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Quantification and reduction of deformations in multilayer soft-NIL stamps

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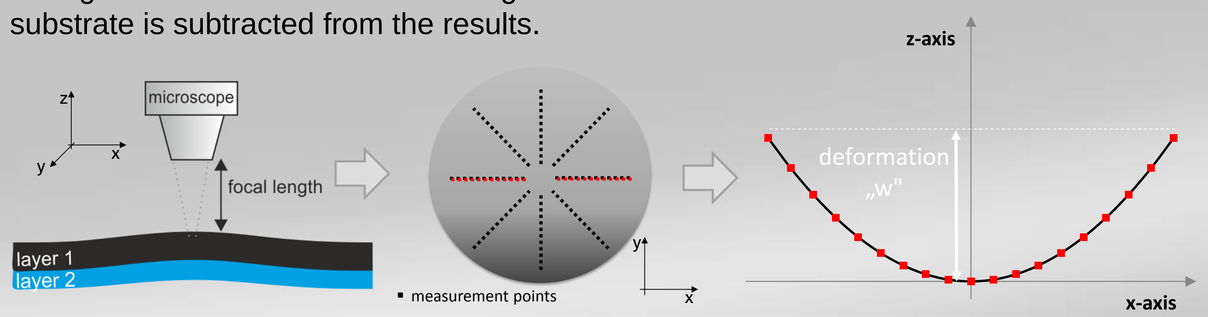
Introduction

Soft NIL stamps typically consist of multiple layers. That leads to bending stresses due to different thermal coefficients and shrinkage [1]. A simple method is introduced to quantify and correlate the deformation to processing parameters and compare them with a mathematical model. The deformation of stamps consisting of a backplate and one or two additional layers is investigated. 100mm wafers with OrmoStamp coatings are investigated and a new room temperature curing PDMS version is introduced.

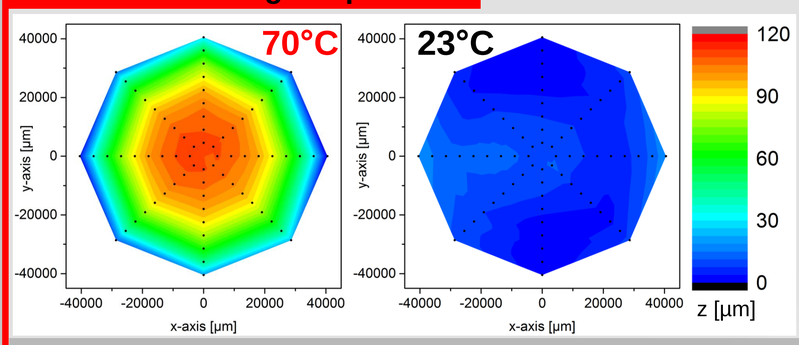
Method

Investigation of the surface with an optical profilometer (Zeta 300). Measurement of the focal length of the microscope for every mapped point (color scale). Cross-section through x-axis is used for determining the deformation "w". The initial deformation of the substrate is subtracted from the results.



Substrate bottom side is measured to avoid influence of coating inhomogeneities.
Reference measurements with a laser scanning flatness tester (Canon LSF-500) confirm the results.

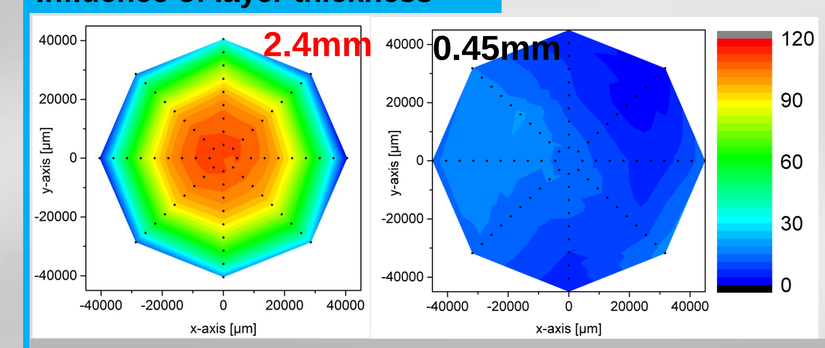
Influence of curing temperature



Surface profile of composite stamps consisting of PDMS (2.4mm thick) on quartz glass (300µm thick) for different curing temperatures.

→ Highly reduced deformation using room-temperature-cured PDMS.

Influence of layer thickness



Surface profiles of composite stamps consisting of PDMS on quartz glass (300µm thick). The curing temperature was 70°C.

→ Reduced layer thickness results in decreased deformation.

Mechanical model for 2 layers [1]

Deformation "**w**" calculated using trigonometric relations from the radius of curvature R_c.
R_c is determined by the thermally induced bending moment M_T and the effective bending stiffness D_{eff} of the layer system. The sample weight is also considered for the calculations.

Table with material parameters used for the calculations.

Material	Young's mod. "E"	CTE "α"	Poison ratio "υ"
Quartz glass	74.8 kN/mm²	3.2 ppm/°C	0.238
Silicon	186 kN/mm²	2.6 ppm/°C	0.27
OrmoStamp	0.65 kN/mm²	105 ppm/°C	0.3
PDMS	0.002 kN/mm²	340 ppm/°C	0.5

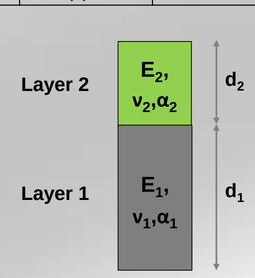
$$R_c = -\frac{D_{eff}}{M_T}$$

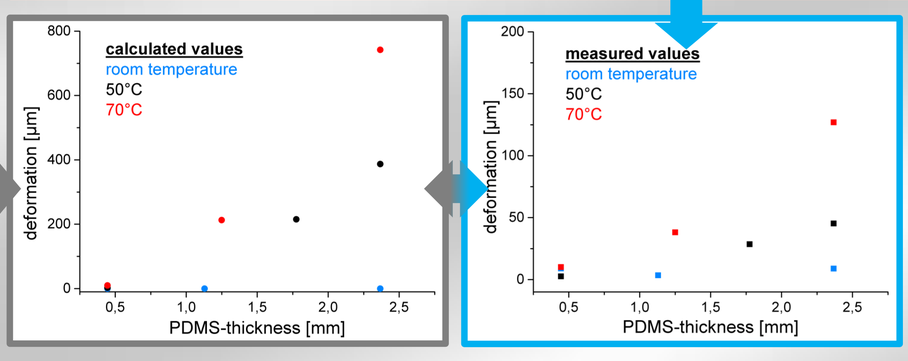
$$D_{eff} = D_1 + D_2 + D_{12}$$

$$M_T = \frac{1}{2} \cdot d_1 \cdot d_2 \cdot \Delta\sigma_T$$

with $\Delta\sigma_T = (\alpha_2 - \alpha_1) \cdot \Delta T \cdot \frac{E_1^0 \cdot E_2^0}{E_1^0 \cdot d_1 + E_2^0 \cdot d_2} \cdot (d_1 + d_2)$,

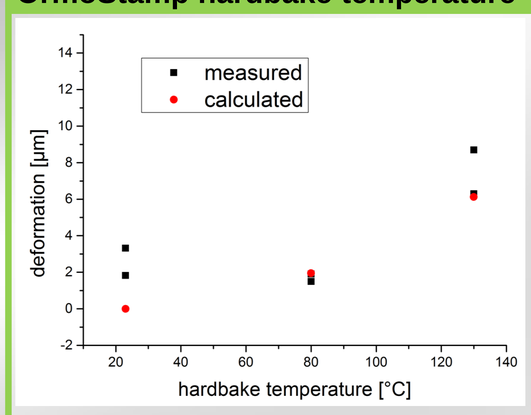
E^0 is the biaxial modulus $E^0 = {}^{E}/_{(1-\upsilon)}$ and σ the thermal stress.





→ Calculated values about 5x higher than measured values.
→ For thick top layers mechanical model does not suffice.

OrmoStamp hardbake temperature

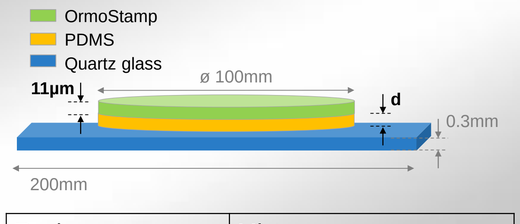


→ Very good agreement of model and measurement for 80°C and 130°C
→ Increasing deformation for higher curing temperatures.
→ Deformation at room temperature can only be explained by crosslink-induced shrinkage (→not considered at the moment).

Deformation of 6 Si-wafers (550µm thick) coated with 11µm OrmoStamp and varied hardbake temperature, compared to calculated values.

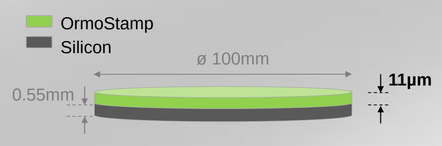
Sample preparation

Composite stamp:
PDMS (Sylgard184) casted on a glass plate with defined thickness. Curing at different temperatures. For room temperature, HMS301 is used instead of standard curing agent.
OrmoStamp: Spin coated (2000rpm, 30sec) on stamp and UV-cured.

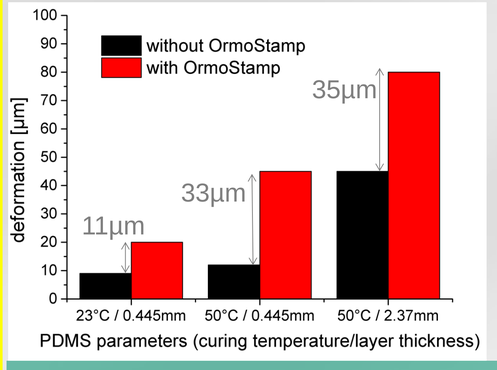


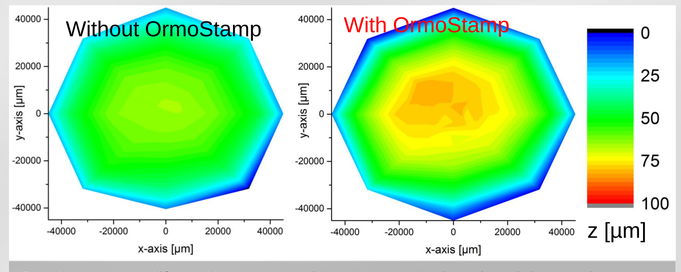
Recipe	Mixture
Standard(50°C)	10:1 with PDMS curing agent
Room temperature	10:1 with HMS301

100mm wafer:
OrmoStamp coated on silicon wafer with 2000rpm for 30 seconds.
Hardbake performed in an oven at different temperatures for 30 minutes.



Multilayer stamp





Surface profile of composite stamps (top) with and without OrmoStamp (no hardbake) and deformation measurements compared for both cases (left).

→ OrmoStamp causes bending in multilayer stamps although no hardbake is applied.

Conclusions

- Room temperature curing PDMS is a promising option for reduced deformation in composite stamps.
- OrmoStamp hardbake temperature strongly influences bending. This leads to the assumption of a correlation between Young's modulus and hardbake.
- Mathematical model in good agreement for thin coating layers, an adapted model has to be found for thick layers.
- Within multilayer stamps deformation effects add up, further investigations are needed to understand the correlations.

Reference [1] M. Papenheim, K. Dhima, S. Whang, C. Steinberg , H.-C. Scheer, Appl. Phys. A, 481-487 (2015)

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