

# 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 ( $T_i = T_g + 60K$ ) 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

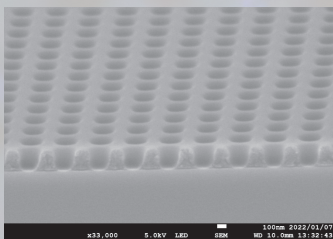
#### Cons

- 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

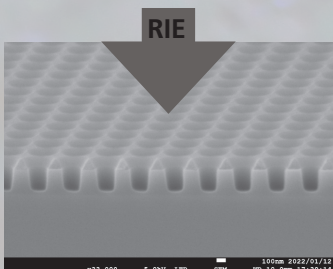
### NIL Technological Benefits

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

→ NIL is the most effective fabrication method of nanostructures



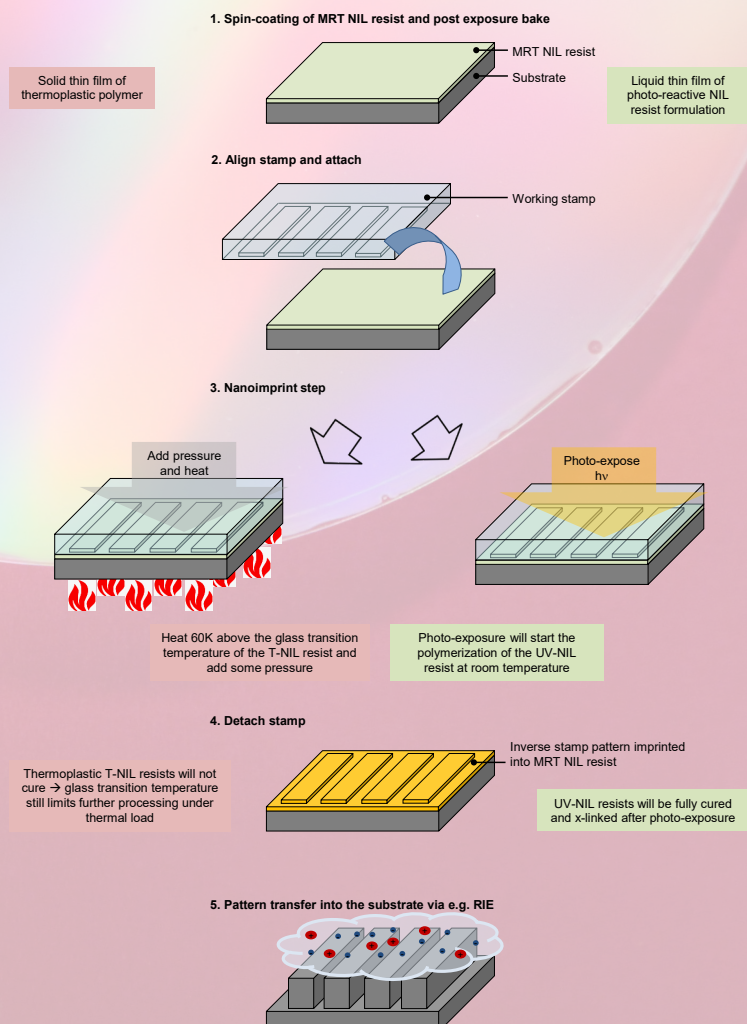
mr-NIL212FC imprint of  $\varnothing = 200\text{nm}$ , AR = 1, residual layer thickness <10nm).



Pattern transfer into  $\text{SiO}_2$ , selectivity : 2.25

### Thermal Nanoimprint Lithography (T-NIL)

### UV-Nanoimprint Lithography (UV-NIL)



# 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<sub>2</sub>, Al or sapphire.

Product series (Chemistry behind)	Material Key Performance Indicators	Standard film thickness*	Tailored film thickness*
<b>UV-NIL, Photo-NIL</b> mr-NIL210 (Acrylic)	<ul style="list-style-type: none"> <li>Compatible to gas-permeable <b>flexible working stamp materials</b> (e.g. PDMS, PDMS-like and others)</li> <li>Excellent liquid thin film long-term stability and homogeneity</li> <li>Enables minimized residual layer thickness control</li> </ul>	100nm 200nm 500nm	100nm – 38µm
mr-NIL212FC (Acrylic)	<ul style="list-style-type: none"> <li>Compatible to gas-permeable flexible working stamp materials (e.g. PDMS, PDMS-like and others)</li> <li>Compatible to low intensity light sources (&lt; 40 mW cm<sup>-2</sup>)</li> <li><b>Higher dry etching stability</b> compared to mr-NIL210 (&gt;2 for SiO<sub>2</sub>)</li> <li>Enables minimized residual layer thickness control</li> </ul>	100nm 200nm 500nm	100nm – 500nm
mr-NIL200 (Acrylic)	<ul style="list-style-type: none"> <li>Low viscosity: excellent compatibility to gas-impermeable working stamps (e.g. OrmoStamp<sup>1</sup>, SiO<sub>2</sub>, Ni)</li> <li><b>No primer or adhesion promoter necessary</b> for many substrate materials</li> <li>Oxygen insensitive curing chemistry</li> </ul>	100nm 200nm 300nm	100nm – 500nm
mr-UVCur265F (Acrylic)	<ul style="list-style-type: none"> <li>Solvent-free and low viscosity for <b>inkjet dispensing</b></li> <li>Low autofluorescence and excellent biocompatibility</li> <li>UV/vis transparent with good thermal stability</li> </ul>	Inkjet	700 nm**
<b>UV+T-NIL</b> mr-NIL 6000E (Epoxy)	<ul style="list-style-type: none"> <li>For combined <b>UV- and T-NIL approaches</b></li> <li>Fast process cycle times due to isothermal NIL-process</li> <li>Outstanding dry etching stability</li> <li>No primer required</li> <li>Compatible to PDMS-based working stamp materials</li> </ul>	100nm 200nm 300nm	100nm – 3µm
<b>Thermal-NIL, T-NIL</b> mr-I 9000M (Thermoset)	<ul style="list-style-type: none"> <li>Thermosetting polymer (crosslinking at imprint temperature, isothermal NIL-process)</li> <li>T<sub>g</sub> = 35 °C, no T<sub>g</sub> after imprinting (stable up to 260°C after imprint)</li> <li><b>Excellent dry etching stability</b></li> <li>Optically clear after imprint for permanent applications</li> </ul>	100nm 200nm 300nm	100nm – 1000nm
mr-I 7000R (Thermoplast)	<ul style="list-style-type: none"> <li>Purely organic, stamp release force optimized</li> <li><b>Higher etching stability over PMMA</b></li> <li>T<sub>g</sub> = 55°C</li> </ul>	100nm 200nm 300nm	100nm – 300nm
mr-I 8000R (Thermoplast)	<ul style="list-style-type: none"> <li>Purely organic, stamp release force optimized</li> <li><b>Higher etching stability over PMMA</b></li> <li>T<sub>g</sub> = 115°C</li> </ul>	100nm 200nm 300nm	100nm – 300nm
mr-I PMMA35k (Thermoplast)	<ul style="list-style-type: none"> <li>Purely organic</li> <li>T<sub>g</sub> = 105°C</li> </ul>	-	-
SIPOL (Thermoplast)	<ul style="list-style-type: none"> <li><b>Si-containing etch mask</b> for pattern magnification in a bilayer process</li> <li>Perfect match to transfer layer UL1</li> <li>Excellent flow characteristics for fast filling of stamp cavities</li> </ul>	100nm 200nm	60nm – 200nm
mr-I T85 (Thermoplast)	<ul style="list-style-type: none"> <li><b>Based on COC (cyclic olefin copolymer)</b></li> <li>High chemical resistance towards acids, bases and most organic solvents</li> <li>Superior UV/vis transparency</li> <li>Perfect choice for e.g. µ-fluidic and bio applications, lab-on-chip</li> </ul>	100nm 300nm 500nm 1µm	100nm – 20µm

\* 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)

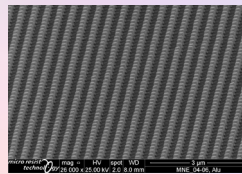
Typical imprint materials

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

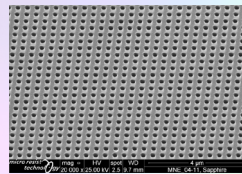
Typical stamp materials

e.g. OrmoStamp<sup>®1</sup>, SiO<sub>2</sub>, glass, Si, Ni, polymers

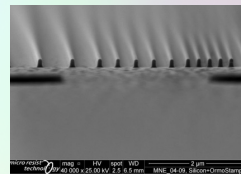
Application examples



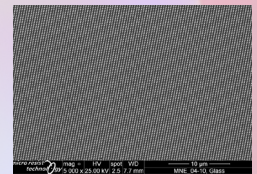
mr-NIL200 pillars on Al (Ø = 200nm, AR 1.5)



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



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



mr-NIL200 pillars on glass (Ø = 200nm, 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<sup>2,3</sup>

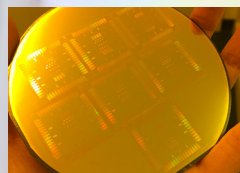
Typical imprint materials

**UV-NIL** mr-NIL210, mr-NIL212FC  
**UV- and T-NIL** mr-NIL 6000E  
**T-NIL** SIPOL

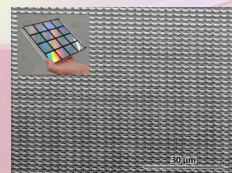
Typical stamp materials

e.g. PDMS-types, KER-4690 UV-PDMS<sup>2</sup>, other polymers<sup>3</sup>

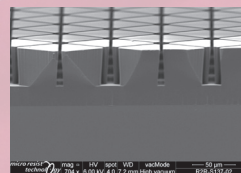
Application examples



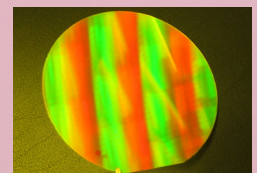
mr-NIL210 on gold coated non-flat polymer film (imprinted with UV-PDMS<sup>2</sup> stamp, residual layer thickness < 10 nm)



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<sup>2</sup>



mr-NIL212FC pillars on sapphire (Ø = 2µm, imprinted with GMN<sup>3</sup> working stamp).

<sup>1</sup> OrmoStamp<sup>®</sup> see separate flyer of MRTs Hybrid Polymers, <sup>2</sup> KER-4690 UV-PDMS, from Shin-Etsu, Japan, available from MRT, <sup>3</sup> 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

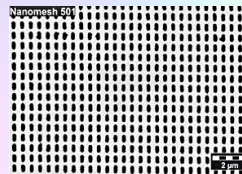
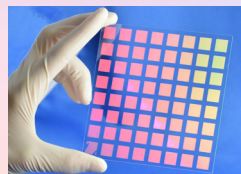
*Typical imprint materials*

**UV-NIL** mr-NIL210/LOR, mr-NIL212FC/LOR<sup>1</sup>

**T-NIL** mr-I 7000R, mr-I 8000R

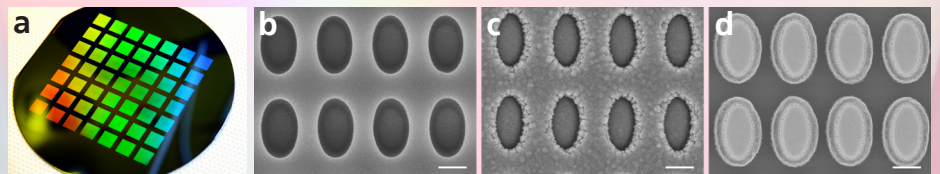
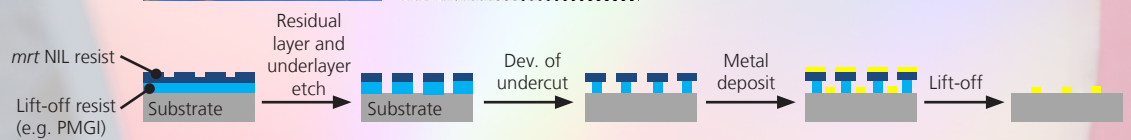
(metal side-wall deposition needs to be considered / avoided)

*Application examples*



Metal nanopatterns after step-and-repeat imprint with mr-NIL212FC on LOR1, left: photograph 10x10 cm<sup>2</sup> 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

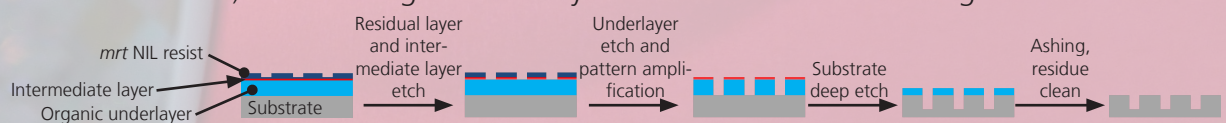
*Typical imprint materials*

**UV-NIL** mr-NIL210/SiO<sub>2</sub>/UL1<sup>2</sup>, mr-NIL212FC/SiO<sub>2</sub>/UL1<sup>2</sup>

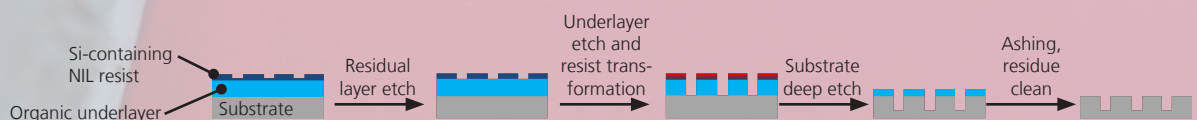
**T-NIL** SIPOL/UL1<sup>2</sup>

*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<sub>2</sub>, Cr, Si-containing polymers)



<sup>1</sup> LOR, Lift-off resist from Kayaku Advanced Materials, US, available from MRT,

<sup>2</sup> UL1 organic underlayer available from MRT

# Nanoimprint Lithography

## Distribution partners



China

*Shaanxi Siddhi Info-Resource Co., Ltd. (Shanghai)*  
Web: <http://www.cssid.com.cn>

*Raymond & Co. (Hong Kong)*  
Web: [http://www.raymondnco.com/en\\_hk/rnct](http://www.raymondnco.com/en_hk/rnct)

France

*INNODYS (Mennecey)*  
Web: <http://www.innodys.com>

South Korea

*K1 Solution, Inc. (Gyeonggi-do)*  
Web: <http://www.k1solution.com>

USA

*Kayaku Advanced Materials, Inc. (Westborough)*  
Web: <http://www.kayakuam.com>

Japan

*HTL Co. Japan Ltd. (Tokyo, Tachikawa-city)*  
Web: <http://www.htlco.co.jp>

Great Britain and Ireland

*A-Gas Electronic Materials Ltd. (Rugby)*  
Web: <http://www.AgasEM.com>

Israel

*STS LTD (Kibutz Netiv Halmed He)*  
Web: <http://www.sts-israel.com>

Taiwan

*E.L.S System Technology Co., Ltd. (Hsinchu)*  
Web: <http://www.els-tech.com.tw>

*All Radiance Optronics Co., Ltd. (Taoyuan City)*  
Web: <http://www.allradiance.com>

*AHEAD Optoelectronics, Inc. (Taoyuan City)*  
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