FP 6 - NMP4 CT2003500120
SUB-PROJECT TOOLS

NANOIMPRINTING STEPPER
With HOT EMBOSSING and UV-NIL CAPABILITY

Gilbert Lecarpentier; International Product Manager

Contributions at VTT from Jouni Ahopelto, Päivi Majander, Tomi Haataïnen

WHAT IS „NANO“ ?

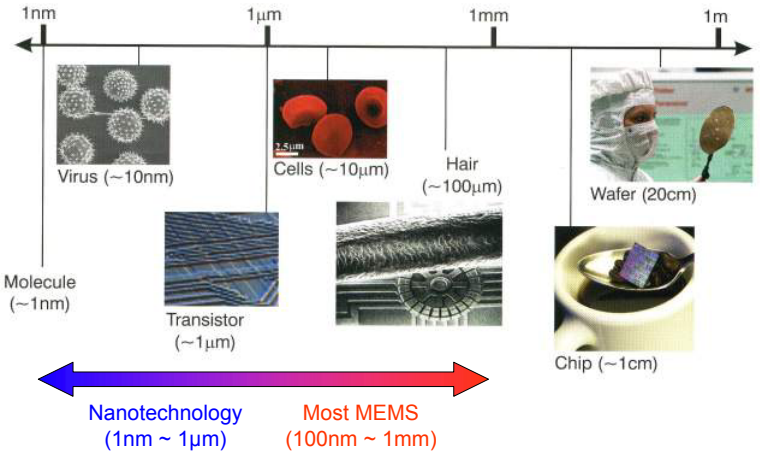
FOR FRENCH KIDS IN 1955 ➔

FOR ALL KIDS (NOT ONLY) TODAY

🡻

🡻 IN THE MIDDLE AGE

WHAT IS „NANO“ ?



Source: Prismark

OUTLINE

- Sub-Project TOOLS
  - WP15: Step and Stamp Nano Patterning Tool
  - WP16: Stencil Mask Alignment and Fixation Tool
  - WP17: Overlay Accuracy in NIL
- NPS300 overview
- Imprint examples
- Summary

SUB PROJECT TOOLS

- WP15: Step & Stamp Nano Patterning Tool
  - For hot and cold embossing, with an alignment accuracy < 250nm.

  →SUSS MicroTec SAS

  →VTT Technical Research Centre of Finland
- WP16: Stencil Mask Alignment and Fixation Tool
  - Accuracy of 1µm at the first and 250nm at the final stage

  →SUSS MicroTec Lithography GmbH

  →EPFL (Ecole Polytechnique Fédérale de Lausanne)

  →CNM (Consejo Superior de Investigaciones Científicas)
- WP17: Overlay Accuracy in NIL
  - Development of an alignment system with an overlay accuracy < 20nm at wafer scale and optionally for the Step and Stamp Nanoimprint Lithography Tool

  →Obducat

  →Lund University

STEP AND STAMP NANO PATTERNING TOOL

NaPa: Work Package 15

Gilbert Lecarpentier

Päivi Majander
Tomi Haataïnen

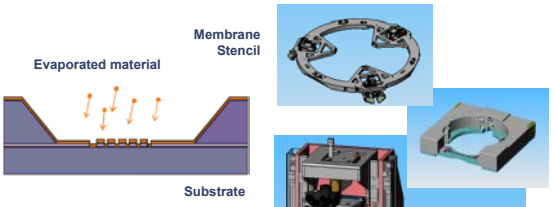
- The NPS300 benefits of the over 20 years experience in designing high accuracy, high force device bonder
- It is the main topics of this presentation

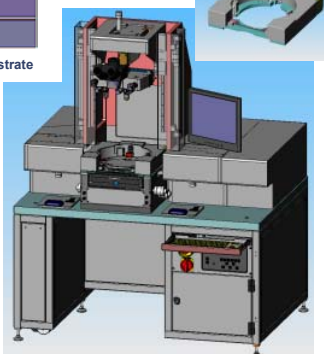
  → details will follow

STENCIL MASK ALIGNMENT / FIXATION TOOL

NaPa: Work Package 16

Sven Hansen
Jürgen Brugger
Francesc Perez-Murano





- Alignment from backside or topside; accuracy down to 250nm
- Adapter frame for stencil tooling prepared for 8-inch fixtures
- To achieve a high alignment accuracy the movement after the alignment is minimized; Alignment gap down to 20µm
- Self leveling is performed by flexure stage

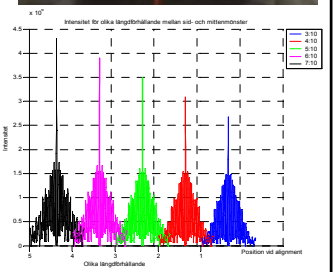
OVERLAY ACCURACY IN NIL

NaPa: Work Package 17

Lars Montelius
Babak Heidari

- The method relies on evanescent wave coupling. It enables subwavelenght precision - purely limited by nanoscaled alignment pattern

+ No need for a transparent substrate or stamp
  + No need for a special stamp or substrate
  + Accuracy based on nanoscale alignment marks
  + Smart pattern allow < 10 nm overlay resolution
  + Active alignment possible during imprint
  + Two stage alignment: <1µm *ex-situ,* <10nm *in-situ*



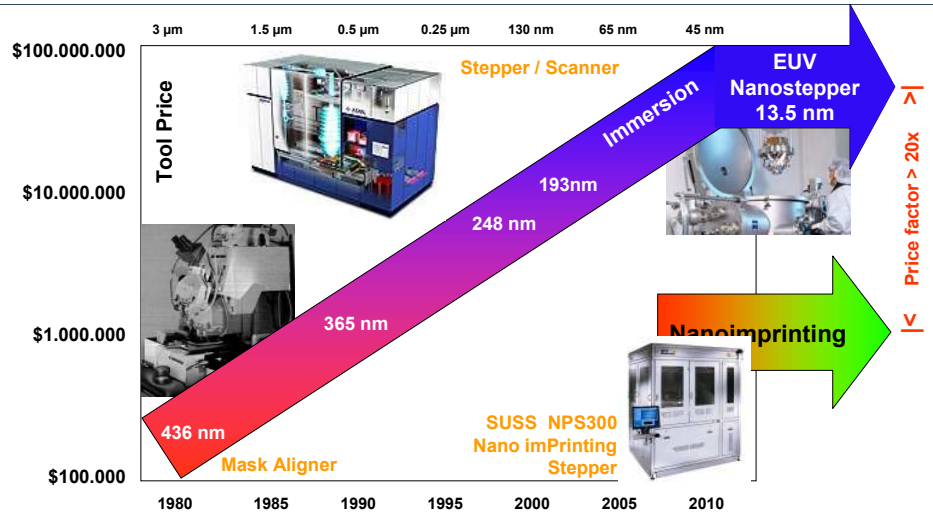
SÜSS MicroTec

NPS 300

NANO IMPRINTING STEPPER

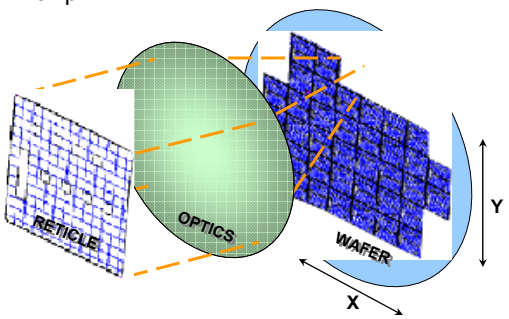
Step & Repeat Nano Imprinting Lithography

RESOLUTION DECREASE = COST INCREASE



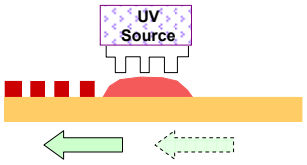
STEP & REPEAT OPERATION

- STEP & STAMP IMPRINT LITHOGRAPHY mimics the operation of an optical stepper in which the substrate is exposed chip by chip

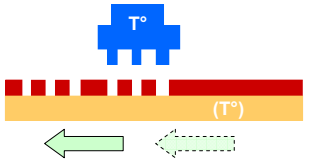


- Sequential imprinting methods can be used to pattern large areas

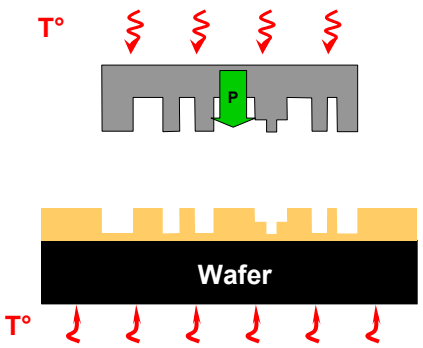
COLD EMBOSSING: UV EXPOSURE



HOT EMBOSSING: HEAT & PRESSURE

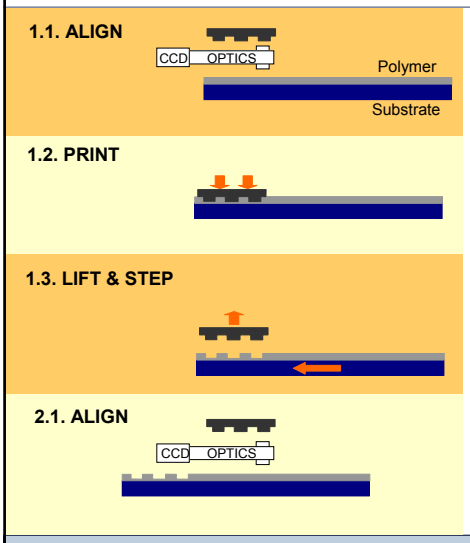


NANOIMPRINTING - HOT EMBOSSING



- **Heat up wafer and stamp, Alignment**
- **Approach**
- **Increase Stamp temperature**
- **Apply Pressure -- > Emboss**
- **Cool Down Stamp**
- **Release Pressure**
- **Separate, Release Stamp**
- **Cool Down Stamp and Wafer if Finished**

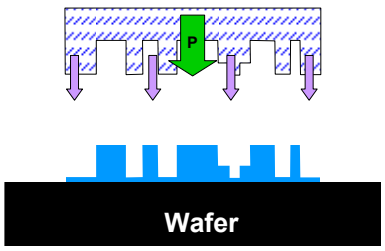
HOT EMBOSSING PRINCIPLE OF OPERATION



1. Stamp-to-Wafer alignment is made along 5 axes (XYT and Parallelism)
2. The stamp is pressed into polymer layer to transfer the pattern
   - Self leveling of the stamp
   - Temperature and pressure are controlled at all time
3. The stamp is lifted and moved to the next site.

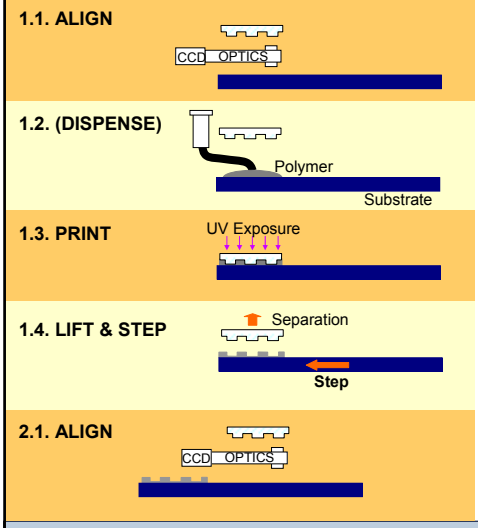
Imprinting is repeated at the new location

NANOIMPRINTING - COLD EMBOSSING / UV-NIL



- **Alignment**
- **Dispense Polymer**
- **Approach**
- ***High Accuracy Alignment***
- **Apply Pressure**
  -- > Self leveling, imprinting
- **Cure with UV Light**
- **Release Pressure**
- **Separate, Release Stamp**

UV-NIL PRINCIPLE OF OPERATION



1. Template-to-Wafer alignment is made along 5 axes (XYT and Parallelism)
2. If required, polymer is dispensed
3. The template is pressed into polymer resist to mold the pattern.
   - Self leveling of the stamp
   - Pressure is maintained while UV exposure is performed
   - Temperature controlled of the substrate can help decreasing process time and increasing resolution thanks to lower viscosity of the embossing material
4. The stamp is lifted and moved to the next site.

Imprinting is repeated at the new location

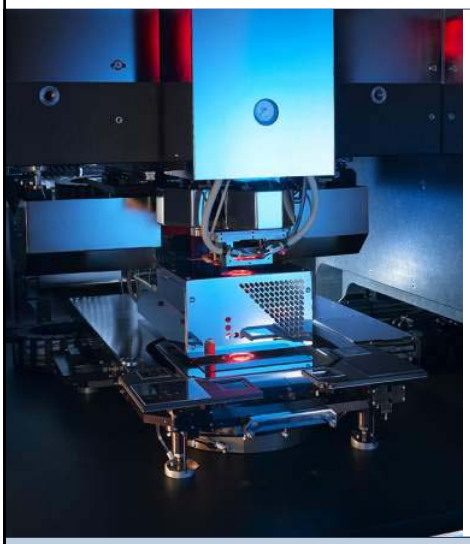
MAIN FEATURES

- **Step & Repeat mode**
- **Aligned Hot & Cold Embossing**

KEY FEATURES

- Sub-20 nm embossing capability
- Alignment accuracy: 100nm
  Overlay Accuracy: 250 nm
  High accuracy alignment: 20nm under development
- Template / Stamp size
  50 ~ 65 mm *(Option up to 100 mm)*
- Substrate ≤ Sq.200mm (∅ 300mm)
- Pre-leveling accuracy 20 µradian
  Self leveling by flexure stage during application of the imprinting force
- Automatic stamp pick-up from tray
- Manual or automated loading/unloading

NPS 300: SPECIFICATIONS AT A GLANCE

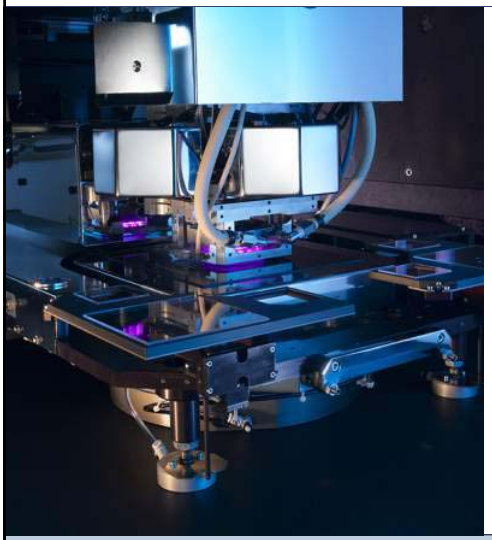


- **Imprinting Arm**
  - Force: 5 N ~ 4,000 N
  - Z resolution: 50 nm
  - Pre-leveling < 20µrad
  - Self-leveling system
- **Alignment XYθ Stage**
  - Resolution XY: 10 nm
  - Resolution θ: 0.8 µradian
- **Alignment optics**
  - Top & Bottom Viewing Microscope
  - FOV: 870 x 690 µm
  - Alignment Accuracy: 100 nm

OPTIONS

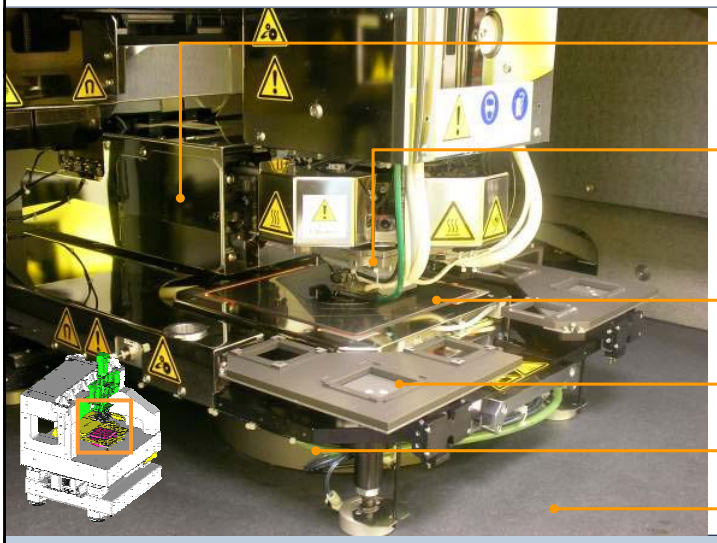
- Automatic alignment
- Advanced laser-levelling system
- Fluid dispenser for cold embossing
- Wafer feeding module

NPS 300: SPECIFICATIONS AT A GLANCE



- **UV NIL Head**
  - Stamp Square 50 ~ 65 mm
    (under development: Sq. 100mm)
  - Force up to 200N (more on request)
  - Exposure Sq. 40mm
  - 375 ± 15nm, > 120mW/cm²
    (under development: Broad band)
  - Uniformity 5%
- **Hot Embossing Head**
  - Stamp Square 50 ~ 65 mm
    (option: Square 100mm)
  - Force up to 4,000 N
  - Temperature up to 450°C

NPS 300: MAIN MODULES (Imprinting Position)



Optics
Protected by heat shield

Imprinting head
Cold or Hot embossing
Change over < 90 min.
Shown in Imprinting position

Substrate chuck
Up to 200 x 200 mm
or Dia. 300mm

Stamp Tray

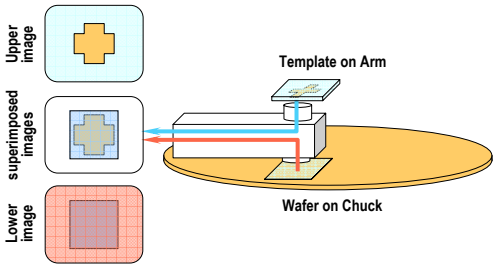
Air Bearing

Granite Base

PARAMETERS TO CONTROL

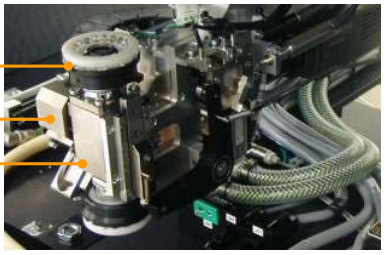
- X/Y/θ Alignment
- Parallelism / Template Leveling
- Force and Force Profile Control
- Temperature Control
- UV Exposure Control
- Material Dispense

STAMP-TO-SUBSTRATE ALIGNMENT

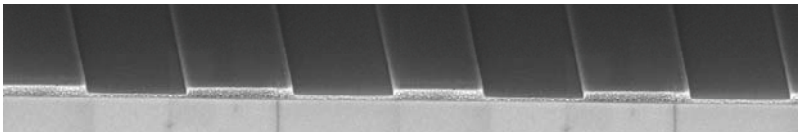


Inter Substrate Microscope

- Look through upper lens (blue path), to locate and center the template alignment marks in the field of view
- Look through lower lens (red path), to align the wafer with the template
- Alignment down to 100 nm



RESIDUAL LAYER CONTROL



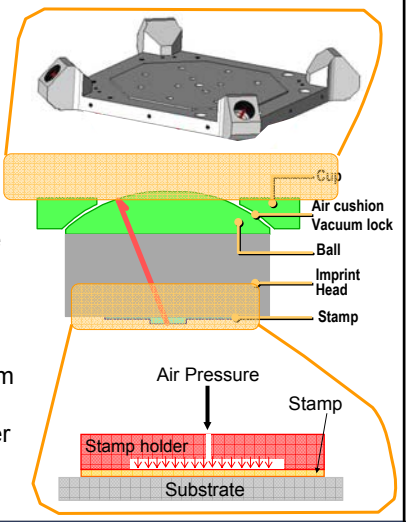
Uniform Residual Layer requires

No Wedge

No Bow

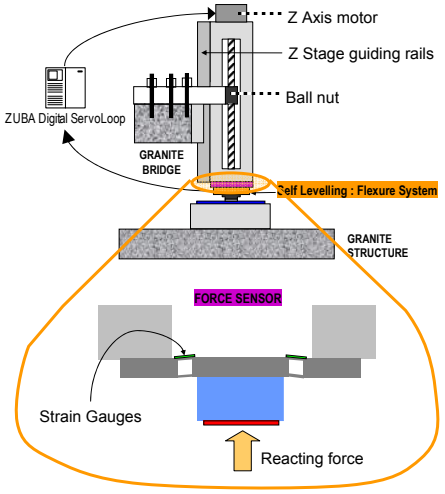
RESIDUAL LAYER CONTROL → LEVELING

- The imprinting Arm module includes a pre-leveling system
  - Motorized Sphere
  - Active leveling resolution: 20 µradian (autocollimator measure)
    → 0.2 µradian is required to obtain uniform residual layer (< 10 nm)
- Final leveling is obtained by a flexure stage
  - < 5N required for self leveling
  - System sustains force up to 10,000N
  - *Sensibility is adapted to the imprinting head*
- Flexure stage cope only with non parallelism
  For waviness compensation an alternative solution is provided by pressurized chamber built-in the stamp support (Thin stamp or PDMS)



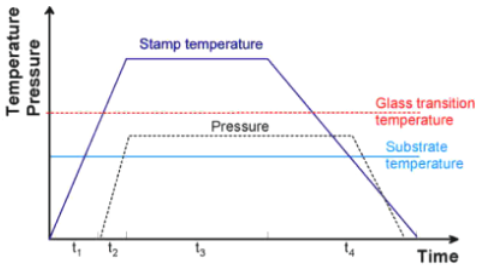
FORCE CONTROL PRINCIPLE

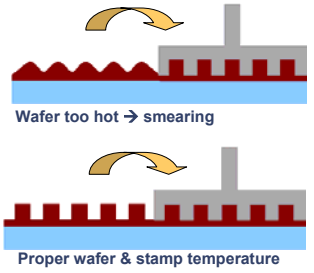
- The imprinting Arm module includes
  - A high resolution Z movement
  - Active Leveling: motorized Ball/Sphere system (driven by data measured through autocollimator
  - Self Leveling using a flexure stage
- The Imprinting Arm can be equipped with two models of Embossing Head:
  - Cold Embossing Head
  - Hot Embossing Head
- Force control range: from 5 to 4,000 N
  Sensor is adapted to imprinting head
- Programmable Force Profile, Controlled in Real Time by the Servo Loop
  Position is also monitored



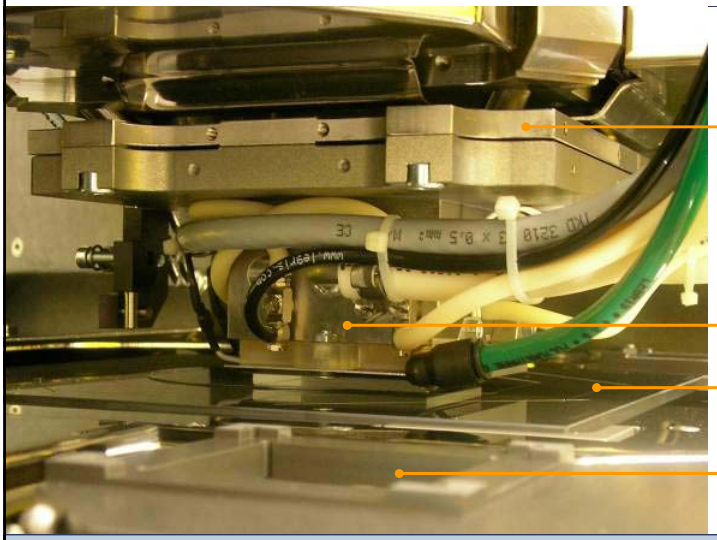
HOT EMBOSSING, TEMPERATURE & FORCE CONTROL

- Independent temperature control on Stamp and Wafer: RT to 450°C
- Only the stamp, and the area under the stamp, is heated above the glass transition temperature of the resist to avoid degrading already imprinted features during the sequentially performed imprinting

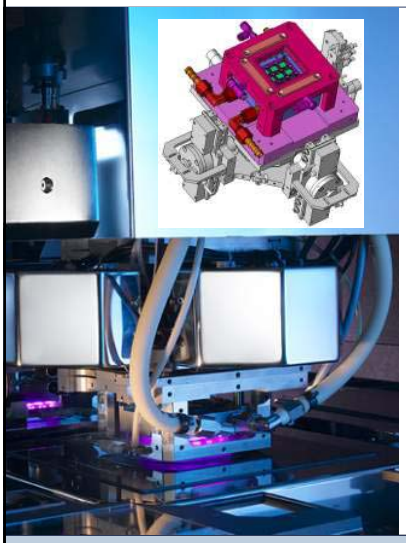




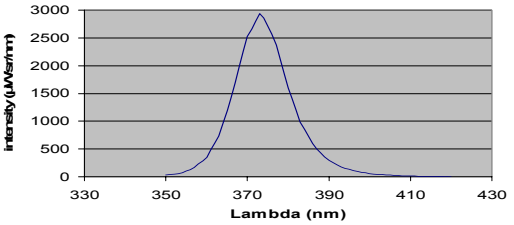
RE-CONFIGURATION IN MINUTES



UV-NIL HEAD - SPECTRUM



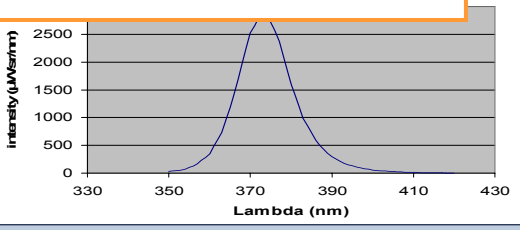
- UV Module consists of a matrix of 16 LED Arrays attached to a water cooled heat sink
  - No warm up time, low power consumption
  - Longer life time, no maintenance
  - Pure UV Spectral Distribution → No heat generated by beam absorption
  - Continuous mode or Pulse mode for High Peak Irradiance (>120mW/cm²)
- Force range: 5 – 200 N



UV-NIL HEAD - SPECTRUM

- UV Module consists of a matrix of 16 LED Arrays attached to a water cooled heat sink
  - No warm up time, low power consumption

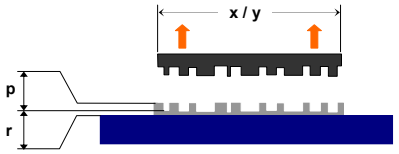
THE DEVELOPMENT OF A BROAD BAND UV SYSTEM IS IN OUR ROADMAP



COLD EMBOSSING MATERIAL DISPENSE

- Dispense the embossing material (polymer/resist) onto the wafer
- Programmable dispense pattern: Puddle, Dot matrix, Lines, etc
- Jet system
  - Dispense extremely low volume
  - Small droplet < 100µm depending upon viscosity

Example:
- 10x10mm stamp, structures ratio 50%
- 300nm structures, 50nm residual layer
→ Volume required 20nl (38 droplets /100µm)

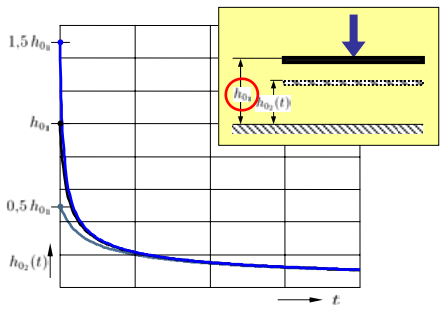


DISPENSING THICKNESS / RADIUS

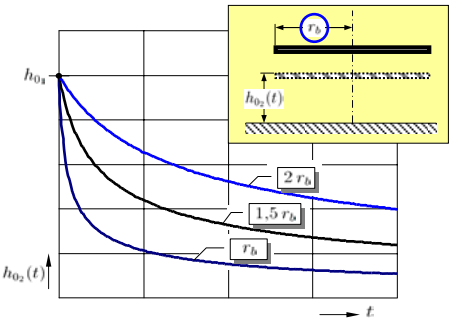
Influence of the ***Initial Gap Height*** on ***Decent Rate***

$$h_{0_2}(t) = \frac{1}{\sqrt{\frac{1}{h_{0_1}^2} - \frac{4\,F_N}{3\pi\,\eta\,r_b^4}\cdot t}}$$

Influence of the ***Imprinting Area*** on ***Decent Rate***

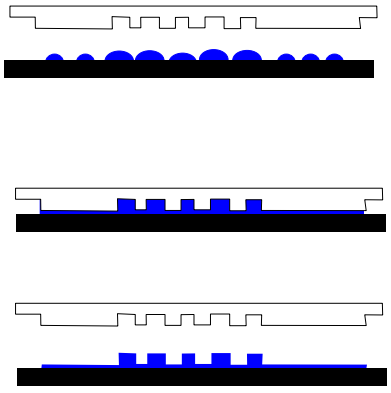


Strong **convergence** of the decent curves in spite of **different initial heights** h_{0_1}



Significant **increase** of the **process time** due to larger **imprinting area**

DROP DISPENSING



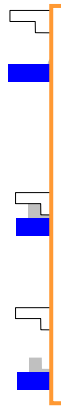
Advantage

- Imprinting area = n x drop area
- Tailored to Pattern density

Disadvantages

- Special dispensing technology and resist is necessary
- The volume of resist must be calculated to the stamp size and feature size

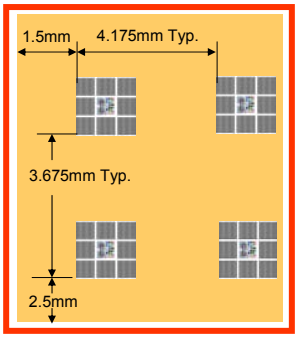
DROP DISPENSING

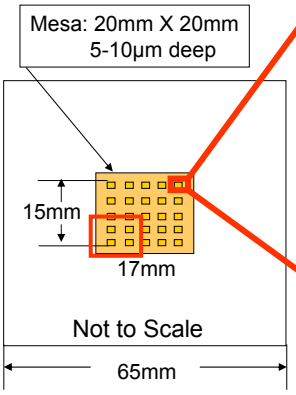


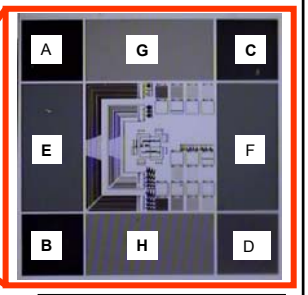
THE INTEGRATION OF A MULTI NOZZLE INKJET TYPE DISPENSING SYSTEM IS UNDER DEVELOPMENT

→Requires low viscosity material < 15 mPa.s

SUSS STAMP LAYOUT (1/3)





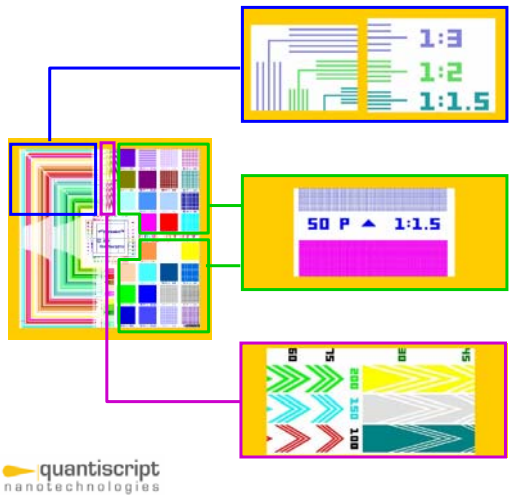


Etching Depth to be 100nm

Gratings Detail
Gap between patterns ~ 2 microns
Fields A,B,C,D = 48 X 48 micron
Fields E,F= 48 X 100 micron
Fields G,H= 100 X 48 micron
A: 100nm Line 100nm space
B: 100nm Line 200nm space
C: 100nm Line 400nm space
D: 200nm Line 200nm space
E: 200nm Line 400nm space
F: 300nm Line 300nm space
G: 200nm Line 600nm space
H: 300nm Line 600nm space

Center cell is 1stImpression cell (30, 40nm sized features removed
Patterns are generated on a Mesa to allow step and repeat in close proximity without damaging previously embossed pattern

SUSS STAMP LAYOUT (2/3)



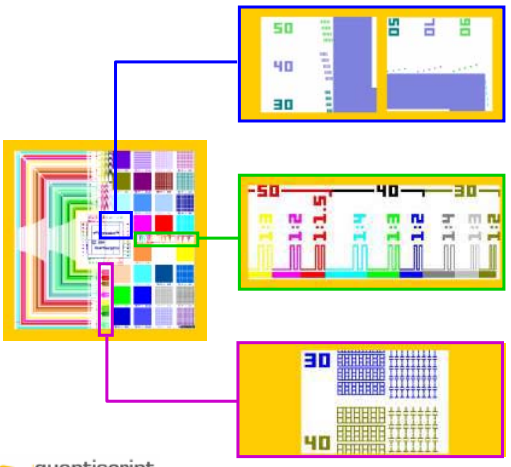
Dense and Isolated raised and Recessed L-Bars
- 5-line groupings at 90, 70, 50nm
- Multiple pitches 1:4 to 1:1.5

Hole
- Arrays with 90, 70, 50 nm
- Multiple pitches from 1:3 to 1:15
- Pillars and recess configuration

Chevron at multiple acute angles
- 100, 150 and 200 nm lines
- 75, 60, 45 and 30 degrees
- Raised and recessed structures

quantiscript nanotechnologies

SUSS STAMP LAYOUT (3/3)



quantiscript nanotechnologies

Micro-Nano Challenge

- Isolated nano structures adjacent to micron-sized features

Serpentine flow assessment

- 8-turn serpentine close/open at opposing ends
- Lines at 90, 70, 50 nm
- Multiple pitches 1:4 to 1:1.5
- Pillars and recess configuration

Semiconductor device-like structures

- Features typical SRAM cells
- Scaled from 90nm down to 30nm
- Raised and recessed structures

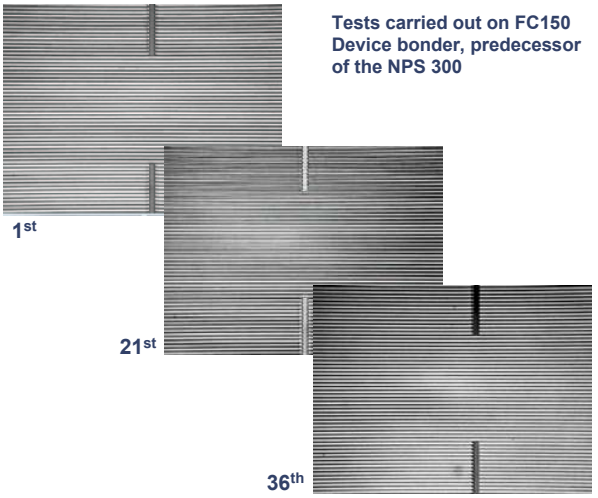
NPS 300 NANO IMPRINTING STEPPER

IMPRINTING EXAMPLES

IMPRINTS IN RESIST, REPEATABILITY

6 x 6 MATRIX

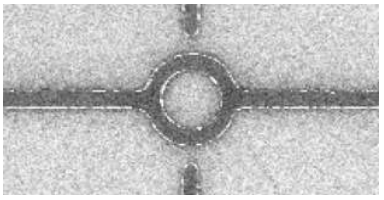
mr-I 8000 resist



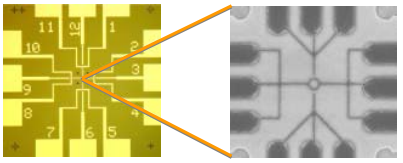
Tests carried out on FC150 Device bonder, predecessor of the NPS 300

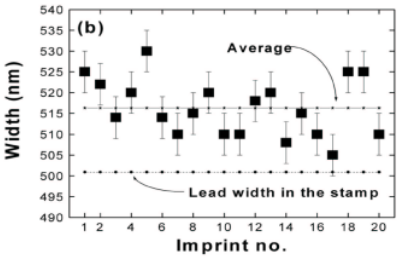
IMPRINTS IN RESIST, MIX & MATCH

- Stamp alignment with features already existing on the substrate
- SSIL can be mixed and matched with UV lithography
- A-B ring defined by imprinting and lift-off
  - Ring was aligned to alignment marks on the wafer
  - Wider leads were subsequently defined by UV lithography and lift-off

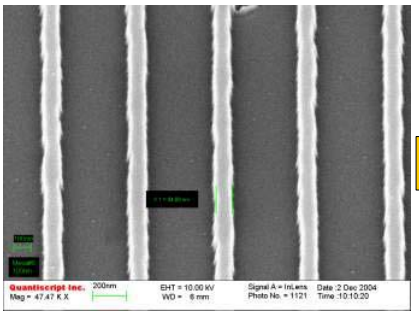


Tests carried out on FC150 Device bonder, predecessor of the NPS 300

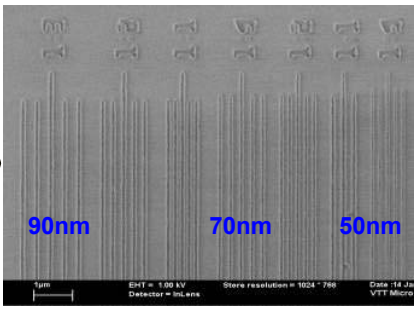




FIST IMPRINTING RESULT ON A NPS300



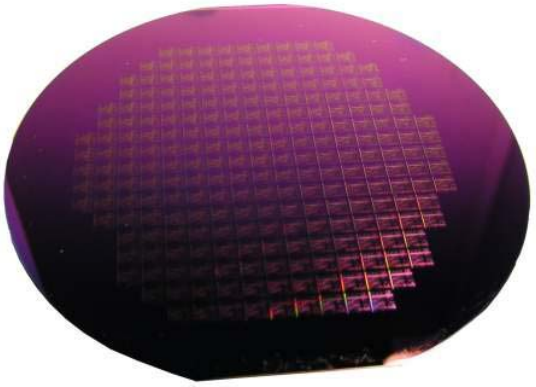
Detail of a fused silica stamp



SEM image of an imprint

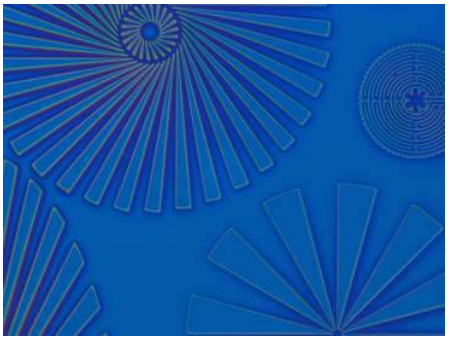
First imprinting results with the cold embossing head of the NPS 300 are limited by the sidewall roughness of the template.

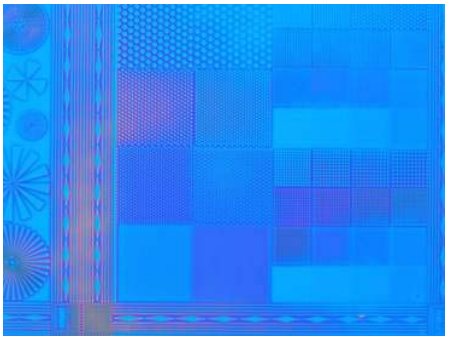
STEP AND REPEAT ON WAFER



- NaPa-Mask Stamp
  - Stamp Size 4x4 mm
  - Features Height ~ 200 nm
  - Feature Size 1 µm to large patterns
- 100mm Silicon Wafer
- Spin Coated with 300 nm thick mr-I 7030
- 237 Imprints
- Hot Embossing
  - Stamp Temperature: 140 °C
  - Substrate Temperature: 70 °C
  - Cycle time ~ 3 minutes (without collimation and arm movements)

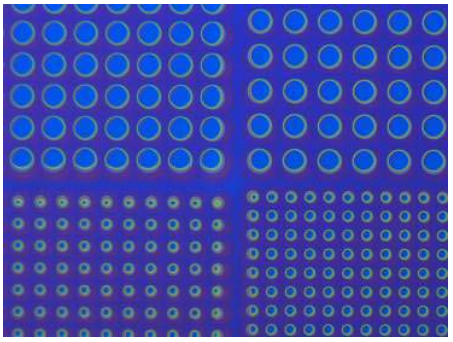
STEP AND REPEAT ON WAFER

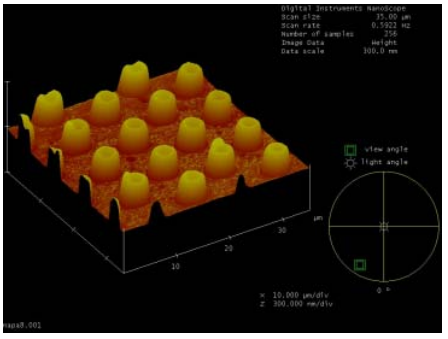




- Imprinted Large to Narrow Patterns

STEP AND REPEAT ON WAFER

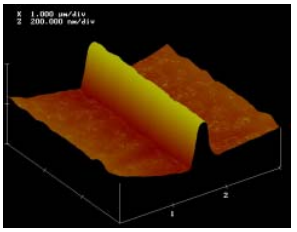


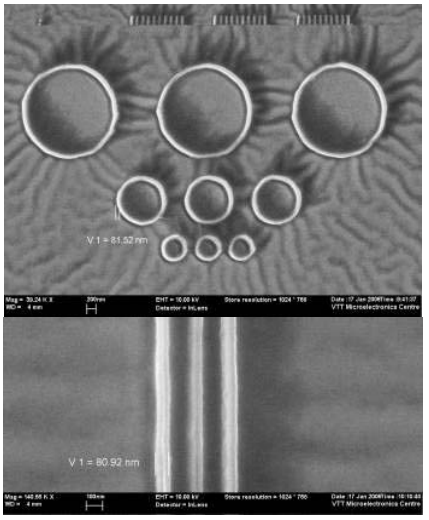


- Imprinted Pillars

CREATION OF LARGER MASTRE STAMP

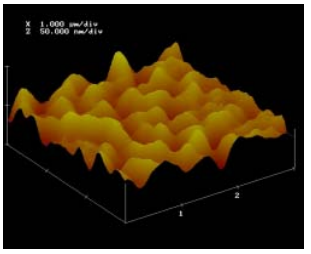
- SEM view of a Ni replicate made from a SSIL imprinted mr-I 7030 template
- The wrinkles around the pattern are due to the melting of the polymer during the sputtering phase, so no relation with the SSIL process

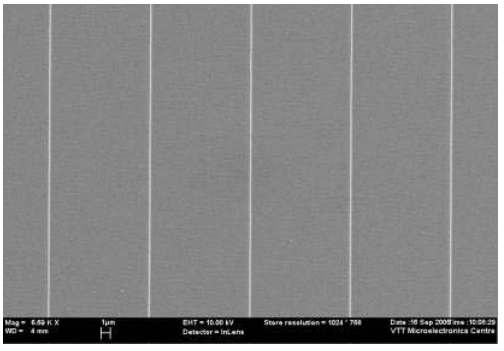


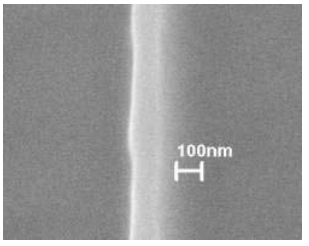


IMPRINTING RESULT ON A NPS300

- SEM image of TiW/Cu/Ni ridge in the stamp (height 180 nm, width 100 nm).
- Surface roughness of the stamp (rms 8 nm).





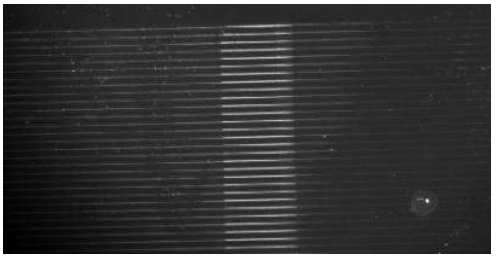


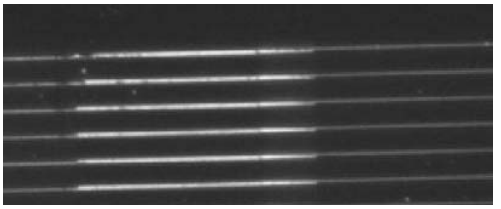
IMPRINTING RESULT ON A NPS300

STITCHING

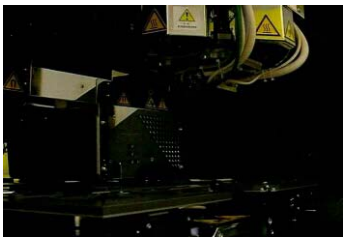
- Stitching grating
- 1.1 x 1.1 mm²
- 100µm overlap
- 150 nm lines
- Hot Embossing Material

- Alignment is < 100nm (Machine specs 250nm)





CONCLUSION



- NPS300 is operational at VTT since September 2005
- Experiments are in progress
  - First focus was on Hot Embossing
  - UV-NIL comes next (started this month)
- New options will be installed by end 2006
  - Low force and high sensitivity leveling
  - Inkjet type dispensing system
- NPS300 is flexible (multi processes capability) HE, UV-NIL, (Later on, Soft Lithography)
- It can be use to manufacture large master stamp at lower cost

ACKNOWLEDGEMENTS

- European Commission → FP 6 - NMP4 CT2003500120
- All NaPa Members who contributed to the elaboration of the specs

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- Pascal Metzger

- Jouni Ahopelto
- Tomi Haatainen
- Päivi Majander

LITHO 2006 NaPa Emerging Nanopatterning Methods

THANK YOU FOR YOUR ATTENTION

Questions

FP 6 - NMP4 CT2003500120
SUB-PROJECT TOOLS

NANOIMPRINTING STEPPER
With HOT EMBOSSING and UV-NIL CAPABILITY

Gilbert Lecarpentier, International Product Manager
GLecarpentier@SUSSMicroTec.fr