Semiconductor Technology from A to Z

Micromechanics

Introduction to MEMS

What Is a MEMS?

MEMS (Micro-Electro-Mechanical Systems) refers to devices that combine mechanical and electrical functions on the same chip – sensors that convert motion, pressure, or sound into electrical signals, or actuators that translate electrical signals into motion. Unlike classical integrated circuits, which work exclusively with charge carriers, MEMS contain movable mechanical structures: free-standing beams, membranes, comb structures, or springs that deflect in the nanometer-to-micrometer range.

Fabrication uses the same basic tools as classical semiconductor technology – lithography, etching, deposition – but goes beyond their usual purpose: while every layer in a transistor is meant to stay permanently bonded to the next, MEMS structures must be deliberately released so they can move. This requires additional concepts such as sacrificial layers and deep, highly anisotropic etching, which play no role in classical fabrication.

Applications are everywhere: accelerometers in smartphones (screen rotation), pressure sensors in tire-pressure monitoring systems, microphones in practically every mobile device, and micromirrors in projectors.

Fabrication: Mechanical, Not Just Electrical

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Application Examples

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Anisotropic Etching of Silicon

Crystal Orientation and Etch Rates

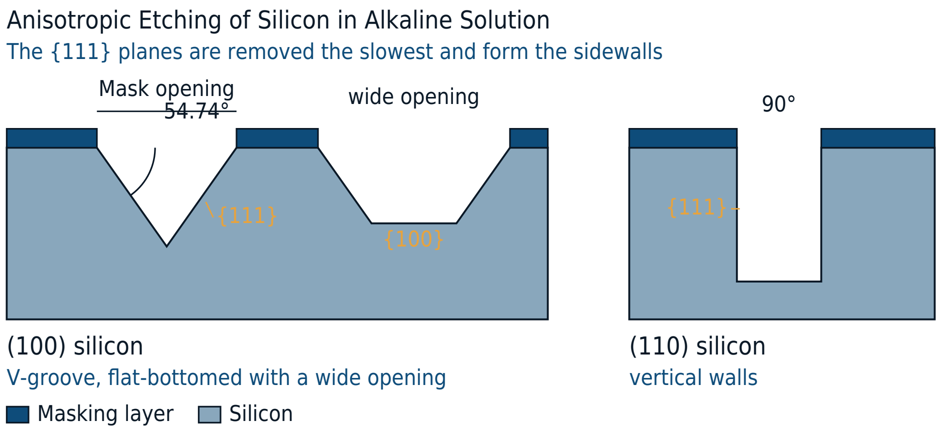
Single-crystal silicon does not etch equally fast in all directions in alkaline solutions such as potassium hydroxide (KOH) or TMAH (tetramethylammonium hydroxide) – this is known as anisotropic etching. The cause lies in the crystal structure: silicon crystallizes in a diamond lattice, and the {111} 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.