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A UV-NIL resist developed for a transitional soft mold process and the subsequent dry etch transfer into hard materials

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Jean Baptiste Doucet, S. Pelloquin, Alexandre Lauvergne, E Daran, Sylvain Auge. A UV-NIL resist developed for a transitional soft mold process and the subsequent dry etch transfer into hard materials. 43rd INTERNATIONAL CONFERENCE ON MICRO AND NANOENGINEERING, Sep 2017, Braga, Portugal. 2017. hal-04466513

HAL Id: hal-04466513

<https://laas.hal.science/hal-04466513v1>

Submitted on 19 Feb 2024

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Laboratory under contract with the Federal University of Toulouse Midi-Pyrénées

1 Printing with nanonex equipment

1

Equipment

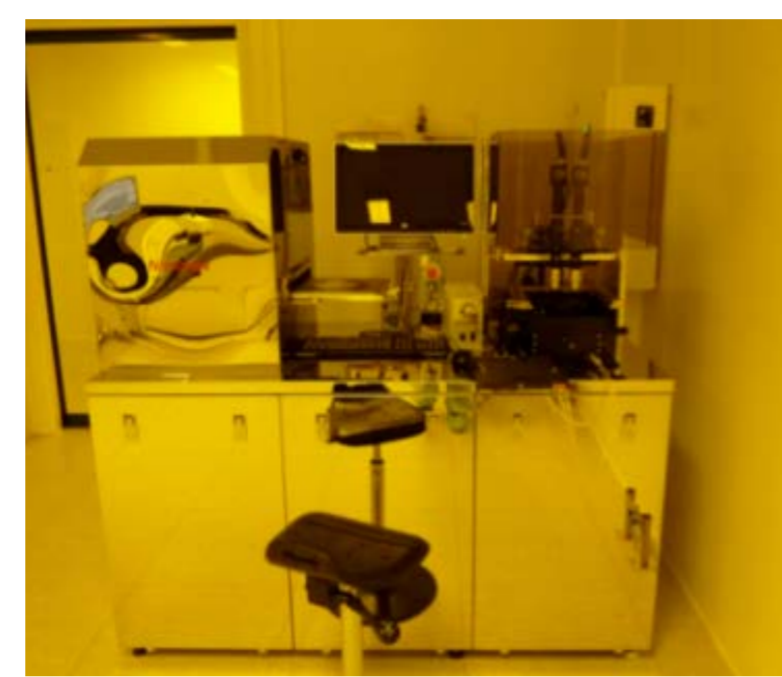
Use a nano-imprint lithography set-up (NX-2500 equipped with a double membrane system) for the molding of a temporary film on a flexible polymer sheet

Advantages of the equipment

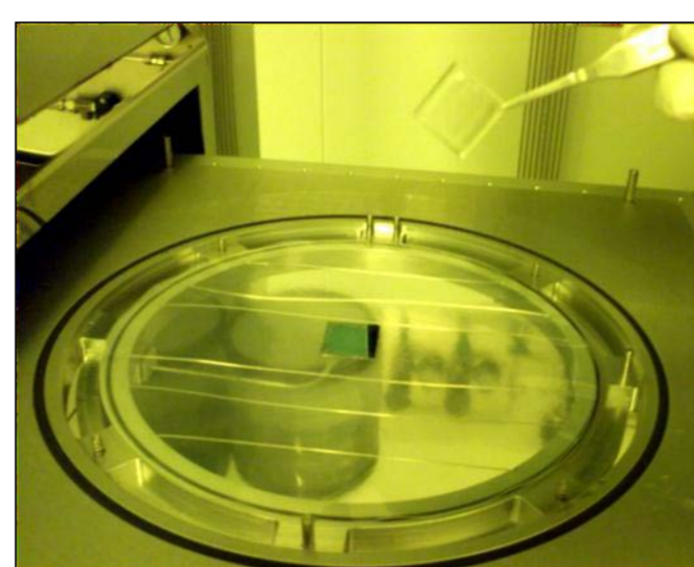
Isostatic pressure
Homogeneous thickness of residual layer
Better suited for fragile substrates such as III-V wafers

<http://www.nanonex.com/>

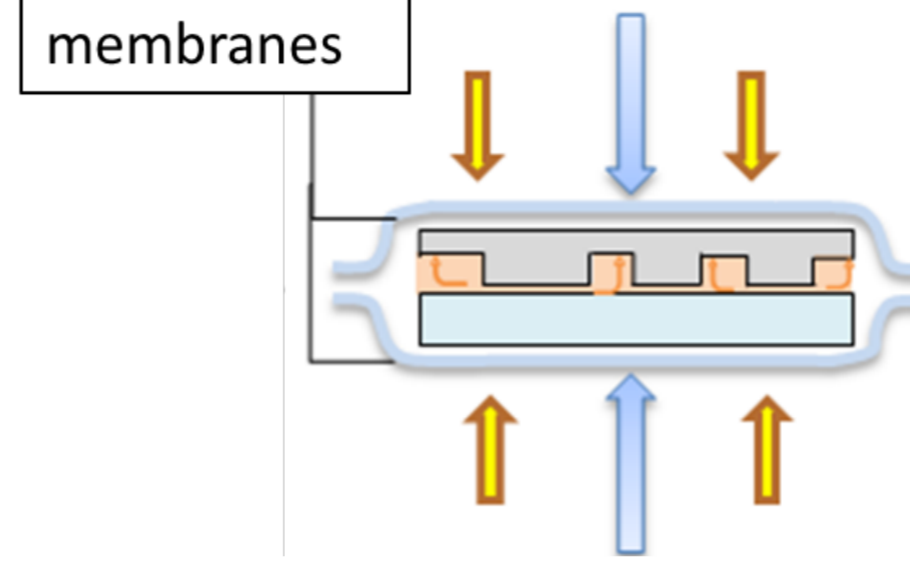
S.Y. Chou et al, Appl. Phys. Lett. 67 (1995) 3114.
M. Vogler et al, Proc. of SPIE Vol. 6517 651727-1(2007)
A.Amirsadeghi et al, App. Surf. Sci. 258 (2011) 1272-1278



Nanonex NX 2500

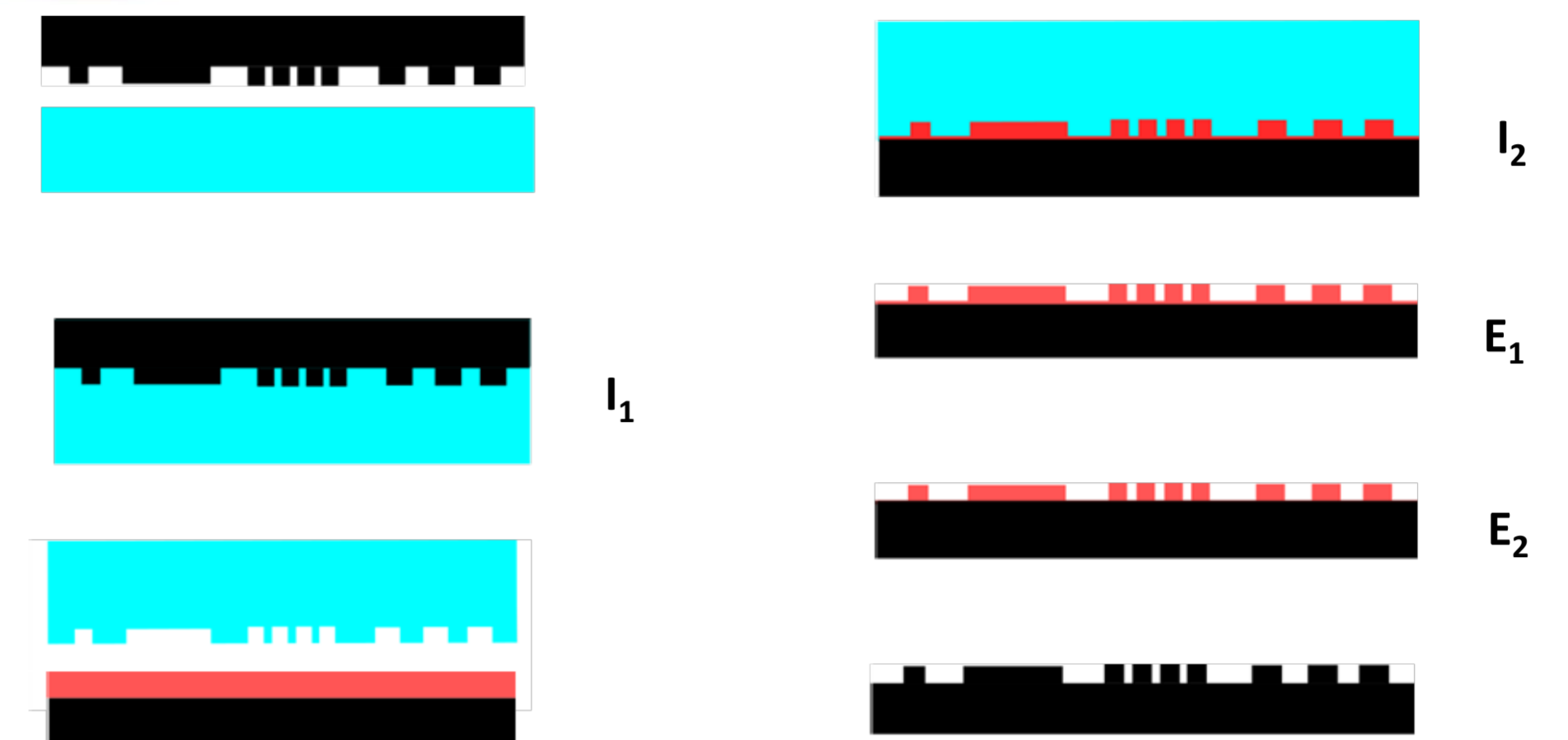


Air cushion system : the pressure is applied uniformly thanks to nitrogen pressure through the membranes



2 Transitional soft mold process

2



Zeonor® (ZEON corp) 188 μm
RESIST
SILICON

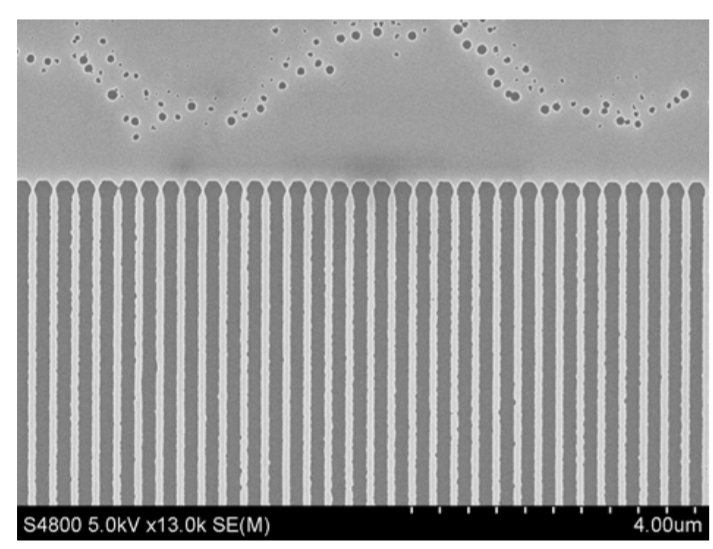
I₁ : Imprint 31 bar 145°C 3 min
I₂ : Imprint 14 bar 3 min UV 2 min
E₁ : Residual layer etching (O₂)
E₂ : Transfert etching in Si (C₄F₈-SF₆-O₂)

Advantages of transitional soft mold

Less sensitive to dust, less mold degradation
Replication of the mold without inversion
Zeonor® : more rigid than flexible PDMS stamps (Young modulus of elasticity over 2000 Mpa instead of 8,2 Mpa for h-PDMS) → no pairing effect

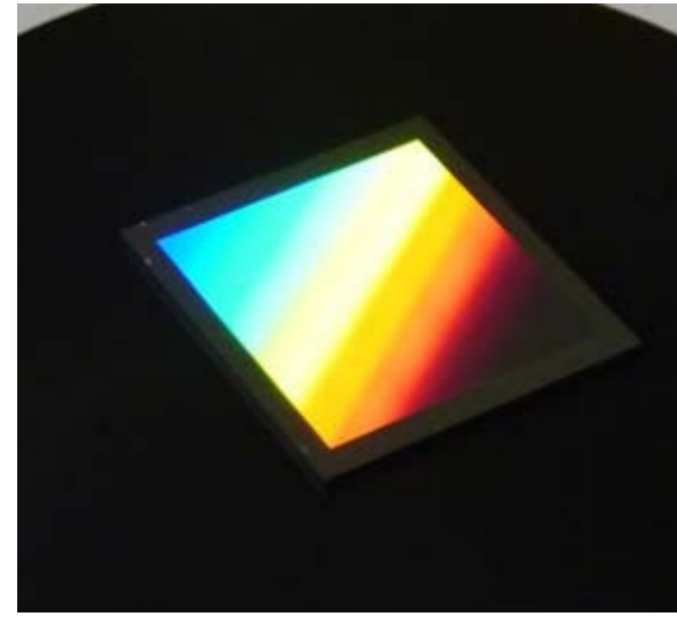
3 Issues encountered with our process and commercial resists

3



NXR-2010

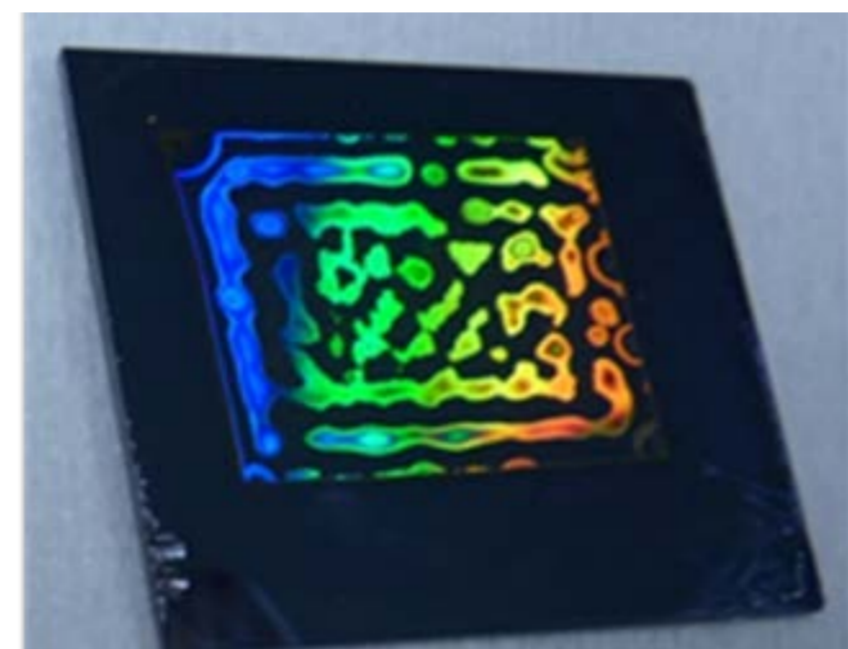
“Bubbles” formation in the resist leading to holes after etching



Mold (gratings)

mr-UVCur21

Dewetting of the resist leading to scattered printed areas

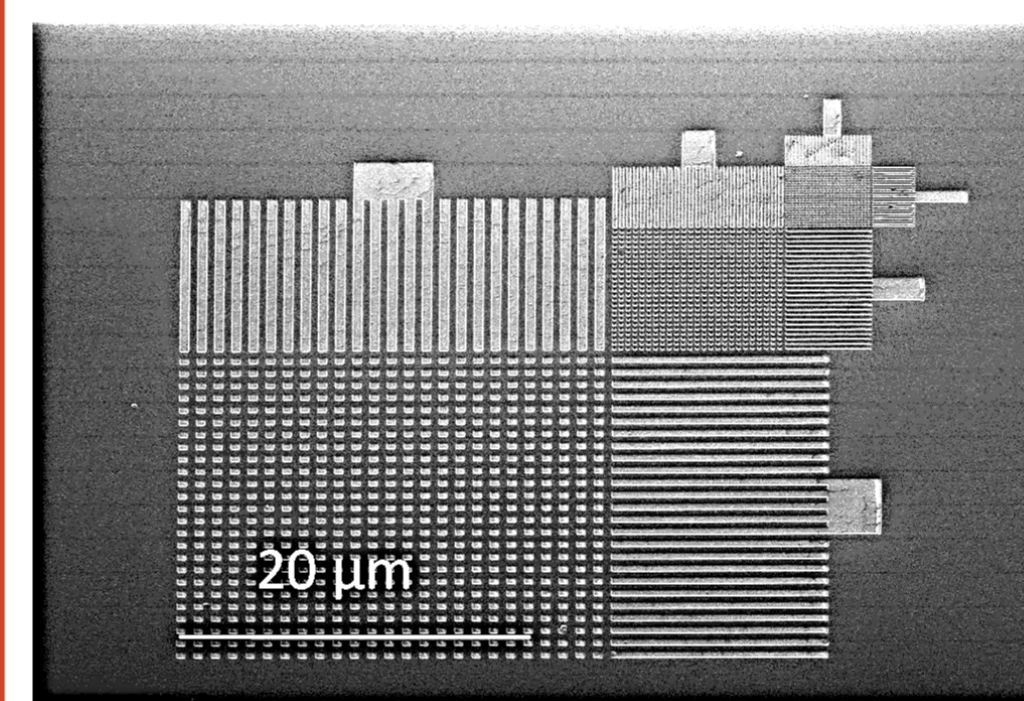


Imprint

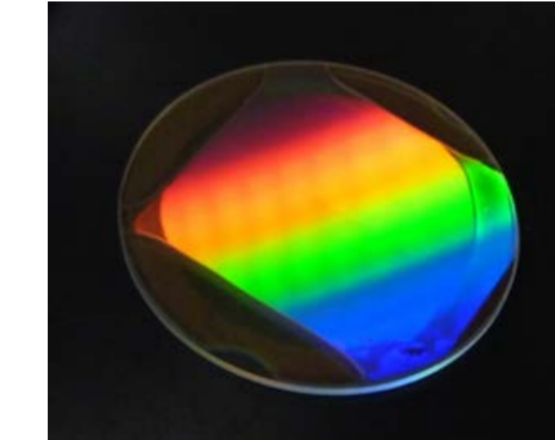
Not adapted to our process

4 Results with our resist NIL-UV135

4

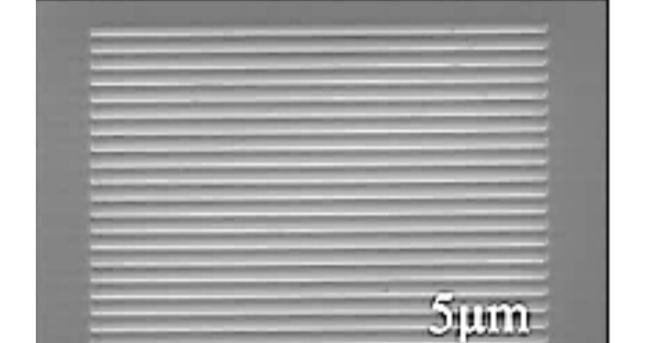


SEM image (tilt 45°) of lines and dots of 500 nm, 200 nm and 100 nm imprinted in the resist on Silicon



Gratings imprinted into resist from a silicon mold on a transparent substrate (visible light is decomposed by the gratings)

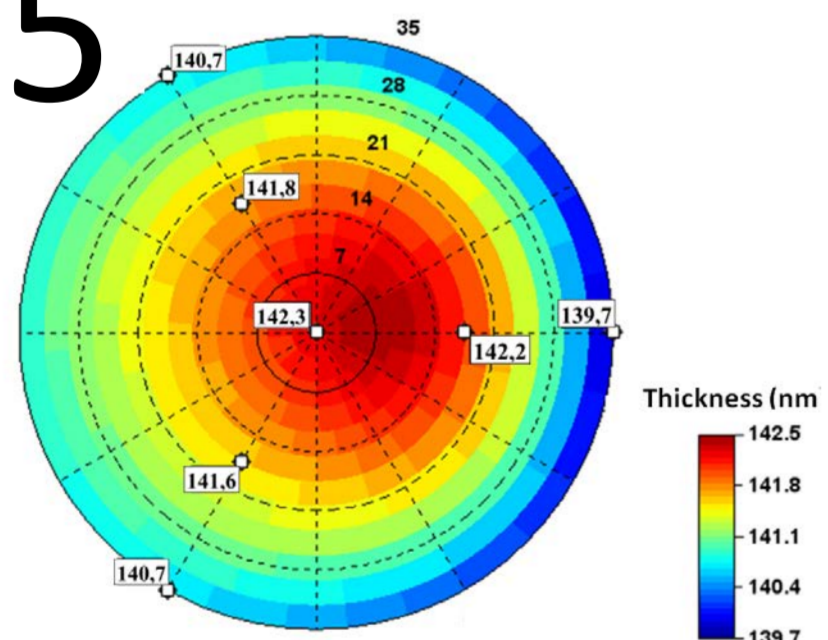
No dewetting
No “bubbles”



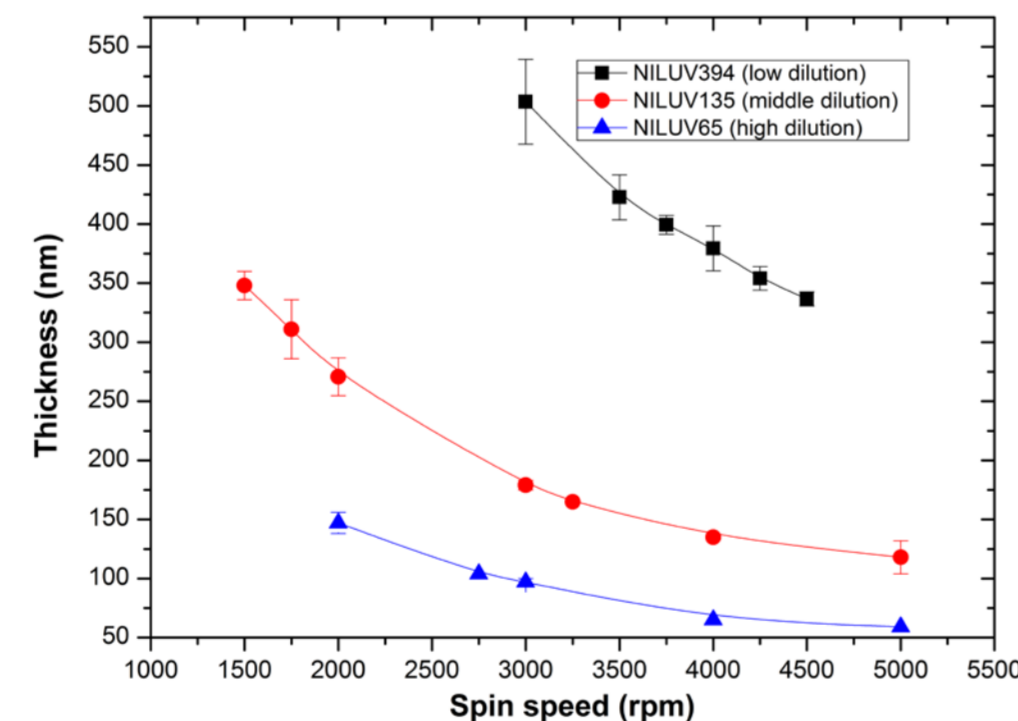
SEM image (tilt 45°) of lines of 250 nm with 500 nm period
- Top : imprinted in the resist
- Down : dry etch transferred into Si

5 Our resist properties

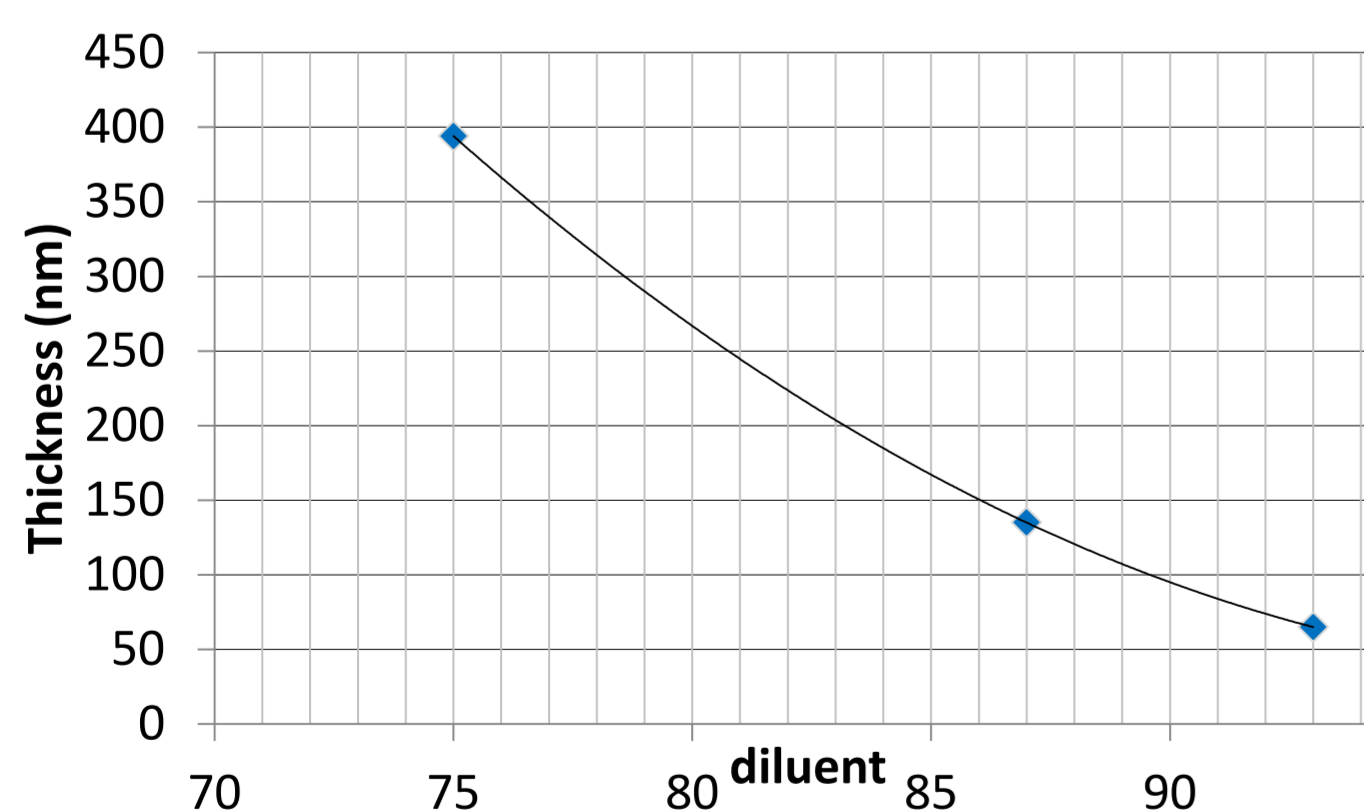
5



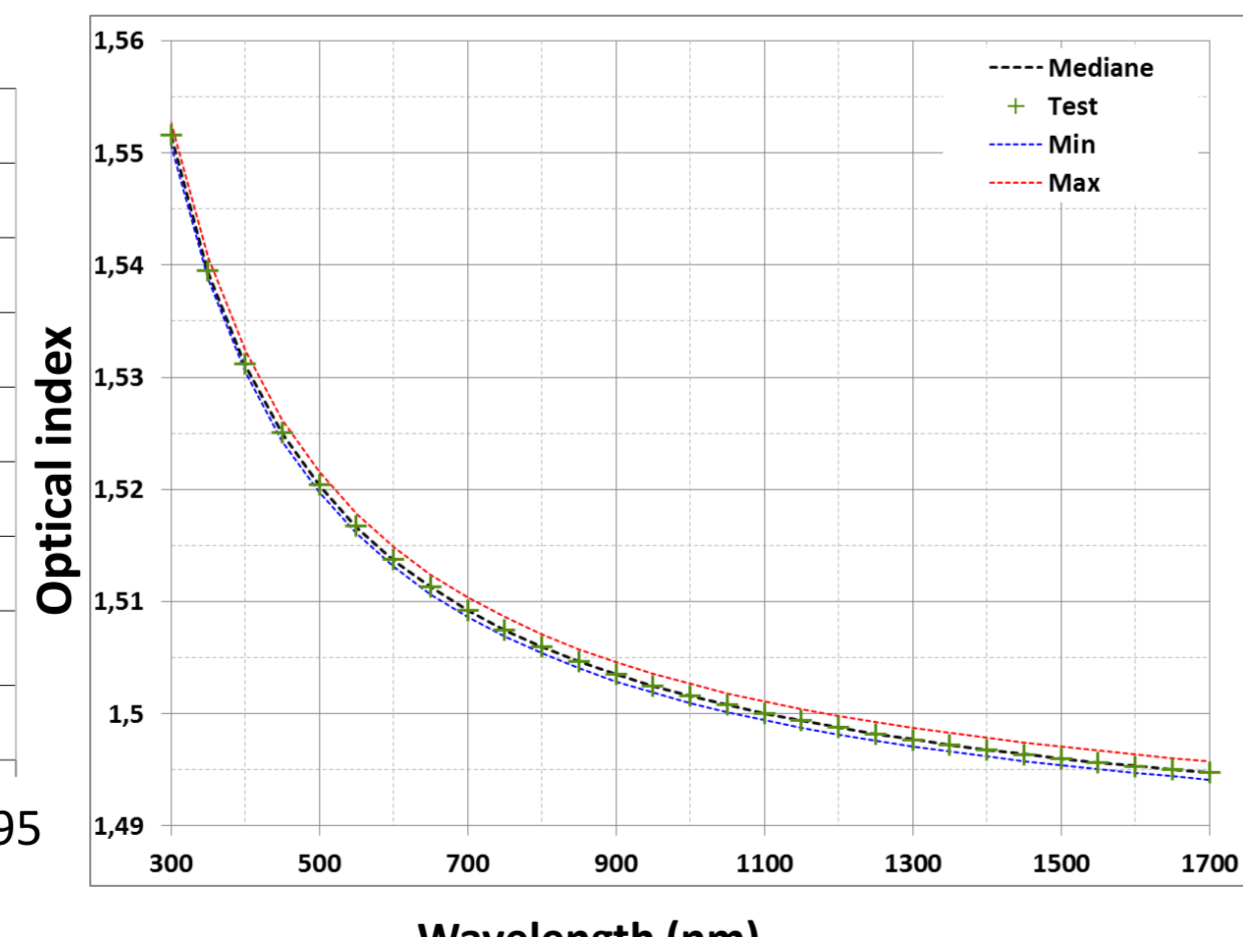
Resist thickness (nm) homogeneity over 7 cm ϕ after imprint (@ 4 krpm ; 4 krpm/S ; 30 S) by ellipsometry



Resist thickness (nm) after imprint depending on spin speed; dilution



Resist thickness(nm) after imprint depending on % diluent (@4 krpm ; 4 krpm/S ; 30 S)

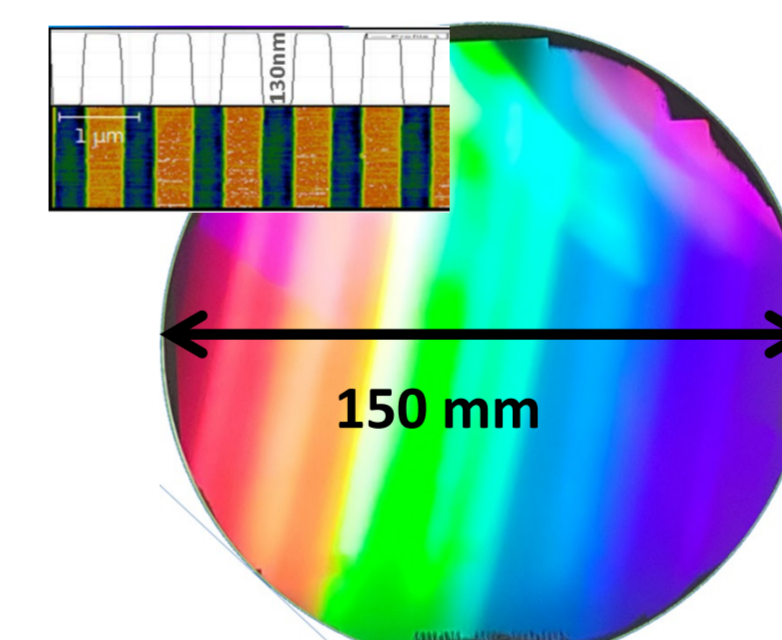


Resist optical index depending on wavelength measured by ellipsometry

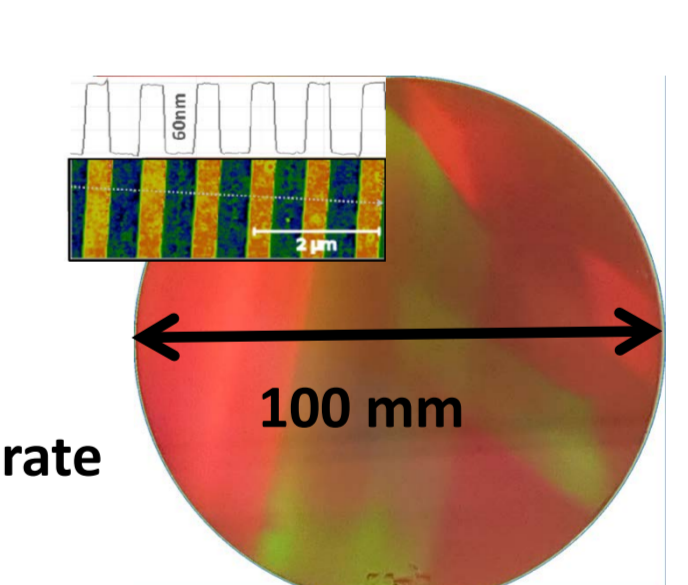
6 Applications to research projects

6

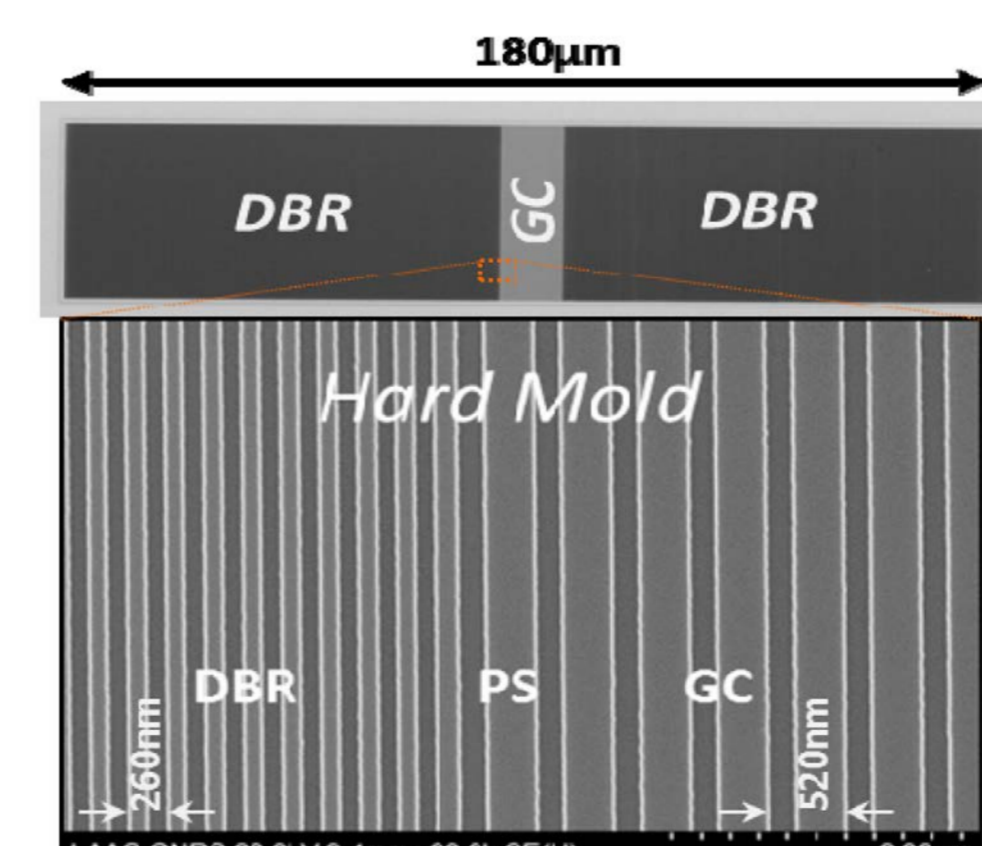
- 1) Thermal imprint in zeonor
- 2) UV imprint in NIL-UV135 with zeonor temporary mold
- 3) Dry etch transfer into substrate



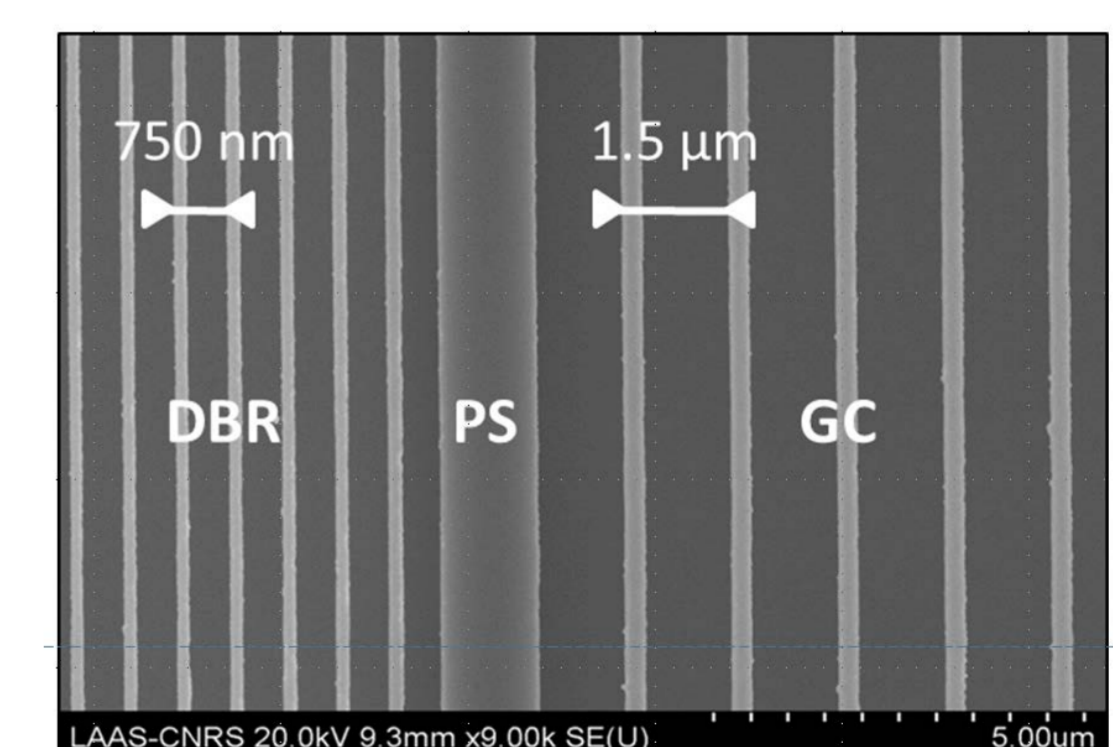
Photography of a GMRF (Guided Mode Resonance Filter) pattern on 6" silicon mold made by optical stepper and dry etching. Grating periodicity is 880 nm with an etching factor of 57±3%. Rainbow shapes come from diffraction of light, Insert is an AFM micrograph



Photography of a GMRF (Guided Mode Resonance Filter) pattern transferred on the top layer of a full 4" SiO₂/a-Si/SiO₂/a-Si/glass sample (respective thicknesses 61, 49, 120, 74 nm on 500 μm thick glass). Insert is an AFM micrograph. Red and green shapes come from diffraction of light



SEM micrograph of a silicon mold of a CRIGF (Cavity Resonator Integrated Grating Filter, made of a Grating Coupler (GC) and Distributed Bragg Reflectors (DBRs) separated by a Phase Shift (PS)) that was successfully transferred into substrate thanks to the NIL process with NIL-UV 135 resist



SEM micrograph of a GaAs heterostructured CRIGF (Cavity Resonator Integrated Grating Filter, made of a Grating Coupler (GC) and Distributed Bragg Reflectors (DBRs) separated by a Phase Shift (PS)) made by transfer into the substrate thanks to the NIL process with NIL-UV 135 resist

S.Pelloquin et al, Microsys. Technol.(submitted)

7 Conclusions /Future work

We designed a new UV nanoimprint resist adapted to the use of a transitional soft COP or COC mold to replicate or transfer submicro or nano features into hard materials such as silicon, silica or gallium arsenide. We have used this resist successfully to transfer submicro or nano features from a silicon mold into silicon, silica or gallium arsenide on small samples or full 4" wafers. This enables for instance the making of optical filters on transparent substrates on which direct stepper lithography can not be done easily. The knowledge of the resist content provides a good reliability of the process and enables adaptation of the resist to new applications (such as final optical index adjustment). Among currently investigated and future works or those implying the use of the resist as an optical layer that will remain on the final device (as it is, or with optical index adaptation) and its use for nanoscale metal deposition by lift-off process.