Nanoscribe Microfluidic Devices at SNF

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Introduction **2**

Protocol assumptions: **2**

Additional training material for nanoscribe use **2**

Nanoscribe microfluidic device protocol 3

DeScribe settings for microfluidic applications 3

Design rules for nanoscribe microfluidic devices **4**

Bottom of the device must be 100% flat against the silicon surface 4

No overhanging components 5

Single Z value for each X,Y 5

Time to make different microfluidic device components **6**

Choosing an objective (63x or 25x) **8**

Using the Nanoscribe **11**

1. Pretreat 4” Si wafer with O2 plasma 11

Post-fabrication steps for microfluidic devices molds 12

Make reusable mold out of smoothcast polymer **13**

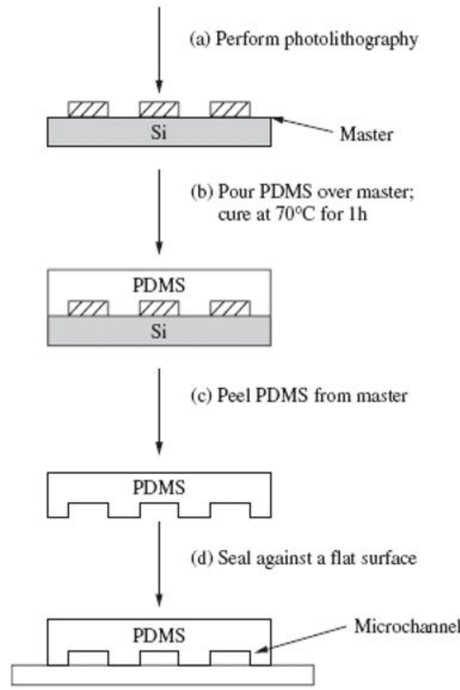
Pdms protocol **13**

NOA protocol **13**

Introduction

The Nanoscribe is the world's highest resolution 3D printer, with a resolution under 1 μm with the 63x objective and under 3 μm with the 25x objective. Its ability to create structures with varying heights makes it ideal for creating unique microfluidic device designs that are not achievable with standard lithography techniques.

This is a general protocol for creating master molds of microfluidic devices with the Nanoscribe at SNF. Once the master mold is made, replicas of microfluidic devices can be made by curing PDMS on the mold (see panel on right).



Typically, with this protocol a secondary polyurethane ("Smoothcast") master mold will be made from the original PDMS, due to the original Nanoscribe mold having low mechanical integrity and often breaking after a few uses. The secondary Smoothcast mold can be used indefinitely to make PDMS microfluidic devices. The protocol for making the secondary Smoothcast mold can be found below.

For users who desire stiffer microfluidic devices, organic solvent compatibility, or a way to make replicas of optical components made with the Nanoscribe, this protocol also includes a link to a protocol to make devices out of Norland Optical Adhesive (NOA).

This protocol will work for most applications. This protocol was developed with funding from the nano@Sstanford fellowship.

Protocol assumptions:

- Already trained on basic use of the Nanoscribe
- Can draw device in Solidworks or equivalent
- Working knowledge of DeScribe software

Additional training material for nanoscribe use

- Training videos
- [UPenn protocol]

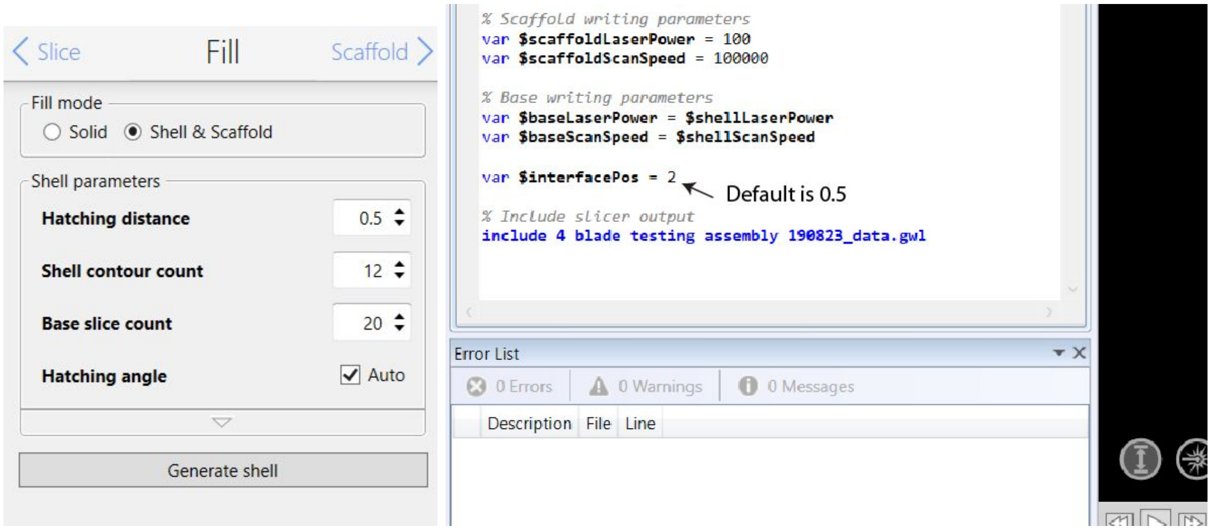
Nanoscribe microfluidic device protocol

DeScribe settings for microfluidic applications

- Using the shell and scaffold method of fabrication is required to decrease the fabrication time to the point that making a microfluidic device with the Nanoscribe becomes reasonable
- You also want enough solid baselines so that the device sticks well to the wafer and doesn't leak
  - Even with these settings, the Nanoscribe mold can only be used 3 – 4 times before breaking
    - We have addressed this issue using a method of creating a secondary mold. See the section on "Smoothcast" below.

Never use last session parameters in DeScribe or it won't hash the file into boxes correctly!

- Modified default 25x parameters, shell and scaffold
  - Shell and scaffold
  - Base slice count = 20
    - Can probably get away with less than this, but it helps keep mold stuck to Si wafer
  - Interface position = 2 μm
    - Write into surface so it sticks
    - This is set manually once the job file has been created.
- Modified default 63x parameters, shell and scaffold
  - Shell and scaffold
  - Base slice count = 12
  - Interface position = 2 μm
    - Write into surface so it sticks
    - This is set manually once the job file has been created.

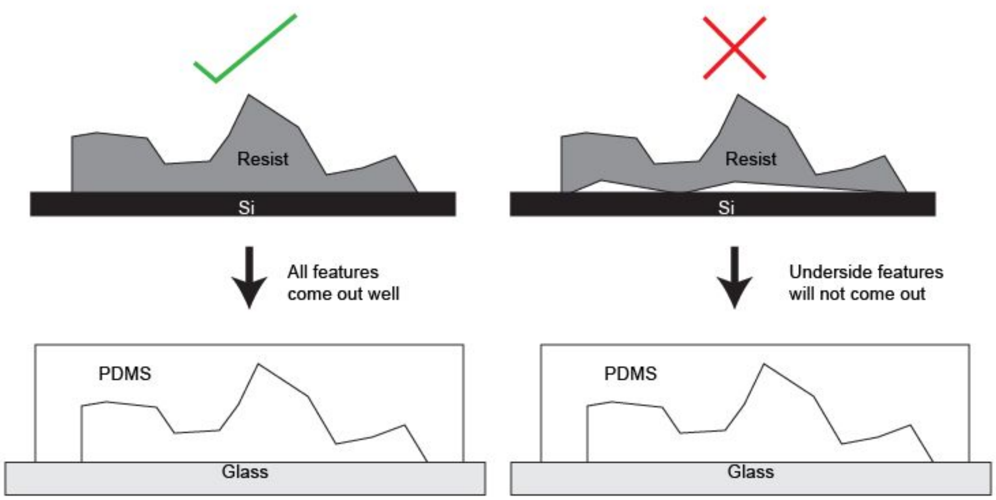


Design rules for nanoscribe microfluidic devices

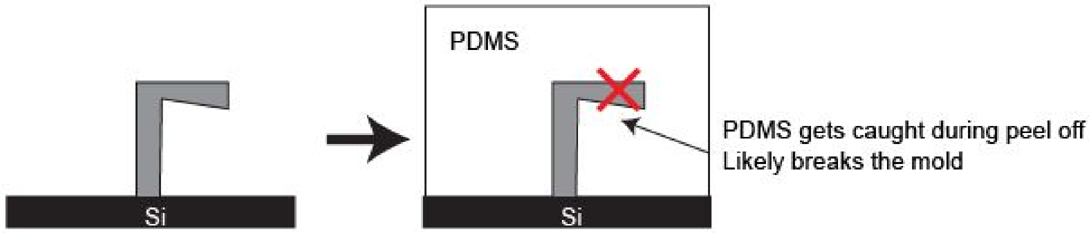
Note: If using Nanoscribe polymer as device rather than a mold then these rules don't apply

1. Bottom of the device must be 100% flat against the silicon surface

The device must only be enclosed on 3 sides, with one side touching the wafer completely. It is impossible to use it as a mold otherwise.



2. No overhanging components

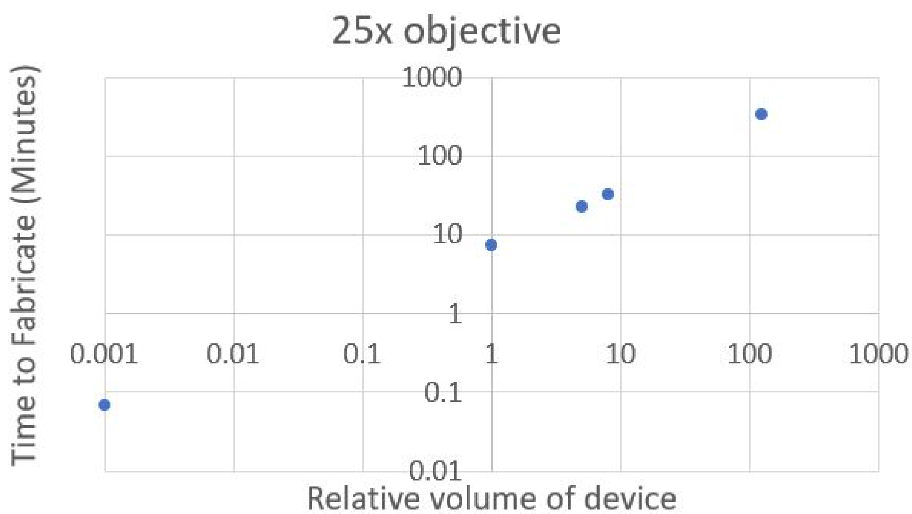


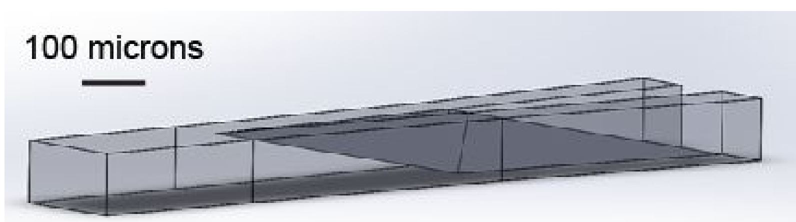
3. Single Z value for each X,Y

This rule can be derived from the previous two rules. Any features with more than one Z value will not come out

Time to make different microfluidic device components

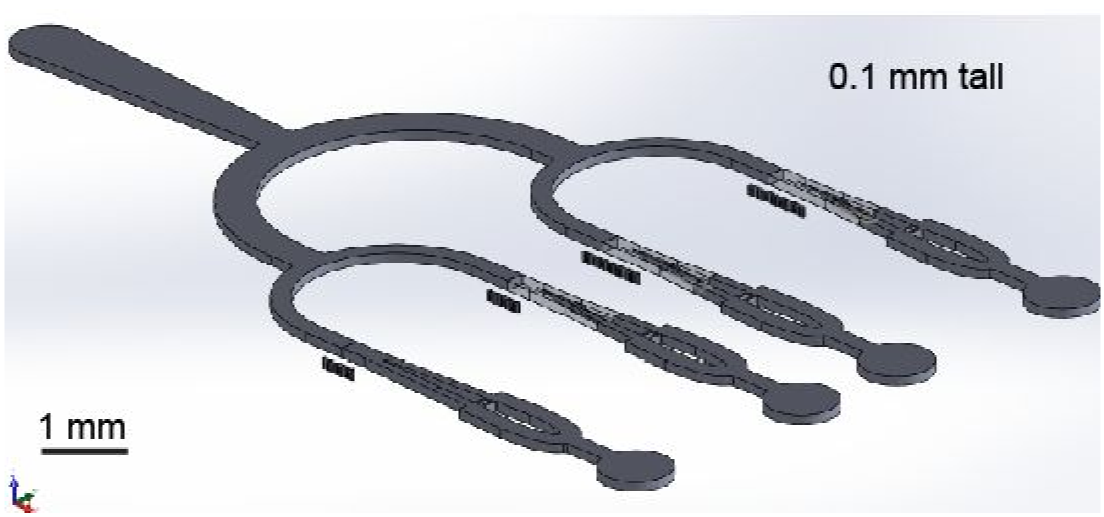
The fabrication time is approximately linear with device volume



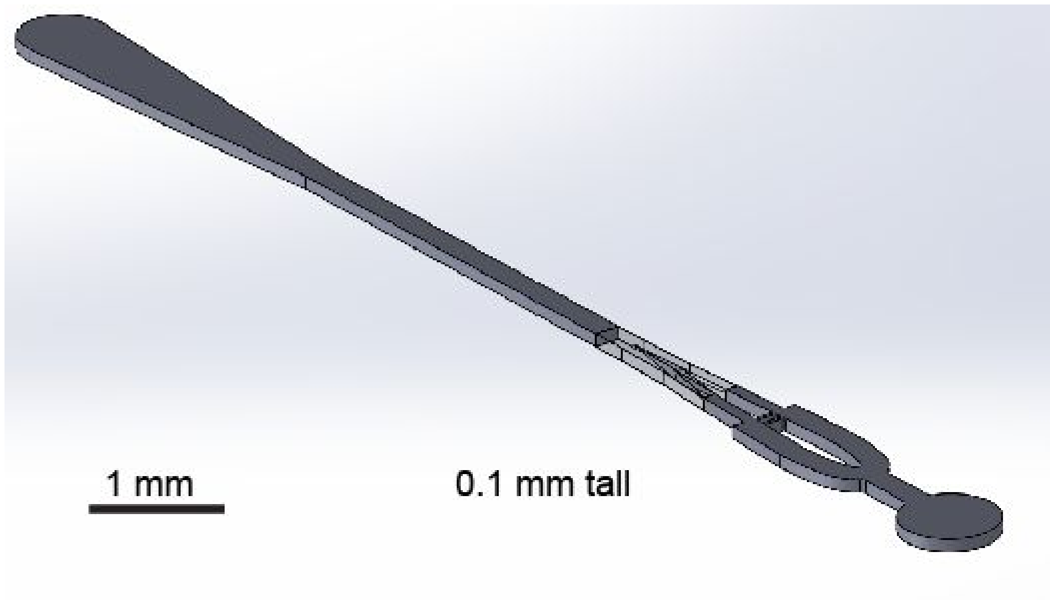


25x: 6 min

63x: 2 h



25x: 5 hours



25x: 1 hour 20 minutes

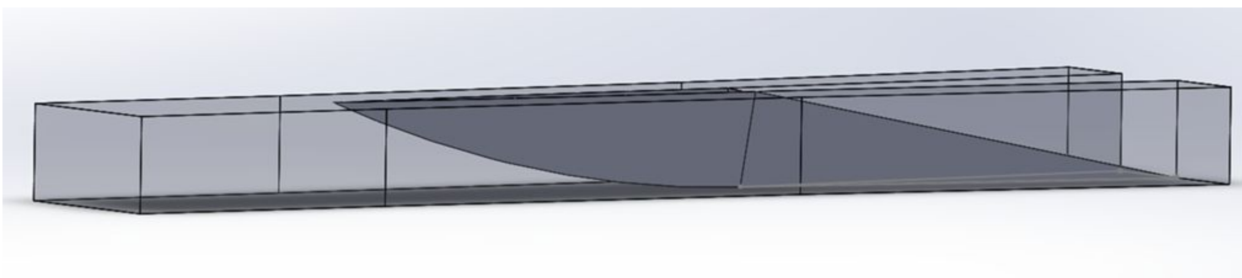
Choosing an objective (63x or 25x)

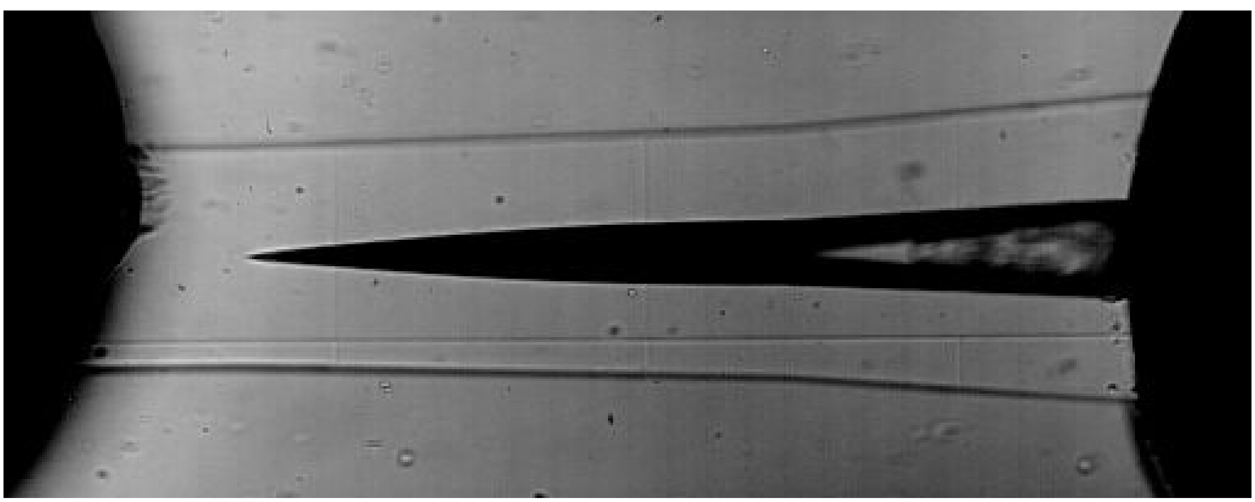
- Takes about 20 times longer to fabricate with the 63x objective versus the 25x objective
    - Can take >24 hours to fabricate a single device
    - $35 / hour, can add up to use the 63x objective
    - Often like to make multiple versions of a microfluidic device. Can add up even more
- 63x objective has much better resolution
    - 63x: 0.2 μm XY, 0.7 μm Z
    - 25x: 0.6 μm XY, 3 μm Z

Most of the time, the 25x objective will give better resolution than standard lithography methods and is more than acceptable for making microfluidic devices

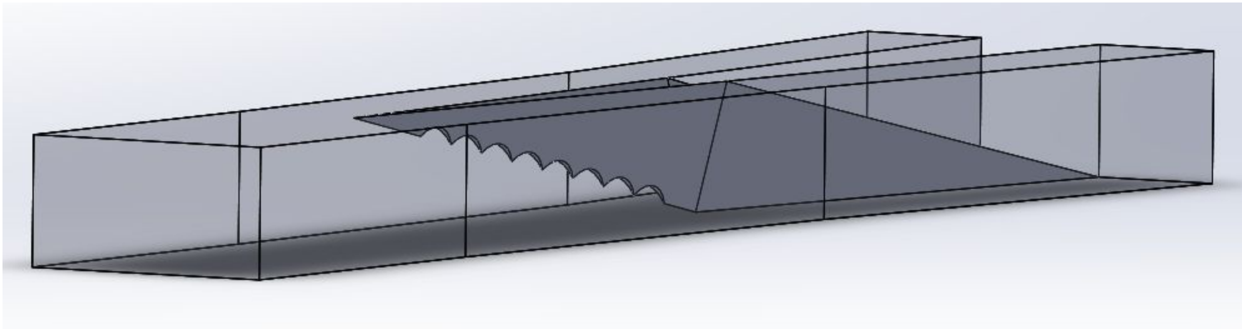
<u>Devices made with 25x objective:</u>

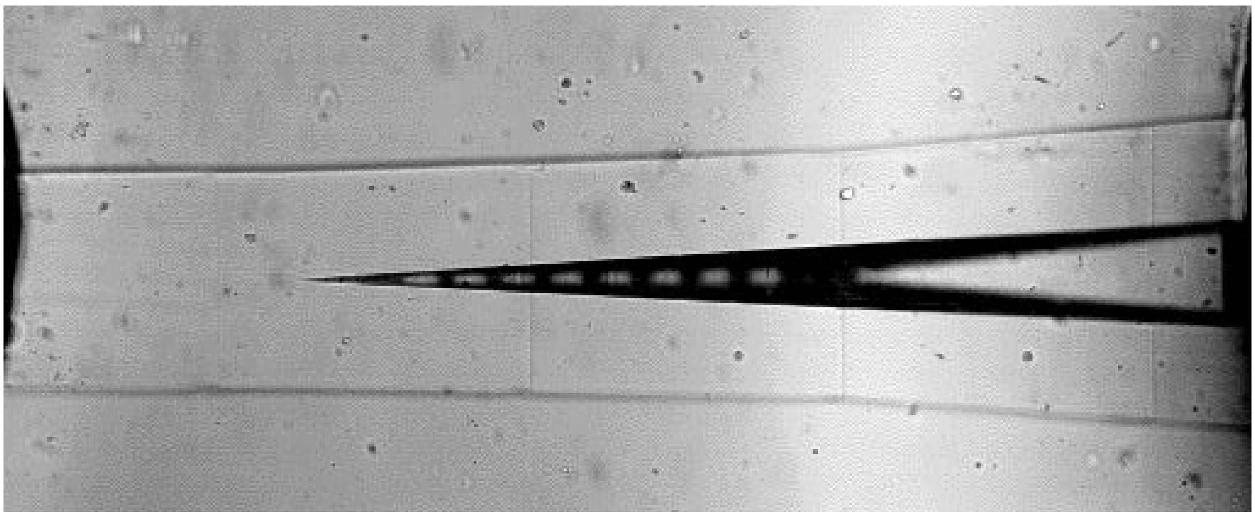
100 μm height, 200 μm width





100 μm height, 200 μm width

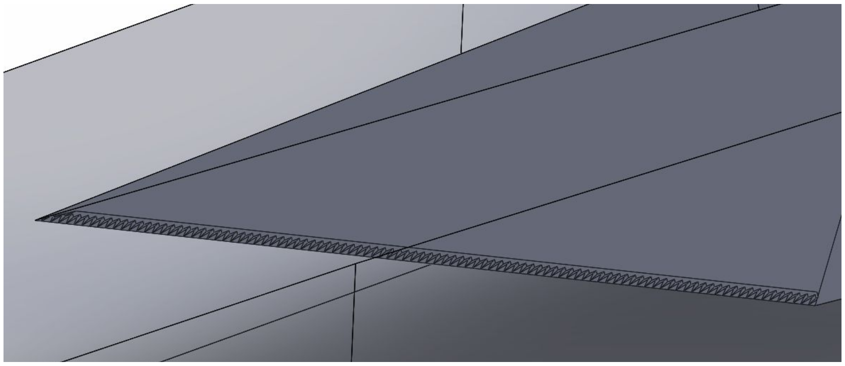


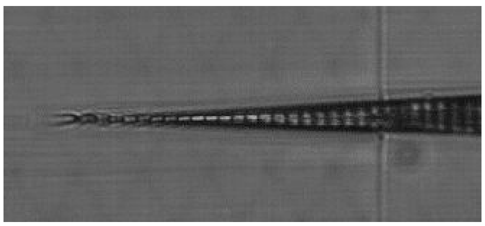


Lose some of the sharpness of the serrated tips with the 25x objective

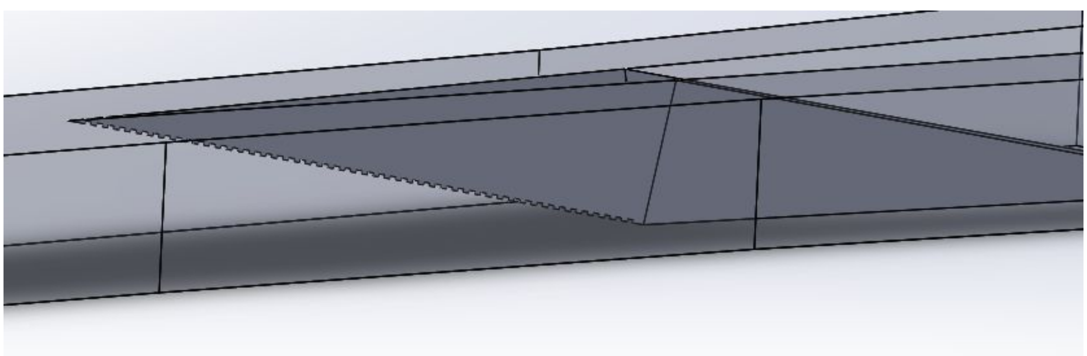
63x objective can be used to make interesting small features that can't be made with the 25x objective

Rough edge: 5 µm wide, 1 µm tall. Blade made with 63x. Doesn't come out at 25x





Serrations: 5 µm wide, 2 µm deep. Serrations don't come out at 25x (resolution is 3 µm)



To allow use of the 63x mold to make small features on a larger device, the 63x features can be aligned to features made with the 25x objective or traditional SU-8 lithography.

Using the Nanoscribe

1. Pretreat 4" Si wafer with O2 plasma

Etching the Si wafer with oxygen plasma prior to use helps to increase the adhesion between the mold and the wafer. It also helps to remove any surface roughness from the wafer.

4 inch Si wafers are the only size appropriate for current substrate holders
They are available in SNF stockroom

SNSF Flexible Cleanroom Plasma Cleaner (Spilker)

In order to use the SNSF plasma cleaner in Spilker, you must first be trained by Tom Carver (carver@stanford.edu) and become a qualified user of the SNSF Flexible Cleanroom. To do this, you need to follow each of these steps in the order as listed here:

1. complete the process to become lab member of SNSF (Note: this includes establishing a valid Badger account)
2. review General Cleanroom Manual
3. review and complete the Flexible Cleanroom User Agreement (Note: this includes completion of online safety training modules through EH&S)

A good starting recipe for Si plasma etching is:

Gas 2 (oxygen): 2
RF Power: 300 W
Plasma Time: 600 seconds.
Plasma Type: Direct (ask Tom Carver if you don't know what this means)

When the plasma cleaner is done, it will be very hot. Use a cleanroom wipe as an oven mitt if you ar going to remove the metal shelf to more easily access the silicon wafer. You can carry the wafer to SNF next door in a petri dish covered with foil or with the outside ring coated with tape.

SNF Plasma Cleaner (Allen Room 155A)

In order to use the SNF plasma cleaner, you must first be trained by Carsen Kline (carsen@stanford.edu).

ALWAYS RUN A DUMMY PROCESS WITH THE SNF PLASMA CLEANER!

I have not used the SNF plasma cleaner. If you have a protocol that works for treating Si wafers, please contact Swaroop (skommera@stanford.edu) so that he can add it to this protocol.

Post-fabrication steps for microfluidic devices molds

1. Develop in SU-8 Developer for about 10 minutes.
    a. **Do not sonicate, or the device will come off the surface of the wafer**
2. After developing, hard bake at 200 C for 5 min to fully cure the resin on the inside of the shell and scaffold.
    a. Can also UV cure if a UV lamp is available.
    b. Taller structures may need longer hard baking time
    c. Don't go too long or the features may melt together
3. Silanize mold to prevent PDMS from sticking to the Si wafer
    a. Silane: 1H,1H,2H,2H,-Perfluoroctyltrimethoxysilane
    b. In a fume hood with a desiccator, drop a few drops of silane onto a glass slide next to your device mold
        i. Use a disposable glass pipette with a reusable rubber squeezer to add the silane. Avoid using a reusable adjustable pipette so that silane does not get on that.
        ii. Silane is extremely corrosive and care should be taken to not get it on you. Use proper PPE, including a lab coat, gloves, and goggles.
    c. Close the desiccator and turn on the vacuum. Wait at least 2 hours for the silane to deposit onto the device mold
    d. Take out the mold and properly dispose of the glass slide
4. Pour the first PDMS for the Smoothcast replica mold
    a. The 4" wafer is often too big for the microfluidic device you are making. Pouring PDMS on the whole wafer would be a waste. To make the pouring area smaller, you can adhere a ring of PDMS on the Si wafer around the device mold to avoid wasting PDMS. Just push a flat piece of PDMS down on the Si wafer and it will stick sufficiently.

Make reusable mold out of smoothcast polymer

- The original nanoscribe mold often breaks after a few uses
- You should use the first PDMS cast from the Nanoscribe mold to make a more robust replica mold out of Smoothcast
- Link to Smoothcast protocol

PDMS protocol

- Used to make standard microfluidic devices
- Link to PDMS protocol

NOA protocol

- Used to make stiff microfluidic devices (100x stiffer than PDMS); good organic compatibility; can be used to make optical components
- Link to NOA protocol