Semiconductor Technology from A to Z

Micromechanics

Bulk vs. Surface Micromachining

Bulk Micromachining: Etching Into the Depth

Bulk micromachining uses the substrate itself as the building material: deep etching into the wafer exposes three-dimensional structures such as membranes, cavities, or trenches. The anisotropic KOH/TMAH etching covered in an earlier chapter is a classic example – as is the DRIE process, which enables even steeper, deeper structures. Because this works directly in the crystal, bulk micromachining can produce comparatively large, mechanically robust structures, often tens to hundreds of micrometers deep.

The drawback: bulk micromachining consumes wafer volume and can only be combined to a limited extent with classical CMOS electronics on the same chip, since the deep etch steps could damage sensitive circuit structures. In addition, the crystal orientation of the substrate largely determines the possible shapes – on (100) silicon, for example, always the characteristic 54.74° angle, unless DRIE is used instead.

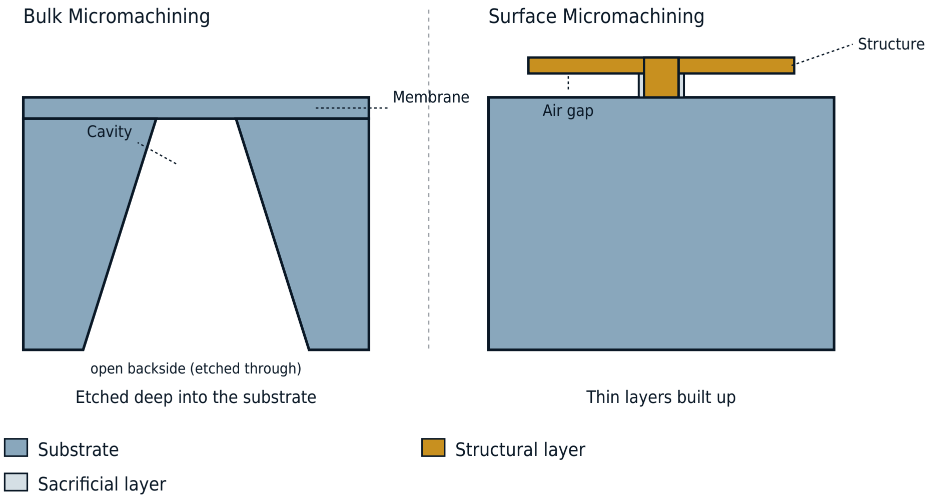
Surface Micromachining: Building Up on the Surface

Surface micromachining takes the opposite approach: instead of etching into the substrate, thin layers are built up on the wafer surface and then partially removed – exactly the principle of the sacrificial layer technique covered in an earlier chapter. The actual mechanical structure is formed from deposited layers just a few micrometers thick, such as polysilicon, rather than from the substrate itself.

This allows significantly smaller, more finely structured devices and tighter integration with classical CMOS electronics on the same chip, since fabrication uses process temperatures and tools similar to standard semiconductor manufacturing. The trade-off: the resulting structures are mechanically less robust than those from bulk micromachining, since the thin layers withstand lower forces before breaking or permanently deforming.

Bulk vs. Surface Micromachining

Two fabrication philosophies compared



Bulk: robust, deep structures from the substrate itself.
Surface: fine, CMOS-compatible structures from thin layers.

Which Process for Which Application?

The choice between the two approaches depends mainly on how large the required structure is and whether electronics need to be integrated on the same chip. Pressure sensors and microphones, which need a comparatively large, robust membrane, often rely on bulk micromachining. Accelerometers with fine comb structures, where the readout electronics should sit directly next to the mechanical element, are instead often fabricated using surface micromachining.

In practice, many modern MEMS devices combine both approaches: for example, a cavity exposed by bulk micromachining as the base structure, on top of which finer sensor elements are built using surface micromachining.