High accuracy dual side overlay with KOH through wafer etching.

Introduction

Through wafer etching of silicon using anisotropic wet chemical etchants like KOH is a key process in the fabrication of many types of MEMS devices. Using wet anisotropic etching the direction of through wafer etching and hence the front to backwafer overlay (FTBO) is determined by the crystal orientation. With deep reactive ion etching (DRIE), the FTBO depends on many parameters like equipment properties and settings.
In this work, a dual side 2 mask process is used in combination with an advanced front to back side alignment (FTBA) system to characterize the precision (see figure 1) of KOH through wafer etch processes. It was found that the pattern shift of the front side of the wafer (frontwafer), compared with the back side of the wafer (backwafer) is 2-3 μm, determined by the crystallographic tilt of the wafers. However, the 3 sigma value of the FTBO is less than 350 nm. This indicates that when the crystal orientation of a batch of wafers is precisely known, high accuracy through wafer etch using anisotropic wet chemical etching is made possible in a high volume production environment.

Experimental

The FTBO is measured using electrical overlay test structures [1], (see figure 2). The process flow is summarized in figure 3. Wafers with electrical overlay test structures are fabricated on double side polished silicon Czochralski grown wafers, diameter 100 mm. The front side and backside exposures are performed with an ASML PAS5500 waferstepper equipped with an FTBA system. The conductive film required for the electrical overlay test structures is made of 100 nm PVD TiN, virtually not etched in KOH 33% at 85 ^{o}C.
To discriminate the FTBA shift from the front to back offset caused by the crystallographic tilt (crystal shift), the backwafer pattern is exposed in two groups; group I with 0^{o} rotation and group II with 180^{o} rotation of the flat edge (see figure 4). By this, FTBA shift and crystal shift can be numerically solved.

Results and discussion

The electrical overlay test structures are measured on 5 wafers, the result are summarized in table I. The calculated FTBA shift and crystal shift are given in table II. For the calculation of the crystal shift, the average FTBA shift is used. The 3sigma values on the FTBO (table I) can be as low as 232 nm. Compared with deep reactive ion etching (DRIE) [2] (see figure 5) the precision of KOH etching is much better, however, the accuracy is lower. As can be seen in table II, the FTBA shift is, as expected very low hence the crystal shift is by far dominating the front to back overlay error. Consequently, if the crystal shift can be precisely specified by the wafer manufacturer or measured by X-ray, etch tests etc., through wafer KOH etching can be both very precise and very accurate. The combination of high accuracy FTBA exposures with KOH through wafer etch on wafers with known crystal shifts will facilitate cost effective fabrication of MEMS that requires high overlay precision and accuracy.

References

[1] H.W. van Zeijl, J. “Slabbekoorn, Characterization of Front- to Backwafer Alignment and Bulk Micromachining Using Electrical Overlay Test Structures”, Smart Sensors, Actuators and MEMS, Proc. SPIE, Vol. 5116, May 2003, pp. 617-626.
[2] N. Launay, et. al., “Design and characterization of a novel icp plasma tool for high speed and high accuracy drie processing”, Proc. IEEE MEMS 2008, Tucson, Arizona, USA, Jan 13-17, 2008, pp.311-314

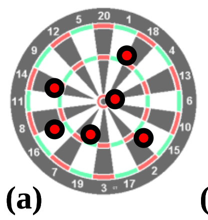

Figure 1. Examples of accuracy and precision, (a) accurate but not very precise and (b) precise but not very accurate.

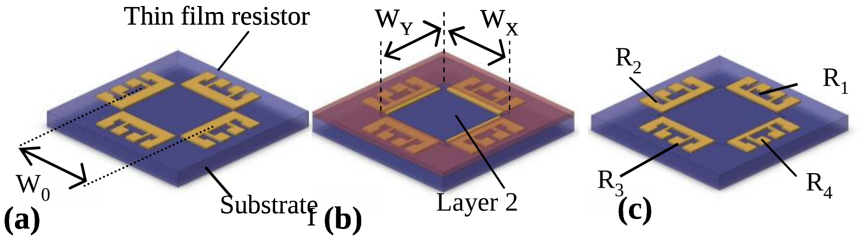

Figure 2. Principle of electrical overlay measurements. In (a) a resistor pattern is etched in a TiN (layer 1), in (b) layer 2 is exposed (b) and etched (c). The overlay of layer 2 to layer 1 is determined from electrical line width measurements on R_1, .., R_4. Note that $W_X > W_0$ and $W_Y > W_0$.

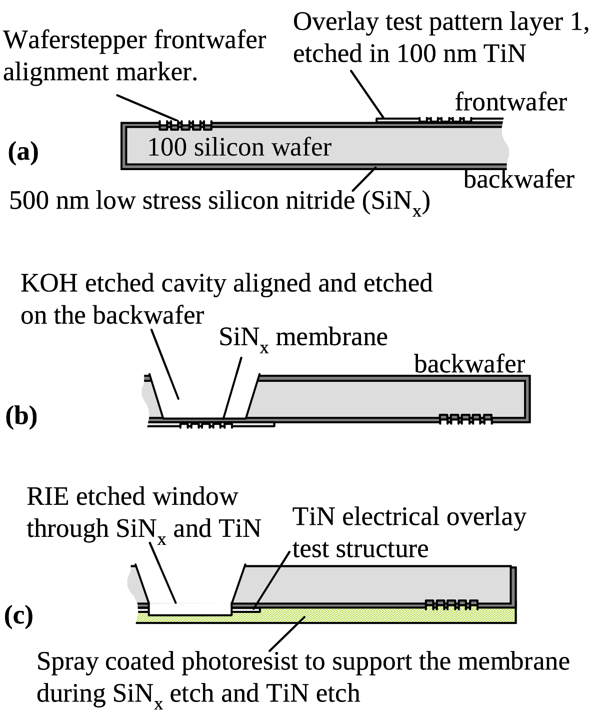

Figure 3. Process overview of the electrical overlay test device test device,

Table II. Calculated FTBA shift and crystal shift

Wafer nr	Rotation (º)	FTBA shift (µm) X	FTBA shift (µm) Y	Crystal shift (µm) X	Crystal shift (µm) Y
1	0	-0.018	-0.080	-0.228	2.381
	180			0.211	-2.374
2	0	-0.003	-0.084	-1.461	1.841
	180			1.473	-1.843
3	0	-0.007	-0.084	-0.196	-1.016
	180			0.199	1.016
4	0	-0.007	-0.078	-1.426	-2.299
	180			1.430	2.311
5	0	-0.010	-0.093	-0.507	1.026
	180			0.505	-1.044
	Average	-0.009	-0.084		
	3σ	0.049	0.052		

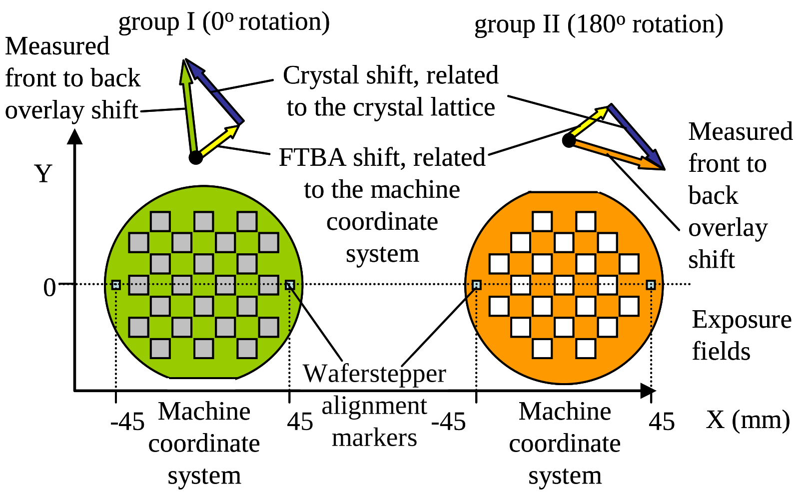

Figure 4. Two sets of exposures on the same wafer to discriminate the FTBA shift form the crystal shift.

Table I. Measured front to back wafer overlay for two wafer orientations

Wafer nr	Rotation (º)	Measured front to back overlay (mm) X	Y	$3\sigma_X$	$3\sigma_Y$	Number of data points
1	0	-0.237	2.298	0.655	0.685	462
	180	0.202	-2.457	0.814	0.616	480
2	0	-1.470	1.758	0.340	0.376	695
	180	1.464	-1.926	0.303	0.372	735
3	0	-0.205	-1.100	0.557	0.484	711
	180	0.190	0.933	0.602	0.469	716
4	0	-1.435	-2.382	0.232	0.387	752
	180	1.421	2.227	0.261	0.379	823
5	0	-0.516	0.942	0.296	0.436	738
	180	0.496	-1.128	0.330	0.399	791

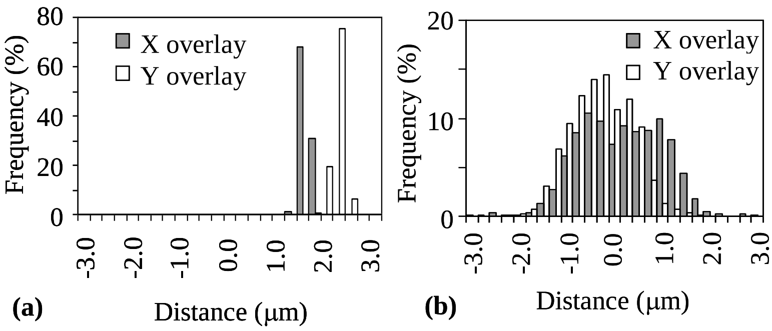

Figure 5. Front to back wafer overlay for KOH through wafer etch (a) and DRIE through wafer etch (b).