoformed shape
2. Using 5x and 10x magnification (or higher), inspect the device for microscopic mechanical failures, such as:
  - a. Parylene cracks
  - b. Torn Parylene
  - c. Metal cracks
  - d. Metal delamination
3. If any defects are found in functional device areas, the device should not be used  
*Note: defects such as Parylene cracks only in the tabs or metal cracks only in the label which do not impact the electrodes, traces, or bondpads are ok*

### 6.2 ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY (EIS)

*Equipment: Potentiostat with faraday cage*

*Materials: 50 mL beaker*

*Ag/AgCl reference electrode*

*Platinum counter electrode*

*PBS*

1. Gently rinse the fixtured cuff electrode with DI water, then place it in a 50 mL beaker with the electrodes towards the bottom of the beaker and the wires/lead towards the top
2. Slowly fill the beaker with PBS until the electrodes are submerged; do not add enough PBS to submerge connection point and/or lead
3. Rinse the Ag/AgCl reference electrode and platinum counter electrode in DI water, then place them in the beaker, taking care not to touch the Parylene cuff
4. Connect the reference electrode, counter electrode, and one lead wire (working electrode) to the potentiostat in a 3-electrode setup
5. Perform EIS using 25 mV<sub>rms</sub> over the range of 1 to 10<sup>6</sup> Hz
  - a. If impedance magnitude at 1 kHz is greater than 100 kΩ or impedance phase shows uncharacteristic behavior, the electrodes is open and the device should not be used
6. Move the working electrode connection to the other lead wire
7. Repeat step 5 for the second electrode

8. To test the insulation integrity of the lead connection point, add more PBS to the beaker until the lead connection is submerged and repeat EIS – any significant changes in impedance and phase indicate leakage in the connection point
9. Remove the reference and counter electrodes from the beaker and rinse with DI water
10. Remove the fixtured device from the beaker and gently rinse with DI water

### 6.3 CYCLIC VOLTAMMETRY (CV)

*Equipment: Potentiostat with faraday cage*

*Materials: 3x 50 mL beaker  
Ag/AgCl reference electrode  
Platinum counter electrode  
0.05 M H<sub>2</sub>SO<sub>4</sub>  
PBS*

1. Gently rinse the fixtured cuff electrode with DI water, then place it in a 50 mL beaker with the electrodes towards the bottom of the beaker and the wires/lead towards the top
2. Fill a second 50 mL beaker with 0.5 M H<sub>2</sub>SO<sub>4</sub> to a height such that, when the fixtured electrodes are added, only the electrodes will be submerged; do not add enough H<sub>2</sub>SO<sub>4</sub> to submerge connection point and/or lead
3. Purge the H<sub>2</sub>SO<sub>4</sub> with N<sub>2</sub> for at least 10 minutes
4. Move the fixtured cuff electrode to the H<sub>2</sub>SO<sub>4</sub> beaker
5. Rinse the Ag/AgCl reference electrode and platinum counter electrode in DI water, then place them in the H<sub>2</sub>SO<sub>4</sub> beaker, taking care not to touch the Parylene cuff
6. Connect the reference electrode, counter electrode, and one lead wire (working electrode) to the potentiostat in a 3-electrode setup
7. Perform CV for 30 cycles from -0.2 to 1.2 V (250 mV/s scan rate)
  - a. Calculate electroactive surface area
  - b. Calculate charge storage capacity
8. Move the working electrode connection to the other lead wire
9. Repeat step 7 for the second electrode
10. Remove the reference and counter electrodes from the beaker and rinse with DI water
11. Remove the fixtured device from the beaker and gently rinse with DI water
12. Place the device back in the empty beaker, then repeat steps 6.3.2 through 6.3.11 using PBS in place of H<sub>2</sub>SO<sub>4</sub>

### 6.4 CROSSTALK

*Equipment: Crosstalk setup*

1. Connect each electrode to one channel of the crosstalk setup
2. Run crosstalk measurement using 0.5 V, 1 kHz sine wave
  - a. Equipment sends the signal down one channel and measures potential of all other channels
  - b.  $\text{Crosstalk} = (V_{\text{read}} / V_{\text{send}}) \times 100$
  - c. If crosstalk is greater than 5%, the device should not be used

## 7 PACKAGE DEVICE

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### 7.1 CLEAN

*Materials: 3x 50 mL beaker*

1. Using a scalpel or precision scissors, cut the electrode tabs off of the cuff electrode, taking care not to damage any functional parts of the device
2. Using tweezers, place a droplet of IPA over each piece of tape on the bondpad tabs and gently remove the tape, taking care not to damage the device
3. Using tweezers, place a droplet of IPA over any tape on the wires/lead and gently remove the tape, taking care to hold onto the lead and prevent stress on the cuff electrode
4. Fill one beaker with ~25 mL of IPA and two beakers with ~25 mL of DI water
5. Dunk the device into the IPA (ensuring any portion which will be implanted is submerged) and gently agitate for 30-60 seconds
6. Move the device to the first water beaker (ensuring any portion which will be implanted is submerged) and gently agitate for 30-60 seconds
7. Move the device to the second water beaker (ensuring any portion which will be implanted is submerged) and gently agitate for 30-60 seconds
8. Remove the device from the water and allow to air dry

### 7.2 PACKAGE

*Packaging procedure will be developed in Y2*

## APPENDICES

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### A. MATERIAL SOURCES

*Note: Standard materials (e.g. acetone, DI water, cleanroom wipes, etc.) are not listed*

Material	Supplier
H20E Silver Epoxy	Epo-TEK, Billerica, MA
4902 Epoxy	Loctite, Westlake, OH

### B. EQUIPMENT MODELS

*Note: Standard equipment (e.g. tweezers, microscopes, N2 gun, scale, etc.) are not listed*

Equipment	Model #	Supplier
Vacuum oven with N <sub>2</sub>	TVO-2	Cascade Tek Inc., Longmont, CO
	VO914A	Lindberg/Blue M, New Columbia, PA
Potentiostat	Reference 600	Gamry Instruments Inc., Warminster, PA
Crosstalk Setup	Custom setup – see section 6.4 for specifications	