Positive resists for a T-NIL / UVL hybrid lithography

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Hybrid lithography combines thermal nanoimprint lithography (T-NIL) with optical/UV-lithography (UVL), where both lithography processes are performed within one single resist layer [1], in contrast to a Mix and Match process [2] where two different resist layers are used. Similar to Mix and Match, hybrid lithography offers the benefit to make use of both techniques in an optimum way. The small structures are defined through nanoimprint lithography (imprint of large structures requires high volumes of polymer to be transported) and the larger structures are defined by optical lithography (small structures are limited by diffraction) [3].

The T-NIL/UVL hybrid lithography starts with the nanoimprint, which has to be a thermal one, as the resist must not be crosslinked during the imprint step. Then the optical lithography is run with a conventional photo mask, where the lithography has to be accomplished over a pre-patterned surface, which is critical. If required this step can be aligned with respect to the imprinted pattern [4]. The imprint temperature has to be chosen in a way that the exposure properties of the resist are not affected, meaning in particular that the photoactive component (PAC) of the resist must not degrade. At the same time the temperature has to be sufficiently high to obtain a successful imprint with a small residual layer. Therefore the imprint has to be done above the glass temperature, T_g. Unfortunately the degradation temperature of the PAC and T_g are in the same range, thus the choice of temperature und time for the imprint process are critical as well.

In principle, positive and negative tone resists can be used likewise. It was already shown that hybrid lithography works with the negative tone resist SU-8 [5, 6, 7], which is suggested by its low T_g. There are also first results for a positive tone resist, where, compared to SU-8, the process conduct turns out to be more difficult because of the typically high T_g. However it pays off, as the positive tone resist results in a better pattern definition within the transition region between the exposed and the unexposed area [8].

In order to see whether this is the case in general we tested two standard positive tone resists, which, according to the manufacturers data, are comparable, AZ 1505 (MicroChemicals) and AR-P 3510 (Allresist). Both are based on Novolak and have the same PAC. T_g is about 100°C. Already at a temperature of 120°C strong degradation of the PAC has to be faced.

Our results clearly show that the two materials differ substantially. AZ 1505 requires a higher imprint temperature than AR-P 3510 (Fig. 1). After development in the hybrid process AR-P 3510 appears unreasonably rough (Fig. 2). With an optimisation of the process parameters a well-defined result can be achieved (Fig. 3).

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[5] L.H.D. Skjolding et al, Microelectron. Eng. 86 (2009) 654-656
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[7] M. Wisssen et al, Proc. SPIE 6792 (2008) 67920V
[8] EMLC Conf., January 2010, Grenoble

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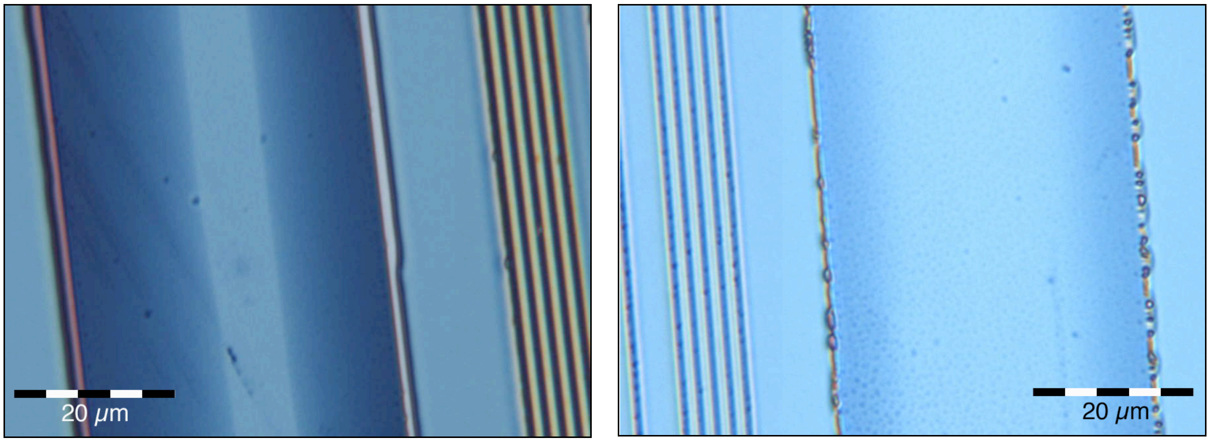

Fig. 1: Typical imprint result obtained in a commercial imprint system (EV 520 HE) at T = 120°C, p = 2 kN, 20 min, initial layer thickness 180 nm. The micrographs show a 40 µm wide line besides several 1 µm wide lines. Left: AR-P 3510: Acceptable imprint depth, relatively low residual layer. Right: AZ 1505: Imprint depth very low, high residual layer.

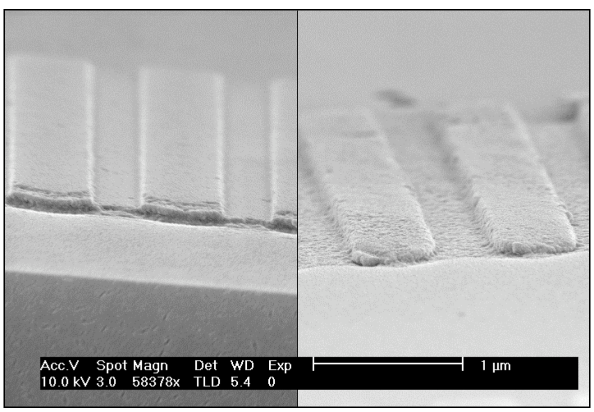

Fig 2: Hybrid lithography for both resists. (SEM micrographs at 80° inclination, view from the opened lithography window in direction of the imprinted lines). Left: AR-P 3510, right: AZ 1505. The surface of the AR-P looks porous/grainy. The higher residual layer for AZ is clearly visible.

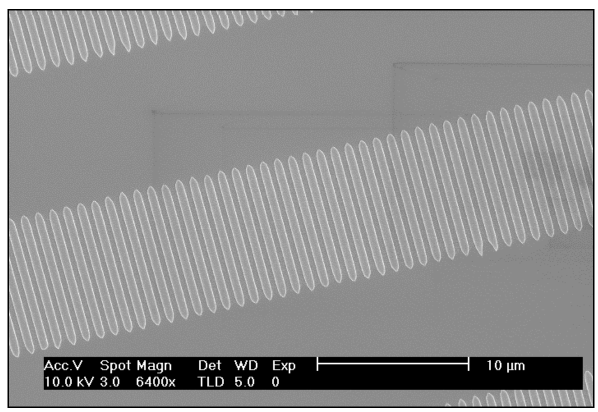

Fig. 3: Hybrid lithography result for AR-P 3510. The narrow lines (300 nm/500 nm) are defined by T-NIL at 115°C, 2kN, 10 min. The UV lithography test pattern consists of 10 µm lines, arranged perpendicular to the imprinted lines. The transition region at the lithography edge is well defined.

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