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PROOF-OF-CONCEPT EXPERIMENT REPORT

MASTER FABRICATION FOR MICROFLUIDIC DEVICES

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Proof-of-Concept experiment details

Received sample: Optical masks on acetate film based on company design

Planned analysis:

Production by optical lithography and deep RIE of a silicon master

Replica of the silicon master in PDMS

Fabrication: optical lithography

Imaging: metal coating and scenning electron microscopy

Main aim of the proposal: evaluate the feasibility of a process consisting on the fabrication of a master made in silicon or polymer by meand of a suitable nanolithographic technique and its transfer by replica molding on a PDMS film .

Results

The main task was to fabricate Silicon masters with several designs for microfluidic devices. The starting idea is to transfer the desired geometries on a silicon wafer then to functionalize the so obtained master with an anti-sticking coating (silane functionalization of the surface). At this point the stamp is ready to be used to produce the PDMS replica.

Due to a technical problem with the ICP-RIE dry etching setup the initial experimental strategy was changed. The problem was bypassed by transferring the microstructures to a negative photoresist (SU8 series) instead of the Silicon substrate. This resist can act as master, thanks to its anti-sticking feature. The mask at the beginning was design for a different process flow and, at this point, the tone has to be inverted in order to obtain the final microfluidic design transferred to the SU8 photoresist.

Mask tone inversion

The tone of both *Abilo* and *Standard I* purchased masks was inverted by transferring them on to a glass substrate (5” x 5”). The glass was cleaned in piranha solution, washed and dried with N_2 gun. A Cr layer (200 nm) was deposited with magnetron sputtering setup. At this point the adhesion promoter Omnicoat and SU8 photoresist were spin coated on the substrates. Both *Abilo* and *Standard I* masks were used to transfer the microfluidic designs to the photoresist via photolithography, and finally the resist was developed in a proper solution. The exposed Cr surface was chemically etched in solution (Acidic Cr-etching solution) then the resist removed to obtain the final Cr mask on the glass substrate with the opposite tone respect to the starting one.

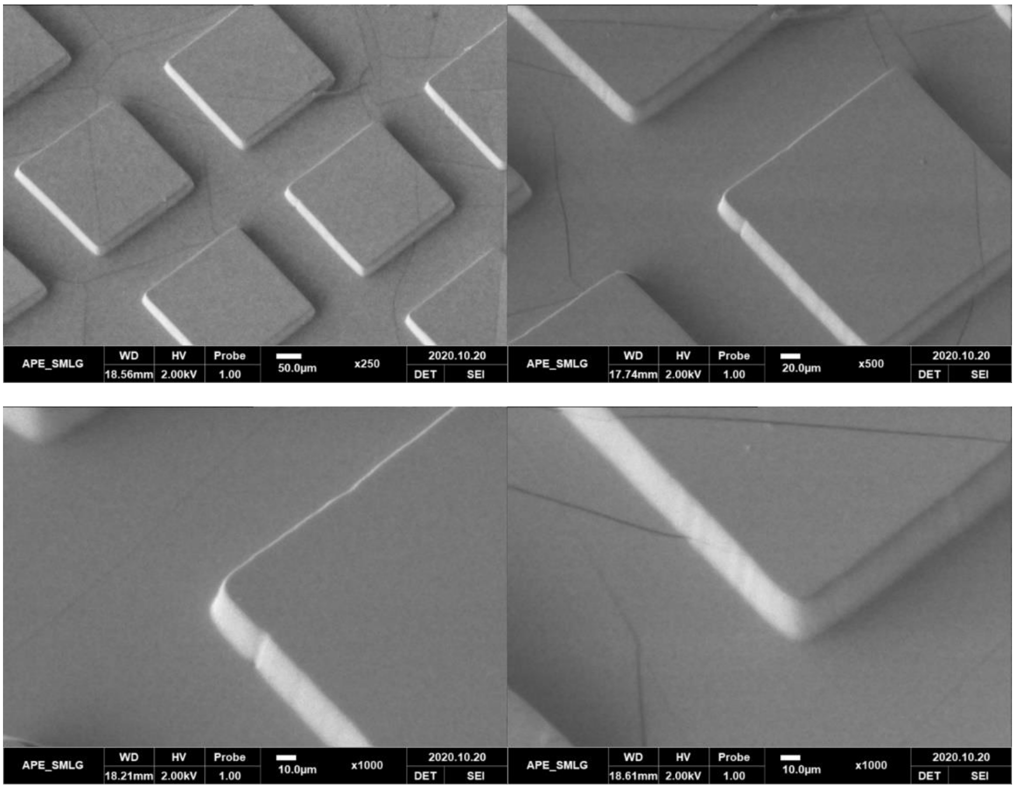
SU8 master fabrication

On a silicon wafer the SU8 photoresist was spin coated to reach a thickness of 30 µm. At this point the sample was exposed to the UV light via photolithography technique exploiting the new home made Cr mask. The layer was then developed, rinsed in IPA and dried with N_2 gun.

PDMS replica fabrication

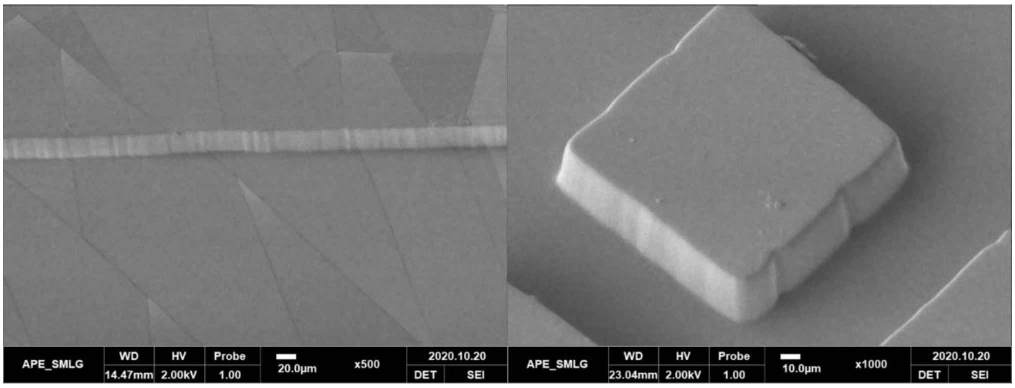
The SU8 master was used to produce the PDMS replica by the company operators. After the fabrication and inspection with optical microscope of the PDMS devices, they expressed concerns about the verticality of the structures as well as the wall roughness of the samples, therefore about the provided SU8 master.

For this reason both the replica and the master were inspected with the SEM in our facility. Especially from the analysis of the replicas it was possible to observe that the walls are quite vertical, but in some structures the bottom of the channels might be narrower than the top of the same.



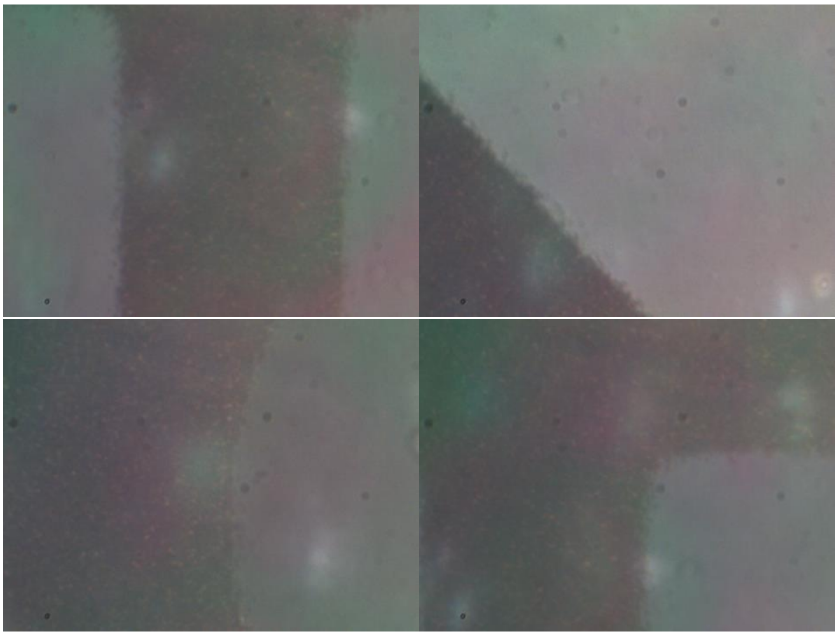
From this point of view the fabrication of the master might be improved while at the same time the not perfect vertical structures might not influence the device operation since the dimensions of the channels are way much bigger respect to the variation of the wall geometry.

On the other hand it was possible to observe that the channel walls are not uniform as reported in the following images. A certain roughness of the wall as well as some defects characterize the fabricated devices.



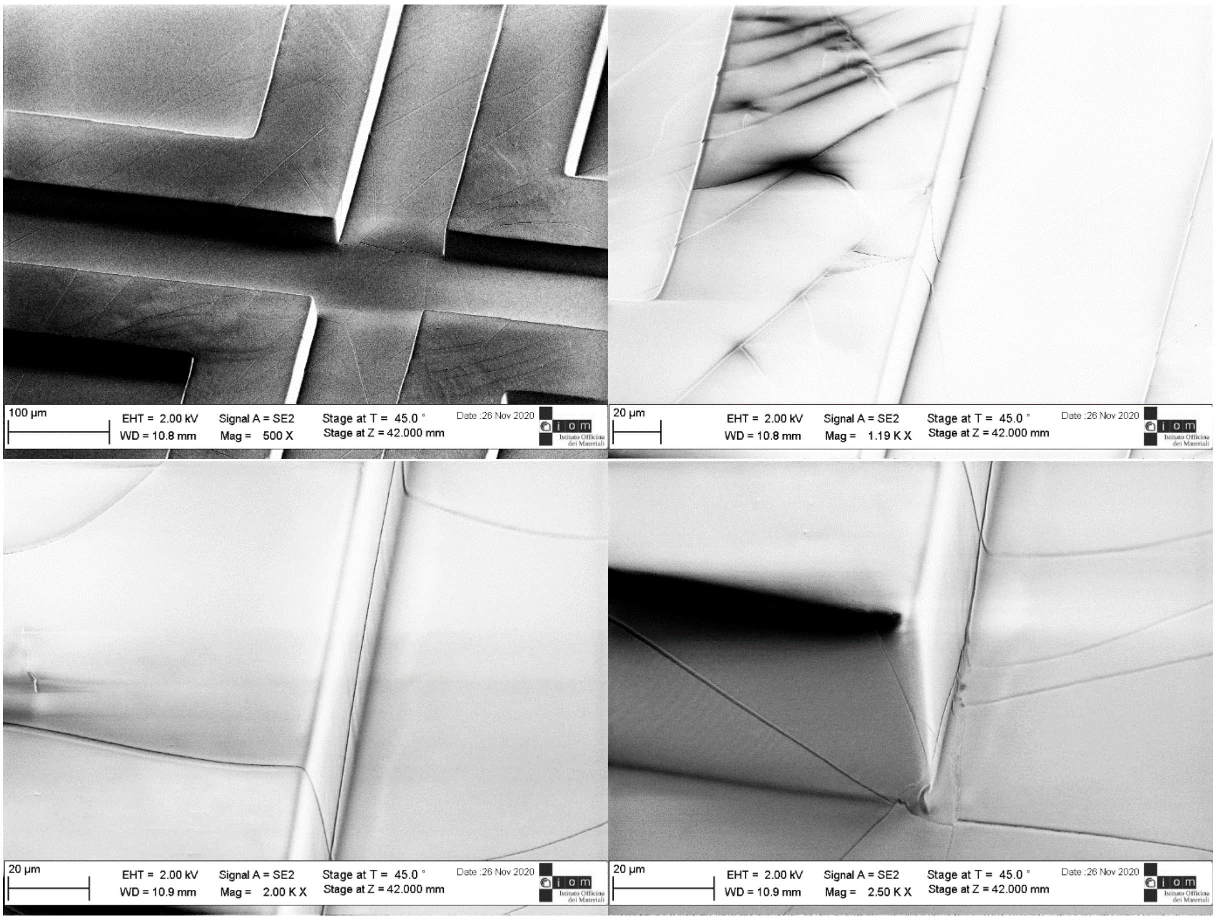
Wall roughness

To better understand the critical step we started inspecting the purchased photomasks. They are printed on a polymeric substrate, usually characterized by lower resolution and quality respect to those fabricated on glass substrate and Cr layer. From the images collected with an optical microscope, it is possible to notice the low quality of the ink shapes determining the structures.



To be sure that the defects are depended to the quality of the mask we decided to use a glass/Cr mask purchased from the same company (with random structures and patterns).

The same processes before reported were followed to fabricate a SU8 master. The SU8 stamp were used to produce PDMS replica. The PDMS samples were inspected with SEM and the relative images are here reported.



From the SEM images it is possible to observe that the wall roughness is not present anymore in the samples. The cracks you can see on the structures are due to the metallization of the surface with 5nm of Au/Pd layer to improve the quality of the images.

Conclusions

A slightly inclined geometry of the walls determining the microfluidic channels might be present in replicas. To avoid this features, the microfabrication of the master should be improved. At the same time the dimensions of the channels are way bigger than the variation observed, therefore it is possible to fairly assume the device operational behavior is not affected by this phenomenon.

It was possible to understand that the wall roughness is due to the poor quality of the plastic/ink mask. This issue is easily solved if the photolithography is performed with glass/Cr mask, characterized by higher resolution and quality.

We recommend the use of Cr/glass mask to produce the masters. At the same time, the Cr/glass mask usually is around three times more expensive than the plastic/ink one (350€ vs 100€). For this reason an alternative strategy might be use plastic/ink masks when several designs have to be tested while the Cr/glass masks might be used once the final design is chosen. It is important to keep in mind that the wall roughness will always characterize the samples when the plastic/ink mask is used, therefore the company should evaluate the quality of the tested designs compared with the cost of the masks.

With these warning in mind, the process is feasible.

This report has been written by Marco Lazzarino (Trieste, 25 November 2020)