Fabrication, Sensing & Application of MEMS/NEMS Technology

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Abstract

The fabrication technology for MEMS is similar as semiconductor devices. MEMS manufacturing processes include Photolithography, Wet etch, Micro electrical discharge machining (EDM), Laser micromachining and the most important process is the silicon surface machining that is the oldest and best understood approach. Due to specific demands for MEMS/NEMS devices these other fabrication methods are used. After general survey of micro-technology some of the specific MEMS/NEMS fabrication processes and sensing will be discussed like surface micromachining, SOI technology, LIGA etc.

Keywords: *MEMS, Si – Based Surface, SOI technology, LIGA*

I. Background

MEMS/NEMS is a system that is quickly making the size of the electronic devices compact. MEMS/NEMS is based on concept of addition of mechanics or mechanical to an electronic chip gives a tremendous boost to functionality and performance well beyond one might expects at first glance. The world of mechanics, perhaps the oldest technology, is extremely rich and diversified. Think of all the mechanical equipment in the micro world and the hundreds of principles used in Mechanical Engineering. It was very difficult to reduce the world down to chip size machines. But there's more. There are so many chip-scale mechanical devices, range from meshing gears to sensitive levers. These all devices can be fabricated in existing semiconductor foundries. The ability to miniaturize large mechanical machines and devices to chip-scale with cost-effective processes in existing factories gives MEMS/NEMS technology incredible power. Most technology may not realize the full potential of MEMS/NEMS that will unfold over the next few decades. And if that is not enough, we can add light and other forms of energy from the EM spectrum to create a truly incredible convergence of science and technology. MOEMS lets us add optics and physics to the already powerful assemblage. This is certainly the zone in technology where all sciences converge and all can benefit. MEMS/NEMS is the right size scale for interacting with objects and material from the macro-world, but also small enough to interact with biological systems.

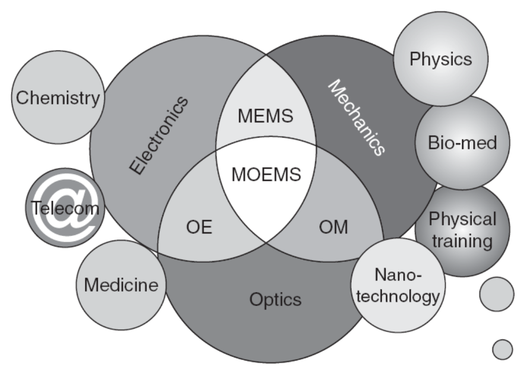


Fig.1 optical amplifier

MEMS are basically a Si-chip containing mechanical parts. The mechanical part is movable and takes energy from semiconducting chip. Si and Ge are used for fabrication but Si is mostly used for fabrication due to cheap in cost. The most important term in MEMS/NEMS is "Mechanical" but what does it really mean? Mechanical suggests motion and moving mechanical parts.

II. Introduction

MEMS/NEMS is a special class of semiconductor type devices that uses a mechanical part with integrated circuit. So that whole structure is known as micro electro-mechanical system. The most important term in MEMS is mechanical, due to which science achieves a moving part with semiconducting IC's. It takes power from integrated circuit and due to IC power, mechanical part works. Motion-detecting devices like accelerometers were introduced by MEMS, and they all had moving parts that were essential to operation. Today most types of MEMS devices do have moving parts that are used to sense or control. Ordinary electronic semiconductor devices have no moving parts and the only motion, if we can even call it that is flow of electrons through electrical conductors, transistors, and other electronic devices (solid state devices). But demands require moving parts for MEMS/NEMS runs into a difficult situation with the simplest fluid handling devices. The ink-jet printers employ tiny print head chips too rapidly and accurate eject fluid ink when triggered by an electronic signal. These ink-jet chips are classified as MEMS devices by most of us. The majority of ink-jet chips generate fluid propulsion by heating ink in a cavity using a resistance heater. The micro-scale used in these chips allows the heater to instantly "boil" the ink causing fluid ink to jet out of the mouth of cavity of the machine. The simplest way to include ink-jet devices in MEMS is to add a class where inanimate devices produce motion. My own inclusive (including all required services) definition for MEMS/NEMS is, a device causes motion in a controlled manner using an electrical signal and/or electrical energy. Note that we require the use of electrons, either as the energy source or signal. While it is possible to construct micromechanical systems that do not use any form of electricity, such as a pneumatic system, these would not fall within the MEMS/NEMS definition.

MEMS are not necessarily part of nanotechnology although the media try to group these two areas together. MEMS does quite well on a micro-scale and there may not be the same incentive to drive down size as there is for electronic chips. In fact, MEMS devices are being produced in older foundries that are no longer competitive in older foundries that are no longer competitive in the general electronics area. When the device feature size shrinks down to the sub-micrometer range some quantum mechanical effects may become observable, like classical physics laws and scaling laws. The sub-micrometer range particle size called mesoscale and the smaller one called nanoscale. Some fabrication techniques like electron-beam lithography realized the nanometer range devices such as scanning probe microscopes (SPM). So we can sat that MEMS/NEMS technologies and devices have the potential to be employed in realization of structures operating at the meso and nanoscale levels, some have suggested that once the mechanical device falls into the nanometer range (1 to 100 nm), it could be called *nanoelectromechanical system* (NEMS). But nanotechnology is much more than about size so the NEMS terminology may only cause confusion. Today, micro-electronic devices have feature sizes down to 90nm, and a few have moved to the 65nm none, but they are not considered *Nano electronics*.

III. Basic Principles

The two key features for MEMS/NEMS are mechanical, that can be equated to motion and electrical.

IV. Fabrication Technology

- The fabrication of microelectronic devices and micro-systems has these process steps.
- Layer Deposition
- Lithography
- Etching/Pattern Transfer.
- Now, in this paper we explain some fabrication techniques of MEMS/NEMS or we can also say that Si-MEMS.

1. Surface Micromachining

Surface micromachining provides a CMOS compatible fabrication technique for free standing structures and allows a higher structure density than bulk-micromachining. The basic idea of surface micromachining is the sacrificial layer concept. The functional layer which will define later movable part of the device is deposited on a pre-structured sacrificial layer. After appropriate structuring of the functional layer, the sacrificial layer is removed in an isotropic etch process. The thickness of the used layer is mostly in the same range as standard thickness in a CMOS or Bi-CMOS processes. For etching fully CMOS compatible processes can be chosen. Mainly the material used for sacrificial layer is phosphorous-silicate glass (PSG), SiO_2, porous silicon, poly-Si, polyimide, AuAl and the material used for functional layer is Poly-Si, SiO_2, TiNi, NiFe, W etc. The devices manufactured by this process are accelerometer (BOSCH'S) and pressure sensors.

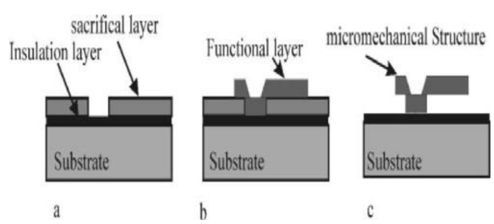
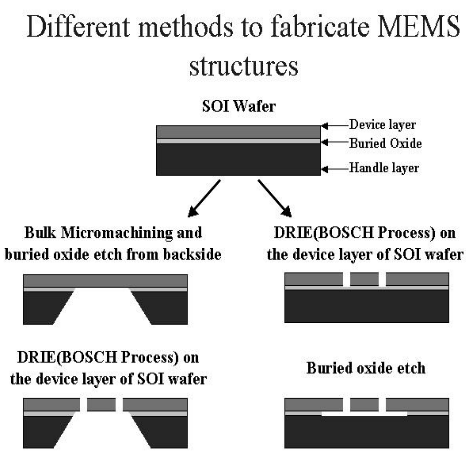


Fig. 2 Surface Micromachining

2. Silicon on insulator Technology (SOI)

The use of SOI **(**Silicon on insulator) technology can simplify the complexity of a fabrication process for free standing structures considerably. The reason is that the buried oxide layer provides an etch stop for both, front side etching (e.g. DRIE) and backside etching (e.g. anisotropic wet etching). Further on, an excellent isolation to the substrate by a high quality buried oxide between device layer (functional Si) and handle wafer is provided. Due to increased industrial use the prices for SOI-wafers have decreased drastically in the last few years. Fabrication processes based SOI offer interesting advantages, both under economical and technological view points. Two diffrent methods of fabrication using SOI-technology are shown in fig. On the left hand side a combination of bulk micromachining and surface micromachining is used. A membrane is etched from the backside with the buried SiO2 as etch stop layer. Finally, the exact shape of the free standing structures is defined by DRIE from the front side and the remaining oxide layer might be removed. On the right hand side, only processing from one side is used. However, in this case there are several layout restrictions as it is not possible to structure the sacrificial layer as simple as in a standard surface micromachining process.



3. LIGA

LIGA (the German acronym for "Lithography Galvanik Abformung" = Lithography electroplating and molding) is a non-Si technology. However, it is shortly presented here to provide a complete overview of the different technology concepts for MEMS/Microsystems. A schematic representation of the LIGA process is given in Fig. In the classical LIGA concept X-ray lithography is used which provides a large depth of focus and allos the definition of very thick resist patterns (up to 100 micrometer). In this process the resist narrowditch (trenches) are filled up by an electroplating process (e.g. Au or Ni). Therefore, this additive structuring process will define the negatve metal structure of the resist pattern. The metal mold can than be used for a further plastic molding process.

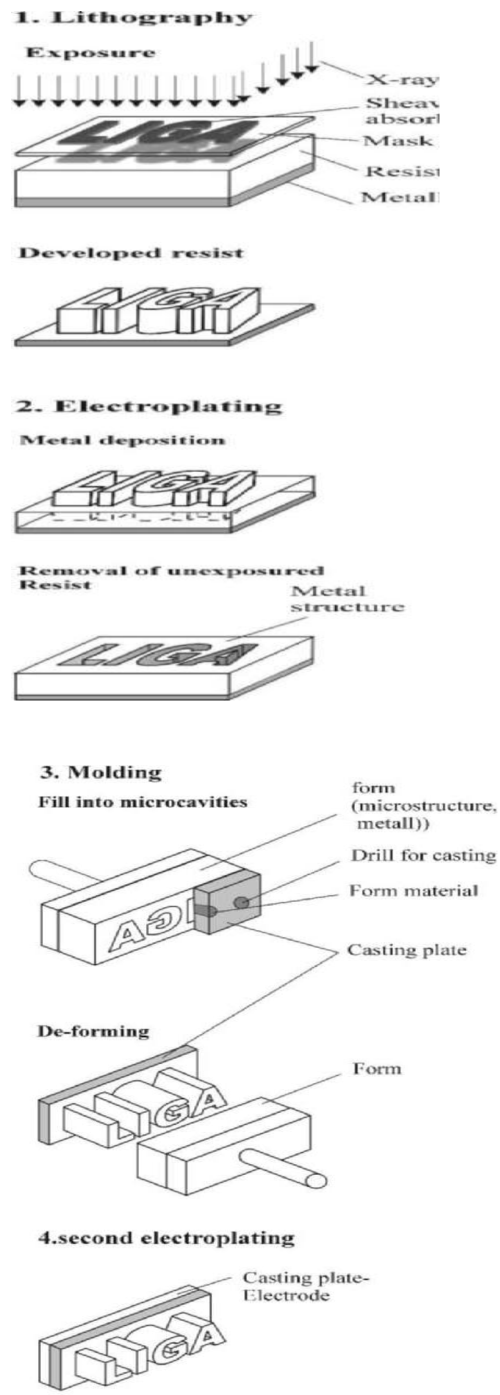


Fig. 3 LIGA Lithography

This plastic mold can be used as final product or it can be used as mold for second electroplating, providing a metal structure as final product or as copy of the master form (Final product).LIGA technology is especially suited for the production of simple micro-structure elements with high aspect ratio.However, in its classical form it cannot provide microsystems. To overcome this limitation. LIGA-based processes have been integrated into Si-technology

MEMS Sensing

There are many types of electronic and photonic sensors that can detect everything from pressure to magnetic fields. But the addition of mechanics adds new dimensions and enhances older principles. MEMS/NEMS technology can mimic all of the human senses and even move far beyond the limited human ranges. The largest class of MEMS devices, approximately two thirds, falls into the sensor class. MEMS and sensors are often grouped together in technical forums. Some MEMS sensors, like pressure types, are replacing more costly and cumbersome products made from assembled parts. But MEMS are able to do things that were not possible, or were previously impractical. The most important sensor today is motion detection and measurement. MEMS devices have been used for over a decade to build accelerometers that are used as crash sensors for air bag systems. Today's accelerometers are much more sensitive, but also much more robust and reliable. Accelerometers can now accurately measure acceleration and deceleration in X, Y, and Z directions. However, the two axis X-Y accelerometer has become very popular and finding applications in everything from automobiles to toys. Latest the single axis accelerometer is one of the earliest MEMS designs. In the past several years, this basic idea has evolved into two-axis and three-axis type devices. Recently **Sandia** has announced the world's most sensitive accelerometer that can be used for ultrasensitive yet robust seismic instruments. The simplest accelerometers use a parallel plate capacitor structure as sensor since it can be made at low cost with silicon fabrication technology. Acceleration and deceleration change the capacitor cell spacing that corresponding changes capacitance. If on chip electronic are present, the circuitry can analyze the response and carry out functions such as triggering an airbag deployment system.

V. MEMS/NEMS Applications

MEMS have endless applications but its maximum number of applications is in sensing fields.

1. MEMS sensors

- Air bag Accelerometer
- SUV Gyroscopes
- More inertial MEMS for automotive
- Automotive pressure sensors
- Consumer products
- Printing, ink-jet devices
- MEMS in safety
- Control systems
- RF-MEMS
- Energy Devices
- Military
- Drug delivery

Summary

Modern Si-based MEMS technology makes use of full range of processes provided by the micro-electronic area. However, different very special processes are needed to meet the specific demands of MEMS/Microsystems. Today most of the high volume products such as accelerometers, Gyros, and digital micro mirror devices are fabricated with surface micromachining technology. A very promising development is the SOI-technology, which simplifies the fabrication process and therefore can reduce process costs and increase yield considerably. The addition of optics to produce MOEMS devices adds a final dimension of technology that yields considerable versatility. MEMS devices still wants major developments so that it would change human life full of comfort.

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