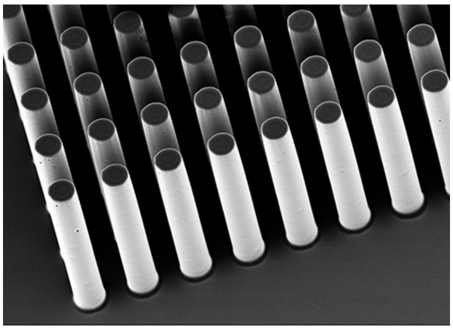
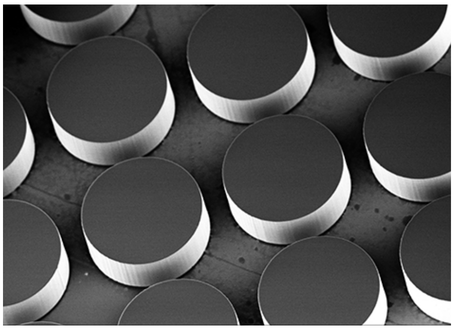
Structuring a Photoresist-Coated Wafer With Photolithography Using the ibidi Micro Illumination System

The ibidi Micro Illumination System enables the fabrication of 3D microstructures on 3-inch silicon wafers coated with light-sensitive photoresist at the micro scale. During the process, selective exposure causes the illuminated regions to become either soluble or insoluble, depending on whether a positive or negative resist is used. The soluble photoresist is subsequently removed, leaving a well-defined, microstructured layer on the wafer. The design of the photomask determines the areas exposed and the resulting structures. This approach is highly flexible, as photomasks can be easily adapted to specific research requirements.





This Application Note provides a protocol for coating a 3-inch silicon wafer with the negative photoresists SU-8 5 or SU-8 50. The wafer is then microstructured through photolithography using the ibidi Micro Illumination System, resulting in a master mold for PDMS. This mold serves as a template for lab-on-a-chip applications, including the fabrication of microfluidic channels.

ibidi Solutions for Structuring a Photoresist-Coated Wafer With Photolithography

- ibidi Micro Illumination System

Related Documents

- Instructions ibidi Micro Illumination System (PDF)
- Application Note 72: RGD Micropatterning Using the ibidi Micro Illumination System for Spheroid Generation and Cultivation (PDF)
- Application Note 73: 2D Whole Protein Pattern Based on a PLL-PEG-Passivated Coverslip Surface Using the ibidi Micro Illumination System (PDF)
- Application Note 74: 3D Hydrogel Constriction in the µ-Slide I Luer Using the ibidi Micro Illumination System (PDF)
- Application Note 76: Photo-Induced Cell Migration Using the ibidi Micro Illumination System (PDF)

1 Material

1.1 Reagents and Buffers

- CZ-Si wafer 3-inch (10BDE, Micro Chemicals)
- SU-8 5, SU-8 50 (permanent negative epoxy photoresist, Kayaku Advanced Materials)
- SU-8 solvent PGMEA (Micro Chemicals)
- Hellmanex III (634-0666, VWR)
- Hydrofluoric acid (HF) (7664-39-3, Sigma-Aldrich)
- Milli-Q water
- Optional for silanization and soft lithography (PDMS):
  - 1H,1H,2H,2H-perfluoroctyltrichlorsilane (L16606.09, Thermo Fisher)
  - Polydimethylsiloxane (PDMS) (761036, SYLGARD® 184, Sigma-Aldrich)
  - Isopropanol (CP41.4, Carl Roth)

1.2 Equipment

- ibidi Micro Illumination System (76000, ibidi)
- 3” photomask (compugraphics, MacDermid Alpha)
- Hot plate
- Spin coater
- Desiccator
- Pressurized air
- Petri dishes, double-sided tape, aluminium foil

2 Pre-Treatment of the Silicon Wafer

Important Note

Working with hydrofluoric acid (HF) is extremely dangerous and requires preparation and safety precautions. Therefore, it is important that everyone working with HF has received proper training on its hazards, safe handling procedures, and emergency response.

1. Immerse the wafer in an ultrasonic bath containing Milli-Q water for 5 minutes.
2. Rinse the wafer with 10 ml of Milli-Q water.
3. Transfer the wafer to an ultrasonic bath with 2% Hellmanex III solution for 20 minutes.
4. Rinse the wafer with 10 ml of Milli-Q water.
5. Place the wafer in an ultrasonic bath filled with Milli-Q water.
6. Rinse the wafer twice with 10 ml of Milli-Q water.
7. Put the wafer in hydrofluoric acid (HF) for 2 minutes.
8. Rinse the wafer five times with 5 ml of Milli-Q water.
9. Dry and store the wafer upon further use in a drying cabinet set to 50°C.

3 Spin Coating and Soft-Bake of the Wafer

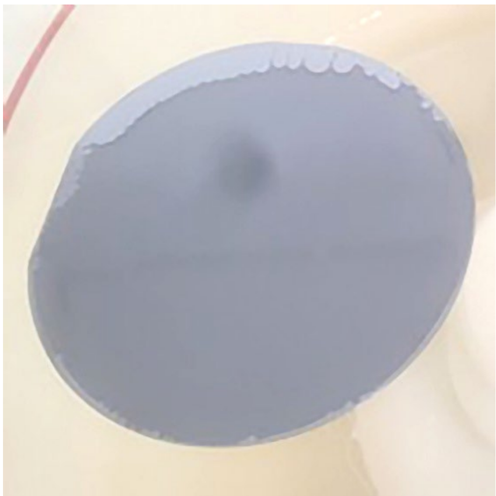
Important Note for Substrate Coating

For ultra-high viscosity materials, it is crucial to carefully optimize the dispense rate, dispense volume, and spin parameters to prevent the formation of bubbles or voids in the final film. When manually coating the photoresist, transfer a small amount of the material into a beaker with an integrated pour spout and allow any bubbles to dissipate. Pour the photoresist directly from the beaker, keeping it close to the wafer surface to ensure even application. The use of a pipette or dropper is not recommended. The final film thickness will be determined by the combination of spin speed and spin time.

Important Note for the Soft-Bake Process

Soft-bake times and temperatures may vary depending on the application. Process optimization is recommended to ensure optimum pattern profiles and stable lithographic and adhesion performance.

1. After completing the pre-treatment of the wafer (described in Section 2), place the wafer on a hotplate covered with aluminium foil for 5 minutes.
2. Transfer the wafer to the spin coater and activate the vacuum.
3. Dispense 1 ml of photoresist per inch of the wafer diameter onto the surface.
   - **SU-8 5:** 3 ml of SU-8 5 (film thickness range: 5–15 µm)
   - **SU-8 50:** 3 ml of SU-8 50 (film thickness range: 40–100 µm)
4. Adjust the spin coater settings according to the manufacturer’s guidelines.
   - **SU-8 5:** spin: 1500 rpm, 40 seconds (film thickness: 10 µm)
   - **SU-8 50:** spin: 1500 rpm, 40 seconds (film thickness: 100 µm)
5. Immediately after the coating process, place the wafer on the hotplate to soft-bake the photoresist.
   - **SU-8 5:** 2 minutes at 70°C
   - **SU-8 50:** 10 minutes at 70°C



A 3-inch wafer coated with SU-8 50 and subjected to a soft-bake process, resulting in a final film thickness of 100 µm.

4 Pattern Illumination

Important Note

Ensure that the used photoresist reacts to light with a wavelength of 365 nm. The illumination time and the selected intensity needed may vary depending on the specific photoresist and the layer thickness.

1. Place the photomask into the mask holder with the chrome layer facing upwards.
2. Place the soft-baked wafer with the side of the photoresist facing down on the desired pattern on the chrome mask.
3. Put the whole mask holder, containing photomask and wafer, into the ibidi Micro Illumination System.
4. Close the lid, select the corresponding settings, and start the illumination process, following the Instructions of the ibidi Micro Illumination System.
   - **SU-8 5:** 50% intensity, 10 seconds
   - **SU-8 50:** 50% intensity, 10 seconds

5 Post-Exposure Bake and Development

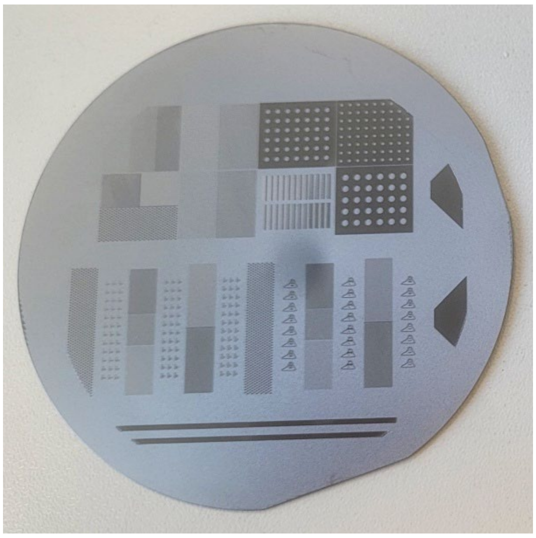
Important Note for Post-Exposure Bake

The post-exposure bake involves heating the wafer. The specific conditions may need to be optimized based on the photoresist type, layer thickness, and desired pattern resolution. This may involve adjusting the bake temperature and time to achieve the best results.

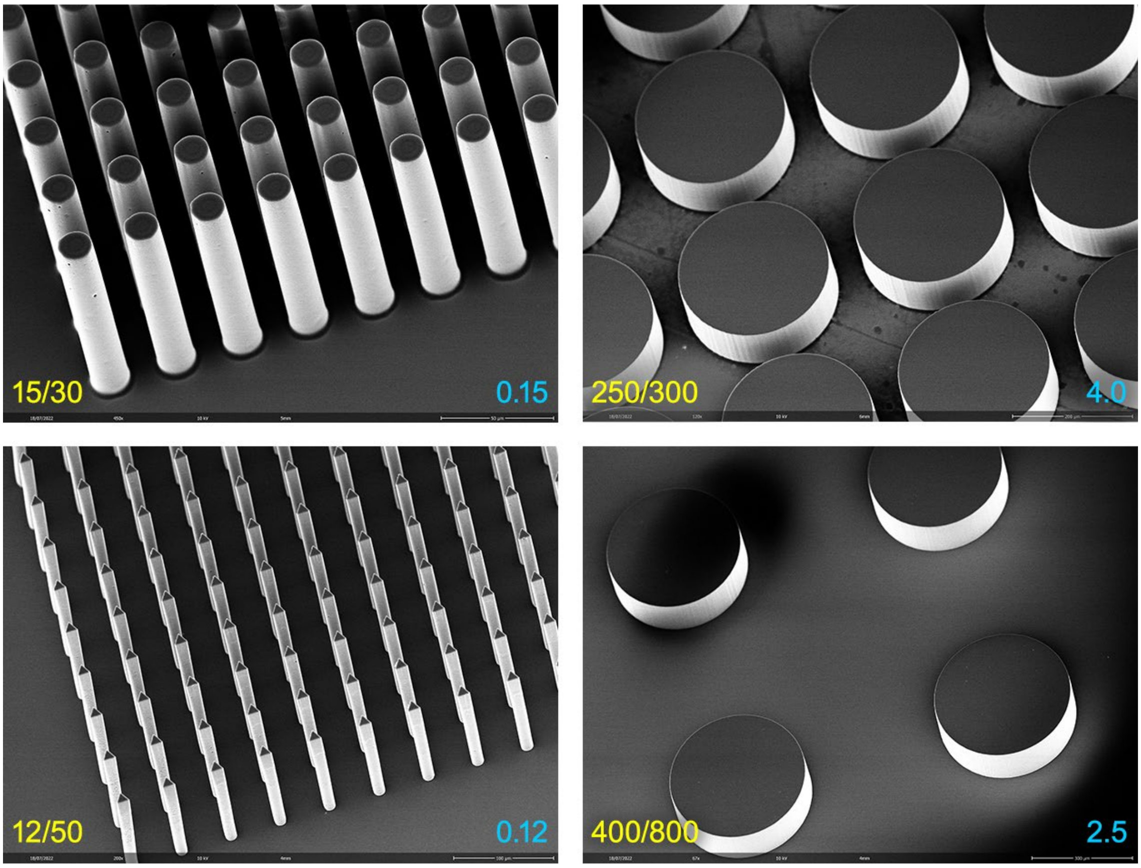
Important Note for Development

Always use the appropriate developer solution based on the type of photoresist. The developer should effectively dissolve the exposed or unexposed photoresist—depending on whether a positive or negative resist is used—without damaging the underlying silicon substrate. Continuously optimize the development process parameters, including developer concentration, development time, and agitation method, to get best results for your application.

1. After exposure, place the wafer on a hotplate for the post-exposure bake.
   - **SU-8 5:** 2 minutes at 70°C
   - **SU-8 50:** 4 minutes at 70°C
2. Prepare a Petri dish containing 50 ml of the developer PGMEA.
3. Prepare a Petri dish containing 50 ml isopropanol.
4. Immerse the post-exposure-baked wafer in the PGMEA bath for 4 minutes.
5. Transfer the wafer to the isopropanol bath for 1 minute.
6. Repeat steps 4 and 5 at least five times until no more streaks are visible on the wafer.
7. Dry the wafer gently using pressurized air.
8. Optional: Perform a hard-bake to further cure the remaining photoresist and enhance its resistance to subsequent processing steps. Hard-bake temperatures should be maintained between 50°C and 70°C to minimize thermal distortion of the pattern.



Macroscopic view of a 3-inch wafer after illumination, post-exposure bake, and development shows that the SU-8 50 photoresist polymerized in the exposed regions, while the unexposed areas dissolve during the development process.



Scanning electron microscope (SEM) images of the fabricated 3-inch wafer containing microscopic structures. The yellow annotations indicate the diameter and center-to-center distance of these structures, while the blue annotations denote their aspect ratio.

6 Optional: Silanization and Soft-Lithography

Important Note for the Silanization

Ensure that the silicon wafer surface is clean and free of contaminants. This typically involves cleaning with solvents. Choose an appropriate silane coupling agent based on the desired surface functionality. To achieve a complete and uniform silane layer, optimize reaction conditions, including temperature, humidity, and reaction time.

Important Note for Soft-Lithography

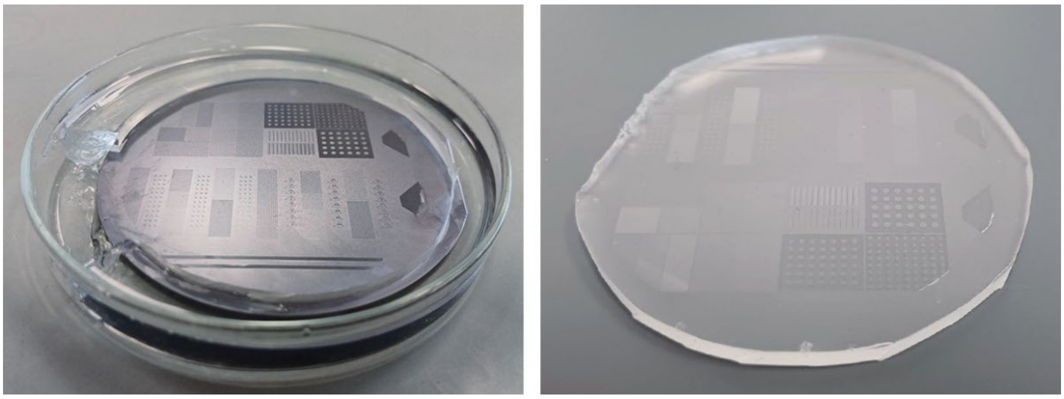
To optimize the PDMS soft-lithography process, ensure precise preparation of the master mold. Carefully control the curing conditions and gently demold the PDMS to preserve microstructure integrity. Treat the PDMS surface as needed to enhance its properties and inspect the final mold for defects to ensure high-quality results.

6.1 Silanization of the Wafer

1. Clean the wafer gently with pressurized air.
2. Utilize a small shell of aluminium foil containing 2 ml 1H,1H,2H,2H-perfluoroctyl-trichlorsilane.
3. Place the aluminium shell in the desiccator.
4. Position the wafer on the aluminium shell, ensuring the structures are oriented downwards.
5. Apply a vacuum for 30 minutes.

6.2 Soft-Lithography

1. Mix PDMS in a ratio of 10 (base) :1 (hardener).
2. Degas the liquid PDMS for 60 minutes in a desiccator.
3. Stick the wafer via double-sided tape into a plastic Petri dish.
4. Pour the degassed PDMS onto the silanized wafer.
5. Put the wafer into an oven at 50°C and let it cure overnight.
6. The cured PDMS contains the negative replica of the wafer's microstructures.



The structured 3-inch wafer was fixed to a Petri dish using double-sided tape. The degassed PDMS was poured onto the silanized wafer and cured overnight (left). The PDMS containing the negative structures of the structured wafer can be cut directly from the wafer (left) or completely detached (right) for further use.

