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mr-UVCur26SF

Characteristics

mr-UVCur26SF is a photo-curable resist formulation for UV-nanoimprint lithography (UV-NIL, Photo-NIL). It is especially developed for cost-efficient material deposition at room temperature, e.g. by inkjet dispensing or gravure coating. Due to the very fast curing speed mr-UVCur26SF can be effectively applied in high-throughput roller-based UV-NIL processes (roll-to-roll or roll-to-plate).

The main features of mr-UVCur26SF are:

- Very fast curing during photo-radiation
- Low viscosity for fast filling of stamp cavities and for enabling the inkjet dispensability
- Excellent imprint properties
- High etching selectivity in pattern transfer processes
- Non-yellowing upon UV exposure

Process Option 1 – Inkjet dispensing and nanoimprint lithography

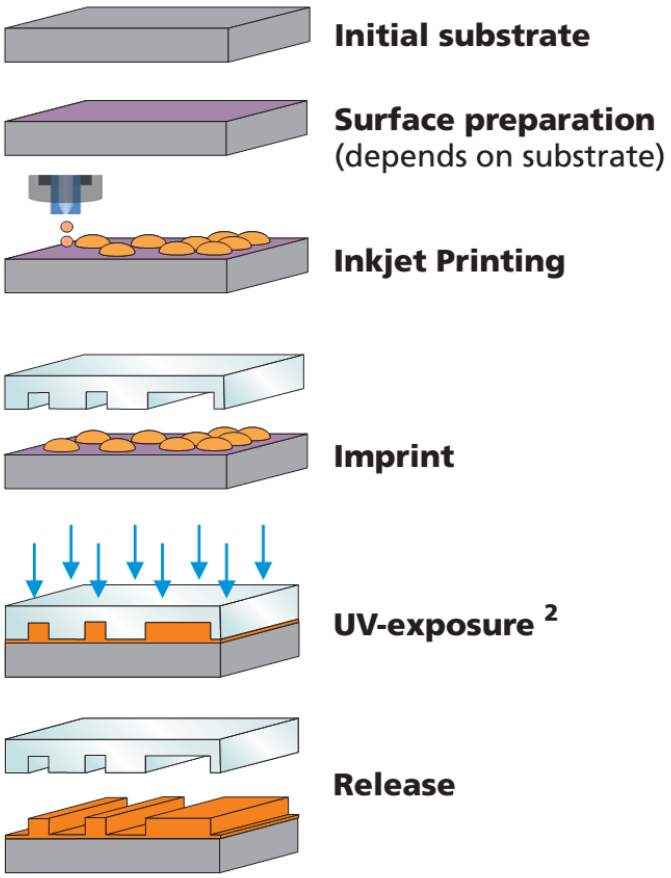

Fig.1: Process flow for nanopatterning with mr-UVCur26SF by inkjet dispensing ([2] Mercury bulb or UV-LED up to 405 nm can be used)

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Processing Guidelines – mr-UVCur26SF

Standard Processing Conditions for inkjet dispensing of mr-UVCur26SF

Best patterning results are obtained at temperatures of 20 – 25 °C and a relative humidity of 40 – 46 %. Unexposed mr-UVCur26SF has to be processed under yellow light in order to avoid unexpected pre-polymerization. This guideline describes standard inkjet dispensing on rigid substrates and a subsequent nanoimprinting process of mr-UVCur26SF. The specific process parameters to be applied depend on substrate, application, and equipment.

Process parameters

Material	**mr-UVCur26SF**
Substrate preparation	*Rigid substrates (Si, SiO_2, etc.)* *Option 1*: Spin clean with isopropanol and dehydration bake at 200 °C for 5 min on a hotplate or for 30 min in an oven. *Option 2*: Short oxygen plasma (recommended). Primer coating using mr-APS1 is strongly recommended for improved adhesion (see separate processing guidelines, *micro resist technology*).
Ink-jet parameters	Piezo-actuated nozzle
Temperature	Room temperature or above for stable drop generation
Frequency	Please refer to the data sheet of your individual inkjet printhead manufacturer.
Voltage	
Pulse length	
Nozzle cleaning [1]	Organic solvents, e.g. acetone or isopropanol (check solvent compatibility of your tool with the inkjet printhead manufacturer).
Prebake	Not required (solvent-free formulation)
Exposure dose [2]	>700 mJ cm^{-2}
Hardbake	Not required

[1] Preferably applied during the hour following the dispensing to avoid clogging of the nozzles.
[2] UV broadband exposure, intensity measured at λ=365 nm. Monochromatic LED irradiation can be applied from 365 to 405 nm, the minimum dose increases with increasing radiation wavelength or by using monochromatic radiation sources.

Substrate Preparation

Hard substrates: The substrates have to be free of impurities, particles and moisture. Si and SiO_2 substrates should be spin-cleaned with acetone or isopropanol, baked at 200 °C for 5 min and cooled down to room temperature immediately before drop deposition. Alternatively, short oxygen or ozone plasma cleaning and surface activation is strongly recommended.
The application of an adhesion promoter is highly recommended and mandatory in some cases. For mr-UVCur26SF the adhesion promoter mr-APS1 (available from *micro resist technology* GmbH) is most suitable. For the application of mr-APS1 please refer to the separate processing guidelines of this product.

Drop Generation and Resist Deposition

Spin-coating of mr-UVCur26SF is **not recommended**; the resist has been especially developed for inkjet dispensing technology.

Reliable results are obtained by using piezo-actuated inkjet printheads. The inkjet parameters, such as voltage, amplitude, pulse length as well as temperature should be selected and fine-tuned in order to generate stable and reproducible drops. Inkjet parameters may vary depending on the equipment and nozzle. In general, the smaller the nozzle size the smaller the drop volume. Please refer to the recommendations and the fact sheet of your individual inkjet printing tool manufacturer.

Remaining mr-UVCur26SF residuals in the nozzles and in the resist reservoir can be cleaned by organic solvents, e.g. acetone or isopropanol. To avoid clogging of the nozzles, please make sure that the nozzle is clean directly after inkjet dispensing. Before starting dispensing, the operator has to take care that no remaining solvent is inside the printhead assembly before refilling it with resist. It is strongly recommended to purge the inkjet printhead with an appropriate volume of resist mr-UVCur26SF before starting the dispensing. Inadvertent contamination of the resist will have a detrimental effect on the final resist behavior during e.g. subsequent reactive ion etching.

A drop / burst of drops of mr-UVCur26SF or an array of droplets is deposited onto the cleaned substrate surface. The optimal volume to be dispensed depends strongly on the NIL stamp architecture, on the pattern density and on the targeted residual layer thickness.

State-of-the-art inkjet printheads with heating units for the nozzle as well as for the resist reservoir are available. Rough rule of thumb: by increasing the resist temperature 10 K the viscosity is divided in half. The viscosity evolution of mr-UVCur26SF with temperature is given in Fig. 3.

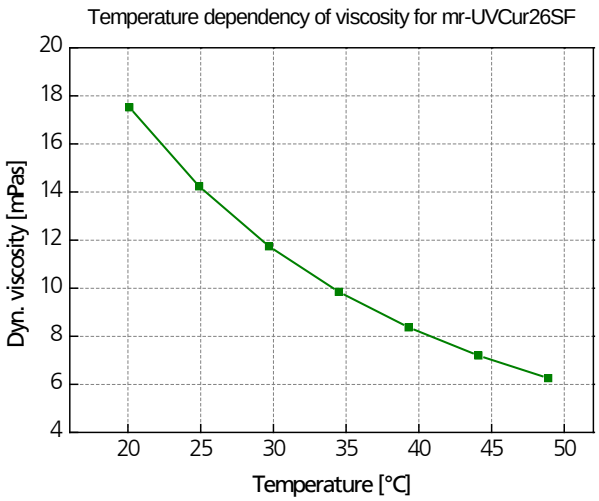

Fig. 2: Temperature dependence of the viscosity of mr-UVCur26SF.

Process Option 2 – Roll-to-Roll NIL

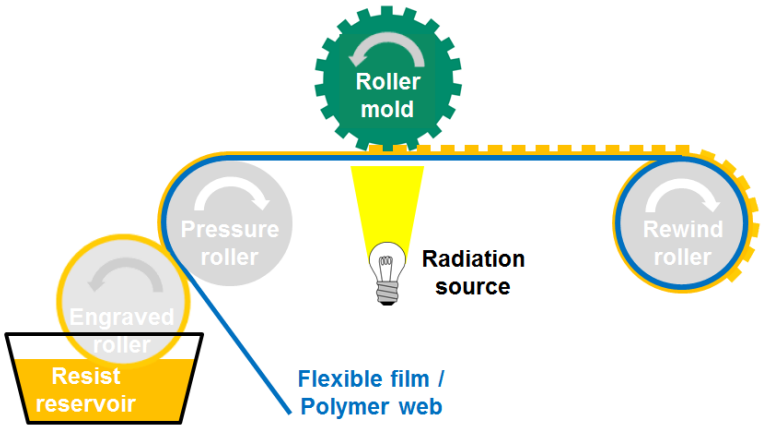

Fig.3: R2R-UV-NIL process using mr-UVCur26SF deposited for example by gravure coating.

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Standard Processing Conditions for R2R-UV-NIL Processes with mr-UVCur26SF

Best patterning results are obtained at temperatures of 20 – 25 °C and a relative humidity of 40 – 46 %. Unexposed mr-UVCur26SF has to be processed under yellow light in order to avoid unexpected pre-polymerization. There are several technological options of performing R2R-UV-NIL on flexible substrates. Roller tools differ mainly in the kind of resist deposition (e.g. gravure coating, slot die coating, inkjet dispensing) and in the kind of radiation source (Hg bulb lamp, LED with different wavelengths). mr-UVCur26SF was designed to address most of the different technologies applied in R2R-UV-NIL. But since the R2R-NIL technology is not standardized yet, no specific process recommendations can be made.

Process parameters

Material	**mr-UVCur26SF**
Substrate preparation	*Flexible polymeric substrates (PET, PC, PMMA, etc.)* The best option is to use flexible substrates which already contain a protective film. This will minimize defects during the imprint originated by particles. After the protective film has been delaminated, make sure that no further particle contamination on the target substrate will occur. For improving adhesion a short corona treatment is recommended.
Resist deposition	Different deposition methods can be used during R2R-UV-NIL, e.g. gravure coating, slot die coating, or inkjet dispensing. Please refer to the data sheet of your equipment manufacturer about material compatibilities.
Cleaning	Organic solvents, e.g. acetone or isopropanol, can be used for getting rid of non-cured resist.
Prebake	Not required (solvent-free formulation)
Exposure dose [2]	>700 mJ cm^{-2}
Hardbake	Not required, but beneficial to avoid stress in the polymer matrix or to improve substrate adhesion

[1] Preferably applied during the hour following the dispensing to avoid clogging of the nozzles.
[2] UV broadband exposure, intensity measured at λ=365 nm. Monochromatic LED irradiation can be applied from 365 to 405 nm, the minimum dose increases with increasing radiation wavelength or by using monochromatic radiation.

Substrate Preparation

Flexible substrates like PET, PEN, PC, or PMMA: The polymer foils or sheets have to be free of particles. This can be achieved by using protected foils. Make sure that after delamination of the protective film no particle contamination will occur. To improve the adhesion of mr-UVCur26SF to your plastic web a short Corona treatment can be applied. In general, there is no further treatment of a plastic substrate necessary to further increase adhesion.

Resist Deposition

The resist deposition during R2R-UV-NIL strongly depends on the web coating unit, e.g. gravure coating, slot die coating or inkjet printing can be used. No general recommendations can be made in this case because all process parameter depend on the used deposition technology. Please refer to the separate data sheet provided by your equipment manufacturer about the recommended material characteristics and process parameters for achieving sufficient deposition and a homogeneous film thickness.

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General Processing Conditions for mr-UVCur26SF

Prebake

A prebake is not necessary in case of mr-UVCur26SF, since it does not contain any solvents. A heating step is not compulsory and strictly not recommended. A heating step after the deposition of the resist droplets using high temperatures above 80 -100 °C will probably cause an evaporation of resist components. This can change the final resist characteristics dramatically. The user is strongly advised to not heat the resist above room temperature after dispensing and before imprinting.

Stamp preparation

Stamp materials: In principle**,** any kind of common hard stamp material can be used for an imprinting step, e.g. Si, SiO_2, or Ni. The application of an anti-sticking layer (ASL) is highly recommended and mandatory in most cases to guarantee low imprint defect rates. For defect-free imprints and low release forces with hard stamps it is recommended to treat the stamp before use with a release agent. The most common release agent for stamps made of silicon or silicon dioxide is F_{13}-TCS (trichloro-(1*H*,1*H*,2*H*,2*H*-perfluorooctyl)-silane, CAS number [78560-45-9]), commercially available from many suppliers of specialty chemicals.
Hard polymer stamps: As polymeric working stamp various materials can be applied. One commercially available product is OrmoStamp® (*micro resist technology* GmbH) which is fully compatible with the mr-UVCur26SF. Please refer to separate processing guidelines for the preparation of working stamps using OrmoStamp®.
Soft polymer stamps: Soft polymer stamp based materials like polydimethylsiloxane (PDMS) or perfluoropolyethers (PFPE) are not compatible to mr-UVCur26SF!

Imprint conditions

After the deposition of droplets using inkjet dispensing, the stamp with nanometer-scale patterns is pressed on top of the droplets with a certain pressure. Due to the low viscosity of the resist and the capillary forces, very small pressures are effective for sufficient pattern filling. Imprint pressure and time necessary to get complete filling of the stamp cavities depend on the pattern density and pattern width. The mr-UVCur26SF resist can be imprinted in any tool suitable for step&repeat nanoimprint lithography. Commercial nanoimprinter machines such as provided e.g. by EV Group (Austria), Süss MicroTec (Germany) or NILT (Denmark) may be used.

Exposure

The resist has to be exposed by light for photo-curing. Sufficient curing is attained at doses of >700 mJ cm^{-2} using broad band UV light. Applying higher doses or broader UV wavelength ranges do not affect the imprint quality nor the properties of the cured polymer. Furthermore, monochromatic LED radiation sources can be used. Typically applied LED wavelengths are in the range from 365 nm to 405 nm. In general, the higher the monochromatic radiation wavelength, the higher is the necessary radiation time. Keep the substrates always horizontal until the resin is fully cured. Once mr-UVCur26SF has been fully cured (after light radiation), the stamp can be separated from the imprinted structures.
mr-UVCur26SF will not cure under the influence of oxygen or air. This implies that the exposure must be done in an oxygen-free environment, such as under appropriate hard stamps. PDMS or other oxygen permeable materials cannot be used as working stamp.

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Residual layer removal

The residual layer remaining in the recessed areas of the polymer film after imprint is removed by oxygen reactive ion etching (RIE) in order to open the windows down to the substrate.

Hardbake

In order to improve the final pattern stability during e.g. dry etching, a hardbake of the imprinted patterns can have a beneficial influence. This can be done using a hotplate or an oven, respectively. A temperature ramp while heating and cooling is beneficial in order to avoid stress or reduced substrate adhesion. Duration and temperature of the hardbake depends on factors such as substrate or device constraints etc.

Removal

As the mr-UVCur26SF resist forms highly cross-linked polymer networks during photo radiation, harsh conditions for wet-chemical removal are necessary. Hot piranha etch can be used successfully. The usage of solvents/developers, like PGMEA, NMP, mr-REM 660 (containing NMP), NEP, mr-REM 500 (containing NEP) etc., in an ultrasonic bath at elevated temperatures (40–60 °C) for several hours will usually result in a peel off of the failed imprinted structures.

Storage

Standard storage temperature of mr-UVCur26SF is 25 °C. mr-UVCur26SF and non-radiated material have to be stored under yellow light. Keep the bottle closed when not in use.
Under these conditions a shelf life of 12 months from the date of manufacture is ensured.

Disposal

Unexposed resist shall be disposed of as halogen free solvent.
Exposed resist shall be disposed of as solid chemical waste.

Environmental and health protection

The mr-UVCur26SF formulation should be handled with the same care as usual for all chemicals. Please read the material safety data sheet (MSDS) provided by the manufacturer carefully before starting your work with mr-UVCur26SF.

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Attachment

Specifications of the liquid mr-UVCur26SF

Product		mr-UVCur26SF (liquid)
Dynamic viscosity [1]	[mPa·s]	15.0 ± 1.0
Refractive index n_D^{25}		1.475 ± 0.002
Spectral sensitivity	[nm]	300-410
Filtration level	[µm]	0.1

[1] at 25 °C, shear rate 1000 s^{-1}

Physico-Chemical Properties of the cured mr-UVCur26SF

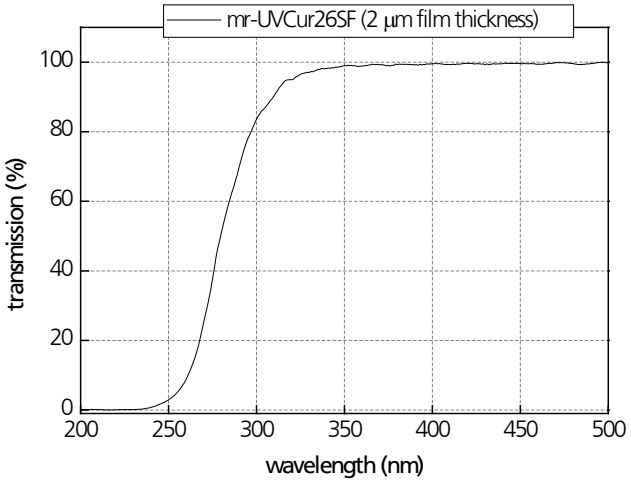

Fig.4: Absorption spectrum of cured mr-UVCur26SF (film thickness 2µm) showing >95% transmission above 350 nm.

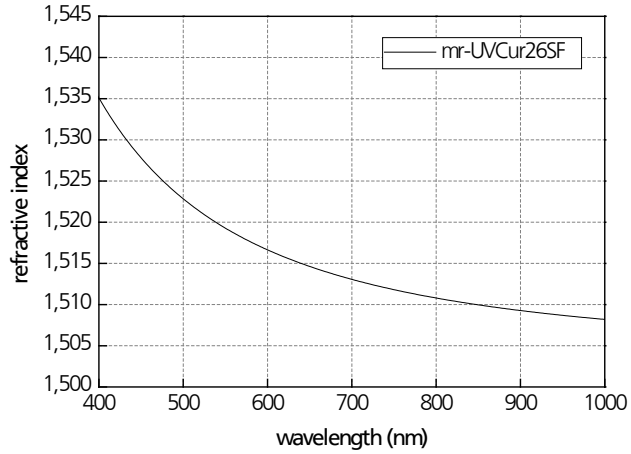

Fig.5: Dispersion curve of cured mr-UVCur26SF.