Microelectromechanical Systems (MEMs)
Process Integration - Surface Micromachined

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Sandia National Labs
Moving Mirror Project
RIT Surface Micromachined Projects
Aluminum Diaphragm Pressure Sensor
Polysilicon Gate MOSFET Pressure Sensor
INTRODUCTION

Surface microelectromechanical systems are built using thin films of polysilicon and other materials on the surface of a silicon integrated circuit.

Movable Mass

Spring
SAMPLE

Sandia Agile MEMs Prototyping, Layout tools, and Education

2.0 μm Poly (level 3)
1.5 μm TEOS, B doped, CMP
1.5 μm Poly (level 2)
0.5 μm TEOS, B doped,
1.0 μm Poly (level 1)
2.0 μm TEOS, B doped
0.3 μm Poly (level 0)
0.2 μm Si2N4
0.6 μm SiO2
Substrate
Level 0 poly is fixed to substrate, used for conductors
2 µm TEOS is etched for anchors and dimples
Level 1 poly is first moving layer for poly used for gears and is
undercut etched to form flanges
0.5 µm TEOS is used for space between moving parts and hubs and
guides, this layer is etched to anchor hubs and guides
Level 2 poly is the hub or guide
1.75 µm poly is the spacer between final layer poly and underlying
layers, this layer is CMP to give flat surface for level 3
Level 3 poly is used for linkage between two objects in Level 1
SAMPLE ; SANDIA AGILE MEMs PROTOTYPING

2.0 µm Poly (level 3)
1.5 µm Poly (level 2)
1.0 µm Poly (level 1)
0.3 µm Poly (level 0)
0.2 µm Si2N4
0.6 µm SiO2
Substrate
THREE LEVEL POLYSILICON DEVICE

Gear

50 μm

Electrostatic Drive

Linkage

Pin (under linkage) in slot

Slider

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To demonstrate the SAMPLE process scientists at Sandia National Labs built several projects including the hinged mirror driven by a comb gap drive MEMs actuator.
Comb gap drive converts linear motion. Two linear drives at 90° can be used to convert linear to rotary motion. Apply electrostatic force 90 degrees out of phase to give circular motion.
LINKAGE AND GEAR REDUCTION

Linear Motion Input Driven 90° Out of Phase

X and Y electrostatic drive and gear reduction connected to a rack and pinion drive to give linear motion at high force to push up/down hinged mirror

Rotary Motion

Linear Motion Output
HINDGED MIRROR
LOCK MECHANISM
Sandia Microelectronics Development Laboratory

5 levels, CMP, 2-3 µm Poly
Cantilevers
Springs
Accelerometer
Electrostatic Comb Drive
Mirrors
Optical Modulators
Optical Arrays
Gears
Inductors
Contactors
RIT POLY CANTILEVER STRUCTURES
ALUMINUM DIAPHRAGM CAPACITIVE MICROPHONE

Jon Stephan, 1995
Intel Corporation
Folsom, CA

1 µm Aluminum

2.0 µm Gap
ALUMINUM DIAPHRAGM PRESSURE SENSOR

Kerstin Babbitt - University of Rochester
Stephanie Bennett - Clarkson University
Sheila Kahwati - Syracuse University
An Pham - Rochester Institute of Technology

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ALUMINUM DIAPHRAGM PRESSURE SENSOR

Sensor

C sensor: 5 to 25 pF
VDD = -10V

Oscillator

VO
GND

R load: 1 MΩ
C load: 20 pF
C parasitic = 10 pF

0 to 5 mm Hg Pressure Range
Acknowledgement - Funding for this project was through the National Institute of Health and the Department of Pediatric Cardiology at Strong Memorial Hospital, University of Rochester, NY
SURFACE MICROMACHINED POLY DIAPHRAGM

Poly Covered Trench

John Castellana, 1997
BSµE  RIT

200 µm

2 µm Poly

1.5 µm Gap
**SURFACE MICROMACHINED POLY DIAPHRAGM**

1. Photolithography
2. Etch in BHF
3. LPCVD 2.0 μm Poly
4. Photolithography
5. Etch Poly in SF6+ O2
6. Etch SiO2 in BHF
POLY DIAPHRAGM FIELD EFFECT TRANSISTOR

2 \mu m n+ Poly

Vsource

Vgate

Aluminum Plug

Vdrain

1000 Å Oxide

P+ P+
n-type silicon

75 \mu m

Contact Cut to Poly Gate

Etch Holes

Poly Diaphragm

Kerstin Babbitt, 1997
BSEE U of Rochester
Add alignment marks and squares in each corner for each level.
POLY DIAPHRAGM

5x

2.5 µm

25 µm
POLY DIAPHRAGM PRESSURE SENSOR TEST RESULTS

An Pham – 1999
Rochester Institute of Technology
POLY DIAPHRAGM PRESSURE SENSOR PACKAGING

500 µm
TIP SHAPING

- Bond Pads
- Reference Electrode
- Microelectrode Sites
- 150 μm
- ≈ 3.5 mm
REFERENCES

11. www-mat.ee.tu-berlin.de/research
1. Look up the surface micromachined devices made at Analog Devices, Inc.