Experimental analysis for process control in hybrid lithography (T-NIL + UV-L)

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When thermal nanoimprint (T-NIL) and optical lithography in a simple contact printer are combined with each other in a hybrid process, in which imprint (first step) and photolithography (second step) are performed into the same photoresist layer, adequate process control requires a characterization of the material properties of the photoresist that goes far beyond lithography.

The glass transition temperature T_g is the first parameter which is required for imprint - the values given by the manufacturer obviously refer to the base resin only, not to the photoresist in its final composition (base resin + photo active component + additives + solvent) and in particular not to the photoresist as used for imprint, i.e. a spin-coated layer after prebake with some solvent remaining. Thermal expansion measurements were found to be less suitable for determination of T_g, as a clear identification of the glass transition requires temperatures too high. The classical DSC (differential scanning calorimetry) is not applicable as it would require the photoresist in dry form, without solvent. We found that stress measurements[1] with spin-coated wafers are appropriate to indicate the glass transition temperature (see Fig. 1).

Furthermore, photoresist degradation due to thermal loading is an important issue, which is decisive for successful lithography after an imprint step. It is well-known that temperature degrades the photo active component (following an Arrhenius-type of behavior) and that, additionally, thermal cross-linking may occur. Unfortunately, the information on hand is quite vague and refinement is hampered, as the exact components and the composition ratios of commercial photoresists are not communicated by the manufacturers. Thus also the thermal loading response of the photoresists has to be measured. We did this in a way close to the hybrid process investigated, namely by measuring the lithographic response (development after exposure) of photoresist layers beforehand treated in an imprint tool at different imprint temperatures. To enable dissolution rate measurement via laser interferometry (Fig. 2), the imprint was performed with a flat stamp. The results clearly show how the lithographic response is affected by a previous imprint step: the dose increase required to compensate for partial degradation increases with imprint temperature and time (Fig. 3). We found that any time delay between imprint and lithography drastically increases the dose and development time required for complete layer removal (see Fig. 2, 4).

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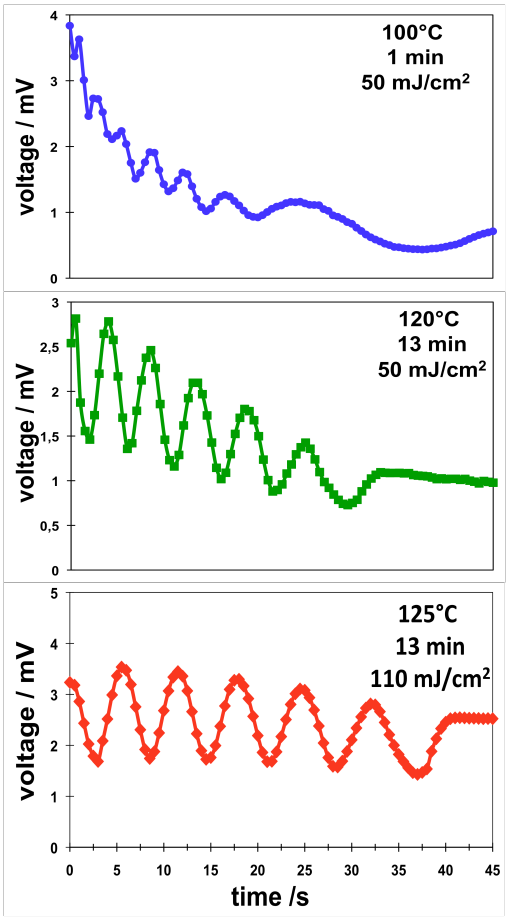
[1] P. Paniez et al, Microelectronic Engineering 9 (89) 585



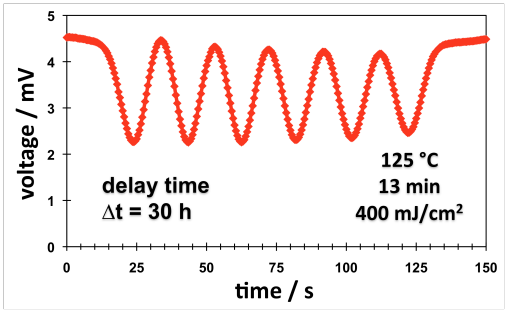


Figure 2: Dissolution measurement via laser interferometry (535 nm) after different temperature loadings. Bottom: Temperature loading and delay time before exposure and developement results in higher doses to clear and higher development time.

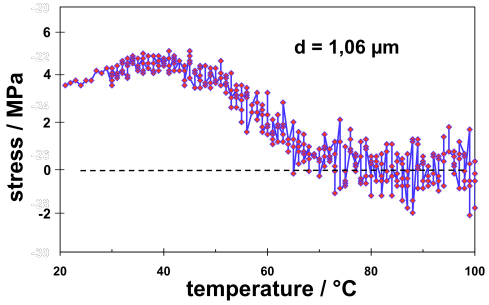


Figure 1: Stress induced by the photoresist as a function of temperature. The saturation characterizes the glass transition temperature.

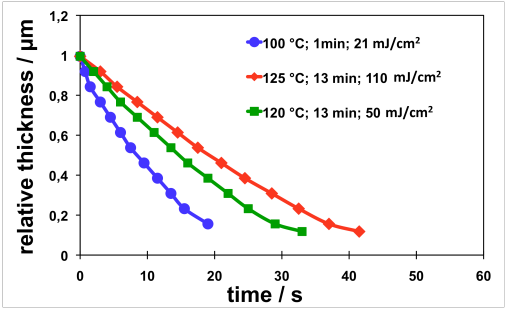


Figure 3: Impact of thermal pre-treatment on the time-dependence of the dissolution process after exposure at different dose levels.

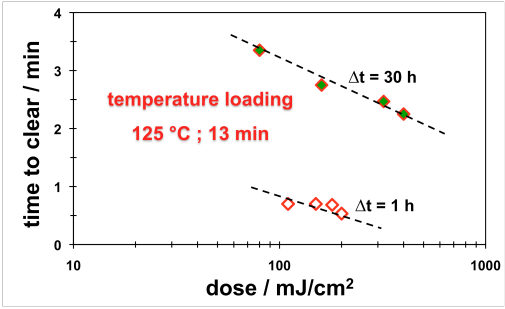


Figure 4: Impact of delay time between thermal treatment and exposure and development on the required time and dose to clear.