ALIGNMENT ACCURACY IN A MA/BA8 GEN3 USING SUBSTRATE CONFORMAL IMPRINT LITHOGRAPHY (SCIL)

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Substrate Conformal Imprint Lithography (SCIL) originally invented by Philips Research is an innovative nanoimprint technology. With this technology substrates up to 200 mm can be patterned with features down to a few nanometer resolution, delivering a unique uniformity of the imprint and the residual layer. The SCIL process was implemented as an option in a standard SUSS Mask Aligner in 2009 and is available on MA/BA6, MA/BA6 Gen3 and MA/BA8 Gen3 (Figure 1).

Figure 1. SUSS MA/BA8 Gen3 with SCIL toolset

Figure 2. SCIL stamp holder

The SCIL technology uses a three layer stamp for structure transfer (see Figure 3 and Figure 4). This stamp is composed of a thin glass back plate (~200 µm), a soft PDMS buffer layer (~500 µm) and a high modulus PDMS layer (100 µm) with the structures to be transferred. With this setup of the stamp absolute distortions like magnification errors but also the relative distortions due to elastic deformation during the imprint are minimized. Furthermore distortions of the structures during the imprint process are avoided by using only a small imprint pressure (20 mbar) and mainly capillary forces to pull the stamp into the resist layer.

SCIL can be of interest to many applications like LED, Lasers, Solar, Optics and MEMS. In some of them an alignment of the stamp to the

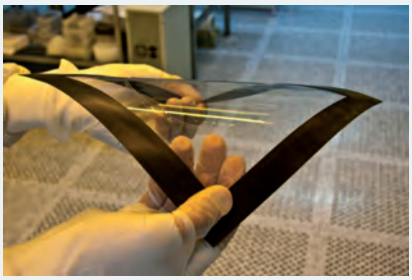

Figure 3. Flexible SCIL working stamp

substrate prior to the imprint is required. Due to the composite SCIL stamp, the overlay alignment capabilities should mainly be limited by the mechanical capabilities of the Mask Aligner.

To investigate SCIL performance on SUSS Mask Aligner platform a three months visit of Robert Fader (Fraunhofer IISB) at Philips Research / Philips Innovation Services in Eindhoven was financed by the Fraunhofer IISB. This stay was supported by Philips Research and SUSS MicroTec. Philips Research provided its facilities and Philips Innovation Services the cleanroom for the corresponding experiments. Goal of the investigations during the stay was to determine the overlay accuracy of SCIL at the SUSS Mask Aligner and to measure process induced distortions of the SCIL stamp over large distances.

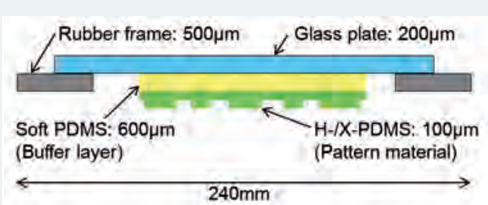

Figure 4. Schematic cross section of a SCIL stamp

For the analysis of the overlay alignment accuracy a master with common box in box fiducials (Figure 5) has been used to replicate a stamp and imprint wafers of 4" and 6" size. In a first step the alignment marks were imprinted into an epoxy resist layer on a silicon wafer and afterwards transferred into the silicon wafer by dry etching using the structured resist as

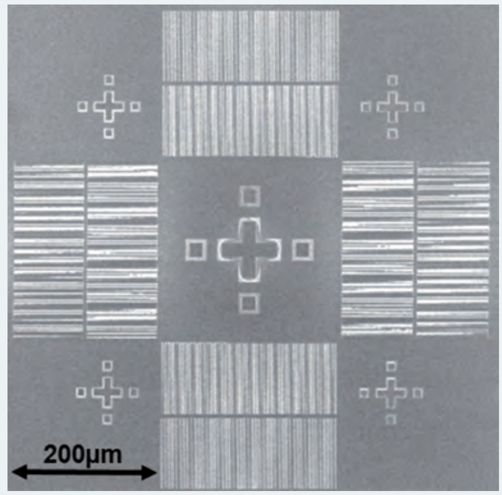

Figure 5. Box in box fiducials

etching mask. Subsequently, this wafer was again coated with the resist and a second aligned imprint was performed (Figure 6). Because the used master structure included

Figure 6. Aligned second imprint on transferred marks.

big and corresponding small box in box fiducials, the small fiducials could be aligned to the big ones using the same stamp (Figure 6). The stamp had just to be shifted. The alignment error could be determined by measurement of the relative position of the features imprinted in the second step with respect to etched marks (Figure 7).

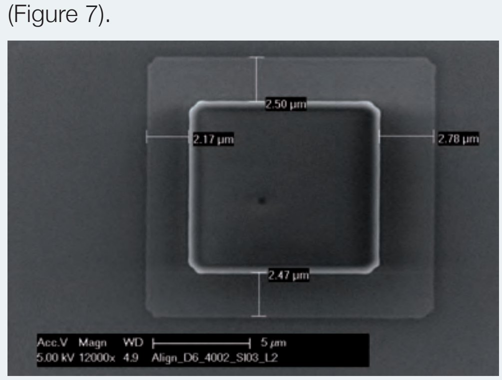

Figure 7. Relative position determination with SEM

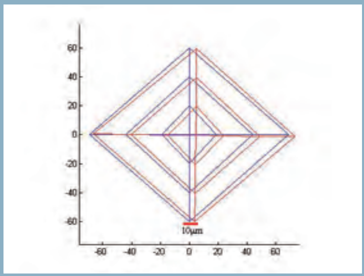

Figure 8. Alignment error without offset correction, X and Y axis show units in mm, alignment errors are magnified with a factor of 1000

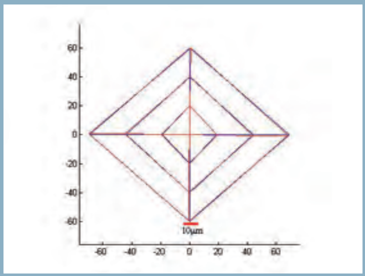

Figure 9. Alignment error with offset correction, X and Y axis show units in mm, alignment errors are magnified with a factor of 1000

The alignment in the Mask Aligner is performed with standard 10x magnification objectives. The imprinted wafers were measured in a SEM. All results showed that there is a reproducible offset mainly in imprint direction (Figure 8) which was adjusted by an offset correction in the Mask Aligner software (Figure 9). The offset is induced by the movement of the stamp from the SCIL actuator towards the resist coated substrate and, therefore, also dependent on the process gap. The results after offset correction showed that the overlay accuracy was within the specified mask aligner accuracy in all cases (<1 µm).

In order to characterize distortions of imprinted structures and deviations of specific distances (Figure 10) in the imprinted patterns compared to the original GDS-design (which was used for the master design) several imprints were performed with two different stamps. These measurements were done to investigate, if the SCIL process creates systematic distortions due to the bending of the stamp towards the substrate during the imprint process. Furthermore the measurements can be used to check reproducibility of the stamp replication process. Therefore, two separate SCIL stamps were prepared and with each stamp a number of imprints were performed. On each imprinted wafer a matrix with 15 different distances up to 40 mm has been defined (Figure 10) and these were measured in a SEM. These measurements with the two stamps were compared to each other and to the GDS pattern design, which was used to build the Si master wafer as a basis for replicating the stamps.
First the SEM stage accuracy was determined by repeatedly measuring distances on an imprinted wafer. These measurements showed that the stage accuracy was 200 nm in X-direction and 250 nm in Y-direction.

	S7		S11		S13	
	Distance in µm:	Standard deviation in µm:	Distance in µm:	Standard deviation in µm:	Distance in µm:	Standard deviation in µm:
GDS-File	27586.2	-	40000	-	31000	-
Stamp 1	27587.2	0.2	39999.4	0.4	31000.2	0.5
Stamp 2	27587.0	0.5	39999.2	0.2	31000.6	0.5

Table 1. Average results of three measured distances

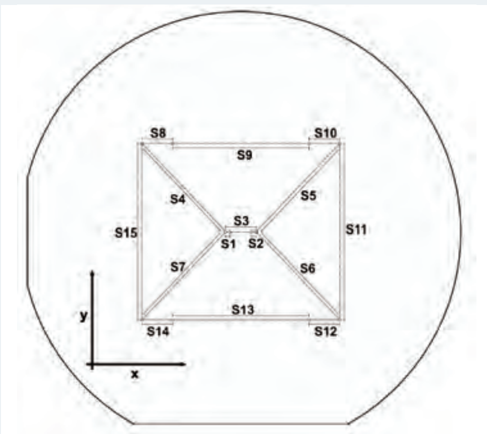

Figure 10. Measured distances on a 100mm wafer

The measured distances on the imprinted wafer for the two stamps vary in a range of a few hundred nanometers (400 nm maximal) which is within the measurement error (Table 1). This error results from the accuracy of the stage in the used SEM. The difference between the distances in the GDS file and the distances on the imprinted wafers are the same for the two stamps (Table 1). Therefore, this difference is constant for different stamps and a result of accumulated, mostly thermally induced, errors.

In summary all results of the performed experiments approved the assumption that the SCIL process itself does not induce any relevant distortion of the SCIL stamp. More than this it does not apply a misalignment that is above the standard specifications of a Mask Aligner.

THE AUTHORS

Robert Fader studied physics at the Friedrich-Alexander-University in Erlangen. After graduating in 2010, he continued doctoral research at the Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen in electrical engineering. Subject of his doctoral thesis is Substrate Conformal Imprint Lithography.

Ulrike Schoembs has been responsible for product management of the manual mask aligners at SUSS MicroTec since 2009. Having set off a practical career in mechanical engineering Ulrike joined SUSS MicroTec in 2003 and started off in various positions in Applications and Product Engineering. 2006 she has received an academic degree in precision and micro engineering. Since 2006 she is also holding a teaching position in microsystems engineering at the University of Applied Sciences Munich.

Marc Verschuuren started working at Philips Research in 2001 after he finished his bachelor in chemical engineering. Marc currently holds a position as senior scientist and project leader. Past work at Philips Research focused on material science in combination with electrical and optical device fabrication and characterization. Main topics include sol-gel chemistry, metal and semiconductor nano particles and surface chemistry. The common factor in this work was using soft-nanoimprint technology to pattern a variety of materials. Diverse projects within Philips research include the development of this technique, which led to the licensing of SCIL to Suss MicroTec in 2008. In 2010 he obtained his PhD on the subject of: Substrate Conformal Imprint Lithography for nanophotonics.