KOH-Etching of the Curved Electrode of an In-plane Moving Edge Actuator

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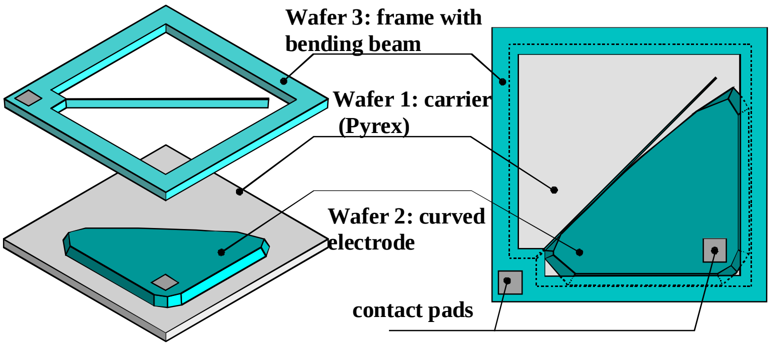
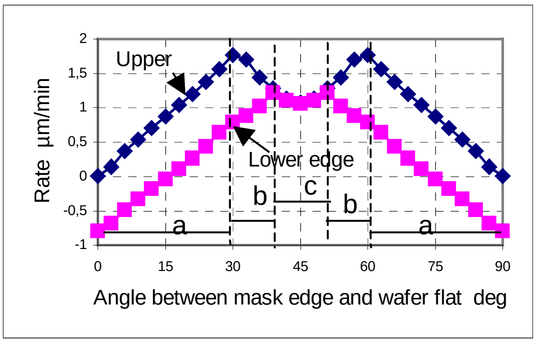


Fig. 1: Concept of the moving edge actuator

Fig. 1 shows the concept of the electrostatic moving edge actuator. The in-plane curved electrode is made by anisotropic KOH etch technique. This etchant generates vertical sidewalls along the <100>-mask edges so that a thin beam (width: wafer thickness) for the in-plane bending can be produced. In addition nearly vertical sidewalls are also generated along mask edges deviating about ± 4° from the <100>-orientation. An indication that vertical sidewalls occur is the equality of etch rates for their upper and lower edges (fig. 2). Therefore a vertical structure can be etched having a curved contour.

The mask of the curved electrode is realized by using a modified triangular structure. The hypotenuse is replaced by segments of a polygon. The design problem consists in finding the mask polygon from which the resulting course of vertical sidewalls fits equation (1).



$$y = d_{max}\left(\frac{x}{L}\right)^n$$ (d_{max}: maximum possible deflection,

L: length of curved electrode) (1)

Fig. 2: Etch rates as functions of the angle α between the direction of the mask edge and the flat of a {100}-wafer.
a: sidewalls with inclination of about 55°;
b: sidewalls consisting of two facettes;
c: nearly vertical sidewalls

At first the curve of equation (1) is approximated by a polygon with an angle increment of $\Delta\alpha = 0{,}1°$.

The mask is constructed by the displacement of the segments of the polygon by the distances of underetching corresponding to their direction = 45°-Δα and to the etching time. The underetch rates of KOH 30% 80°C are known for all directions of mask edges in steps of Δα=3° (file of etchant of simulator SIMODE). By a parabolic interpolation between 41° and 49° we can use $v(45 \pm \Delta\alpha) = (0{,}00555\Delta\alpha^2 + 1{,}0775)$ µm/min (2)
to calculate the rates in steps of $\Delta\alpha = 0{,}1°$ (equation (2) fits the rates of fig. 2 in region c).

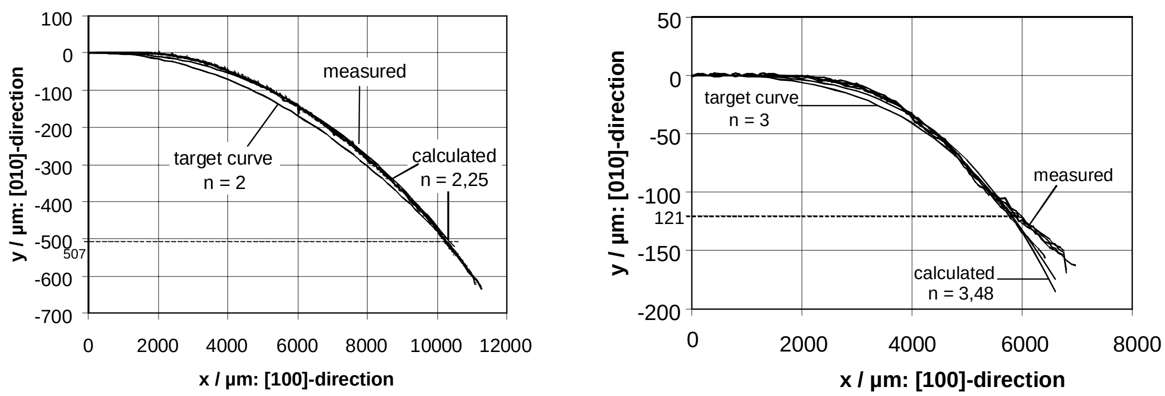


Fig. 3: Measured contours of curved electrodes

An example of the measured contours of the realized curved counter electrode is shown in fig. 3. The best fits were found with the exponents n = 2,25 and n = 3,48 which exceed a little the target values of n = 2 and n = 3, respectively. This indicates the realizibility of sidewalls with a defined curved course. The deviations arise from the inaccuracy of the etch rates.