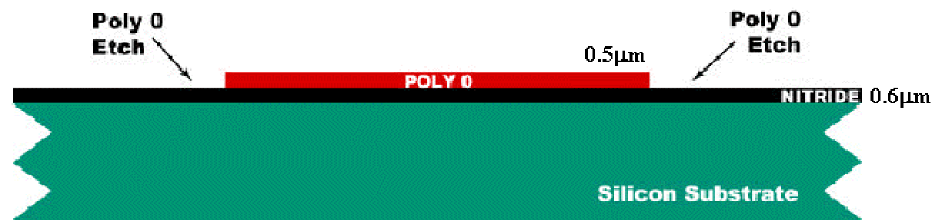
Micromotor surface-micromachine fabrication process

Extracted from MUMPs Handbook Revision 6.0

Step 1 The photoresist is lithographically patterned by exposing it to UV light through the first level mask (POLY0) and then developing it. The photoresist in exposed areas is removed leaving behind a patterned photoresist mask for etching.

Deposit and define insulation and ground conduction layers:



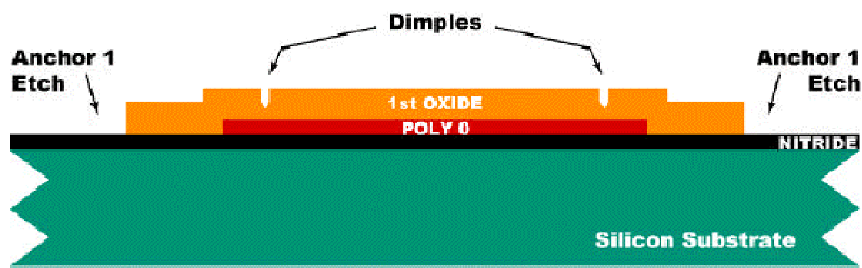
Step 2 Reactive ion etching (RIE) is used to remove the unwanted polysilicon. After the etch, the photoresist is chemically stripped in a solvent bath. This method of patterning the wafers with photoresist, etching and stripping the remaining photoresist is used repeatedly in the MUMPs™ process.

Step 3 A 2.0 µm layer of PSG is deposited on the wafers by low pressure chemical vapor deposition (LPCVD). This is the first sacrificial layer.

Deposit 1st sacrificial layer and define "dimples"

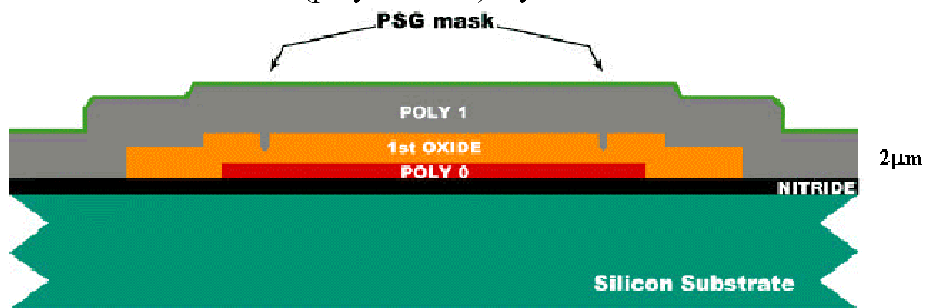
Step 4 The wafers are coated with photoresist and the second level (DIMPLE) is lithographically patterned. The dimples, 750 nm deep, are reactive ion etched **(timed-etch)** into the first oxide layer. After the etch, the photoresist is stripped.

Define 1st sacrificial layer

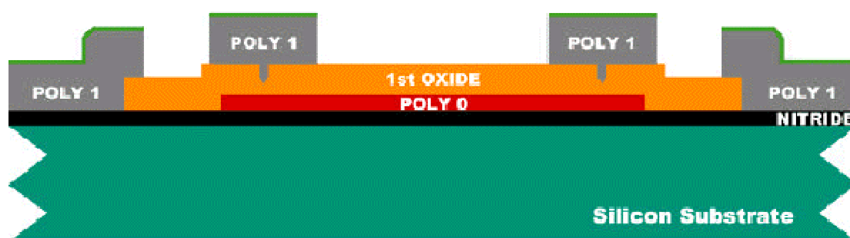


Step 5 The wafers are re-coated with photoresist and the third level (ANCHOR1) is lithographically patterned. The unwanted oxide is removed in an RIE etch and the photoresist is stripped.

Deposit and define 1st structural (polysilicon 1) layer

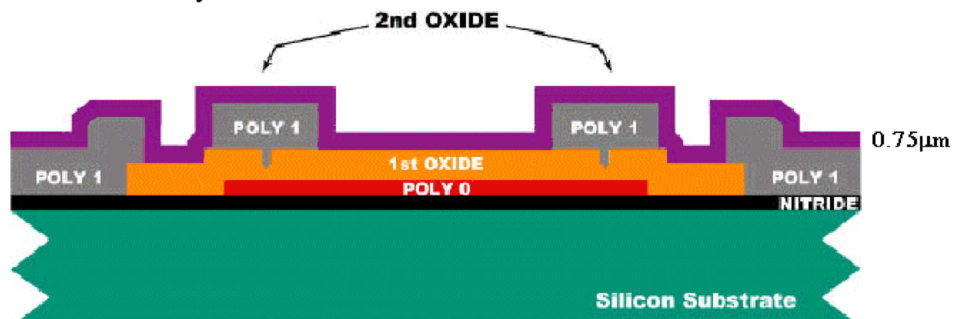


Step 6 A blanket 2.0 µm layer of un-doped polysilicon is deposited by LPCVD followed by the deposition of 200 nm PSG and a 1050°C/1 hour anneal. The anneal serves to both dope the polysilicon and reduce its residual stress.



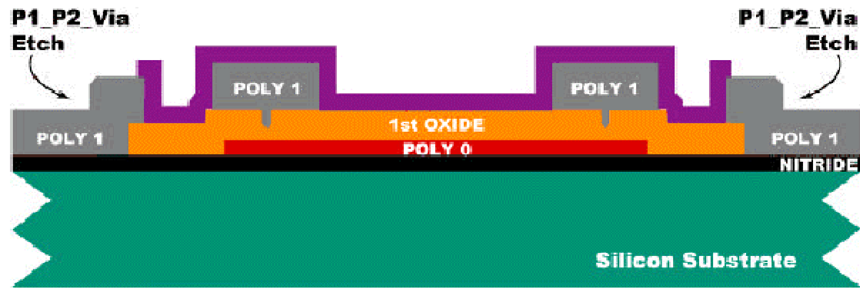
Step 7 The wafer is coated with photoresist and the fourth level (POLY1) is lithographically patterned. The PSG is first etched to create a hard mask and then Poly 1 is etched by RIE. After the etch is completed, the photoresist and PSG hard mask are removed.

Deposit 2nd sacrificial layer



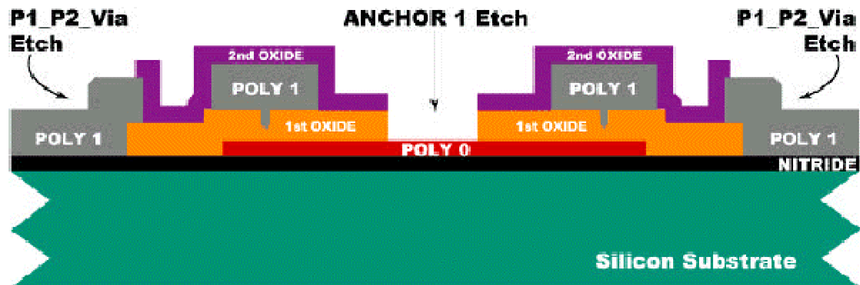
Step 8 The Second Oxide layer, 0.75 µm of PSG, is deposited on the wafer. This layer is patterned twice to allow contact to both Poly 1 and substrate layers.

Define 2nd sacrificial layer



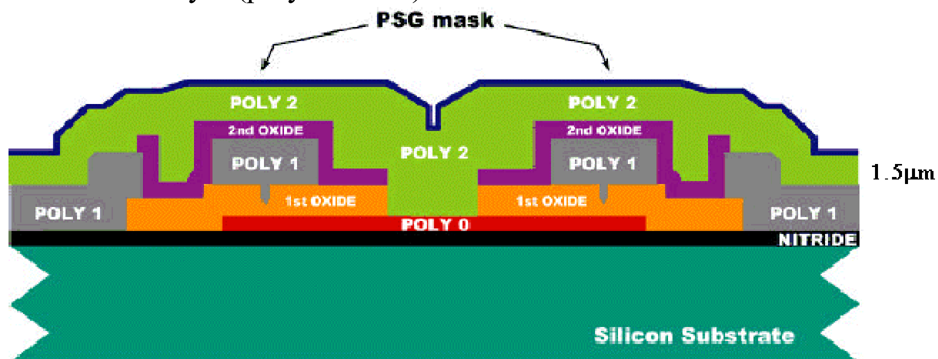
Step 9 The wafer is coated with photoresist and the fifth level (POLY1_POLY2_VIA) is lithographically patterned. The unwanted Second Oxide is RIE etched, stopping on Poly 1, and the photoresist is stripped.

Open "anchor" for rotor hub to ground plane



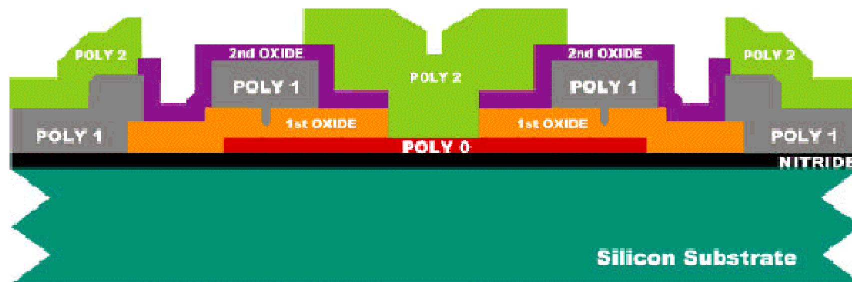
Step 10 The wafer is re-coated with photoresist and the sixth level (ANCHOR2) is lithographically patterned. The Second and First Oxides are RIE etched, stopping on either Nitride or Poly 0, and the photoresist is stripped. The ANCHOR2 level provides openings for Poly 2 to contact with Nitride or Poly 0.

Deposit 2nd structural layer (polysilicon 2)



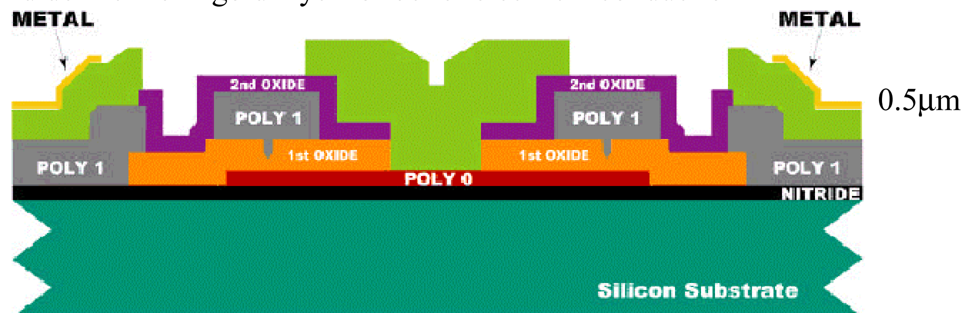
Step 11 A 1.5 μm un-doped polysilicon layer is deposited followed by a 200 nm PSG hardmask layer. The wafers are annealed at 1050°C for one hour to dope the polysilicon and reduce residual stress.

Define 2nd structural layer



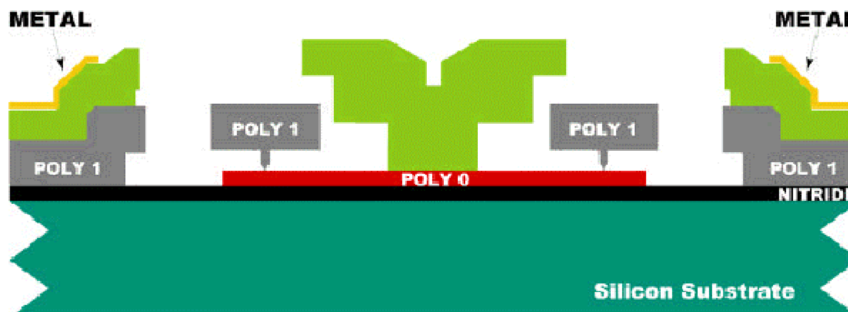
Step 12 The wafer is coated with photoresist and the seventh level (POLY2) is lithographically patterned. The PSG hard mask and Poly 2 layers are RIE etched and the photoresist and hard mask are removed. All mechanical structures have now been fabricated. The remaining steps are to deposit the metal layer and remove the sacrificial oxides.

Deposit and define metal gold layer for better electrical conduction



Step 13 The wafer is coated with photoresist and the eighth level (METAL) is lithographically patterned. The metal (gold with a thin adhesion layer) is deposited by lift-off patterning which does not require etching. The side wall of the photoresist is sloped at a reentrant angle, which allows the metal to be deposited on the surfaces of the wafer and the photoresist, but provides breaks in the continuity of the metal over the reentrant photoresist step. The photoresist and unwanted metal (atop the photoresist) are then removed in a solvent bath. The process is now complete and the wafers can be coated with a protective layer of photoresist and diced. The chips are sorted and shipped.

Sacrificial release



Step 14 The structures are released by immersing the chips in a 49% HF solution. The Poly 1 "rotor" can be seen around the fixed Poly 2 hub. The stacks of Poly 1, Poly 2 and Metal on the sides represent the stators used to drive the motor electrostatically.