Preparation of surfaces with patterned roughness for sensing applications

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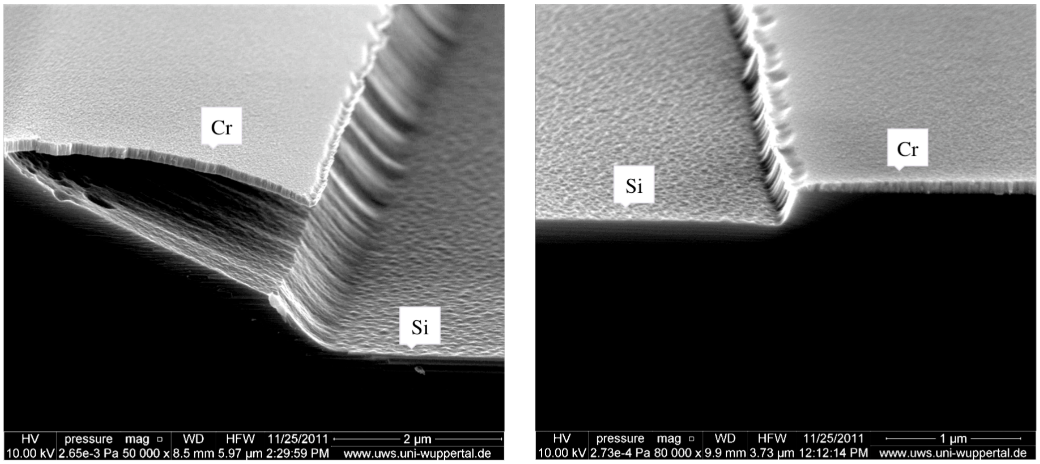
Position/alignment sensors based on reflection can be realized by sub-dividing the reflecting area into regions of high and low reflectivity. This can e.g. be done by taking advantage of the directional reflection of a smooth, polished surface and contrasting it to the random reflection of a surface with definite roughness, which results from a dry etch process that has been optimized in this respect. In view of a low-cost, large area preparation of such sensing elements a division into sub-areas is suggested via optical lithography for patterns in the micron range or via nanoimprint lithography (NIL) for patterns in the sub-micron range.

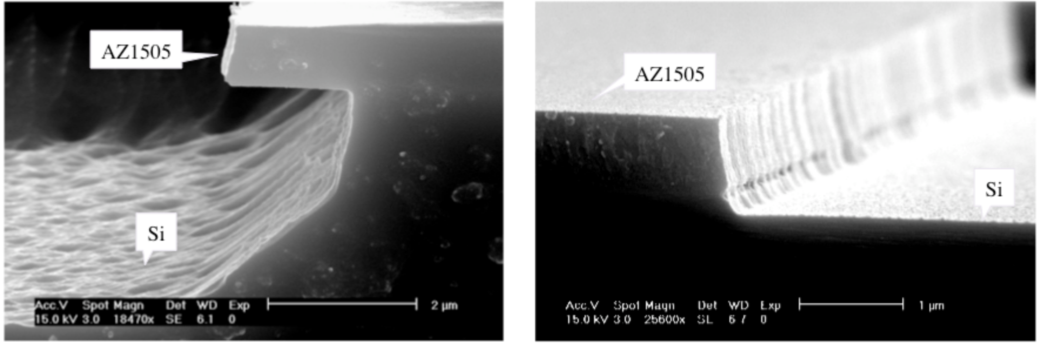
For dry etching we chose a Si substrate and a RIE process in SF_6/O_2, an etching gas mixture well known for its susceptibility to grass formation during Si etching [1,2]. Different mixture ratios were investigated. With low O_2-admixture the etch-rate is high and dominated by chemical processes, with increasing O_2-admixture the etch-rate drops and becomes more and more sputter-dominated. Two different masking materials were employed, photoresist layers ($\approx 1\ \mu m$) and hard masks made from Cr ($\approx$ 100-200 nm). The Cr masks were prepared in a lift-off process, either by sputtering or by evaporating the Cr layer.

Some of the results are documented in the figures. Fig. 1 shows typical etch results obtained with two different SF_6/O_2 ratios for the two different masks. At a low O_2 content a strong under-etching of the mask occurs, as expected; obviously, the mask-substrate interface is prone to chemical attack by the free fluorine. In case of a sputter-deposited Cr mask a surface-near deep wedge-shaped undercut develops; this is due to the slight lifting of the Cr boundary in case of sputter-deposition, which requires a rip-off of the continuous layer deposited. – In case of an evaporation of the Cr such a rip-off does not occur. With a high O_2 content the etching is almost anisotropic. Fig. 2 gives the etch-rates obtained. It becomes clear that loading [1] has to be taken into account to interpret the etch result – the photomask consumes oxygen, thus increasing the Si etch-rate and reducing the sidewall protection. Fig. 3 is a first result obtained with respect to defining locally flat and rough surfaces side by side. It was achieved in a 3-step-procedure to provide a definite roughness. The main etch-step (Fig. 1d, 120 mTorr, 225 W, 2min) was interrupted by a strong passivation step (40 mTorr, 100W, 1 min). This results in protrusions about 50 nm in size and height within the rough part of the pattern; such pyramidal structures are well suited to scatter light in off-normal directions, as envisaged.

[1] H. Jansen et al, J. Microelectronic Engineering **27,** 475-480 (1995)
[2] M. Schnell et al, IEEE 0-7830-5772-8 (2000)



(a) $O_2 / SF_6 = 0.24$; Cr mask (b) $O_2 / SF_6 = 2.58$; Cr mask



(c) $O_2 / SF_6 = 0.24$; photoresist mask (d) $O_2 / SF_6 = 2.58$; photoresist mask

Figure 1: Cross sections of etch profiles for different etch masks and different gas flow ratios. A low O_2 content results in a strong undercutting (a,c), at high O_2 content an almost anisotropic etching is obtained (b, d).

The roughness of the etched surface is not yet sufficient for random reflection.

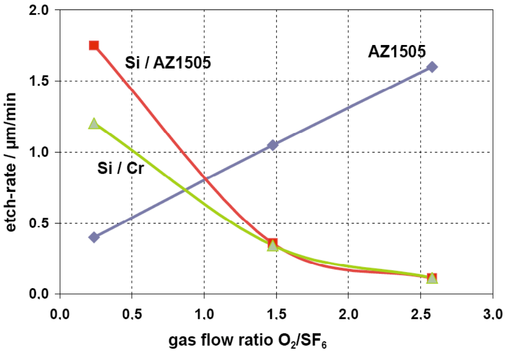


Figure 2: Etch-rates of photoresist (AZ1505) and Si (Cr- and AZ1505 etch mask) with different O_2/SF_6 gas flow ratios at 120 mTorr, 225 W.

(For visibility, the etch-rate of the photoresist was multiplied by 10).

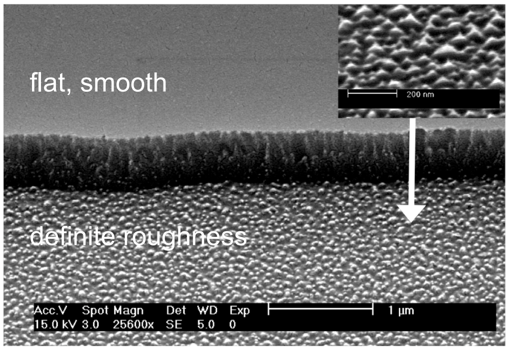


Figure 3: Roughness pattern obtained in a 3-step process (see text). The (previously) masked Si is smooth; the etched areas show random pyramids (about 50nm in size) providing reflection in random directions.