Protocol: Polyimide Shuttle Film Fabrication

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Description: This document describes the microfabrication of ~40 µm thick polyimide (PI) films used to create laser micromachinined shuttles. The thicker polyimide film is obtained using 5 sequentially applied layers of PI-2611, each ~8 µm thick. For each PI layer after the first foundational layer, the soft-bake temperature step is increased by 2 minutes to promote solvent removal and significantly reduce the formation of trapped bubbles in the resulting film.

Note: Standard equipment and materials (e.g. tweezers, microscopes, DI water, cleanroom wipes, N_2 gun, scale, etc.) are not listed in materials lists.

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1 Substrate Preparation

1.1 Clean Silicon Wafer

Note: this step assumes you are working with wafers that require a gentle clean before use and can be skipped if you are using pre-cleaned wafers
Note: this step should be performed immediately before polyimide deposition (step 2.2)
Materials: *4" prime silicon wafer(s)*
Acetone
Isopropyl alcohol (IPA)
Equipment: *Oven or hot plate*

1. Label wafer backside (wafer ID and date) using a diamond scribe or permanent marker
2. Rinse wafer with acetone, IPA, DI water; blow dry with N_2

3. Bake wafers at 110 °C in an oven at atmosphere for at least 30 minutes (overnight is OK), or on a hot plate for >5 minutes

2 Multi-Layer Polyimide Deposition

Note: all 5 spin coat and soft-bake steps must be completed before the final high-temperature cure

2.1 Prepare Polyimide

Note: use PI-2611 (HD Microsystems) stored and handle per manufacturer instructions
Note: PI should be defrosted and degassed ahead of time (>3 hours) to minimize dissolved gas (for example, performed during step 1.1 or before)
Materials: PI-2611 polyimide precursor
Amber bottle
Equipment: Vacuum chamber

1. Defrost PI-2611 at room temperature in fume hood at least 3 hr to allow dissolved gases to escape
2. Transfer an appropriate volume to an amber bottle
3. Degas in a vacuum chamber (~30 inHg) for ≥ 1 hr
4. Once degassed, keep the bottle capped when not in use to minimize re-absorption of moisture and solvent loss

2.2 Deposit Layer 1 (Base PI Layer)

Note: this step should be performed immediately after drybake (end of step 1.1)
Materials: Plastic pipette
Equipment: Spin coater
Hot plate
IR thermometer (optional but recommended)

1. Line the inside of the spinner lid with aluminum foil (for easier cleanup)
2. Blow wafer surface with N_2 to remove particles
3. Place wafer (with or without release layer) onto the spinner chuck (using the wafer centering tool, if desired), center it, and engage vacuum to hold it in place
4. Dispense PI-2611 from the bottle on the center of the wafer
    a. PI-2611 can be dispensed directly from the bottle
    b. This should create ~1.5 inch (3.81 cm) diameter puddle
    c. Let the PI puddle rest for 1 min
    d. If any bubbles are present in the photoresist puddle, wait for them to pop or carefully remove using a small plastic pipette, taking care not to touch the wafer surface
5. Spin PI-2611 to 8 µm thickness using the following recipe:
    10 seconds, 500 RPM, accl 4
    15 seconds, 1000 RPM, accl 4
    40 seconds, 2200 RPM, accl 4
6. Rest wafer for 1 minute
7. Bake Layer 1 on a leveled hot plate using the following soak steps
    85 °C for 2 minutes
    140 °C for 2 minutes

160 °C for 2 minutes

8. Cool wafer to near room temperature on a flat surface before next coat

2.3 Deposit Layers 2-5

Note: this step should be performed immediately after previous step

For Layers 2-5, repeat the following sequence until final layer is deposited:

1. Blow wafer surface with N_2 to remove particles
2. Place wafer (with or without release layer) onto the spinner chuck (using the wafer centering tool, if desired), center it, and engage vacuum to hold it in place
3. Dispense PI-2611 from the bottle on the center of the wafer
    a. PI-2611 can be dispensed directly from the bottle
    b. This should create ~1.5 inch (3.81 cm) diameter puddle
    c. Let the PI puddle rest for 1 min.
    d. If any bubbles are present in the photoresist puddle, wait for them to pop or carefully remove using a small plastic pipette, taking care not to touch the wafer surface
4. Spin PI-2611 to 8 µm thickness using the following recipe:
    10 seconds, 500 RPM, accl 4
    15 seconds, 1000 RPM, accl 4
    40 seconds, 2200 RPM, accl 4
5. Rest wafer for 1 minute
6. Bake Layer n (where n= 2–5) on a leveled hot plate using the following soak steps and per the time recommended times:
    85 °C for t_n minutes
    140 °C for t_n minutes
    160 °C for t_n minutes
    t_2 = 4 minutes, t_3 = 6 minutes, t_4 = 8 minutes, t_5 = 10 minutes
7. Cool wafer to near room temperature on a flat surface before next coat (to avoid thermal shock and allow continued removal of residual solvent)

2.4 Final Cure of 5-Layer PI Stack

Equipment: Cee® Apogee® 300 Bake Plate

1. Place wafer on N_2-purged hot plate or programmable bake system
2. Bake at 350 °C per the following recipe
    a. Ramp up at 2 °C/min (or per hard-bake SOP)
    b. Bake for 30 min to completely imidize PI-2611
    c. Ramp down at 2 °C/min to room temperature
3. Turn off hot plate and remove wafer after cooled to near room temperature

2.5 Measure PI-2611 Thickness

Materials: Coated wafers from step 2.4

Equipment: Profilometer

1. Measure total PI-2611 thickness (using height of a step) using a profilometer
2. Log measurement into logbook

APPENDICES

A. MATERIAL SOURCES

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

Material	**Supplier**
PI-2611 Polyimide Precursor	HD Microsystems, Sayreville, NJ

B. EQUIPMENT MODELS

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

Equipment	**Model #**	**Supplier**
Ball bonder	626	Hybond, Escondido, CA
Fine-pitch capillary	SBB-33090-515A-ZP94	Small Precision Tools, Lyss, Switzerland
Wedge bonder	527A	Hybond, Escondido, CA
'Waffle' tool	7045W-TI-10050-3/4-M	Small Precision Tools, Lyss, Switzerland
USB interface board	C3100 (discontinued)	Intan Technologies, Los Angeles, CA
Acquisition Board	OEPS-9030 (alternative to above)	Open Ephys, Atlanta, Georgia