

Fabrication, Sensing and Applications of NEMS/MEMS 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. Several different fabrication methods are used due to specific demands for MEMS/NEMS devices. 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. [1]

Key Words: (Micromachining, fabrication, silicon insulator technology, electromechanical systems)

1. INTRODUCTION

Nano Electro Mechanical Systems/ MicroElectro Mechanical Systems is a system that is quickly making the size of the electronic devices component. NEMS/MEMS is based on the addition of mechanics to an electronic chip which gives a boost to functionality and performance well beyond expectations. The world of mechanics, being the oldest technology, is extremely diversified. Think of all the mechanical equipment the micro world and the hundreds of principles used in Mechanical Engineering. Miniaturization of large mechanical machines and devices to chip scale with cost-effective processing has led in giving MEMS/NEMS technology an incredible power. [2]

MEMS are basically a Si-chip containing mechanical parts. Mechanical parts are movable and takes energy from semiconducting chip. Si and Ge are used for fabrication but Si is mostly used due to cheap in cost. The most important word is 'Mechanical' due to which science achieves a moving part with semiconductor ICs. It takes power from IC and due to IC power, mechanical part works. Motion detecting devices like accelerometers were introduced by MEMS. 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.

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 eject fluid ink when triggered by an electronic signal. The simplest way to include Ink-Jet printers in MEMS is to add a class where inanimate devices produce motion. When the device feature size shrinks down

to the sub-micrometer range, some quantum mechanical effects may be observable. The sub-micrometer range particles size called as mesoscale and the smaller one is called as the nanoscale. [3]Some fabrication techniques like electron-beam lithography realized the nanometer range devices such as SPM. So, NEMS/MEMS technologies and devices can be utilized in realization of structures operating at the meso and nanoscale levels, some have suggested that once the mechanical devices falls into the nanometer range(1nm to 100nm), it could be termed as NEMS. But the technology is much more than the size. Microelectronic devices have feature sizes down to 9nm and a few moved to 65nm.

The standard paths to NEMS are divided into 2 basic approaches. The top-down approach can be summarized as a set of tools designed to build a smaller set of tool. For eg. A mm sized factory that builds a micrometer sized factories which in turn can build nanometer sized devices. The other one is the bottom-up approach and can be imagined as putting together single atoms or molecules until a desired level of complexity and functionality has been achieved in a device such an approach may utilize molecular self-assembly or minimize molecular biology systems.

1.1 Fabrication Technology

The fabrication of microelectronic devices and micro-systems has these steps:

- Layer Deposition
- Lithography
- Etching /Pattern Transfer
- Surface Micromachining

1. Surface Micromachining

Surface Micromachining provides a CMOS compatible fabrication technique for free standing structures allowing a higher structure density than bulk micromachining. The functional layer which defines movable part of the device is deposited on the pre-structured sacrificial layer. After appropriate structuring of the functional layer which will define later movable part of the device is deposited on a prestructured sacrificed layer, the sacrificial layer I removed in an isotropic etch process. The thickness of the used layer is same range as standard thickness in a CMOS or Bi-CMOS. For etching fully CMOS compatible process is can be chosen. Mainly the material used for sacrificial layer is phosphorous-

silicate (PSG), SiO₂, porous silicon, poly-Si, polyamide, AUA1 and the material used for functional layers is Poly-Si, SiO₂, etc. The devices manufactured using this process are accelerometer (BOSCH'S) and pressure sensors.[5]

2. SILICON ON INSULATOR TECHNOLOGY (SOI)

The use of SOI technology can simplify the complexity of a fabrication process for free standing structures considerably. The reason is that the buried oxygen layer provides an etch stop for both, front side etching and backside etching. Further on, an excellent isolation to the substrate by a high quality buried oxide b/w functional Si and handle wafer is provided. Due to increased industrial use, the prices for SOI wafers have decreased drastically. Two different methods of fabrication using SOI tech are shown in the diagram. On the left side, a combination of bulk micromachining and surface micromachining is used. An SiO₂ membrane is etched. Finally the exact shape of the shape of the free standing structure is defined by DRIE from the front side and the remaining oxide might be removed. On the rightside, only processing from one side is used. However, it is not possible to structure the sacrificed layer as there are several layout restrictions.[4]

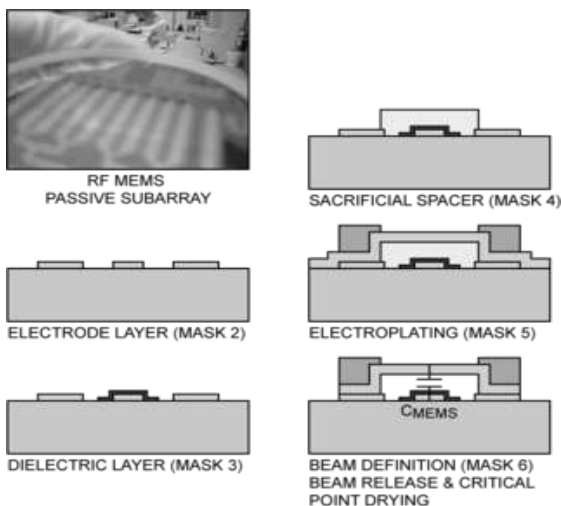


Fig1: fabrication of MEMS

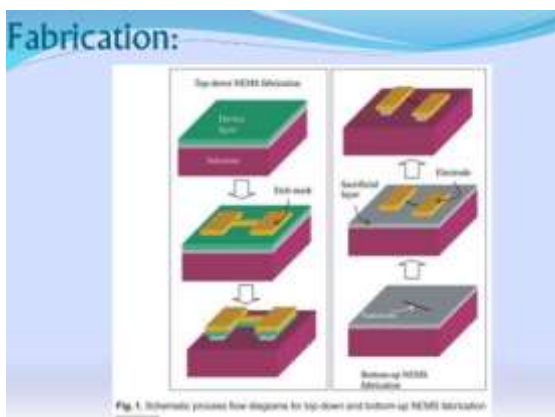


Fig 2: Fabrication.

3. LIGA

LIGA (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 concept for MEMS/Microsystem. In classical LIGA concept, X-ray lithography is used which provides a large depth of focus and allows the definition of very thick resist patterns (up to 100 μm) LIGA technology is especially elements with high aspect ratio.[6]

Primarily the LIGA-process provides high aspect ratio micro structures in polymers. Via electroplating these structures can be replicated in metals like gold, nickel, magnetic nickel-iron alloys or copper. Even replications in ceramics are possible. An industrial low cost production of micro structures is possible when a nickel tool is fabricated for hot embossing or injection moulding.

The main characteristics of LIGA-structures are:

- i. large layout freedom in the mask geometry
- ii. high aspect ratios of up to >100 achievable
- iii. parallel side walls with flank angle very close to 90° (deviation: about 1 μm for 1 mm high structures)
- iv. smooth side walls (R_a in the 10 nm range) suitable e.g. for optical micro mirrors
- v. lateral precision in the few micrometer range over distances of several centimeters
- vi. structural details on side walls in the 30 nm range possible
- vii. different side wall angles via double exposure possible.

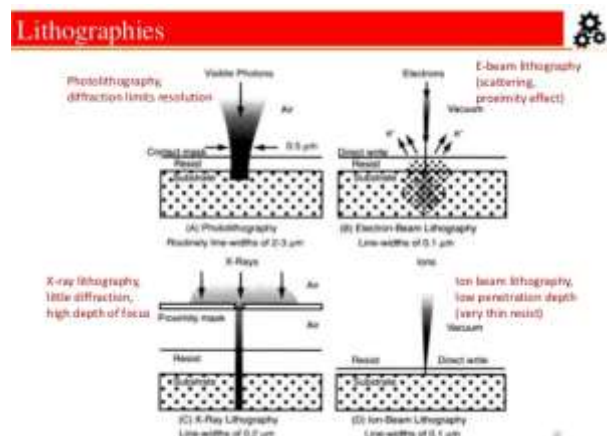


Fig 3: Lithographies

4. NEMS/MEMS Applications

- Airbag Accelerometer
- SUV Gyroscopes
- More inertial MEMS for automation
- Automotive pressure sensors

- Consumer products
- Printing, ink jet devices
- MEMS in safety
- RF-MEMS
- Control systems
- Energy Devices
- Military
- Drug delivery

NEMS applications are visualised in fields like sensing displays, portable power generation, energy harvesting, drug delivery.[10] Integrated piezoelectric resistive detection devices, nano-resonators are also some examples. Applications have either already reached the market or are available as research prototypes comprise ultrasharp tips for atomic force microscopy. Future applications of NEMS that would be economically most interesting are the ones that are the ones that are most hard to be commercialized. Applications combining biology and nanotechnology seem to be the most appealing.[8]

Possible applications of nano motors might be nano fluidic pumps for biochips or sensors. The fields of applications are not yet fully explored but first studies on cell trapping in 3D nano confined objects and self-organizing nano particles are underway. Recent studies in 3D sculpturing are on corner lithography for advanced probing and ultimately sharp probe tips.

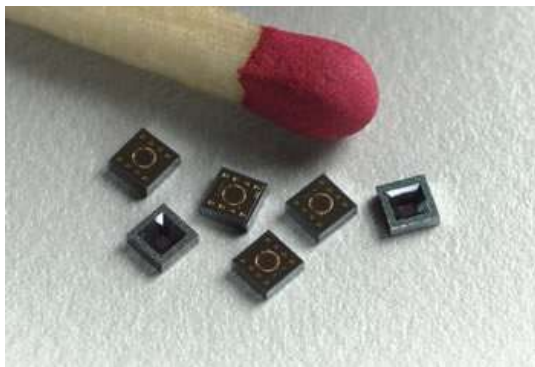


Fig 4: MEMS chips/components.

5. CONCLUSION

NEMS/MEMS is another part of nanofabrication. Nano-Electro Mechanical Systems/ Micro-Electro Mechanical Systems is a system that is quickly making the size of the electronic devices component NEMS/MEMS is based on the addition of mechanics or mechanical to an electronic chip gives a tremendous boost to functionality and performance well beyond one might expect at first glance. The fabrication of microelectronic devices and micro systems has a number

of steps involved in it. The applications include in environment, security, energy etc. Various other applications include portable power batteries, rechargeable batteries and solar storage. Modern Si based MEMS technology uses full available range of ways provided by this field. [7]

However, varied and special processes are required to meet the specific demands of 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 considerable development is the SOI technology, which not only simplifies the fabrication process but also decreases the cost. 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 Systems/ Micro-Electro Mechanical Systems is a system that is quickly making the size of the electronic devices component NEMS/MEMS is based on the addition of mechanics or mechanical to an electronic chip gives a tremendous boost to functionality and performance well beyond one might expect at first glance. The fabrication of microelectronic devices and micro systems has a number of steps involved in it. The applications include in environment, security, energy etc. Various other applications include portable power batteries, rechargeable batteries and solar storage.

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