Semiconductor Technology from A to Z

Micromechanics

Anisotropic Etching of Silicon

Crystal Orientation and Etch Rates

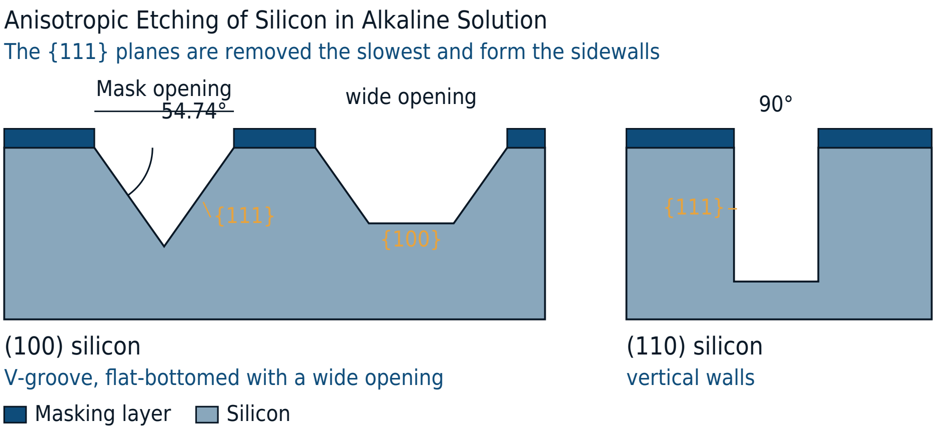
Single-crystal silicon does not etch equally fast in all directions in alkaline solutions such as potassium hydroxide (KOH) or TMAH (tetramethylammonium hydroxide) – this is known as anisotropic etching. The cause lies in the crystal structure: silicon crystallizes in a diamond lattice, and the {111} crystal planes are packed considerably more densely with atoms than the {100} or {110} planes. Because more densely packed planes offer fewer freely accessible bonds to the etchant, they are removed much more slowly – typical etch-rate ratios between {100} and {111} are 100:1 or higher.

The {111} planes therefore form the sidewalls of the etched structure regardless of etch duration: once a {111} plane is exposed, the etch attack there effectively stalls, while {100} or {110} surfaces continue to be removed.

The Characteristic 54.74° Angle

On (100)-oriented wafers – the most common cut in semiconductor manufacturing – the wafer surface lies parallel to the {100} plane. The {111} planes intersect this surface at a fixed angle of 54.74°, dictated by the crystal geometry. Opening the masking layer in a rectangle and etching through it therefore does not produce a vertical trench, but a V-shaped groove with sloped sidewalls inclined at exactly 54.74°.

If the mask opening is wide enough and the etch time long enough, the two {111} sidewalls do not meet at a point; instead, the etch first reaches a flat {100} bottom surface – producing a flat-bottomed trapezoid rather than a pointed V-groove. With a narrow opening or a short etch time, the V-shape persists.



(110) Silicon: Vertical Walls

Using a (110)-oriented wafer instead, whose surface lies parallel to the {110} plane, changes the geometry fundamentally: here the {111} planes stand perpendicular to the wafer surface. A rectangular mask opening therefore produces a trench with exactly vertical (90°) sidewalls instead of the sloped 54.74° flanks seen on a (100) wafer.

This property makes (110) silicon attractive for applications that need high aspect ratios while still relying on simple wet etching – for example, narrow, deep trenches that would require significantly more area on a (100) wafer due to the sloped walls. The drawback: (110) wafers are less common and correspondingly more expensive and harder to source than the standard (100) wafer.