Lecture 4
Surface/Bulk Micromachining

- Agenda:
  - Surface Micromachining
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Surface Micromachining

A wide variety of MEMS devices including micromirrors, gratings, lenses, inertial sensors, micromotors, etc. have been fabricated and some even commercialized by using surface micromachining techniques.

Structural materials: Polysilicon, Al, SiO_2, SiC, ...

Sacrificial materials: SiO_2, polymers, Al, ...

- MEMSCAP's MUMPs Process
- Sandia's SUMMiT Process
- Texas Instruments' Al Process (√)
- Analog Devices' iMEMS Process (later)
- ......

MUMPs

- MUMPs® (Multi-User MEMS Processes) consists of standardized building blocks for MEMS processing and MEMS components
- MUMPs® is a well-established, commercial program that provides customers with cost-effective access to MEMS prototyping and a seamless transition into volume manufacturing. There are now three flavors of MUMPs®: PolyMUMPs, SOIMUMPs, and MetalMUMPs.
- MUMPs® is part of MEMSCAP's complete manufacturing offer, ranging from prototyping (MUMPs) to mass production.

  - MUMPs process was offered first by MCNC in 1992
  - Cronos was spun-off from MCNC in 1999, providing MUMPs
  - Cronos was acquired by JDS Uniphase in April 2000 as a platform for its MEMS business unit
  - MEMSCAP acquired JDS Uniphase's Cronos in 2002

http://www.memscap.com/memsrus/crmumps.html

PolyMUMPs Process

Cross-sectional view of all 7 layers

Features:

- Structural material: Polysilicon
- Sacrificial layer: Deposited oxide (PSG)
- Electrical isolation: silicon nitride
- 3 polysilicon layers

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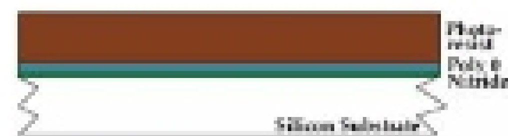
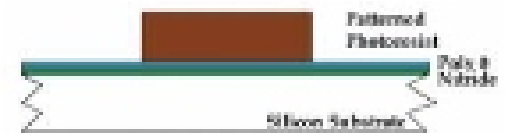
PolyMUMPs Process Flow (1)

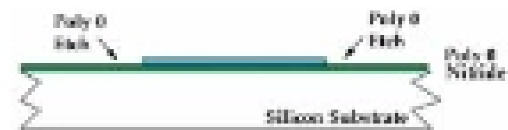
- N+ doping
- Silicon nitride (Nitride) deposition (600nm)
- 500 nm polysilicon (Poly 0) deposition
- Photoresist coating



- Photolithography using first level mask (POLY0)



- RIE Poly0
- Photoresist stripping (in a solvent)



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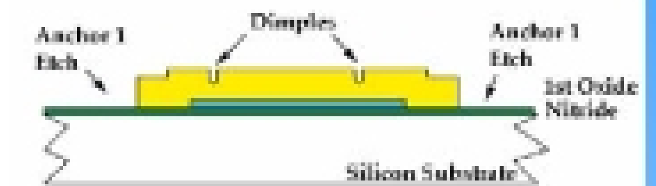
PolyMUMPs Process Flow (2)

- 2.0 µm LPCVD PSG deposition (the first sacrificial layer)

- Second mask (DIMPLE) patterned
- The dimples, 750 nm deep, are etched (RIE) into the first oxide layer.

- Third mask (ANCHOR1) patterned



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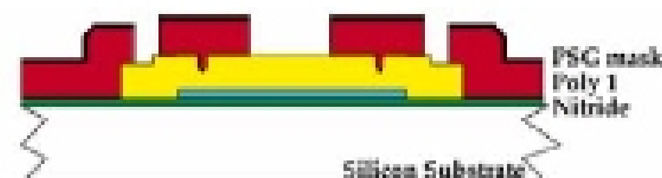
PolyMUMPs Process Flow (3)

- 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.

- The fourth mask (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.



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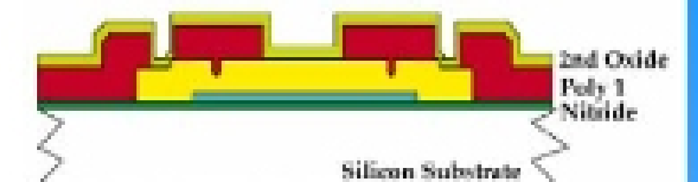
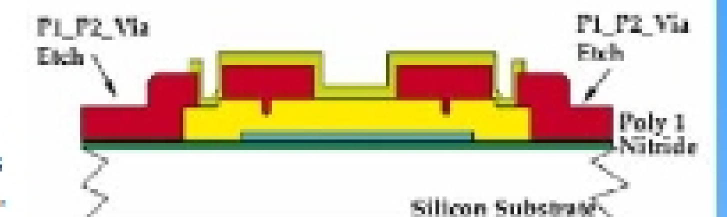
PolyMUMPs Process Flow (4)

- 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.

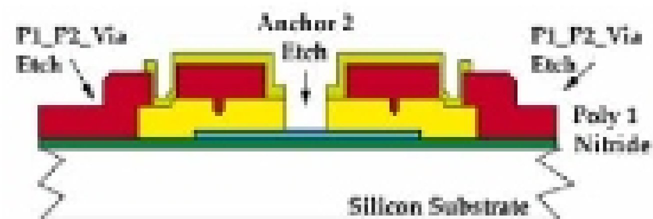


- The fifth mask (POLY1_POLY2_VIA) is lithographically patterned.
- The unwanted Second Oxide is RIE etched, stopping on Poly 1, and the photoresist is stripped.



PolyMUMPs Process Flow (5)

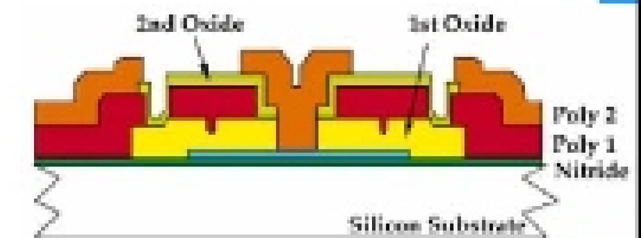
- The sixth mask (ANCHOR2) is lithographically patterned.
- Second and First Oxides are RIE etched, stopping on either Nitride or Poly 0, and photoresist is stripped.
- The ANCHOR2 level provides openings for Poly 2 to contact with Nitride or Poly 0.



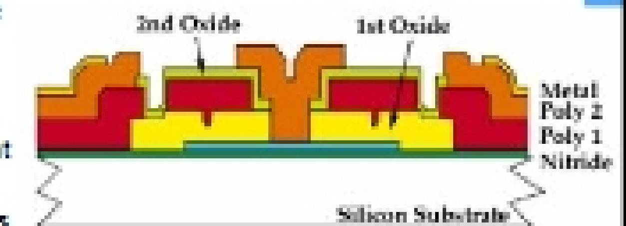
- A 1.5 µm un-doped polysilicon layer is deposited followed by a 200 nm PSG hardmask layer. The wafers are annealed at 1050°C for one hour to dope the polysilicon and reduce residual stress.

PolyMUMPs Process Flow (6)

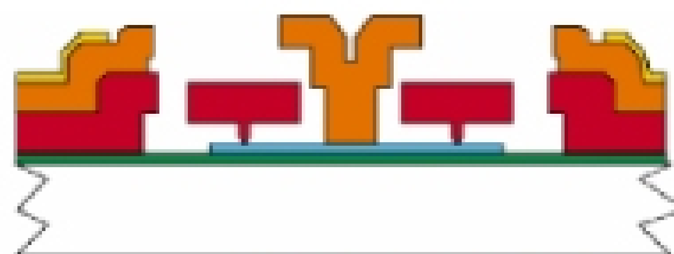
- The seventh mask (POLY2) is lithographically patterned.
- The PSG hard mask and Poly 2 layers are RIE etched and the photoresist and hard mask are removed.
- All mechanical structures have now been fabricated. The remaining steps are to deposit the metal layer and remove the sacrificial oxides



- The eighth mask (METAL) is patterned. The metal (gold with a thin adhesion layer) is deposited by lift-off patterning.
- The photoresist and unwanted metal (atop the hotoresist) 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.



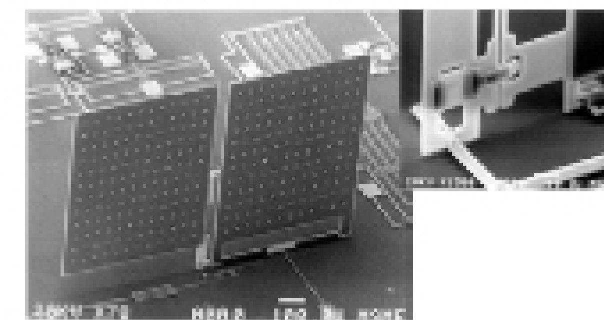
PolyMUMPs Process Flow (7)



- 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.

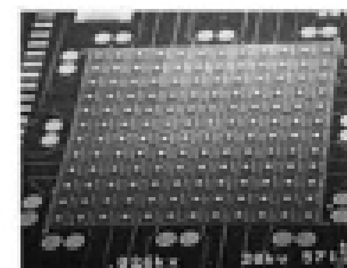
http://www.memscap.com/memsrus/svcsrules.html

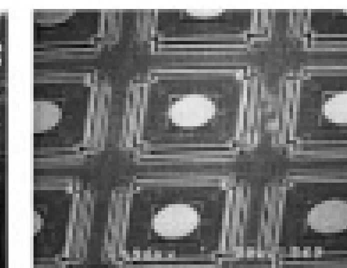
Example Devices by PolyMUMPs



- 2D mirror: K. Pister's group (UC-Berkeley)

- Corner cube reflector: K. Pister's group (UC-Berkeley)





- Micromirror array: V.M. Bright's group (U. Colorado)