Sputtering for an etch-free lift-off in T-NIL

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Lift-off is a simple technique that has proven its capability to define metallic structures on substrates. These patterns can be used directly e.g. as electrodes for devices [1], or indirectly as a hard mask [2] for a subsequent etching step. Lift-off relies on the evaporation of metal onto the top of a resist layer structured by lithography, featuring negative or recessed slopes. Due to the fact that the resist edges remain uncovered, the resist can be lifted off in solvent together with the metal on top of it. The result is a structured metal layer on the substrate.

When nanoimprint is used as the lithography method for the lift off an additional etching step is required to remove the residual layer after imprint. In this way, lift-off structures smaller than 10 nm were demonstrated by thermal nanoimprint lithography (T-NIL) [3]. Our intention is to spare this additional RIE (reactive ion etching) step in order to keep the lift-off as simple and cost efficient as possible.

Our T-NIL approach is based on partial cavity filling [4]. The initial polymer layer is chosen sufficiently thin to avoid any filling of the stamp cavities. This leads to homogeneous and ultra thin residual layers [4, 5]. Such ultra thin polymeric layers can easily be removed by low energy sputtering. We found that intrinsic sputtering during the actual deposition process is adequate for this purpose, when sputtering is used for lift-off instead of evaporation.

Admittedly, due to the relatively high processing pressure, metal deposition in a sputter coater is less directional than in an evaporation machine. In view of lift-off, the coverage of edges thus improved is not beneficial. The lifting of the metal requires a rip-off of the thin layer along the edges, which often results in metallic flags remaining along the metal structures (Fig.1). Under such conditions the adhesion between the metal and the substrate is a critical issue. Fig. 2 demonstrates this for 300 nm lines, 800nm pitch. Due to the limited steepness of the edges of the stamp structures (the submicron structures of the stamp have an angle as low as 70 degree at the upper edge), the sputtered layer was more or less continuous. This hampered the access of the solvent, resulting in non-lifted areas. Other areas were completely lifted, suggesting either a too low adhesion within the small contact area or remnants of polymer under the metal. We ascribe this to adhesion failure, as no adhesion promoter (typically Cr [6]) was sputtered below the Au.

Although the process conditions were not ideal – in terms of the adhesion Au/substrate and the slopes of the stamp pattern, we were able to perform a lift-off with structures of different sizes and geometries. Fig. 3 shows a grid where the lifted area is relatively small; the limiting factor here is the slope of the stamp pattern. In contrast, for the definition of the 800nm dots shown in Fig. 4, the area to be lifted was huge; adhesion is the major problem here.

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[1] L. Montelius, B. et al, Microelectronic Engineering 53 (2000) 521 - 524
[2] B. Cui, Teodor Veres, Microelctronic Engineering 83 (2006) 902 - 905
[3] S. Y. Chou, P. Krauss, Microelectronic Engineering 35 (1997) 237-240
[4] N. Bogdanski et al, Microelectronic Engineering 78-79 (2005) 598-604
[5] C. Auner et al, Organic Electronics 10 (2009) 1466-1472
[6] T. Nielsen et. al, J. Vac. Sci. Technol. B 22(4) 1770 - 1775

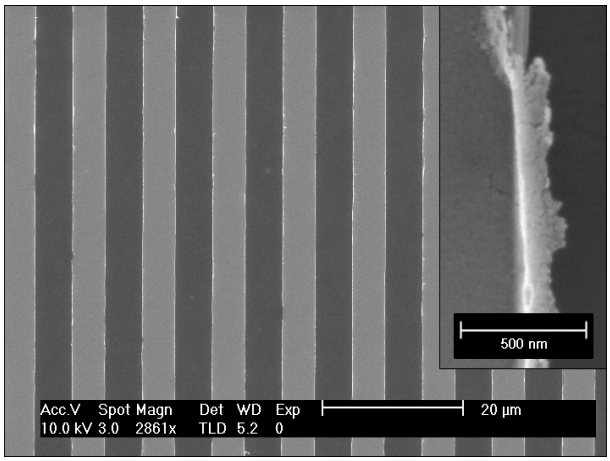

Fig. 1: Lift-off structures with 5 μm lines and spaces. Due to a limited steepness of the stamp pattern edges (about 70°) small flags remain along the metal lines (see insert).

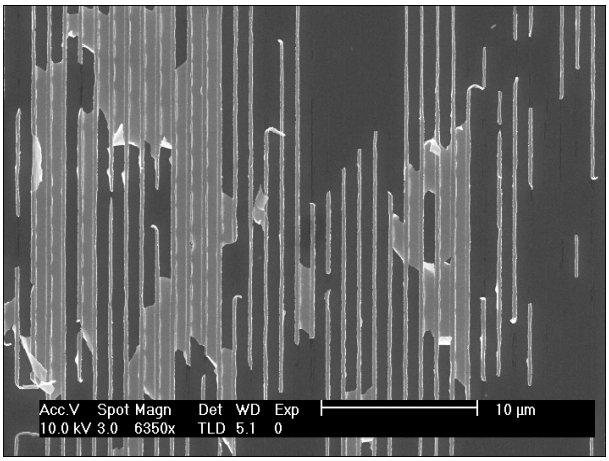

Fig. 2: Lift-off for 300 nm lines, 800 nm pitch. In addition to the low edge steepness (resulting in non-lifted areas) limited adhesion of the Au (no Cr below) results in (partial) rib-off of the narrow lines.

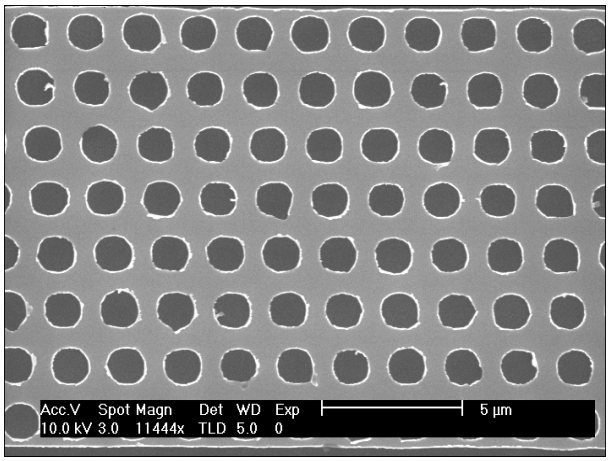

Fig. 3: Definition of negative structures by lift-off. Due to the large contact area the adhesion issue is less critical.

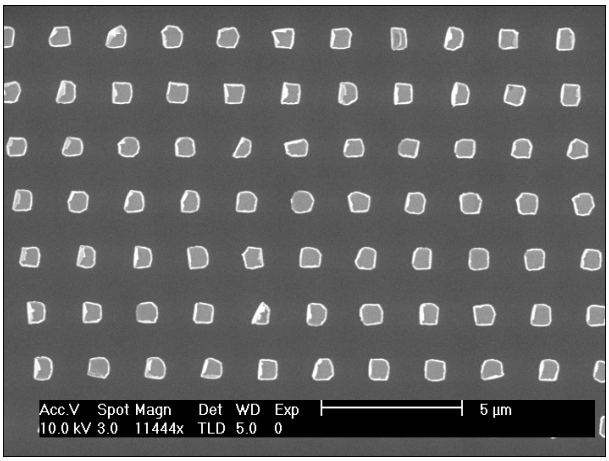

Fig. 4: Definition of positive structures by lift-off is critical with respect to adhesion, as a huge area of metal has to be lifted from only small contact areas (here 800 nm dots).