Crosslinking control during imprint for hybrid lithography (T-NIL + UV-L)

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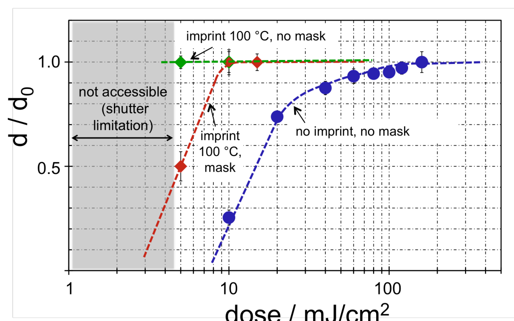
Nanoimprint offers a low cost and easy way to prepare devices in the sub-micrometer range. Its limitations lie in the definition of larger patterns; even more complicated is the imprint of different pattern sizes (micrometer and nanometer scale) with one stamp. With hybrid lithography[1,2] this physical limitation can be overcome; by defining the nanometer-scale patterns by thermal nanoimprint lithography (T-NIL) and the micrometer-scale patterns by optical lithography (UV-L), both techniques are applied to the pattern sizes they are best suited for. We investigate the potential of hybrid lithography for negative tone photoresists, in a 'reversed-order-process' (step 1: UV-L, step 2: T-NIL and step 3: development).

The dose curves shown in Fig. 1 characterize the resist according to our tools (EV620, EVgroup; Weber press). When, according to a reversed order hybrid process, the negative tone resist is first exposed and then imprinted, the hybrid process works as long as the imprint temperature and the exposure dose are high enough; the boundary sketched in Fig. 2 documents the dose to clear after temperature treatment in a typical thermal nanoimprint process. As the temperature loading accelerates and amplifies the effect of the exposure, the dose in a hybrid process has to be chosen lower than with pure lithography (see Fig. 1) – the results show that even the dose loss due to mask transmission has a marked influence. Fig. 3 documents both process parts separately, the lithography step (left) and the imprint step (right). The imprinted patterns feature a residual layer of about 100 nm. This may be a consequence of the exposure already performed before imprint, which may have increased the viscosity of the material and, in case of photo-induced cross-linking, may also have increased the glass transition temperature. Fig. 4 shows a hybrid lithography result obtained with the chemically amplified resist AR-N 4410. The results look very good; the transition between the lithography patterns and the imprinted patterns is well defined. Optical and SEM inspection reveal that the residual layer remaining after the imprint is removed within the exposed regions after development. This provides a major simplification of the total hybrid process, as any step of separate residual layer removal becomes obsolete.
We will present results of a reversed-order hybrid lithography process obtained with different types of negative tone resists (SU-8, ma-N 1504, AR-N 4410) and discuss their potential for residual layer removal during development.

[1] L.H.D. Skjolding et al, Microelectr. Engineering 86 (2009) 654-656.
[2] K. Pfeiffer et al, Microelectr. Engineering 57-58 (2001) 381-387.



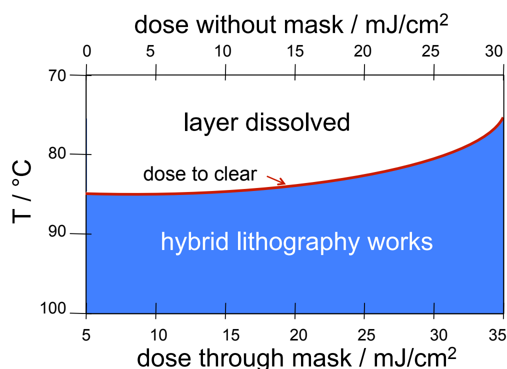


Figure 1: Dose curves for AR-N 4410 with pure lithography (right curve) and a reversed-order hybrid process (left curves). The hybrid exposure was performed with and without mask.

Figure 2: Processing range for successful reversed-order hybrid lithography; the boundary represents the dose to clear. (The doses refer to set values of the exposure tool.)

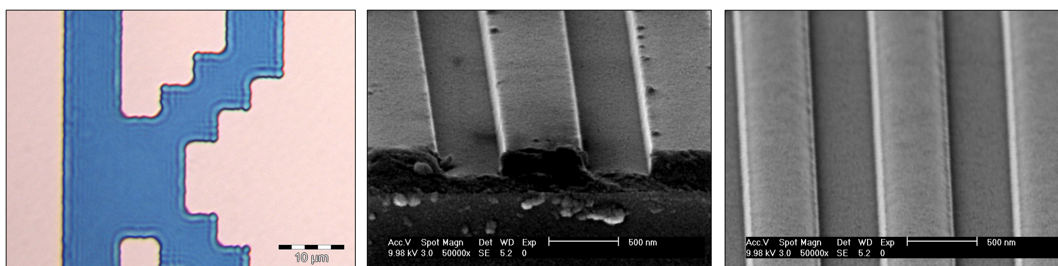


Figure 3: Documentation of the two parts of the hybrid process. Processing details: 1. exposure (10 mJ/cm^2), 2. thermal imprint (100 °C, 100 bar, 5 min), 3. development (1 min, without developer thinning). Left: lithography (imprint with flat stamp), middle/right: imprint after pre-exposure; residual layer ≈ 100 nm.

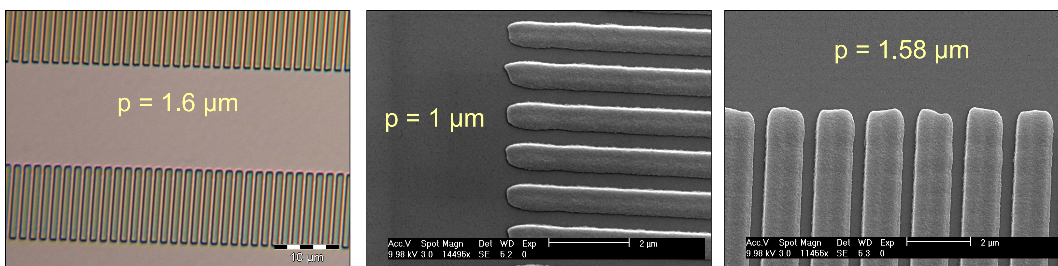


Figure 4: Reversed order hybrid lithography results obtained with the negative tone resist AR-N 4410. The relatively thick residual layer in between the imprinted lines was removed during the development step. This simplifies the overall hybrid process substantially. (Imprinted lines 500 nm and 260 nm, different pitch p as marked in the figures.)