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Methodology for the study of thermal nanoimprint lithography-induced deformation

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► **To cite this version:**

Léopold Boudier, Emmanuelle Daran, Olivier Gauthier-Lafaye, Valentin Gâté, Franck Carcenac, et al.. Methodology for the study of thermal nanoimprint lithography-induced deformation. 48th International conference on micro and nanoengineering, Sep 2022, Louvain (Leuven), Belgium. 2022. hal-04137592

HAL Id: hal-04137592

<https://laas.hal.science/hal-04137592>

Submitted on 27 Jun 2023

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Context

Nanoimprint lithography processes have received particular interest these past decades, especially in microfluidic and microbiology, as they allow the replication of nanometric patterns within a few minutes [1]. As the technology is becoming more and more reliable, the use of the soft nanoimprint (SNIL) process for optic structures is all the more appealing.

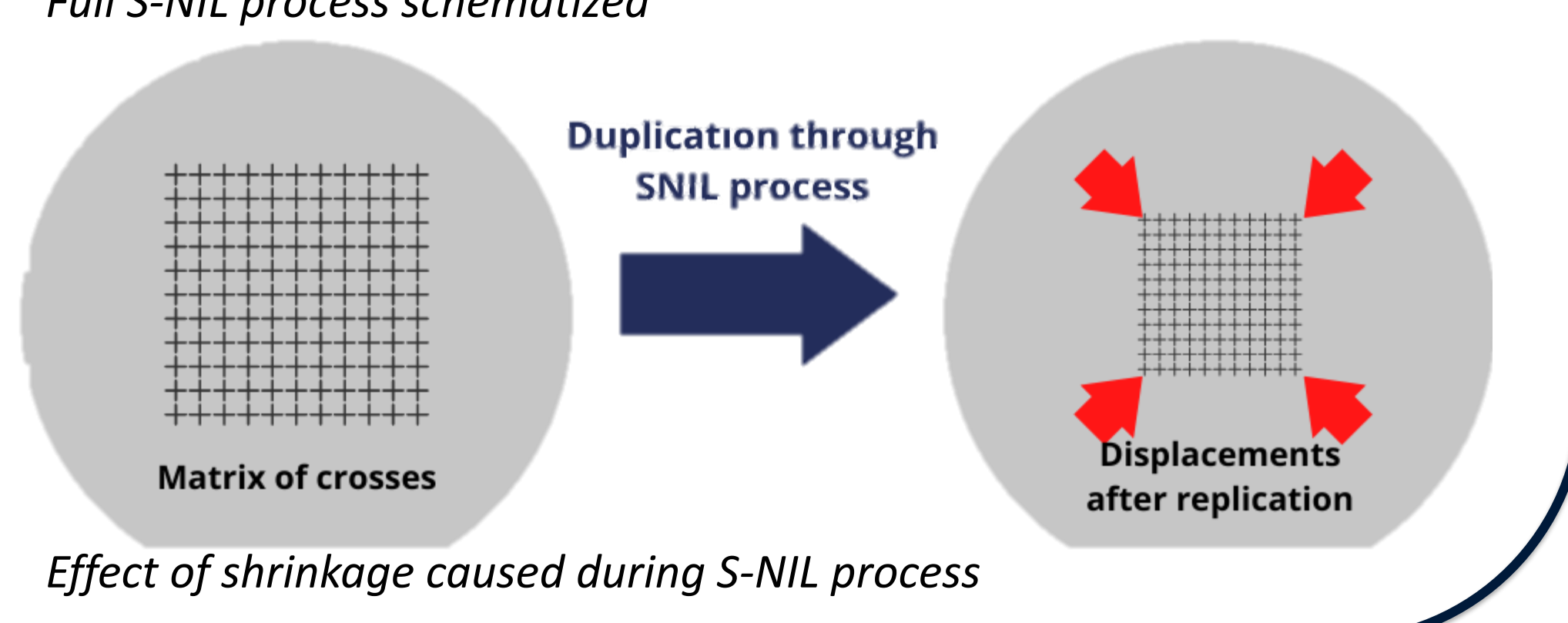
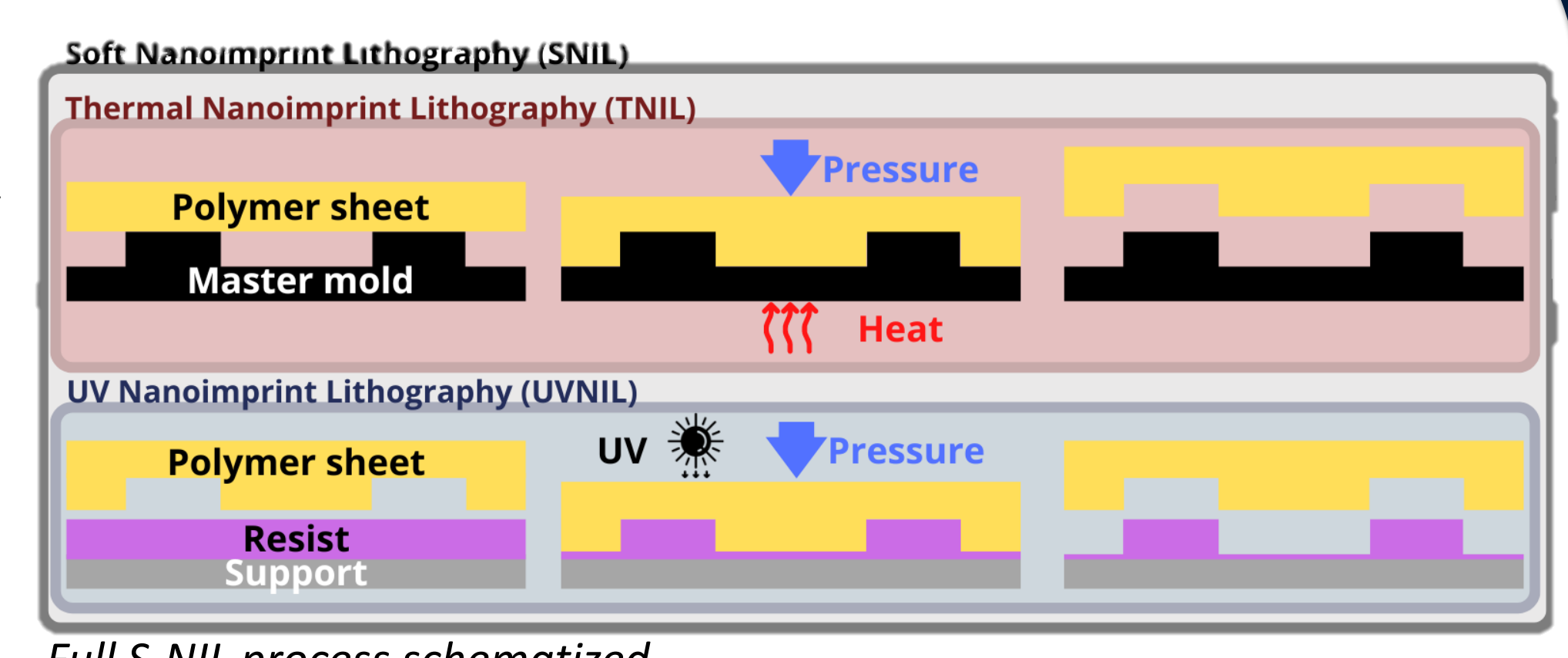
However, the distortions induced by heating during the SNIL process cause displacements of the patterns that make this process unreliable for Mix and Match methods.

This work aims to develop a methodology to characterize these displacements and compensate them to use soft nanoimprint in the mix and match processes

Our Soft Nanoimprint Lithography Process

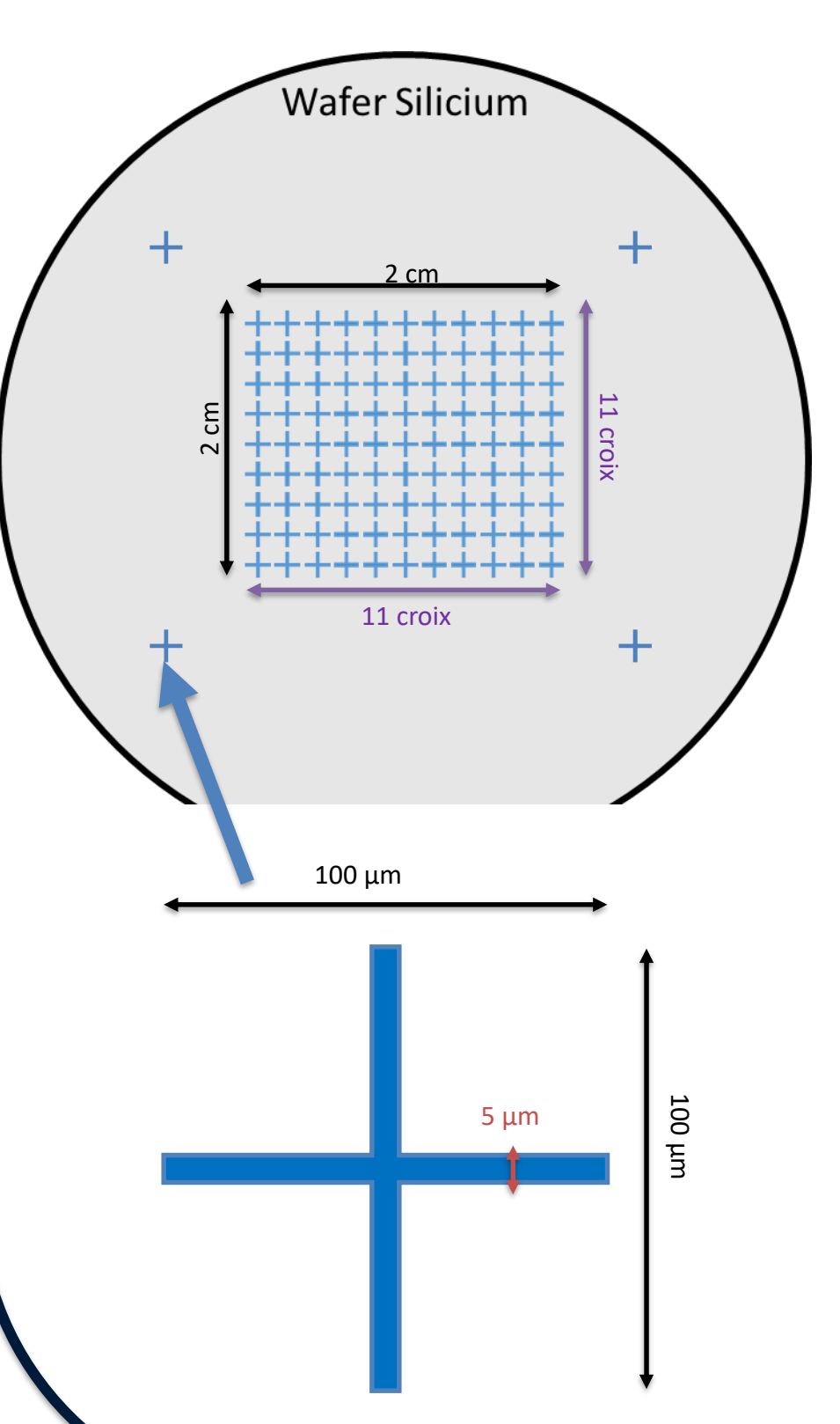
Soft nanoimprint lithography is a 2-step process made using a Nanonex NX2500. The patterns are firstly replicated negatively in a polymer sheet by hot embossing or thermal nanoimprint. The polymer sheet is then used to mold the patterns on a wafer covered with photo sensible resist.

While this process is quick and cheap compared to other processes such as electron beam lithography, it has some major disadvantages like the distortions caused by the thermal step or the spare resist at the bottom of the patterns [2].



Methods

Realisation of the master mold



We create a master mold on a 2 inches silicon wafer. The pattern consists of an 11x11 matrix of 100µm-long crosses spaced every 2 mm.

That way, we can cover a 2cmx2cm area to study the distortions caused by the replication. We consider the center cross to be the origin of our plan.

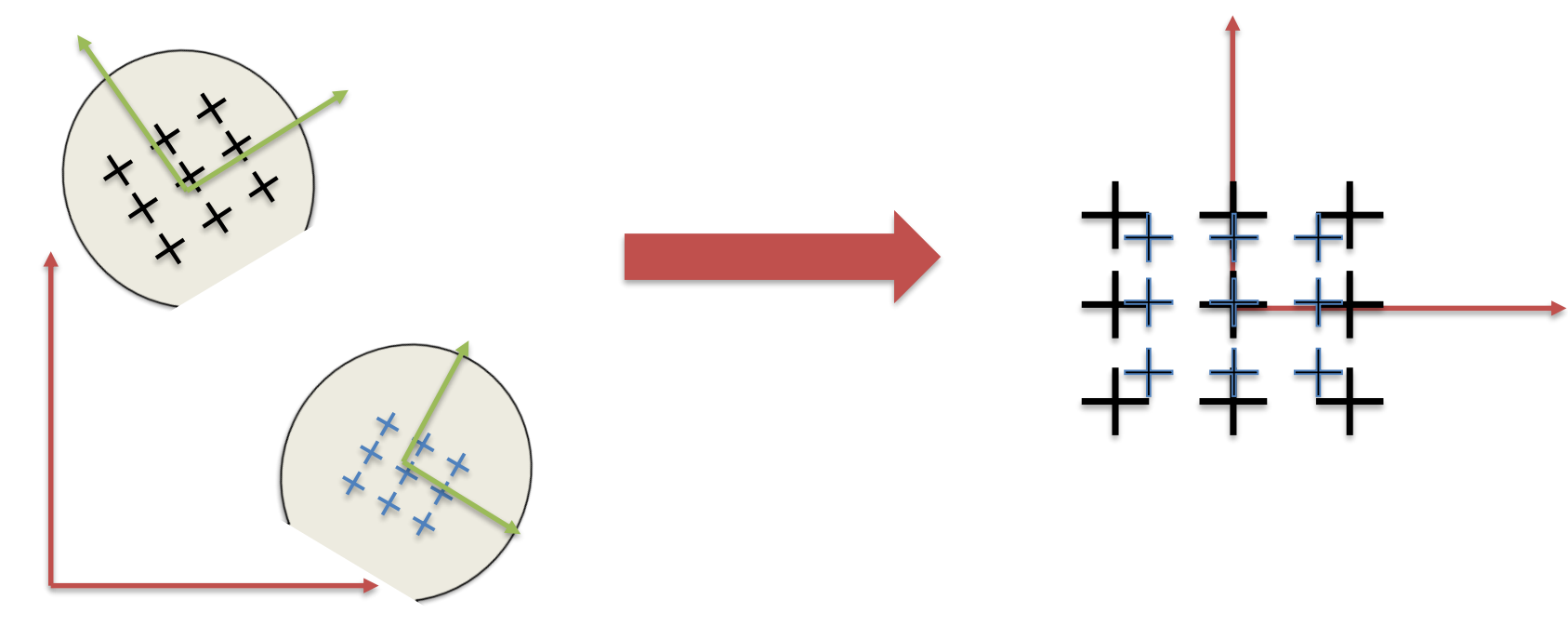
We add 4 more crosses located on the edges to check on the etching and align our measurements during scans

Scan method

We use the electron beam lithography Raith150 scan option to get the position of each cross. To reduce the sample-thermalization-induced distortion, the position of the central cross is measured again after each cross measurement and then compared to this one.

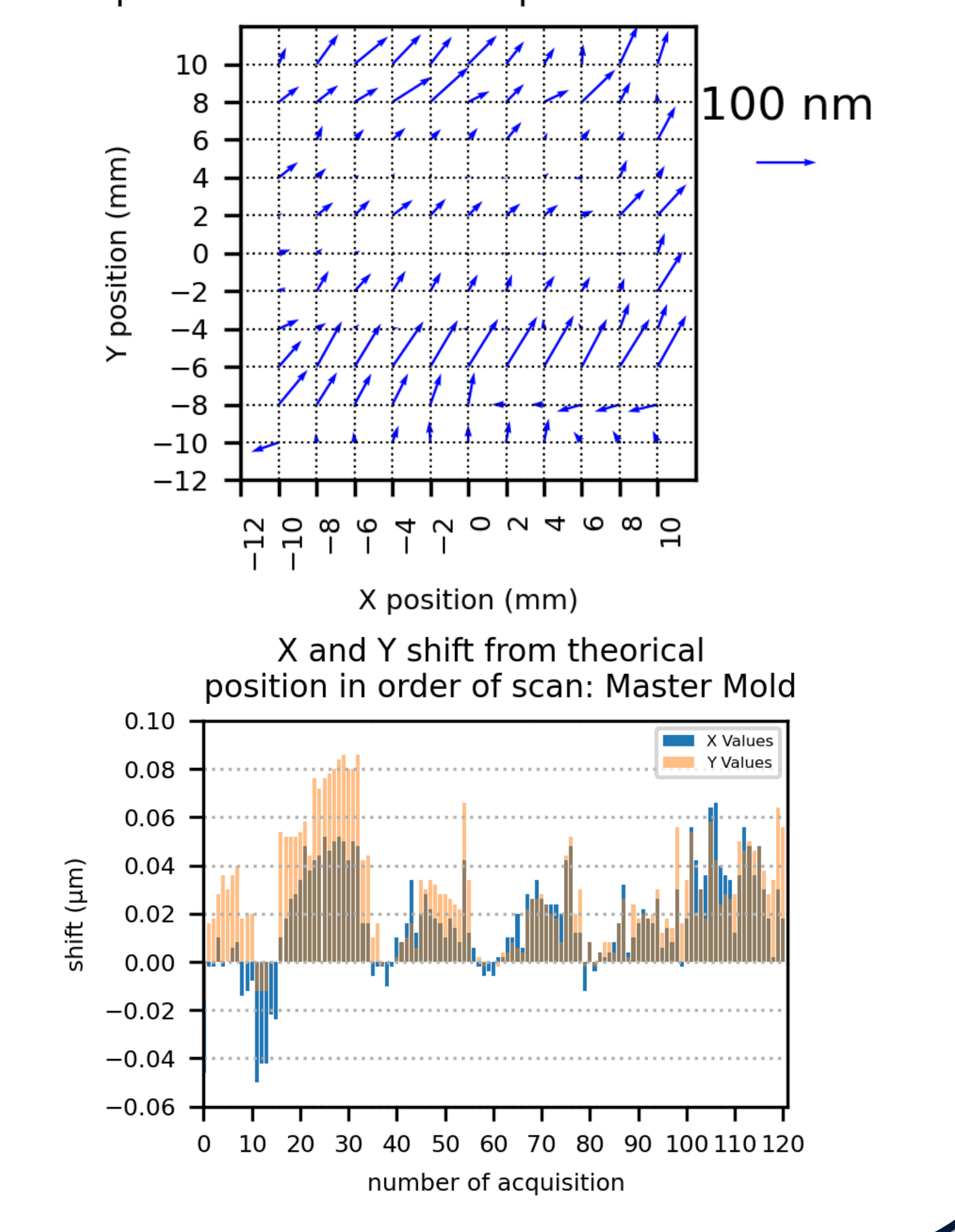
By a change of coordinates through linear transformations, we get the positions in the support referential and superpose it with the master mold.

We then compare the position of each replicated cross to the corresponding cross in the master mold.

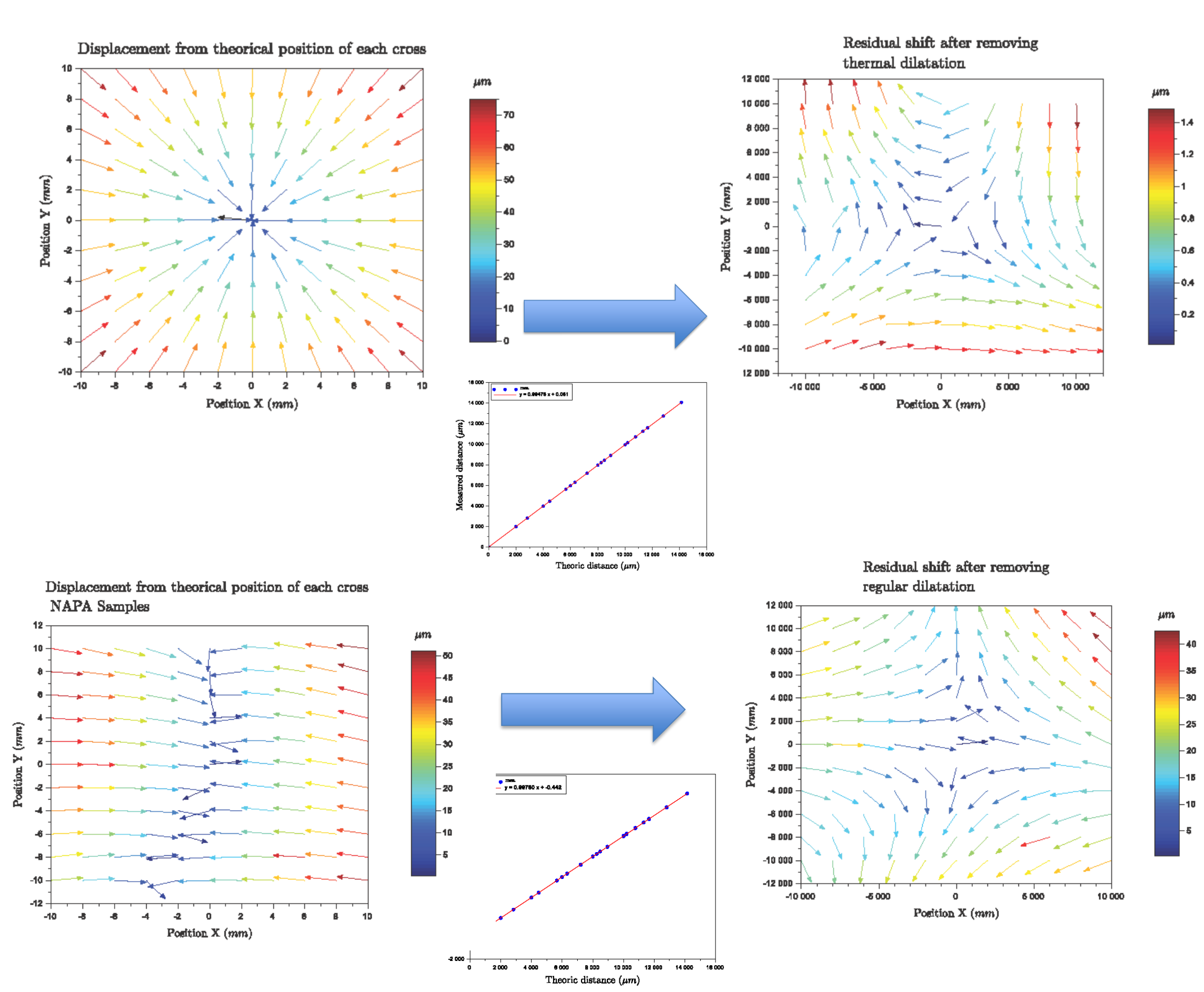


Representation of the base change applied to the matrix of crosses

Relative shift of each cross compared to their theoretic position: Master Mold



Results



Once our method is applied to our replicated samples, we observe a concentric shift toward what we consider our reference point. This type of distortion can be attributed to a shrinkage of the polymer sheet coming back at room temperature after hot embossing.

We observe an average of 0,52% of distortion from the distance to the center cross. However, we also observe an unknown residual distortion that yet cannot be predicted.

Thus, the maximum uncontrolled displacement obtained is 1.5µm.

Also, to check the reliability of our methodology, we applied it to a sample replicated by another method of soft nanoimprint lithography that does not imply a thermal process.

While we could not yet clearly identify a model of displacement, these displacements correspond to a manually made imprint with a cylindrical deformation of the mold

Perspectives

Using this methodology we managed to identify a pattern in our distortion allowing us to predict more precisely the new positions of our patterns. This allows us to drastically reduce the incertitude of our positions and allow soft nanoimprint lithography to be used in mix and match processes at a smaller scale.

It is still necessary to confront this methodology with multiple imprint techniques and multiple polymer sheets to verify its reliability. Also, we still need to create a pre-compensated mold that would align once replicated to the original position.

References

[1] S. Chou, P. Krauss, and P. Renstrom, 'Nanoimprint Lithography', *Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures*, vol. 14, pp. 4129-4133, Dec. 1996, doi: 10.1116/1.588605.
 [2] K. Sharshavina, 'Nouveaux concepts de filtres spectraux ultra-sélectifs pour spectroscopie embarquée', *These de doctorat, Toulouse 3, 2016*. Accessed: May 04, 2022. [Online]. Available: <https://www.theses.fr/2016TOU30264>

This work was supported by the LAAS-CNRS micro and nanotechnologies platform, a member of the french Renatech network