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🌐 PDMS Microfluidic device fabrication

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We use this protocol and it's working

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Abstract

This protocol describes the fabrication of microfluidic devices using Polydimethylsiloxane (PDMS), a silicone-based organic polymer widely used in microfluidics due to its optical transparency, biocompatibility, flexibility, and ease of molding. The protocol involves several key steps, including preparation of a glass hardmask, soft lithography and PDMS casting.



Guidelines

Cleanroom Guidelines

- 1. Personal Items:** Leave items like keys, wallets, and phones outside. If needed inside, keep them concealed under cleanroom garments;
- 2. Food, Drink, and Cosmetics:** No eating, smoking, gum chewing, or use of makeup and perfume. These may introduce contaminants;
- 3. Movement:** Avoid running or unnecessary rapid movements; these stir up particles and increase contamination;
- 4. Health:** Don't enter if unwell to prevent pathogens from contaminating the environment;
- 5. Gowning Protocol:** Follow gowning procedures strictly. Only allow entry with clean, gloved hands, face masks, covered shoes, and safety glasses;
- 6. Hygiene:** Maintain good personal hygiene;
- 7. Hair Covering:** Securely cover all hair and facial hair to prevent contamination;
- 8. Smoking:** Wait at least 20 minutes after smoking before entering to minimize residual smoke contamination;
- 9. Surfaces:** Do not sit or lean on equipment or work surfaces to avoid transferring contaminants;
- 10. Face and Hair Contact:** Avoid touching your face or hair with gloved hands. Exit the cleanroom if necessary, and replace gloves before re-entering;

Materials

REAGENTS AND MATERIALS

Glass hardmask fabrication

2" glass samples, 0.7 mm thick;

TechniEtch Al 80 MOS Aluminium etchant (TECHNIC France, Saint Denis la Plaine, France);

Microstrip 3001® (Fujifilm Electronic Materials, Co., Ltd. Shizuoka, Japan);

Soft lithography

2" Si samples. 0.7 mm thick;

SU-8 50 photoresist (Kayaku, Westborough, USA);

1,2-Propanediol monomethyl ether acetate (PGMEA);

Polymethyl metacrylate mold fabrication and polydimethylsiloxane casting

Polymethyl metacrylate (PMMA) mold 100 mm², 2mm thick;

3mm endmill;

Polydimethylsiloxane (PDMS) (Merck KGaA, Darmstadt, Germany);

Silicone elastomer, curing agent (SYLGARD® 184, Merck KGaA, Darmstadt, Germany);

disposable 100 mL plastic cup;

plastic / glass / metal spatula;

Cleaning

Cleanroom paper towels;

Aluminium foil;

Alconox® detergent (Merck KGaA, Darmstadt, Germany);

Acetone;

Isopropyl alcohol (IPA);

DI water;

Compressed air gun;

Other

Disposable syringe + LS22 syringe tips;

Glass beakers;

100-150 mL glass crystallization dishes;

Adhesive tape;

Polyimide (Kapton) adhesive tape;

Metal tweezers;

Disposable plastic Petri dishes;

Parafilm® plastic paraffin film;

Personal protective equipment

Cleanroom suit and hood (for cleanroom use only);



Laboratory coat;
Nitrile protective gloves;
Laboratory protective glasses;

Laboratory equipment

Broad ion beam milling system (Nordiko 7000, Nordiko Technical Service Ltd, Hampshire, United Kingdom);
Ion beam deposition system (Nordiko 3000, Nordiko Technical Service Ltd, Hampshire, United Kingdom);
Automated coater track system (ASML Veldhoven, The Netherlands);
Direct write laser lithography (DWL) system (Heidelberg Instruments, Heidelberg, Germany);
Laminar flow hood;
Chemical fume hood;
Ultraviolet (UV) light;
Spin coater (H6-15, Laurell Technologies Corporation, North Wales, USA);
Hot plate;
Ultrasonic thermal bath;
Analytical scale;
Vacuum dessicator;
Profilometer;
Optical microscope;
CNC micromill;
Laboratory refrigerator;

Safety warnings

- ❗ Read the chemical products' safety data sheets (SDS) before using them and observe all the manufacturer's recommendations.

Always manipulate dangerous chemicals inside a chemical fume hood while wearing the necessary PPE (laboratory coat, nitrile gloves and eye protection).

Before start

Make sure all the necessary material and reagents are available. Make sure all the equipment needed is available / booked before starting the protocol.

Glass hardmask fabrication

4h 10m

1 Substrate cleaning and preparation



- 1.1 Dispense a critical cleaning detergent solution (ex: Alconox®) into a 100-150 mL glass crystallization dish. Place the dish in an ultrasonic bath previously heated to 65°C, inside a chemical fume hood;
- 1.2 Using pliers, put a glass sample (50 mm x 50 mm, 0.7 mm thickness) in the glass dish. Turn on the ultrasonic bath and incubate for 3 hours at 65°C;
- 1.3 Turn off the ultrasonic bath. Using pliers, remove the sample from the glass dish and wash it sequentially in acetone, isopropyl alcohol (IPA), and deionized (DI) water using laboratory wash bottles;
- 1.4 Blow-dry the glass sample using compressed air;



2 Aluminium deposition - 1500 Å thick film



- 2.1 Using a magnetron sputtering system in an ISO 5 cleanroom, set the deposition parameters to 2000 W power, 80 sccm argon gas flow, and 3.1 mTorr chamber pressure;
- 2.2 Perform the deposition in three steps, each producing a 500 Å film layer over 13.3 seconds. After each deposition step, allow the sample to cool for 100 seconds;

3 Photolithography



- 3.1 Perform Vapor Prime pre-treatment on the glass sample with the 1500 Å thick Al film 40 minutes before UV lithography in a vapor priming oven using the following protocol:



Step	Conditions
Wafer dehydration	2 min vacuum, 10 Torr pressure; 3 min N2 inlet, 760 Torr pressure; Heating up to 130°C;
Priming	3 min vacuum, 1 Torr pressure; 5 min hexamethyldisilazane (HDMS) priming, 6 Torr

Step	Conditions
	pressure;
Purge prime exhaust	1 min vacuum, 4 Torr pressure; 2 min N2 inlet, 500 Torr pressure; 2 min vacuum, 4 Torr pressure;
Return to atmosphere	3 min N2 inlet;

- 3.2 Perform 1.5 μm thickness photoresist (PR) coating on the glass sample with the 1500 Å thick Al film in a photolithography track system using the following protocol:

Step	Time
PR dispense and spin at 800 rpm	5 sec
Spin at 2500 rpm	30 sec
Soft bake at 85°C	60 sec

- 3.3 Perform sample exposure in a Direct Write Lithography (DWL) system using a software mask;

- 3.4 Perform sample development in a photolithography track system using the following protocol:

A	B
Bake at 110°C	60 sec
Cool	30 sec
Develop	60 sec

- 3.5 Check feature size and shape using an optical microscope. PR should be absent from the MF structure locations in the mold. If the PR was not completely removed, repeat the development step in the photolithography track system;

- 3.6 Check PR thickness using a profilometer;



4 Aluminium wet etching

- 4.1 Dispense DI water and Al chemical etchant, with a high etch rate at room temperature, into separate 100-150 mL glass crystallization dishes inside a chemical fume hood; 
- 4.2 Using pliers, put the sample facing upwards in the glass dish containing the Al chemical etchant and place it in an orbital agitator at 200 rpm for 4 minutes inside a chemical fume hood; 
- 4.3 Turn off the orbital shaker and, using pliers, transfer the sample to the glass dish containing DI water, facing upwards. Turn on the orbital agitator at 200 rpm for 1 minute;
- 4.4 Turn off the orbital shaker, and, using pliers, remove the sample from the glass dish, rinse it using a laboratory wash bottle, and blow dry it with compressed air;
- 4.5 Check Al etch using an optical microscope. If Al etch is not complete, repeat steps 4.2 to 4.4, and re-check using the optical microscope; 

5 Photoresist strip

- 5.1 Dispense a PR stripper suitable for SU-8 removal (ex: Microstrip® 3001) into a 100-150 mL glass crystallization dish. Place the dish in an ultrasonic bath previously heated to 60°C, inside a chemical fume hood;  
- 5.2 Using pliers, put the sample facing upwards in the glass dish containing the PR stripper. Turn on the ultrasounds and incubate for 30 minutes;   
- 5.3 Turn off the ultrasonic bath. Using pliers, remove the sample from the glass dish and wash it sequentially in IPA, and DI water using laboratory wash bottles;
- 5.4 Check the PR strip using an optical microscope. If strip is not complete, repeat steps 5.1 to 5.3, and re-check using the optical microscope;

Soft lithography

3h

6 Substrate cleaning and preparation



6.1 Dispense a critical cleaning detergent solution (ex: Alconox[®]) into a 100-150 mL glass crystallization dish. Place the dish in an ultrasonic bath previously heated to 65 °C, inside a chemical fume hood;

6.2 Using pliers, put a silicon oxide sample (50 mm x 50 mm, 0.7 mm thickness) in the glass dish. Turn on the ultrasonic bath and incubate for 3 hours at 65°C;



6.3 Turn off the ultrasonic bath. Using pliers, remove the sample from the glass dish and wash it sequentially in acetone, IPA, and DI water using laboratory wash bottles;



7 Lithography

7.1 Cover a hotplate with aluminium foil. Turn on the hotplate and set the temperature to 110 °C;

7.2 Using tweezers, place the sample on the hotplate, facing upwards and dehydrate for 5 minutes at 110 °C;



7.3 Cover the inside of the spin coater chamber and holder with aluminium foil;

7.4 Using tweezers, place the sample on the spin coater and cool to RT;

7.5 Using a pipette, dispense 4 mL of SU-8 50[®] PR on the sample;

7.6 Set the spin coater to 500 rpm, 100 rpm.s⁻¹ and spin for 10 seconds;



7.7 Set the spin coater to 2965 rpm, 300 rpm.s⁻¹ and spin for 30 seconds. A 30 µm PR layer is obtained;



7.8 Set the hot plate to 65 °C. Using tweezers, transfer the sample to the hot plate and incubate for 4 minutes and 30 seconds at 65 °C. Using tweezers, remove the sample from the hot plate;



7.9 Set the hot plate to 95 °C. Using tweezers, transfer the sample to the hot plate and incubate for 14 minutes at 95 °C; Using tweezers, remove the sample from the hot plate and cool to RT;





- 7.10 Place the sample in contact with the glass hard mask. The sample's SU-8 50[®] PR must be in contact with the Al film side of the glass hard mask. Making sure there are no gaps between the two, mount them in the UV light holder center using Kapton tape;
- 7.11 Place the holder with the samples in the UV chamber;
- 7.12 Expose the sample to UV light at 5.95 W.cm⁻² for 49 seconds; Remove the holder, and separate the sample from the glass hard mask; 
- 7.13 Set the hot plate to 65 °C. Using tweezers, transfer the sample to the hot plate and incubate for 1 minute at 65 °C. Using tweezers, remove the sample from the hot plate; 
- 7.14 Set the hot plate to 95 °C. Using tweezers, transfer the sample to the hot plate and incubate for 3 minutes at 95 °C; Using tweezers, remove the sample from the hot plate and cool to RT; 
- 7.15 Dispense propylene glycol methyl ether acetate (PGMEA) into a 100-150 mL glass crystallization dish and place it in an orbital agitator inside a chemical fume hood; 
- 7.16 Using pliers, put the sample facing upwards in the glass dish containing PGMEA and set the orbital agitator at 200 rpm for 5 minutes and 30 seconds; 
- 7.17 Using pliers, remove the sample from the glass dish and wash it in IPA, using a laboratory wash bottle. Blow dry the sample; 

Polymethyl metacrylate mold fabrication

1h 10m

- 8 Using a 3 mm diameter micromilling tool, mill a polymethyl metacrylate (PMMA) with the following dimensions (H x W x D): 100 mm x 100 mm x 1 mm

Polydimethylsiloxane casting

1h 10m

9 Polydimethylsiloxane (PDMS) preparation

- 9.1 Transfer and weigh the desired volume of polydimethylsiloxane (PDMS) to a 100 mL plastic cup.
- 9.2 Vigorously mix the PDMS with the curing agent in a 10:1 ratio using a metal, glass or plastic spatula;



9.3 Place the plastic cup containing the mixture inside a dessicator. Turn the vacuum on for 1 hour to remove air bubbles;



9.4 If air bubbles are still present after 1 hour, leave the cup inside the dessicator under a vacuum for an additional 30 minutes;

9.5 The ready-to-use PDMS can be stored at -4°C in a sealed cup for up to 15 hours;

10 **SU-8 and PMMA cleaning**

10.1 Inside a chemical fume hood, clean the SU-8 and PMMA mold parts with IPA using a clean room paper towel. Remove all PDMS residues;

10.2 Rinse the molds with DI water using a laboratory wash bottle;

10.3 Blow-dry the molds using compressed air;

10.4 Store the molds between two sheets of clean room paper inside a petri dish to avoid dust buildup;

11 **Mold assembly and filling**

11.1 Align the SU-8 mold and the PMMA plate and fix them in position using adhesive tape;

11.2 Slowly inject the PDMS into the mold using a disposable syringe with a LS22 connector. Avoid bubble formation;



11.3 Stop the injection when PDMS starts leaking from the mold;

12 **Baking and peeling**



- 12.1 Bake the PDMS-filled mold in the oven at 70°C for 1 hour;
- 12.2 Remove the mold from the oven and peel the baked PDMS from the mold bottom using a scalpel and tweezers;
- 12.3 Store the PDMS devices between two sheets of clean room paper inside a petri dish with molded features facing up to avoid dust buildup;

