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Structure Placement Accuracy of Wafer Level Stamps for Substrate Conformal Imprint Lithography

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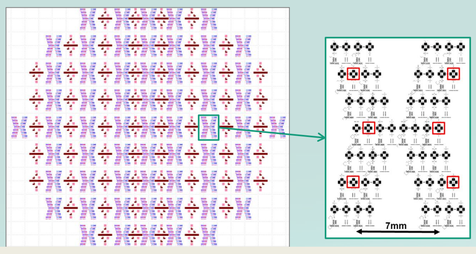
Motivation

Substrate Conformal Imprint Lithography (SCIL) is a nanoimprint technology for large area patterning with nanometer resolution [1]. SCIL has also proven accurate overlay alignment of different SCIL lithography layers [1,2] using standard SCIL stamps which require relatively elaborate fabrication process. In this work, the accuracy of SCIL in terms of absolute structure placement accuracy for large area wafer level imprints is studied systematically for different stamp manufacturing processes. Different back plates and curing temperatures of the stamp are investigated to evaluate if less elaborate SCIL stamp manufacturing processes can be chosen for applications which require reduced placement accuracy.

Experimental

Master

200 mm Si wafer
- Optical lithography at SUSS
- Layout and etching at Philips



Master layout and measured alignment structures (red, zoom-in)

Stamps

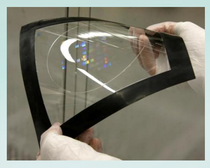
Six stamps manufactured for imprinting at IISB:
- 3 back plate materials: AF32, D263, PMMA
- 2 PDMS curing temperatures: 22°C (RT), 50°C
- PDMS curing time: 1 day
- **standard stamps: AF32 50 °C**

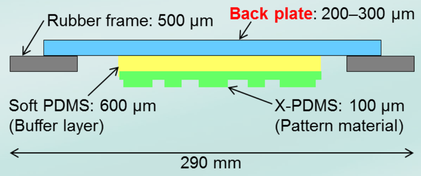
Properties of the back plate materials

Back plate	AF32	D263	PMMA
	Glass	Glass	Polymer
Plate thickness	300 µm	200 µm	300 µm
Thermal expansion coefficient ($E_{thermal}$)	$3.2 \cdot 10^{-6}$ 1/K	$7.2 \cdot 10^{-6}$ 1/K	$\sim 7.5 \cdot 10^{-5}$ 1/K
Young's modulus	74.8 kN/mm²	72.9 kN/mm²	~3.1 kN/mm²

Imprints

8" imprints with each stamp on a MA/BA8 at RT with 8" UV-SCIL tooling at SUSS Microtec:
- resist: Katiobond 110707 (1:1 dilution)
- SCIL process gap: 20 µm



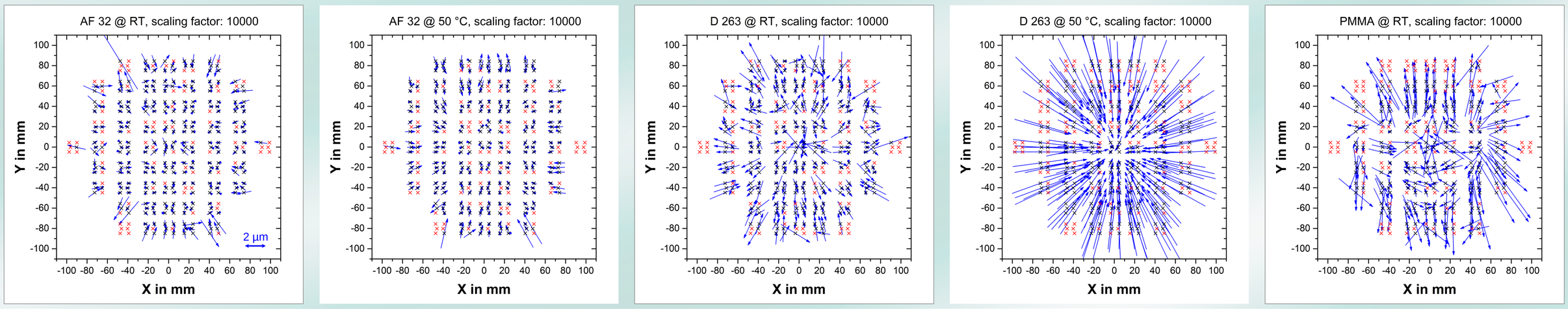


Stamp: picture (left) and schematic

Measurements

Absolute positions of 354 alignment structures measured with Leica LMS IPRO2 at IMS CHIPS:
- absolute positional tool accuracy: 5 nm
- measurement of structure position for Si master and imprints
- small deviations between layout and master
- results for imprints are presented with respect to master positions and imprint center

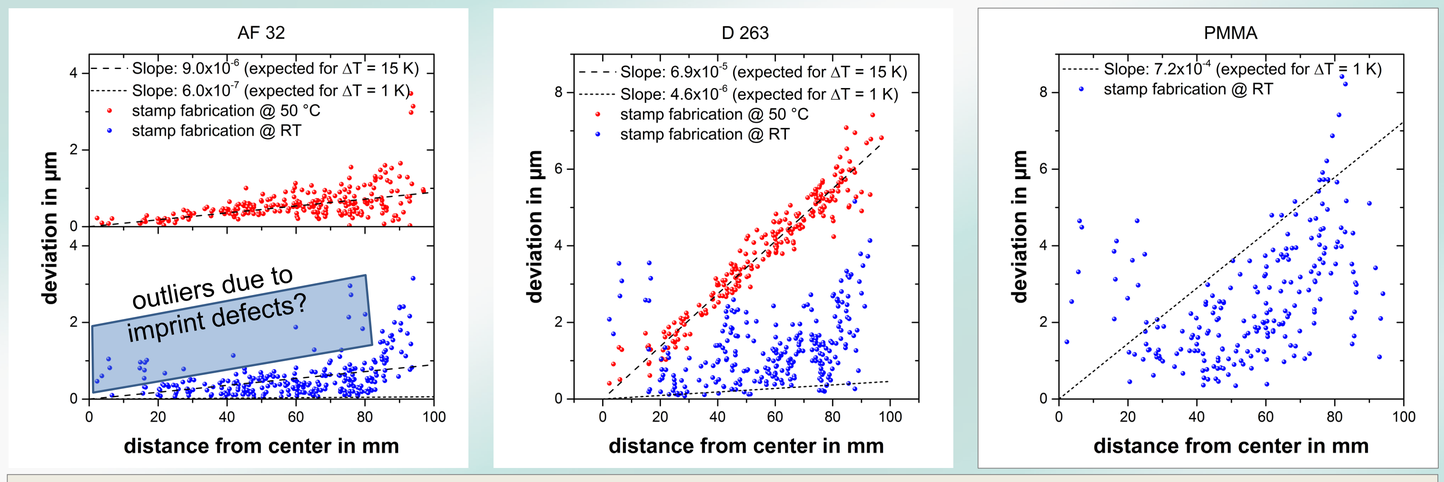
Results and discussion



Displacement vector plots for each combination of back plate material and stamp fabrication temperature (x: not measurable, x: measured)
(length scaling of vectors enlarged by 10000, displacements for PMMA @ 50 °C were too high to be measureable)

Quantitative data for displacement vector lengths

Backplate	PMMA	D263		AF32	
T stamp fabrication	RT	RT	50 °C	RT	50 °C
Average length in µm	2.6	1.4	4.0	0.6	0.6
Median length in µm	2.3	1.2	4.2	0.4	0.5
σ in µm	0.2	1.0	1.5	0.6	0.5



Length of displacement vectors for each back plate material and stamp fabrication temperature vs. distance of measurement point from wafer center

Summary of results

- AF32 RT stamps enable high absolute pattern position accuracy over large area (up to appr. 85 mm diameter deviation ≤ ~1 µm)
- for AF32 RT, only outermost structures show noticeable larger deviations → edge effects for 8" stamp on 8" wafer imprint?
- AF32 50°C stamps on average lead to similar results but a slight trend correlated with the difference in thermal expansion compared to silicon ($E_{thermal,Si}$: $2.6 \cdot 10^{-6}$ 1/K) might be observed
- imprints with D263 RT stamps show significantly larger deviations than imprints with AF32 stamps without a clear trend
- D263 50°C imprints are clearly dominated by stamp contraction governed by back plate
- PMMA RT stamps show the largest deviations for RT stamps
- deviations for PMMA 50°C imprints were too large for the measurement tool to be determined (i.e., > ~12.5 µm)
- observed trends for 50°C stamps are smaller than expected from ΔT ≈ 28 K between stamp fabrication and imprint temperature
- D263 RT and PMMA RT stamps were under mechanical stress (slightly distorted) which might govern the observed deviations

Conclusions

Absolute structure placement accuracy of UV-SCIL was evaluated for three different back plate materials and two different PDMS curing temperatures
- **SCIL enables very good absolute structure placement accuracy** over large area using AF32 based stamps for both investigated stamp manufacturing temperatures
- as expected, **for 50 °C stamps the thermal characteristics of the back plate material dominate the placement accuracy**, showing most accurate results for AF32
- observed deviations for 50 °C stamps are below theoretically values expected from material thermal characteristics → further work is required to understand this effect
- D263 RT and PMMA RT stamps might enable acceptable placement accuracy for certain applications but further experiments are required for final conclusions

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References

[1] M.A. Verschuuren, Substrate conformal imprint lithography for nanophotonics, PhD thesis, Utrecht University, 2010
[2] R. Fader, M. Rommel, A.J. Bauer, M. Rumler, L. Frey, M.A. Verschuuren, R. van de Laar, R. Ji, U. Schömbs, J. Vac. Sci. Technol. B **31**, 06FB02 (2013)