Resists for Nanoimprint Lithography

Ready-to-use Formulations from the Industrial Pioneer of Nanoimprint Lithography (NIL) Materials

- Excellent film quality
- High replication fidelity
- Extra dry etching performance
- Superior working stamp compatibility
- Customized and tailored solutions available
- Safe solvents specified for industrial requirements
- Manufacturing according to ISO 9001 and ISO 14001

- Made in Germany -

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Nanoimprint Lithography
Process description

Nanoimprint Lithography (NIL) is a straight forward, low cost, and high throughput capable technology for the fabrication of nanometer scaled patterns. Main application fields are photonics, next generation electronics, as well as Life Science and sensor applications.

Thermal-NIL, T-NIL

Pros

- Dry polymer thin film with excellent film stability after coating
- No primer required
- Low shrinkage
- Resist still soluble in common solvents after imprinting (most cases)

Cons

- Glass transition temperature (T_g) remains after imprinting (reflow possible)
- Requires temperature ($Ti = T_g + 60$ K) and pressure (up to 5 bar)
- Long process cycle times
- CTE misalignment considerable on large area

UV-NIL

Pros

- Fast process cycle times
- Low pressure (< 100 mbar) at room temperature
- Technology of choice for large area and HVM
- Open for alternative coating technologies (solvent-free formulations possible)
- Resist properties can be easily tailored, functional materials available

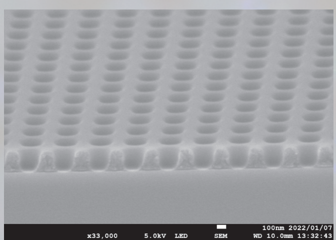
Cons

- Liquid thin film after coating
- Shrinkage during curing needs to be compensated for some applications
- Resist is insoluble in common solvents after imprinting due to cross-linking

NIL Technological Benefits

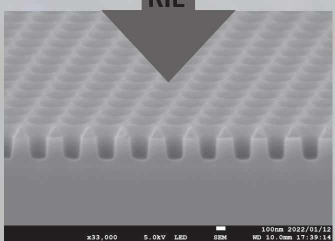
- Spatial pattern resolution <100 nm
- High throughput, fast processing
- Continuous processing (Roll-to-Roll and Roll-to-Plate available)
- Feasiblity almost independend of pattern architecture

→ NIL is the most effective fabrication method of nanostructures

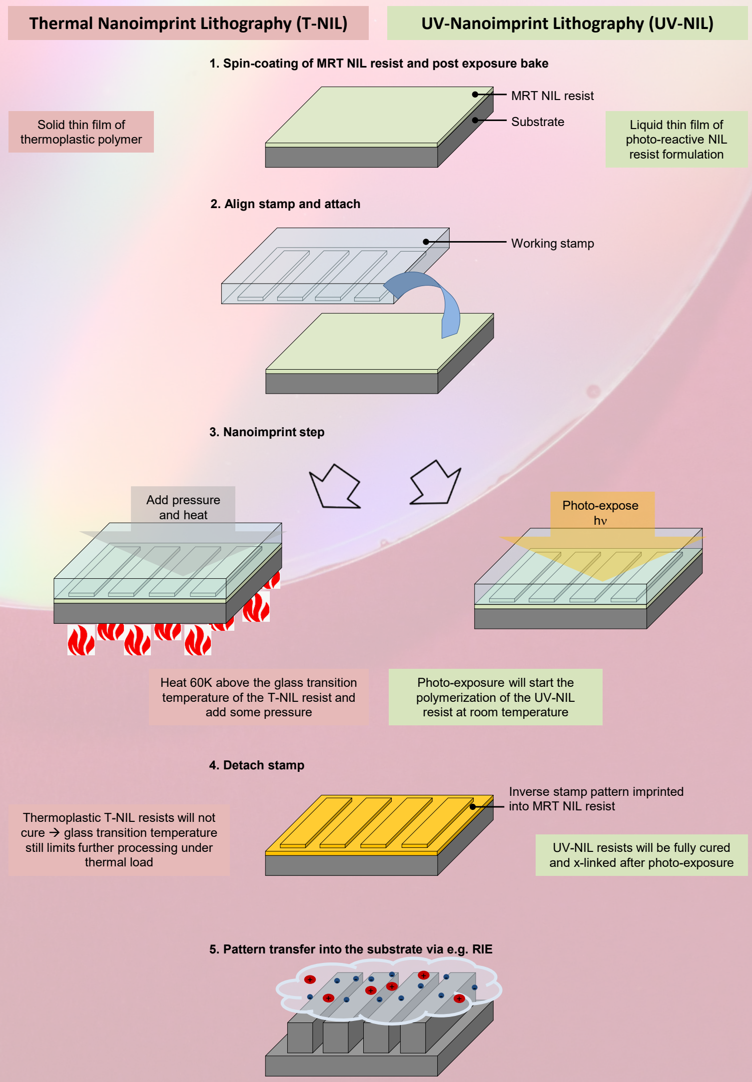


mr-NIL212FC imprint of Ø = 200 nm, AR = 1, residual layer thickness <10 nm).

RIE



Pattern transfer into SiO_2, selectivity : 2.25



Nanoimprint Lithography

Resist solutions – Ready to use formulations

micro resist technology GmbH has provided tailor-made resist formulations for nanoimprint lithography (NIL) since 1999. The unique key features of our products are outstanding film forming and imprinting performance beside excellent pattern fidelity and plasma etch stability. Our nanoimprint resists are mostly applied as dry etch masks for pattern transfer into various substrates, like Si, SiO_2, Al or sapphire.

	Product series (Chemistry behind)	Material Key Performance Indicators	Standard film thickness*	Tailored film thickness*
UV-NIL, Photo-NIL	**mr-NIL210** (Acrylic)	• Compatible to gas-permeable **flexible working stamp materials** (e.g. PDMS, PDMS-like and others) • Excellent liquid thin film long-term stability and homogeneity • Enables minimized residual layer thickness control	100 nm 200 nm 500 nm	100 nm – 38 µm
UV-NIL, Photo-NIL	**mr-NIL212FC** (Acrylic)	• Compatible to gas-permeable flexible working stamp materials (e.g. PDMS, PDMS-like and others) • Compatible to low intensity light sources (< 40 mW cm^{-2}) • **Higher dry etching stability** compared to mr-NIL210 (>2 for SiO_2) • Enables minimized residual layer thickness control	100 nm 200 nm 500 nm	100 nm – 500 nm
UV-NIL, Photo-NIL	**mr-NIL200** (Acrylic)	• Low viscosity: excellent compatiblity to gas-impermeable working stamps (e.g. OrmoStamp[1], SiO_2, Ni) • **No primer or adhesion promoter necessary** for many substrate materials • Oxygen insensitive curing chemistry	100 nm 200 nm 300 nm	100 nm – 500 nm
UV-NIL, Photo-NIL	**mr-UVCur26SF** (Acrylic)	• Solvent-free and low viscosity for **inkjet dispensing** • Low autofluorescence and excellent biocompatibility • UV/vis transparent with good thermal stability	Inkjet	700 nm**
UV+T-NIL	**mr-NIL 6000E** (Epoxy)	• For combined **UV- and T-NIL approaches** • Fast process cycle times due to isothermal NIL-process • Outstanding dry etching stability • No primer required • Compatible to PDMS-based working stamp materials	100 nm 200 nm 300 nm	100 nm – 3 µm
Thermal-NIL, T-NIL	**mr-I 9000M** (Thermoset)	• Thermosetting polymer (crosslinking at imprint temperature, isothermal NIL-process) • T_g = 35 °C, no T_g after imprinting (stable up to 260 °C after imprint) • **Excellent dry etching stability** • Optically clear after imprint for permanent applications	100 nm 200 nm 300 nm	100 nm – 1 µm
Thermal-NIL, T-NIL	**mr-I 7000R** (Thermoplast)	• Purely organic, stamp release force optimized • **Higher etching stability over PMMA** • T_g = 55 °C	100 nm 200 nm 300 nm	100 nm – 300 nm
Thermal-NIL, T-NIL	**mr-I 8000R** (Thermoplast)	• Purely organic, stamp release force optimized • **Higher etching stability over PMMA** • T_g = 115 °C	100 nm 200 nm 300 nm	100 nm – 300 nm
Thermal-NIL, T-NIL	**mr-I PMMA35k** (Thermoplast)	• Purely organic • T_g = 105 °C	-	-
Thermal-NIL, T-NIL	**SIPOL** (Thermoplast)	• **Si-containing etch mask** for pattern magnification in a bilayer process • Perfect match to transfer layer UL1 • Excellent flow characteristics for fast filling of stamp cavities	100 nm 200 nm	60 nm – 200 nm
Thermal-NIL, T-NIL	**mr-I T85** (Thermoplast)	• **Based on COC (cyclic olefin copolymer)** • High chemical resistance towards acids, bases and most organic solvents • Superior UV/vis transparency • Perfect choice for e.g. µ-fluidic and bio applications, lab-on-chip	100 nm 300 nm 500 nm 1 µm	100 nm – 20 µm

** Specification of the film thickness measurement: spin-coating on 4 inch Silicon wafers @ 3000 rpm for 30 sec. followed by the recommended pre-exposure bake conditions*

*** Material developed for inkjet dispensing, film thickness is not adjustable by using a thinner*

Nanoimprint Lithography
Process subtleties

NIL with hard, rigid, and gas-impermeable stamps

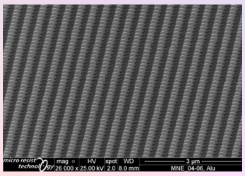
Main application fields
Optics, nanophotonics

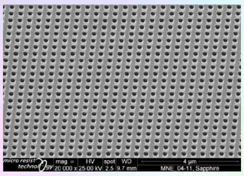
Main technology drivers
No pattern collapse even for high aspect ratio nano-structures
No distortion of working stamp
Long stamp lifetime (additional anti-sticking layer required in many cases)

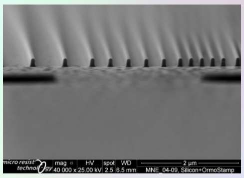
Typical imprint materials
UV-NIL mr-NIL200, mr-UVCur26SF
T-NIL mr-I 7000R/8000R, mr-I 9000M, SIPOL, mr-I T85

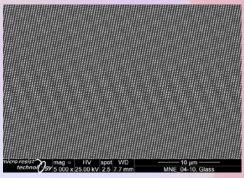
Typical stamp materials
e.g. OrmoStamp®[1], SiO_2, glass, Si, Ni, polymers

Application examples


mr-NIL200 pillars on Al (Ø = 200 nm, AR 1.5)


mr-NIL200 holes on sapphire (Ø = 200 nm, AR 1.5)


mr-NIL200 lines and spaces on Si (width = 75 nm, AR3)


mr-NIL200 pillars on glass (Ø = 200 nm, AR 1.5).

NIL with soft and gas-permeable stamp materials

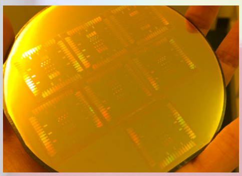
Main application fields
Optics, Nanophotonics, functional surfaces

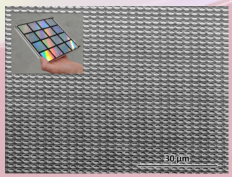
Main technology drivers
Conformal contact also to non-flat substrates
Excellent control of residual layer thickness (RLT)
Working stamp materials with intrinsic anti-sticking properties available[2,3]

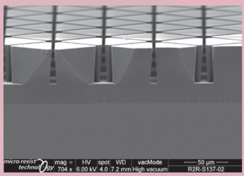
Typical imprint materials
UV-NIL mr-NIL210, mr-NIL212FC
UV- and T-NIL mr-NIL 6000E
T-NIL SIPOL

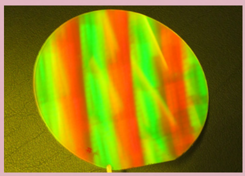
Typical stamp materials
e.g. PDMS-types, KER-4690 UV-PDMS[2], other polymers[3]

Application examples


mr-NIL210 on gold coated non-flat polymer film (imprinted with UV-PDMS[2] stamp, residual layer thickness < 10nm)


Metal direct etch with mr-NIL210 mask (imprinted with PDMS). Courtesy of smart materials solutions, Inc.


Imprint of undercut structures with mr-NIL210 on Si, applied working stamp UV-PDMS[2]


mr-NIL212FC pillars on sapphire (Ø = 2 µm, imprinted with GMN[3] working stamp).

[1] OrmoStamp® see separate flyer of MRTs Hybrid Polymers, [2] KER-4690 UV-PDMS, from Shin-Etsu, Japan, available from MRT, [3] GMN working stamp series of OpTool ApS, Sweden

Nanoimprint Lithography Solutions
Selected processes for specific applications

NIL and lift-off

Main application fields

Nanophotonics, metamaterials, metasurfaces, nanoparticles manufacturing, nanoelectronics

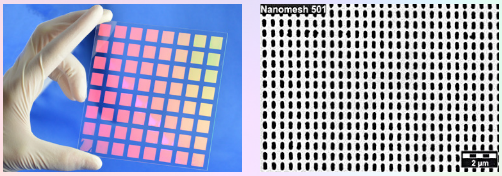
Main technology drivers

Multiple metal architectures in nanoscale possible (stacks of different metals can be realized)
Good control of lift-off performance by combination with UV-NIL
Excellent control of residual layer thickness possible via slight under-filling of stamp cavities
Single layer lift-off possible with T-NIL on small area

Typical imprint materials

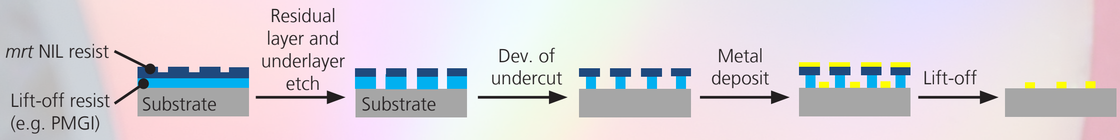
UV-NIL mr-NIL210/LOR, mr-NIL212FC/LOR[1]
T-NIL mr-I 7000R, mr-I 8000R
(metal side-wall deposition needs to be considered / avoided)

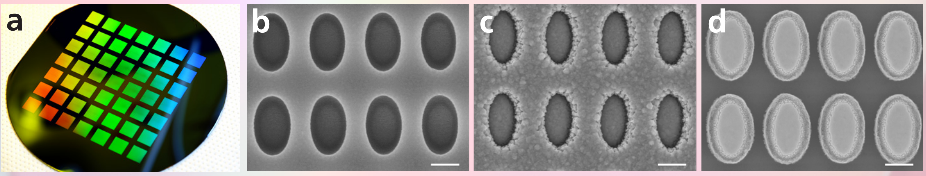
Application examples



Metal nanopatterns after step-and-repeat imprint with mr-NIL212FC on LOR1, left: photograph 10x10 cm² glass substrate after imprint, right: SEM micrograph of a metal nanomesh after lift-off (holes with 200nm length, 100nm width). Courtesy of Profactor GmbH

Process description





Manufacturing process of metallic nanostructures via imprint of mr-NIL212FC on LOR1A, a) image of the imprinted wafer, SEM micrographs b) after development of the underlayer, c) after metal deposition, d) after lift-off (patterns 200nm length, 100nm width). Courtesy of Profactor GmbH

NIL and deep etching via pattern magnification

Main application fields

Optics, nanophotonics, etching of deep trenches

Main technology drivers

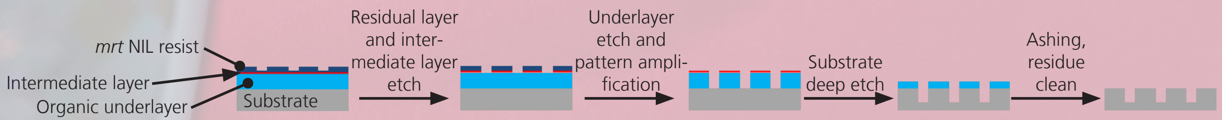
Low aspect ratio imprint → high aspect ratio deep etching

Typical imprint materials

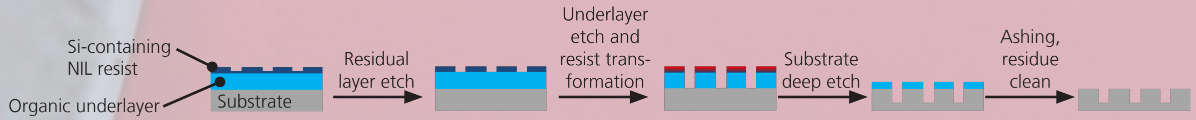
UV-NIL mr-NIL210/SiO_2/UL1[2], mr-NIL212FC/SiO_2/UL1[2]
T-NIL SIPOL/UL1[2]

Process description

1) Pattern magnification by the use of silicon containing NIL resists



2) Pattern magnification by the use of hard mask intermediates (e.g. SiO_2, Cr, Si-containing polymers)



[1] LOR, Lift-off resist from Kayaku Advanced Materials, US, available from MRT,

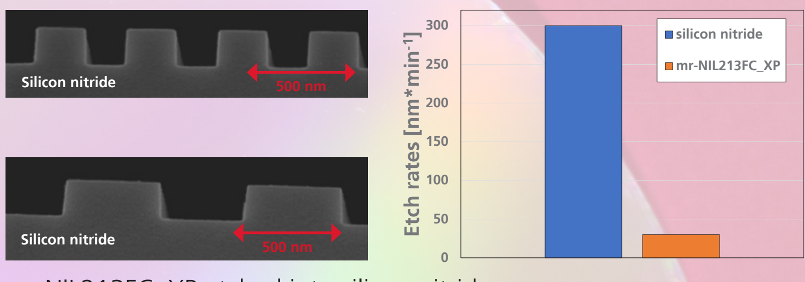
[2] UL1 organic underlayer available from MRT

Nanoimprint Lithography

Recent innovative material developments

NIL materials for large area pattern transfer and high etch resitance: mr-NIL213FC_XP

- ⇨ Fully organic
- ⇨ Etch selectivity more than two times better than mr-NIL210 (1st generation)
- ⇨ Fully compatible to *h*PDMS, PFPE and silicone-based stamps proven
- ⇨ Broad thickness range from 100 nm – 1000 µm



mr-NIL213FC_XP etched into silicon nitride
Etch selectivity 10 (courtesy imec)

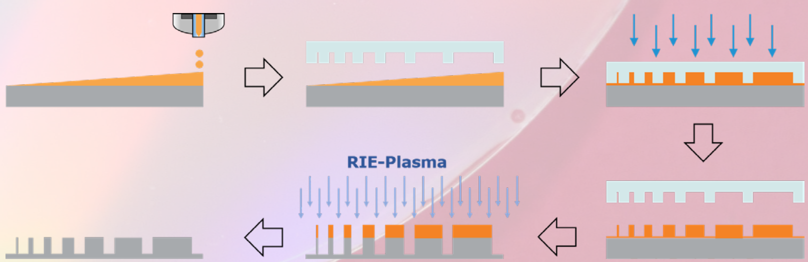
Fully organic primer: ADPROM-1a_XP

- ⇨ Fully organic
- ⇨ Compatible with any PGMEA-based resist
- ⇨ Thickness adjustable to 2 nm
- ⇨ Compatible with processes up to 300 mm wafers
- ⇨ Recommended for substrate like Si, SiN
- ⇨ Compatible resists: mr-NIL212FC, mr-UVCur26SF, mr-NIL213FC_XP

	mr-APS1	ADPROM-1a_XP
Coating	Spin-coating	Spin-coating
Temperature	100 °C	60 °C
Thickness	10 nm	2 nm
Chemistry	Si-containing	Purely organic

Inkjet materials for pattern transfer

MRT offers solvent-free inkjet materials optimzed for inkjet processes in combination with nanoimprint lithography processes (mr-UVCur26SF). New, solvent-based materials with optimized RLT and etching performance are currently under development.



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