On-Chip Passive Elements Using MEMS

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Agenda

- Overview
- Evolution of MEMS
- Realization of passive elements
  - Inductors
  - Capacitors
- Process Dependence
- Conclusions & Challenges

Overview

“There’s plenty of room at the bottom…” Richard Feynman

- MEMS
  Micro Electro Mechanical Systems
  - Very fertile technology
  - Systems obtained by **micro fabrication**

- **Micro fabrication** is the micromachining process which is done by adding layers or etching away some parts of the wafer to have electromechanical devices

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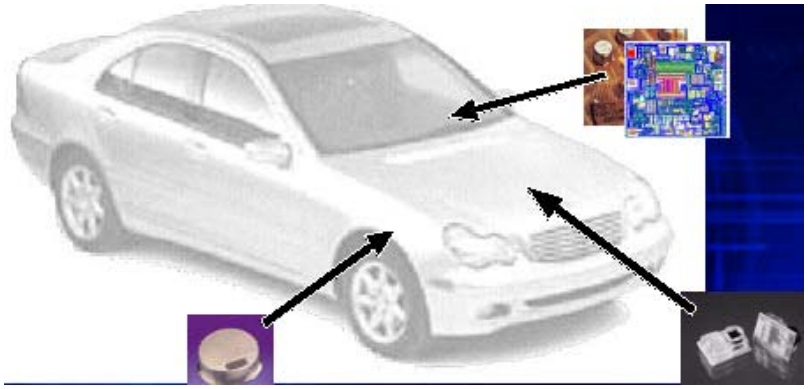
Evolution of MEMS

- From traditional ..



Airbag Deployment
MEMS accelerometer

MEMS Pressure Sensor

Stability Control System
MEMS micro-gyro

Evolution of MEMS (contd..)

- ..to potential

Antennas

Color bi-stable display

Micro-switches

Tunable Passives

Tunable Filters

Directional microphone

On-chip Inductors & Capacitors

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Realization of Passive Elements - Inductors

- Integrated Passive Inductors
  - Low Q Factor
  - High Occupied Surface
  - Cumbersome Packaging

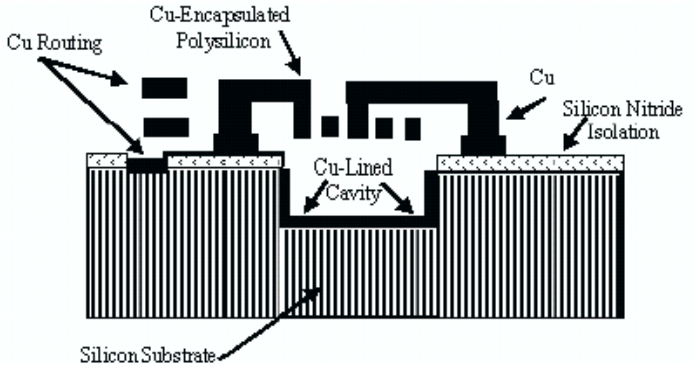
- Micromachined Inductors
  - Improved performance
  - High Q factor
  - Reduced Capacitive effects
  - Integration : light, small volume

Realization of Passive Elements – Inductors (contd..)

1. Under etched Inductors [1]

Remove the substrate under the inductor spiral

- Deep cavity
- Metallization



Q = 30
$\mathbf{F_{res}}$ = 10.7 GHz
L = 10nH (7turns)

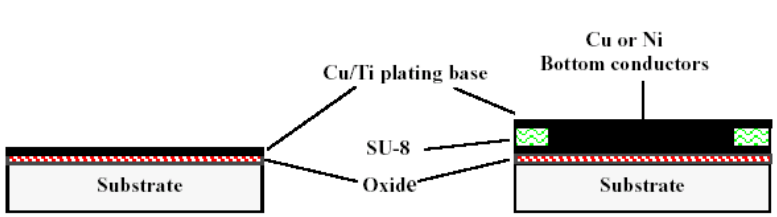
1. Si_3N_4 – isolation
2. Etching - RIE
3. Sacrificial Block formed
4. CMP
5. Patterning of Inductor
6. RTA
7. Released in HF
8. Electroless Cu deposition

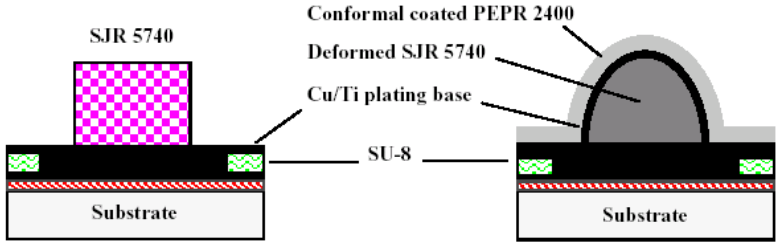
1. H. Jiang *et al, "*Fabrication of High-Performance on-chip suspended spiral inductors by Machining*", IEEE MTT-S Digest, vol.1, pp 279-282, 2000*

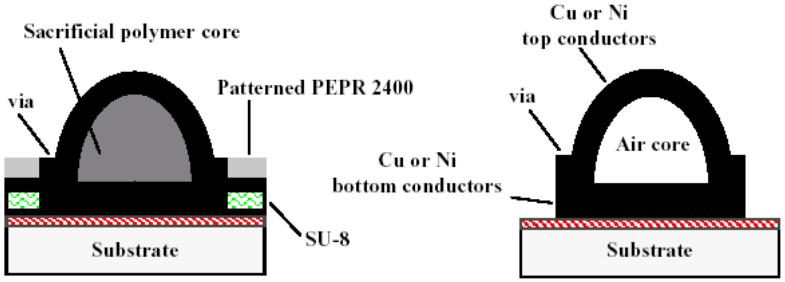
Realization of Passive Elements – Inductors (contd..)

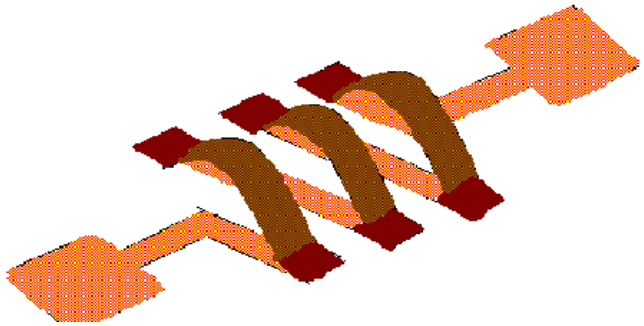
2. 3-D Solenoid Inductors [2]

Higher Q= 60, F_{res} <15GHz



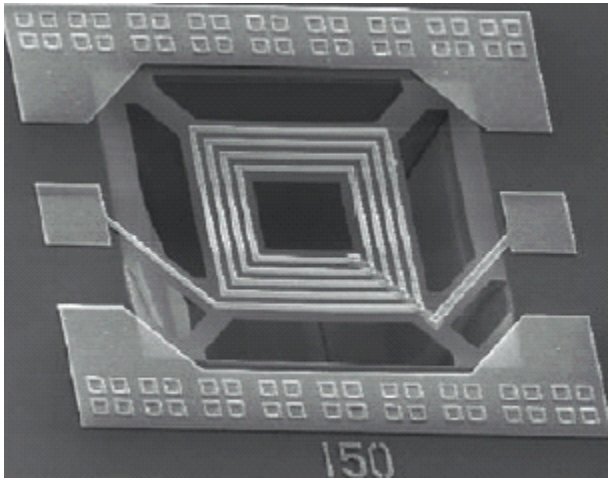




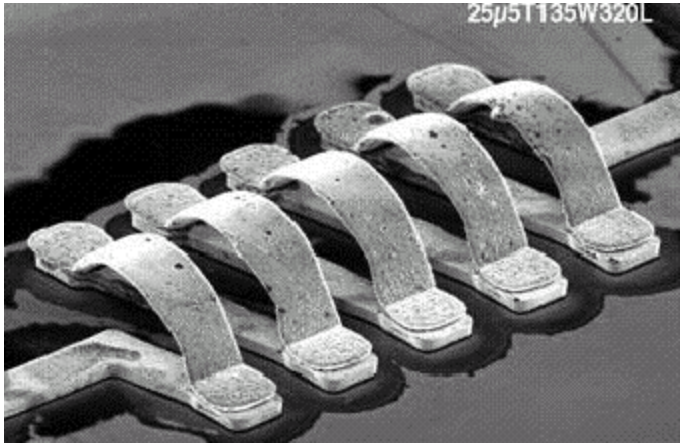


2. N. Chomnawang, J.B. Lee, and W. A. Davis, "Micromachined On-Chip 3D Inductors," *IEEE Emerging Telecommunication Technologies Conference*, Richardson, Texas, USA, September 23-24, 2002.

Realization of Passive Elements – Inductors (contd..)



Under Etched Inductor



3-D Solenoid Inductor

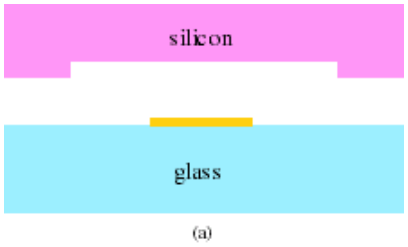
Realization of Passive Elements – Capacitors

- Metal Oxide Semiconductor Capacitor
  - Large Area
  - Losses – Lower Q, Tuning Range limited
  - High process dependence

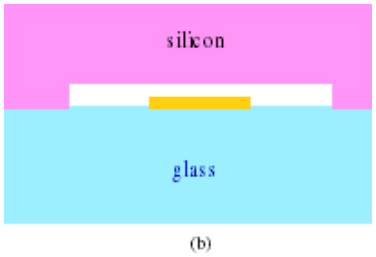
- Micromachined Capacitors
  - Improvement in Q
  - Voltage Controlled – VCO, Resonators, Filters
  - Wider Tuning Range

Realization of Passive Elements – Capacitors (contd..)

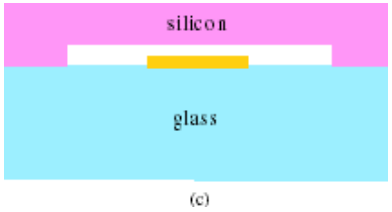
1. Linearly Tunable MEMS Capacitor [3]



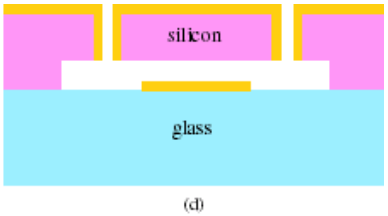
Etching of Silicon and Gold patterning



Bonding

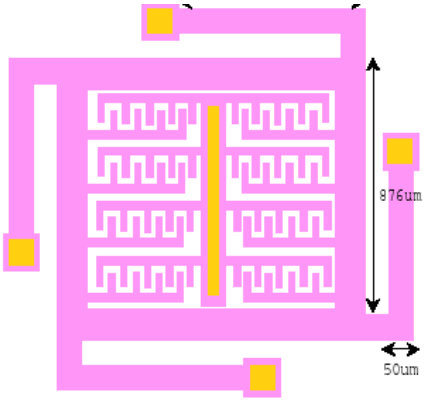


CMP



ICP etching-Au evaporation

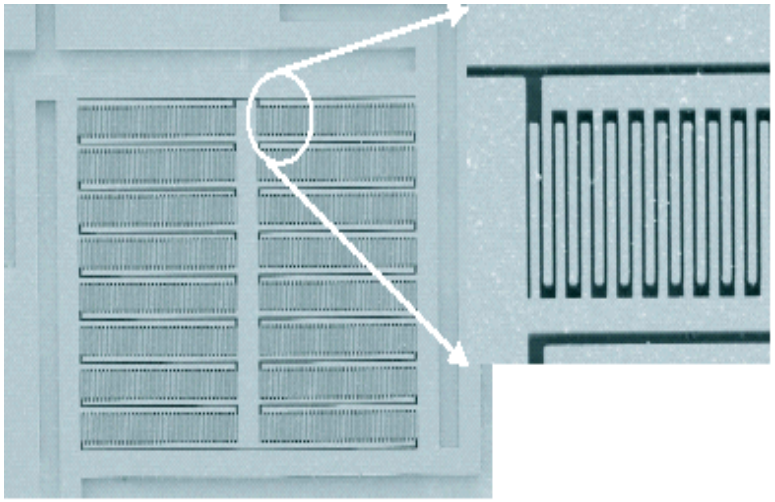
C = 2pF
Q = 6
F_{res} = 10GHz
Tuning Range 10%@ 8V



Top View

3. Seonho Seok *et al,* "A novel linearly tunable MEMS variable Capacitor", *Journal of Micromechanics and Micro-engineering*", Oct, 2001

Realization of Passive Elements – Capacitors (contd..)



SEM Picture of the MEMS Capacitor

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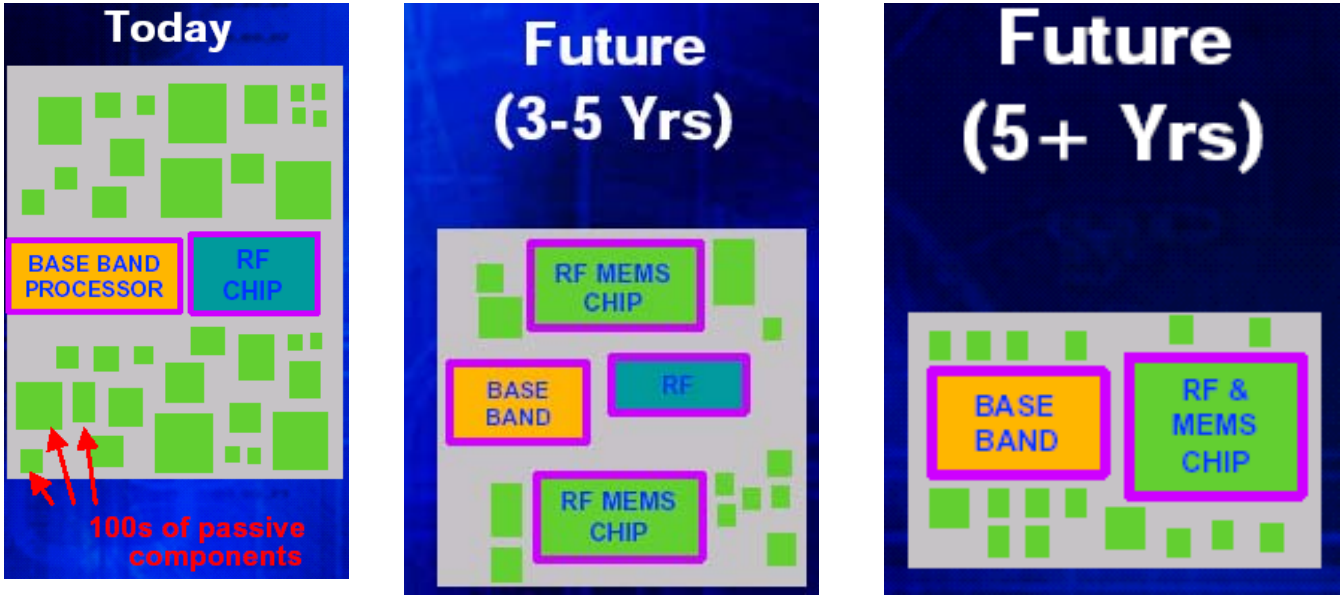
Process Dependence

- Performance affected by:
  - Stiction - *adhesion*
  - Etch Variations – over-etch, under-etch
  - Particulate Contaminations
  - Curvature

Conclusions & Challenges



- Compatibility of the MEMS process with active circuitry processing is critical for the realization of integrated MEMS

THANK YOU