MEMS Technology

Micro-Electro-Mechanical Systems (Micro-System Design)

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Outline

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Introduction

- MEMS = Microelectronics + Micromachining

- Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro-fabrication technology.

- MEMS extend the fabrication techniques developed for the integrated circuit industry to add mechanical elements such as beams, gears, diaphragms, and springs to devices.

- MEMS are not about any one application or device, nor are they defined by a single fabrication process or limited to a few materials.
Why MEMS?

- Electro-Mechanical system
- Small Size
- Low Cost
- Portable devices
Characteristic feature of MEMS

- **Miniaturization**
  
  Miniaturization enables the production of compact, quick-response devices.

- **Multiplicity**
  
  Multiplicity refers to the batch fabrication inherent in semiconductor processing, which allows thousands or millions of components to be easily and concurrently fabricated.

- **Micro-Electronics**
  
  Microelectronics provides the intelligence to MEMS and allows the monolithic merger of sensors, actuators, and logic to build closed-loop feedback components and systems.
Fabrication of MEMS

- IC Fabrication
  - film growth,
  - doping,
  - lithography,
  - etching,
  - dicing, and
  - packaging.

- Bulk Micromachining & Wafer Bonding
  Bulk micromachining is an extension of IC technology for the fabrication of 3D structures for fabrication of mechanical components.
Fabrication

- Surface Micromachining
  - Refer next slide

- Micro-molding

  In the micro-molding process, microstructures are fabricated using molds to define the deposition of the structural layer. The structural material is deposited only in those areas constituting the micro-device structure, in contrast to bulk and surface micromachining, which feature blanket deposition of the structural material followed by etching to realize the final device geometry.

- LIGA (lithography, electroplating, and molding)
Sample process for fabricating a micro-cantilever using Surface Micromachining Techniques

1. **Initial silicon substrate**
2. **Deposit silicon nitride layer to protect silicon substrate**
3. **Grow oxide layer on top of silicon nitride**
4. **Pattern oxide using mask and UV light**
5. **Deposit polysilicon layer (this will be the cantilever beam)**
6. **Remove (through etching) the oxide layer underneath the cantilever**

**Legend**
- **Silicon**
- **Silicon nitride**
- **Oxide**
- **Polysilicon**

**Final product:** micro-cantilever on a chip
Applications

- **Pressure Sensors**
  - MEMS pressure micro-sensors typically have a flexible diaphragm that deforms in the presence of a pressure difference.
  - The deformation is converted to an electrical signal appearing at the sensor output.

- **Inertial Sensors**
  - Inertial sensors are a type of accelerometer and are one of the principal commercial products that utilize surface micromachining.
  - They are used as airbag-deployment sensors in automobiles, and as tilt or shock sensors.
Applications

- **Biotechnology**
  - MEMS and Nanotechnology is enabling new discoveries in science and engineering such as the Polymerase Chain Reaction (PCR) micro-systems for DNA amplification and identification.
  - Micro-machined Scanning Tunneling Microscopes (STMs), biochips for detection of hazardous chemical and biological agents, and micro-systems for high-throughput drug screening and selection.

- **Communications**
  - Electrical components such as inductors and tunable capacitors can be improved significantly compared to their integrated counterparts if they are made using MEMS and Nanotechnology.
  - With the integration of such components, the performance of communication circuits will improve, while the total circuit area, power consumption and cost will be reduced.
Applications

- the mechanical switch, as developed by several research groups, is a key component with huge potential in various microwave circuits.
- The demonstrated samples of mechanical switches have quality factors much higher than anything previously available.

Micro-engines

- Operation of the small gears at rotational speeds greater than 300,000 rpm has been demonstrated. Micro-engines can be used to drive the wheels of micro-combination locks.
- They can also be used in combination with a microtransmission to drive a pop-up mirror out of a plane. This device is known as a micromirror.

Accelerometers
Accelerometer IC 7455

- 3-Axis detection
- Capacitance to voltage conversion
- Amplifier with gain control
- ADC
- SPI/I2C interface on chip for communication with Microcontroller
Application Accelerometer B/D
Challenges

- Huge Initial setup cost
- Very limited options for prototyping or manufacturing devices, and have no capability or expertise in micro-fabrication technology
- The packaging of MEMS devices and systems needs to improve considerably from its current primitive state. MEMS packaging is more challenging than IC packaging due to the diversity of MEMS devices and the requirement that many of these devices be in contact with their environment.
- Often the development of even the most mundane MEMS device requires a dedicated research effort to find a suitable process sequence for fabricating it. MEMS device design needs to be separated from the complexities of the process sequence.
MEMS applications will be driven by processes enabling greater functionality through higher levels of electronic-mechanical integration and greater numbers of mechanical components working alone or together to enable a complex action, integration, and more intimate interaction with the physical world.

Advancing from their success as sensors, MEMS products will be embedded in larger non-MEMS systems, such as printers, automobiles, and biomedical diagnostic equipment, and will enable new and improved systems.
References

- http://www.memsnet.org/mems/applications.html
- http://www.memsnet.org/mems/applications.html
Questions?

Thank You