# SUSS SMILE TECHNOLOGY – LARGE AREA IMPRINT A SOLUTION FOR PATTERNING OF MICRO AND NANO FEATURES

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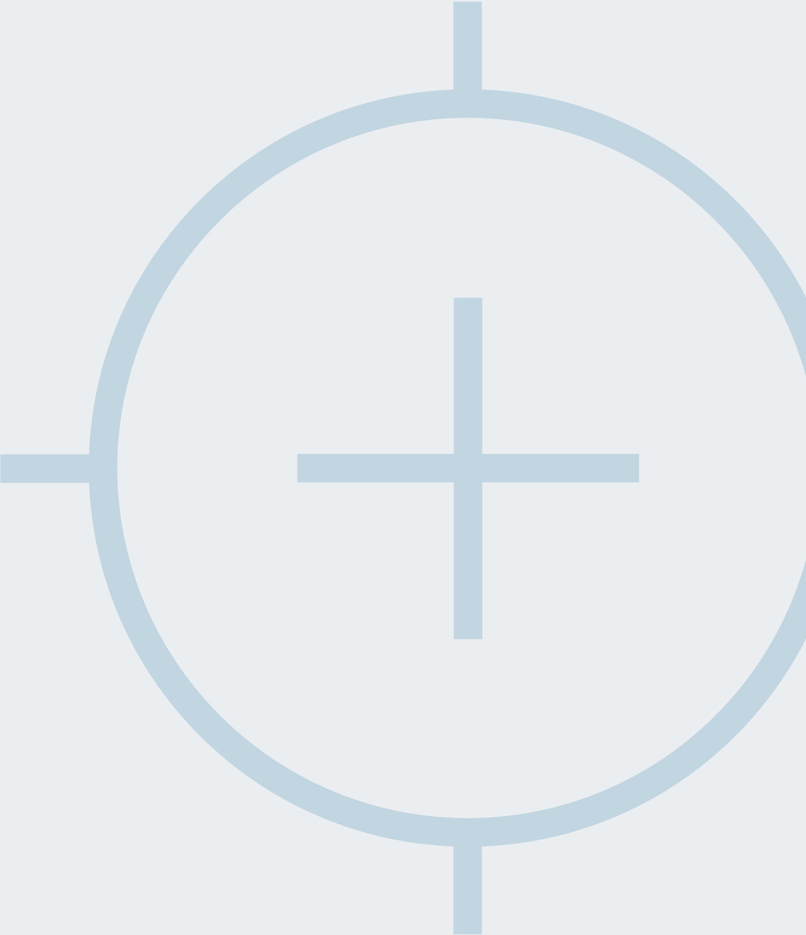

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# SUSS SMILE TECHNOLOGY – LARGE AREA IMPRINT A SOLUTION FOR PATTERNING OF MICRO AND NANO FEATURES

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## INTRODUCTION

Due to the constant growth of the market for wafer-level-cameras and for image sensors, the request for implementing the manufacturing of optical devices such as microlenses in the very well established semiconductor technology is also steadily increasing.

In order to address this opportunity, in the previous years SUSS MicroTec released SMILE (**S**USS **M**icroTec **I**mprint **L**ithography **E**quipment) and had been constantly improving it ever since.

The most critical process specifications typically coming from the microlens market are the accuracy and the uniformity of the thickness of the polymer constituting the optical device, directly affecting the optical proprieties of the end product. It is then clear that the extremely high degree of control that the SMILE technology allows in the imprinting process presents a strong advantage for customers in this field.

In the present article, the current status of the SMILE technology will therefore be reviewed, with particular focus on its flexibility in performing different types of processes.

## CONTROL OF BASELINE THICKNESS AND UNIFORMITY

The final thickness of the polymer employed in an imprint process in a Mask Aligner is controlled by the Wedge Error Compensation (WEC) process.

The base SUSS MA/BA8 Gen3 mask aligner is equipped with a WEC head system that allows reaching the parallelism between substrate and mask (or, as in this case, stamp) with a micrometric precision over a 200 mm surface.

After loading substrate and stamp and before starting the imprint process, the wedge error compensation is performed as follows:

1. The WEC head system moves upwards, until it reaches a physical contact with the mask/stamp loaded onto the mask/stamp holder. Alternatively, three proximity spacers can be swung inwards to keep the contact at a minimum. The upper part of the WEC head, at this moment, is free to move and tilt. When pushed by the Z-axis motor against the stamp, the upper part of the WEC head will tilt until reaching full contact over the whole substrate surface.

2. Once the WEC sensor has detected the contact, the position is set as reference for the Z-axis and from this moment onwards, the process gap is calculated referring to the number of rotation of the Z-axis spindle. Therefore there is no other direct measurement of the distance between substrate and stamp during the process.
3. After setting the “reference” position, the whole stage moves back downwards.

Even though such a design allows for the highest precision when processing hard substrates coated with incompressible resists and hard masks as for standard optical lithography processes, for an imprint process additional considerations have also to be made. The compressibility of the typical materials employed in those processes plays in fact a crucial role. In this case then, the force acting on the whole WEC system becomes a very important parameter: when moving the Z-axis upwards, the viscosity of the process material offers an initial resistance against the Z-axis movement. After this first contact, though, the imprint resist squeezed between the substrate and the stamp spreads towards the edge of the stack, decreasing the resistance sensed by the WEC head, until reaching an equilibrium position.

Furthermore, the standard MA/BA8 Gen3 WEC head can hold a pressure up to 250 N, after which the pneumatic breaks holding its position start to lose their grip and the whole WEC head starts sliding downwards, leading to a mismatch between the actual process gap and the one as shown by the MA8 Gen3 software.

In order to overcome this issue and allow for a higher degree of control of the actual process gap even in the case of processes employing compressible materials, the socalled “Active WEC” technology has been developed by SUSS MicroTec. Here, the base MA/BA8 Gen3 WEC head is additionally equipped with three piezo-actuators and the mask aligner is also equipped with an independent option to measure the actual gap between stamp and substrate, either mechanically (with a set of Heidenhain sensors) or optically (with a spectrometer sensor set). The read-out of those sensors is fed into the controller unit regulating the piezo-actuators and in this way they can automatically bring and / or hold the WEC head to the target position.

A second major advantage of the Active WEC design is the possibility to re-adjust the relative orientation of the substrate with respect of the stamp even during the recipe flow, whereas the standard WEC design does not allow such a balancing motion.

Finally, each piezo-actuator can sustain a pressure up to 1 kN, allowing the WEC head assembly to hold its position without sliding downwards up to a total of 3 kN. Even though, on one side, such a specification permits to squeeze the process polymers to very thin layers, on the other side the operator has also to consider the effect of such a strain applied to the whole stack.

## MA / BA8 GEN3 SMILE TOOLING AND PROCESS OPTIONS

Depending on the type of process, either a 9” x 9” soda lime glass, typically 3 mm thick, or a flexible (0.2 mm thick) AF32 glass is used as stamp carrier. The first allows for a stiffer and more robust support for both the imprint and the general material handling, while the latter for a more controlled contact sequence during the imprint and for the use of readily-coated substrates.

Depending on the chosen process, two different stamp holders are available:

**1. An open version:** The stamp is held by vacuum only at the outer edges and additionally secured by external mechanical clamps. This stamp holder is used for processes employing thick stamp carriers. As described in Figure 1, the imprint process flow is as follow:

**1a** The viscous polymer is dispensed as a puddle onto the top of the substrate; the surface tension will give it a curved shape, with the highest point in the centre.

**1b** By moving the substrate chuck upwards, the resist will have its first point contact where the resist is thickest and then it will be spread outwards, sandwiched by the stamp on top and the substrate in the bottom.

**1c** The chuck will keep moving upwards until reaching the targeted resist thickness.

**1d** The lamp house moves forward and expose the photosensitive resist to cure it, and

**1e** the stamp can then be detached from the imprinted resist on the substrate.

Typical processes carried out using such a tooling are those ones that involve rather thick polymer layers (from 50 µm upwards, depending on the various viscosities) and/or materials with known issues concerning coating results (such as poor adhesion or too large edge bead). A most used application, for example, is the imprint of microlenses for the wafer-level camera and for the image sensor markets.

**2. The closed version** of the stamp holder:
A 9 mm thick glass plate is placed in its centre and additional vacuum grooves allow fixing the substrate both at its edge and at its centre.
This stamp holder can be used with both, thick and thin stamp carriers, provided that the thick ones are still within the depth of focus of the

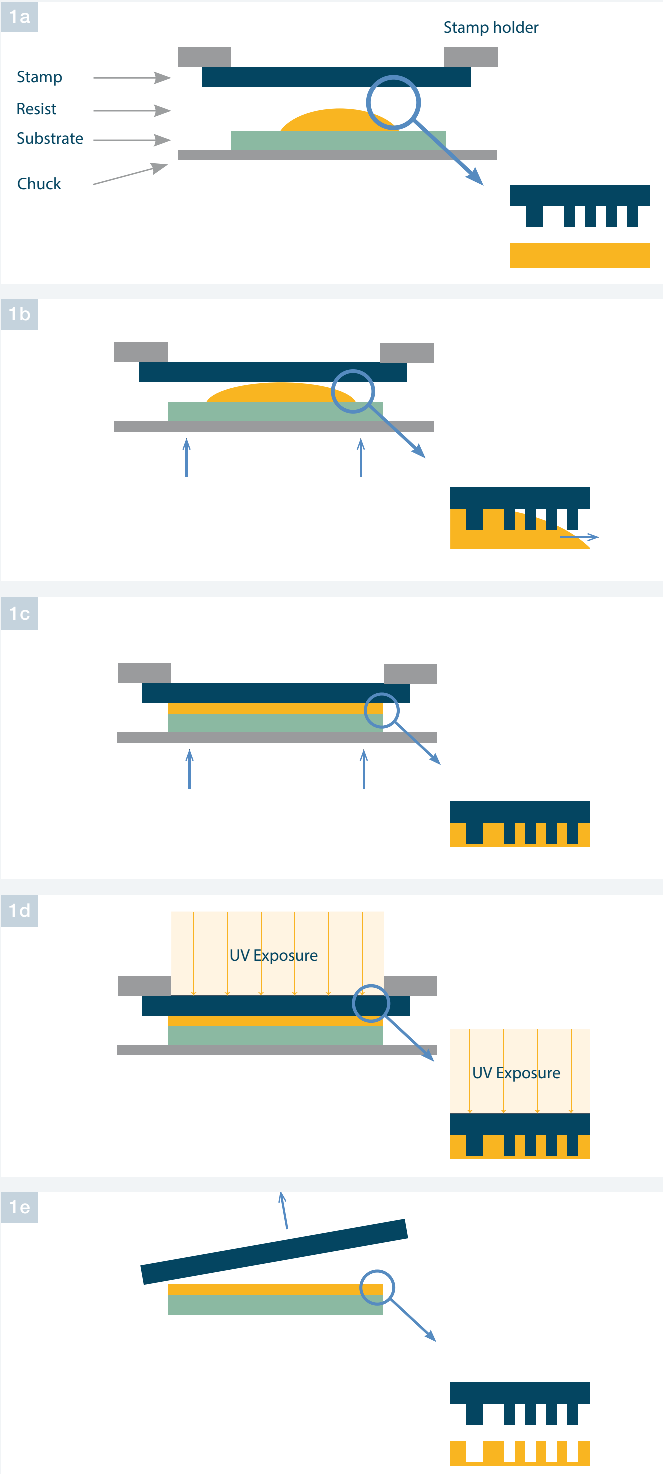

*Figure 1* Imprint process via the puddle dispense method

Mask aligner microscopes and that the whole stamp and substrate stack still fit in the tool. When using thin stamp carriers, the main advantage of this design is the possibility to bend the stamp during the imprint sequence, allowing the use of pre-coated substrates, as described in Figure 2:

**2a** The stamp is held by the stamp holder via both inner and outer vacuum and the coated wafer is placed on the chuck.
**2b** The inner vacuum is released, while a tuneable pressure is applied to the inner region to bend the thin stamp downwards;
the stamp is still held at its edge by the outer vacuum grooves.
**2c** The chuck and the substrates are moved upwards, until the stamp contacts the coated resist locally in the substrate centre.
The chuck moves further up, extending the contact front across the desired active area.
**2d** The chuck is then moved towards the stamp holder so that the stamp and the substrate are in contact over the whole surface.
At this point, the operator can decide whether to apply a defined pressure to the back side of the stamp to push it in the polymer or to adopt a pressure free process, where the polymer is attracted in the stamp structure purely by capillary forces.
**2e** After curing the imprint resist via UV exposure,
**2f** the stamp-substrate stack can be removed from the SMILE tooling and the stamp peeled off.

This method should be employed especially when targeting resist thicknesses below the micrometric range, that the puddle dispense method would not easily achieve. Typical applications are therefore optoelectronics devices such as PSS wafers or optical gratings.

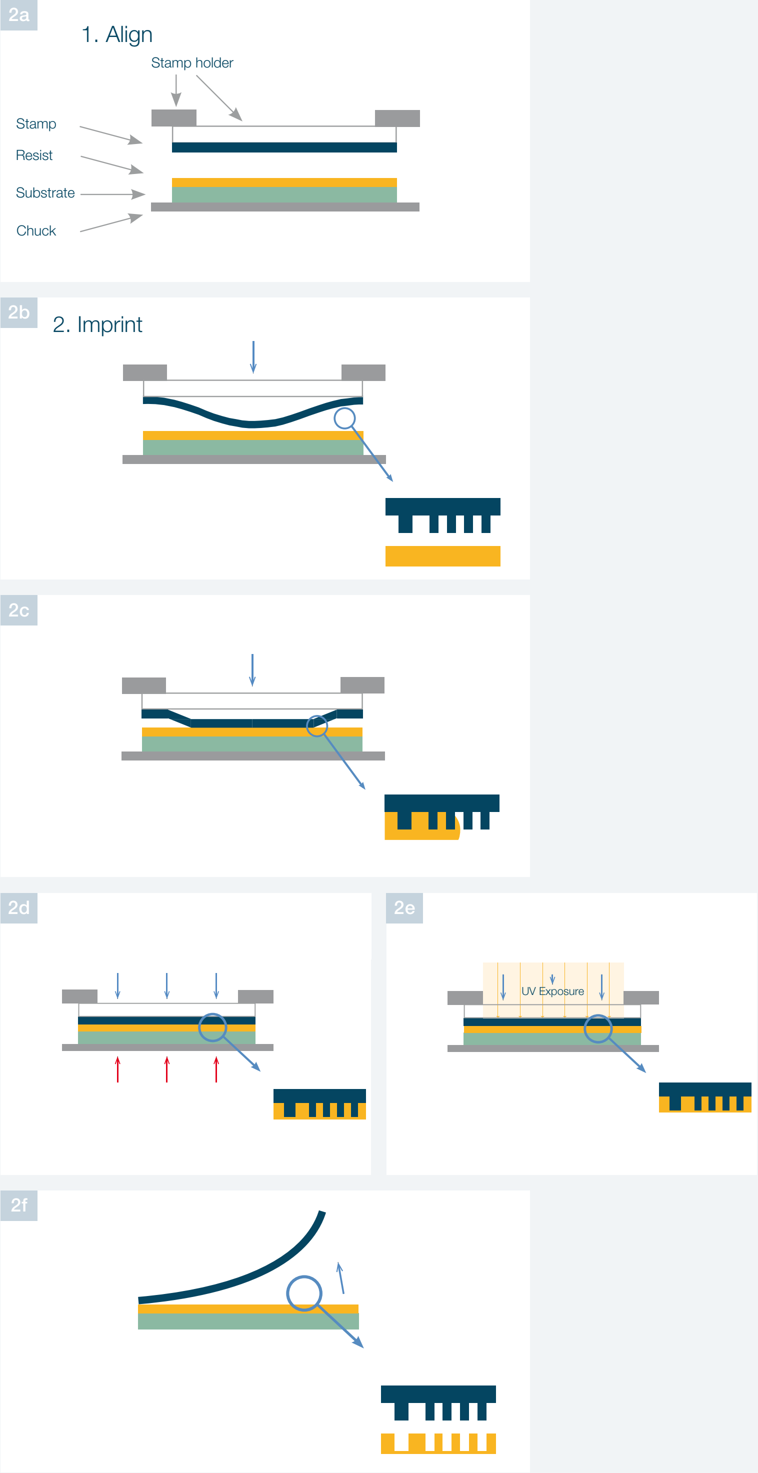

*Figure 2* *Imprint process via the coated substrate method*

Also thick stamp carriers can be used in combination with the closed stamp holder design. In this case, although, the stamp itself cannot be bent and therefore the process flow is based on the puddle dispense method (Figure 1) rather than the one for coated wafers. The main advantage of using a closed holder is, in this specific case, the additional support against stamp warpages.

## STAMP PREPARATION

The stamps used for the imprints can be produced using the SMILE technology as well. Either the open or the closed stamp holder can be employed, depending on the stamp carrier thickness and on the process specifications. The stamp moulding process is analogous to the imprint with the puddle dispense method:

**a** The blank stamp carrier is loaded in the stamp holder, while the master mould on the chuck. Typically, the master mould is treated with an anti-adhesion layer and the stamp carrier with an adhesion promoter.
**b** The high Young modulus stamp material (silicone or acrylate, for example), still in its liquid form, is dispensed in the centre of the master mould and then spread outwards.
**c** The stamp material is then cured, either by UV exposure or by time.
**d** Finally, the stack is unloaded and separated, where now the pattern from the master mould is replicated into the stamp material glued to the carrier.

## CONCLUSION

Recently, SMILE has demonstrated to be an extremely versatile and flexible technology, able to address many different processes from a single platform.

A careful matching of tool hardware, stamp type and process chemistry allows large area imprinting of nano- and microdevices, offering a valuable equipment for many diverse markets.

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