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Mems Technology

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Abstract

"Micromechatronic is the synergistic integration of microelectromechanical systems, electronic technologies and precision mechatronics with high added value."This field is the study of small mechanical devices and systems .they range in size from a few microns to a few millimeters. This field is called by a wide variety of names in different parts of the world: micro electro mechanical systems (MEMS), micromechanics, Microsystems technology (MST), micro machines .this field which encompasses all aspects of science and technology, is involved with things one smaller scale. Creative people from all technical disciplines have important contributions to make. A world now occupied by an explosive new technology known as MEMS (Micro Electro Mechanical systems).

Keywords: Electrostatics, Electromechanics, MEMS, pull-in voltage

1. INTRODUCTION

Microelectromechanical systems (MEMS) are small integrated devices or systems that combine electrical and mechanical components. They range in size from the sub micrometer level to the millimetre level and there can be any number, from a few to millions, in a particular system. MEMS extend the fabrication techniques developed for the integrated circuit industry to add mechanical elements such as beams, gears, diaphragms, and springs to devices.

Examples of MEMS device applications include inkjet-printer cartridges, accelerometer, miniature robots, micro engines, locks inertial sensors micro transmissions, micro mirrors, micro actuator (Mechanisms for activating process control equipment by use of pneumatic, hydraulic, or electronic signals) optical scanners, fluid pumps, and transducer, pressure and flow sensors[1].

Figure 1: MEMS Technology

There has been no shortage of bright ideas in the area of micro sensors, micro actuators, and microelectromechanical devices of all sorts. However, the track record on converting those ideas into commercially successful products has seemed uneven to some, both inside and outside the field. It has taken as much as 15 to 20 years (or more) between early research prototypes and full commercialization for such devices as silicon pressure sensors, accelerometers, ion sensors, and optical displays, somewhat less for some of the passive components such as micro fluidic cells for biological application[2].

2. HISTORY

- 1970s-First academic-type funding of MEMS research (Stanford -Dr. Angell).
- 1982-Dr. Kurt Petersen published "Silicon as a Mechanical Material"
- 1982-1983-First commercially produced MEMS products were released (pressure sensor).
- 1983 -Most major research universities began MEMS
  Programs.
- 1984-5 Fortune 500 companies have MEMS research programs.

The term MEMS first started being used in the 1980's. It is used primarily in the United States and is applied to a broad set of technologies with the goal of miniaturizing systems through the integration of functions into small packages. The fabrication technologies used to create MEMS devices is very broad based. MEM has been identified as one of the most promising technologies for the 21st Century. It has the potential to revolutionize both industrial and consumer products by combining silicon-based microelectronics with micromachining technology.

Around 1982, the term micromachining came into use to designate the fabrication of micromechanical parts for Si micro sensors. The micromechanical parts were fabricated by selectively etching areas of the Si substrate away in order to leave behind the desired geometries. Isotropic etching of Si was developed in the early 1960s for transistor fabrication. Anisotropic etching of Si then came about in 1967[3].

Prior to 1987, these micromechanical structures were limited in motion. During 1987-1988, a turning point was reached in micromachining when, for the first time, techniques for integrated fabrication of mechanisms on Si were demonstrated[2].

3. SYSTEM DEVELOPMENT

3.1 MEMS description

MEMS technology can be implemented using a number of different materials and manufacturing techniques; the choice of which will depend on the device being created and the market sector in which it has to operate. Materials for MEMS manufacturing are:

Silicon

The economies of scale, ready availability of cheap high-quality materials and ability to incorporate electronic functionality make silicon attractive for a wide variety of MEMS applications.

Polymers

Even though the electronics industry provides an economy of scale for the silicon industry, crystalline silicon is still a complex and relatively expensive material to produce.

Metals

Metals can also be used to create MEMS elements. While metals do not have some of the advantages displayed by silicon in terms of mechanical properties, when used within their limitations, metals can exhibit very high degrees of reliability[4].

3.2 MEMS Process

Same as the process steps used for making conventional electronic circuits

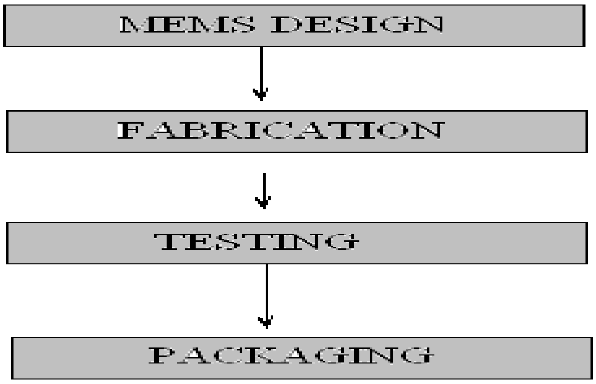

Figure 2: MEMS process

3.3 MEMS design

There are three basic building blocks in MEMS technology, which are, Deposition, Lithography and Etching.

Deposition processes

One of the basic building blocks in MEMS processing is the ability to deposit thin films of material. In this text we assume a thin film to have a thickness anywhere between a few nanometres to about 100 micrometer

MEMS deposition technology can be classified in two groups:

Chemical vapour déposition (cvd)

In this process, the substrate is placed inside a reactor to which a number of gases are supplied. The fundamental principle of the process is that a chemical reaction takes place between the source gases. The two most important CVD technologies in MEMS are the Low Pressure CVD (LPCVD) and Plasma Enhanced CVD (PECVD).

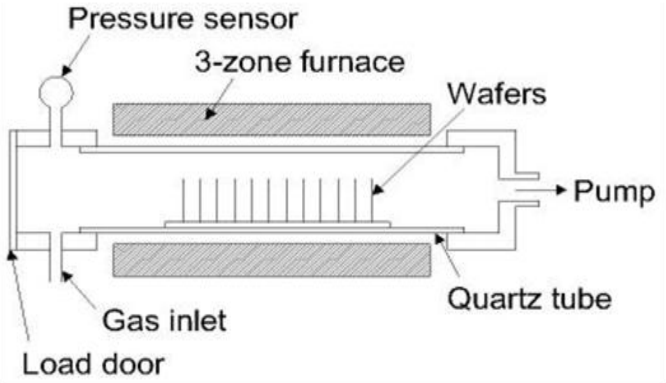

Figure 3: Typical hot-wall LPCVD reactor.

Electrodeposition

This process is also known as "electroplating" and is typically restricted to electrically conductive materials. There are basically two technologies for plating: Electroplating and Electroless plating. In the electroplating process the substrate is placed in a liquid solution (electrolyte).

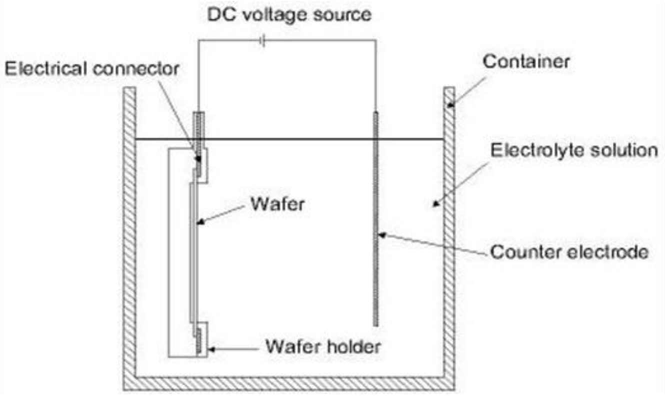

Figure 4:Typical setup for Electrodeposition

Epitaxy

This technology is quite similar to what happens in CVD processes, however, if the substrate is an ordered semiconductor crystal (i.e. silicon, gallium arsenide),it is possible with this process to continue building on the substrate with the same crystallographic orientation with the substrate acting as a seed for the deposition.

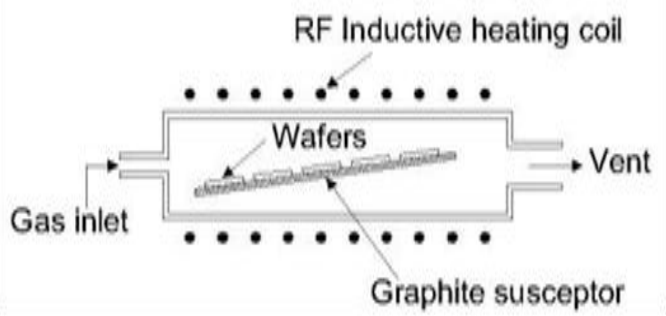

Figure 5: Typical cold-wall vapour phase epitaxial reactor.

Thermal oxidation

This is one of the most basic deposition technologies. It is simply oxidation of the substrate surface in an oxygen rich atmosphere. The temperature is raised to

800° C-1100° C to speed up the process. This is also the only deposition technology which actually consumes some of the substrate as it proceeds[5].

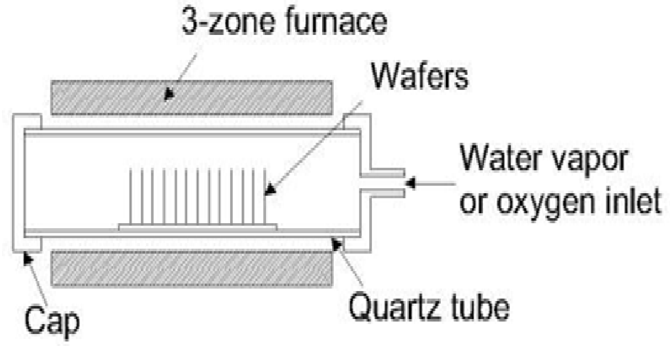

Figure 6: Typical wafer oxidation furnaces

Physical vapor deposition (pvd)

PVD covers a number of deposition technologies in which material is released from a source and transferred to the substrate. The two most important technologies are evaporation and sputtering.[3]

Evaporation

In evaporation the substrate is placed inside a vacuum chamber, in which a block (source) of the material to be deposited is also located. The source material is then heated to the point where it starts to boil and evaporate.

Sputtering

Sputtering is a technology in which the material is released from the source at much lower temperature than evaporation. The substrate is placed in a vacuum chamber with the source material, named a target, and an inert gas (such as argon) is introduced at low pressure.

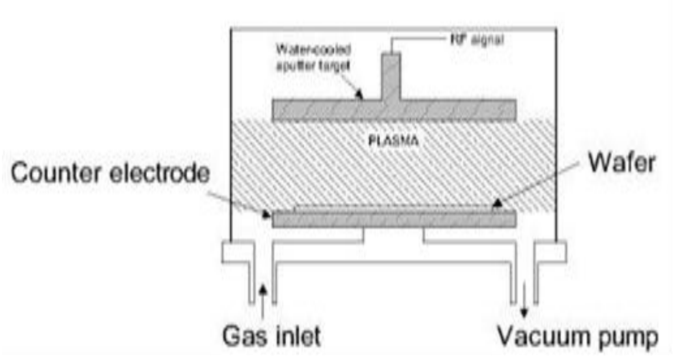

Figure 7: Typical RF sputtering system

Lithography process

Pattern Transfer

Lithography in the MEMS context is typically the transfer of a pattern to a photosensitive material by selective exposure to a radiation source such as light. A photosensitive material is a material that experiences a change in its physical properties when exposed to a radiation source. If we selectively expose a photosensitive material to radiation (e.g. by masking some of the radiation) the pattern of the radiation on the material is transferred to the material exposed, as the properties of the exposed and unexposed regions differs.

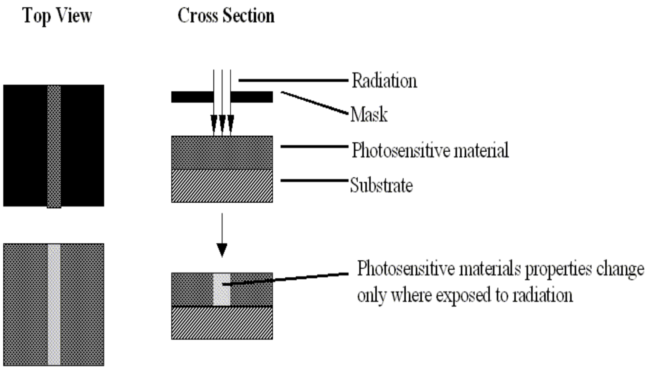

Figure 8: Transfer of a pattern to a photosensitive material.

In lithography for micromachining, the photosensitive material used is typically a photo resist. When resist is exposed to a radiation source of a specific a wavelength, the chemical resistance of the resist to developer solution changes.

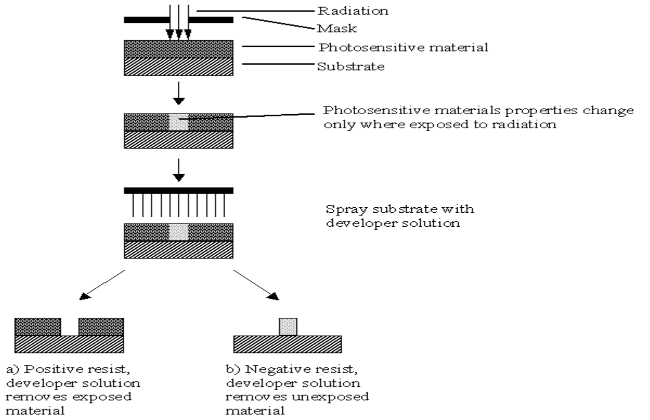

Figure 9:Pattern definition in positive resist & negative resist.

Lithography is the principal mechanism for pattern definition in micromachining. Photosensitive compounds are primarily organic.

Alignment

Alignment marks are included in other patterns, as the original alignment marks may be obliterated as processing progresses. It is important for each alignment mark on the wafer to be labelled so it may be identified, and for each pattern to specify the alignment mark to which it should be aligned.

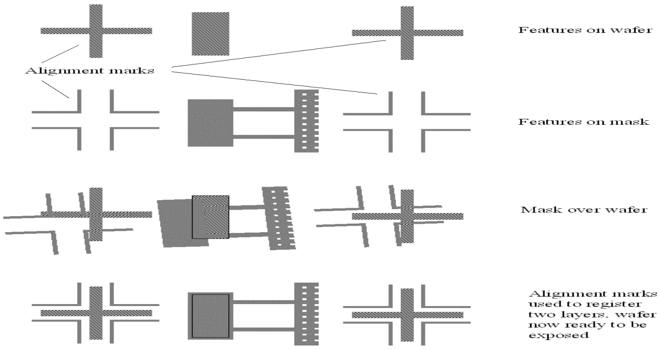

Figure 10:Use of alignment marks to register subsequent layers

Exposure

The exposure parameters required in order to achieve accurate pattern transfer from the mask to the photosensitive layer depend primarily on the wavelength of the radiation source and the dose required to achieve the desired properties change of the photo resist. Different photo resists exhibit different sensitivities to different wavelengths[1].

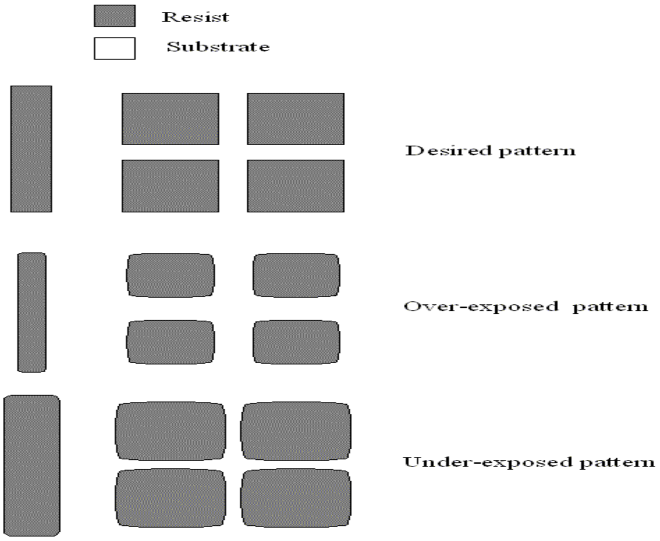

Figure 11: Over and under-exposure of positive resist.

Etching process

In order to form a functional MEMS structure on a substrate, it is necessary to etch the thin films previously deposited and/or the substrate itself. In general, there are two classes of etching processes:

Wet etching

This is the simplest etching technology. All it requires is a container with a liquid solution that will dissolve the material in question. Unfortunately, there are complications since usually a mask is desired to selectively etch the material. One must find a mask that will not dissolve or at least etches much slower than the material to be patterned. Secondly, some single crystal materials, such as silicon, exhibit anisotropic etching in certain chemicals. Anisotropic etching in contrast to isotropic etching means different etches rates in different directions in the material.

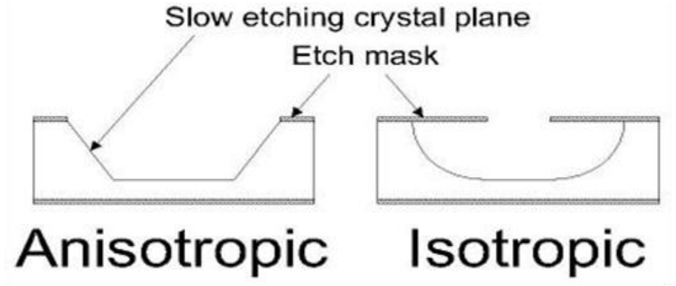

Figure 12: Anisotropic and isotropic wet etching.

Dry etching

The dry etching technology can split in three separate classes called reactive ion etching (RIE), sputter etching, and vapour phase etching. In RIE, the substrate is placed inside a reactor in which several gases are introduced. Plasma is struck in the gas mixture using an RF power source, breaking the gas molecules into ions. The ion is accelerated towards, and reacts at, the surface of the material being etched, forming another gaseous material.

By changing the balance it is possible to influence the anisotropy of the etching, since the chemical part is isotropic and the physical part highly anisotropic the combination can form sidewalls that have shapes from rounded to vertical.

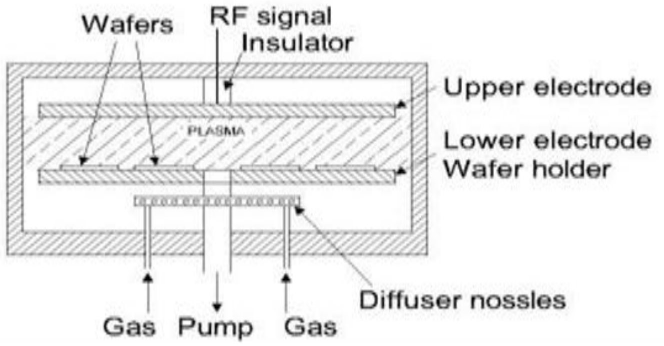

Figure 13: Typical parallel-plate reactive ion etching system.

3.4 Fabrication technologies

The three characteristic features of MEMS fabrication technologies are miniaturization, multiplicity, and microelectronics. Miniaturization enables the production of compact, quick-response devices. Multiplicity refers to the batch fabrication inherent in semiconductor processing, which allows thousands or millions of components to be easily and concurrently fabricated.

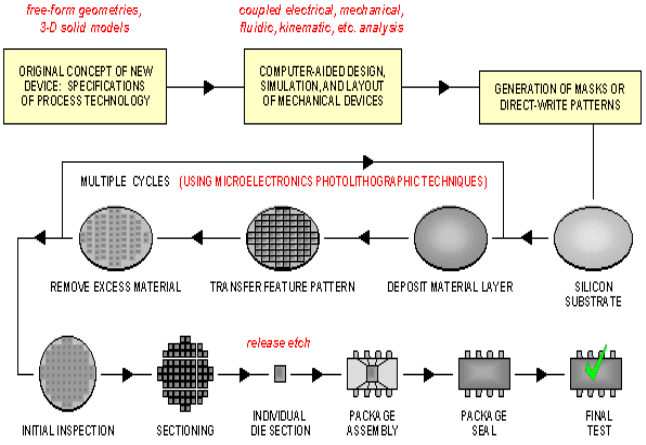

Figure 14: Microfabrication

Furthermore, micro fabrication provides an opportunity for integration of mechanical systems with electronics to develop high-performance closed-loop-controlled MEMS. [3]

3.5 Packaging

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. Currently almost all MEMS and Nano development efforts must develop a new and specialized package for each new device [4].

4. CONCLUSIONS

4.1 Conclusion

The automotive industry, motivated by the need for more efficient safety systems and the desire for enhanced performance, is the largest consumer of MEMS-based technology. In addition to accelerometers and gyroscopes, micro-sized tire pressure systems are now standard issues in new vehicles, putting MEMS pressure sensors in high demand. The medical, wireless technology, biotechnology, computer, automotive and aerospace industries are only a few that will benefit greatly from MEMS.

- MEMS promises to revolutionize nearly every product category by bringing together silicon-based microelectronics with micromachining technology, making possible the realization of complete systems-on-a-chip.
- MEMS will be the indispensable factor for advancing technology in the 21st century and it promises to create entirely new categories of products.

4.2 Advantages

MEMS are devices that integrate mechanical elements, sensors, actuators, and electronics on a common silicon substrate. Many typically have dimensions in the 1 micron to 100 micron range. They have proven to be a key enabling technology of developments in areas such as transportation, telecommunications and health care, but the range of MEMS applications covers nearly every field. The most significant advantage of MEMS is their ability to communicate easily with electrical elements in semiconductor chips. Other advantages include small size, lower power consumption, lower cost, increased reliability and higher precision. [3]

4.3 Future Scope

Future 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. Future MEMS products will demand higher levels of electrical-mechanical integration and more intimate interaction with the physical world. The high up-front investment costs for large-volume commercialization of MEMS will likely limit the initial involvement to larger companies in the IC industry[5].

4.4 Applications

Accelerometers

Accelerometers are acceleration sensors. An inertial mass suspended by springs is acted upon by acceleration forces that cause the mass to be deflected from its initial position. This deflection is converted to an electrical signal, which appears at the sensor output.Accelerometers in consumer electronics devices such as game controllers, personal media players / cell phones[5].

iPod Touch: When the technology become sensitive. MEMS-based sensors are ideal for a wide array of applications in consumer, communication, automotive and industrial markets.

Figure 15: iPod Touch

Micro engines:

A three-level polysilicon micromachining process has enabled the fabrication of devices with increased degrees of complexity. The process includes three movable levels of polysilicon, each separated by a sacrificial oxide layer, plus a stationary level.

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.

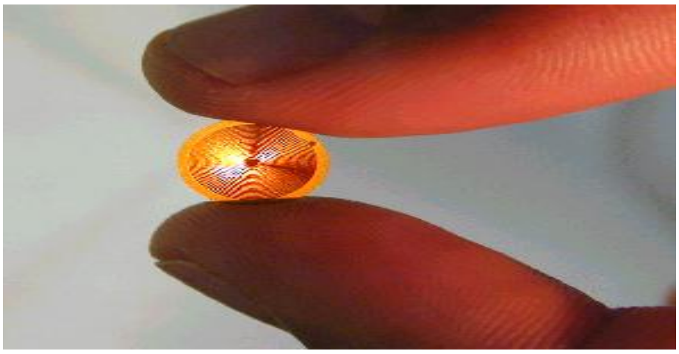

Figure 16: Inertial sensors

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