MICRO-ELECTRO-MECHANICAL-SYSTEMS (MEMS)

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Summary

MEMS (Micro-Electro-Mechanical-Systems), named in 1984, have achieved enormous development not only in R&D but also in industry. In this chapter, MEMS are briefly introduced from concept, and main technology as well as current applications.

1. Definition

Micro-electro-mechanical-systems (MEMS) are integrated devices or systems on micro scale that combine electrical and mechanical components together by employing IC batch fabrication, which can sense, control, and activate mechanical processes to achieve complicate functions on informatics.

2. Main Technology in MEMS

IC fabrication technology is the primary enabling technology for MEMS, which involves film growth, doping, lithography, etching, dicing, and packaging. Based on such technology, MEMS developed their technology— so-called bulk micromachining, surface micromachining, and even Nano-electro-mechanical- systems (NEMS).

2.1. Bulk Micromachining

In bulk micromachining, bulk of the Si substrate is etched away to leave the desired micromechanical elements. Bulk micromachining of Si uses wet- and dry-etching techniques in conjunction with wafer bonding and chemical-mechanical-polishing (CMP) to sculpt micromechanical devices from the Si substrate. It is possible to form structures with few hundreds of microns in depth.

2.1.1. Wet Etching Techniques

Wet etching consists in a selective removal of material by dipping a substrate into a solution that can dissolve it. Due to the chemical nature of this etching process, a good selectivity can often be obtained. It is relatively simple and inexpensive, and is well suited for applications which do not require much complexity, and which are low cost.

Wet etching can be divided into anisotropic etching and isotropic etching. Anisotropic etchants, such as KOH, TMAH, EPW, are widely used. These preferentially etch single crystal Si along given crystal planes, while isotropic etchants, such as HNA, are not sensitive to the crystal orientations.

Etch masks and etch-stop techniques that can be used with Si anisotropic etchants to selectively prevent regions of Si from being etched. Good etch masks are provided by SiO2 and Si3N4, and some metallic thin films such as Cr and Au (gold).

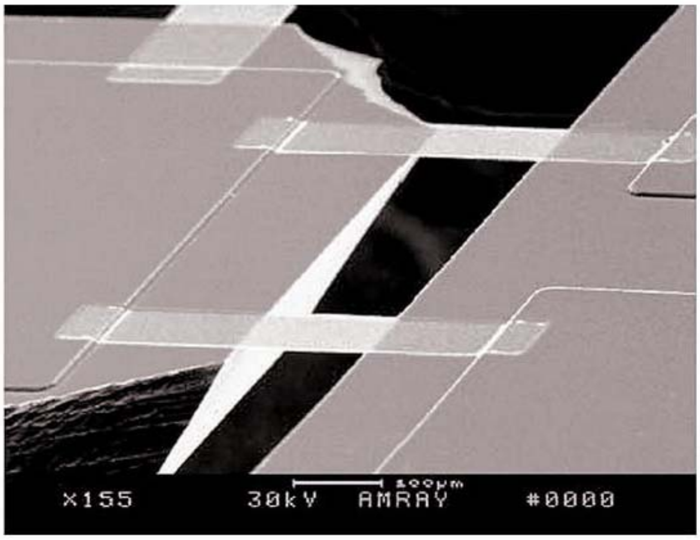

Figure 1. Micro beam fabricated by etch-stop anisotropic etching

2.1.2. Dry Etching Techniques:

A drawback of wet anisotropic etching is that the microstructure geometry is defined by the internal crystalline structure of the substrate. Reactive gas plasmas can perform deep anisotropic dry etching of Si wafers, up to a depth of a few hundred microns, while maintaining smooth vertical sidewall profiles.

In chemical part of reactive ion etching (RIE), plasma is used to break the reactor gas molecules into ions. The ions are accelerated towards, and react with the surface of the material, forming another gaseous material. There is also a physical part which is similar to the sputtering deposition process. By changing the balance between isotropic chemical and highly anisotropic physical etching, it is possible to form sidewalls that have shapes from rounded to vertical.

A special subclass of RIE which continues to grow rapidly currently is deep RIE (DRIE). In this process, etch depths of hundreds of microns can be achieved with almost vertical sidewalls. In this process, two different gas compositions are attended in the reactor. The C4F8 creates a polymer on the surface of the substrate, and the second gas composition (SF6 and O2) etches the substrate. The polymer is immediately sputtered away by the physical part of the etching, but only on the horizontal surfaces and not the sidewalls. Since the polymer only dissolves very slowly in the chemical part of the etching, it builds up on the sidewalls and protects them from etching. As a result, etching aspect ratios of 50 to 1 can be achieved. The process can easily be used to etch completely through a silicon substrate, and etch rates are 3-6 times higher than wet etching.

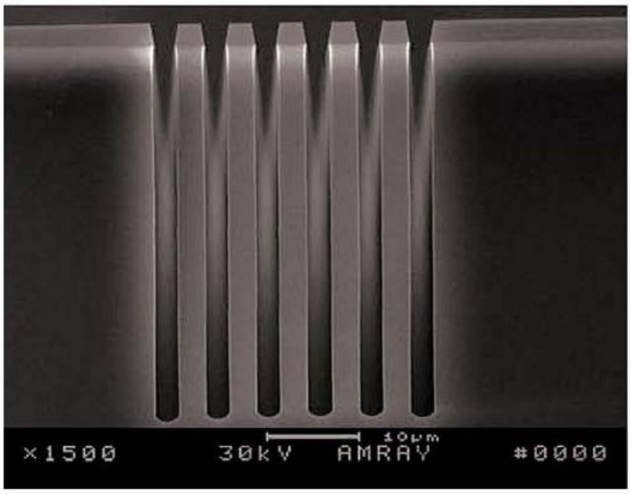

Figure 2. Micro trenches fabricated by DRIE

Xenon difluoride (XeF2) etching is a dry vapor phase isotropic etch for silicon, which is primarily used for releasing metal and dielectric structures by undercutting silicon. Its etch selectivity to silicon is very high, allowing it to work with photoresist, SiO2, silicon nitride, and various metals for masking.

2.1.3. Wafer Bonding Techniques

Wafer bonding can be used to join any two flat mirror-polished clean surfaces with various crystallographic orientations and lattice constants. Typically temperature, force and/or an intermediate layer are used to facilitate bonding. Silicon direct, anodic, eutectic and thermocompression bonding are common, while temporary bonding is increasingly being used with ultrathin wafers.

Anodic bonding joins a silicon wafer with a glass wafer that contains a high concentration of alkali metal oxides (often Pyrex). At elevated temperature (200-500°C), a high-voltage electric field is applied, which dissociates the oxides and drives the metal ions into the glass. The process creates an oxygen-rich layer at the silicon-glass interface. The electric field forces the oxygen ions to the silicon surface, resulting in a strong, irreversible bond.

Eutectic bonds are used when a hermetic or vacuum seal is required, generally for sensors. It uses an intermediate bonding material that forms a eutectic alloy at a specific temperature, such as gold-silicon, gold-tin, or lead-silicon. The metal is usually deposited by plating, while the silicon source can be the wafer or CVD. Solid-liquid mixing occurs at temperatures slightly above the eutectic point and high contact force (40 kN). A hermetic solid seal forms upon cooling.

Adhesive bonding uses photoresist, spin-on glasses or polymers to deposit a planarizing material between two wafers. Such materials can be annealed at low temperature to provide a low-stress wafer stack.

Thermocompression bonding uses glass beads suspended in a carrier paste (glass frit) and deposited onto a substrate either in a blanket form or patterned using screen printing. After deposition, the solvents are removed by degassing, and then heat and pressure are applied to make a hermetic seal.

Temporary bonding is typically accomplished using spin-on wax or dry adhesives to bond a wafer to a carrier face down while the backside is grinded and polished. Later, the wax is melted, or the polymer adhesive is exposed to UV radiation to automatically release the bond. Temporary bonding is needed for ultrathin devices used in smart cards and other portable applications.

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Biographical Sketch

Songlin Feng graduated from Wuhan University and got his Bachelor degree in 1983, he got his D.E.A. and Ph. D on material sciences from Paris VII University in 1987 an in 1990 respectively. He is an active researcher in the frontier of information technologies. On the research of defect in superlattices, his colleagues and he have applied the deep level transient spectroscopy (DLTS) to the investigation of point defects in superlattices; they have determined the relation between the characteristics of deep level in superlattices, in bulk materials which composed the superlattices and the energy band offset of superlattices. With these works, in 1998, he won the unique foreign students Bourse of chancellor of PARIS University in Science. On the research of self-assembled quantum dots, he is one of the pioneer researcher in China, He lead his group to develop a method to enhance remarkably the luminescence of self-assembly quantum dots materials, he has successfully applied the DLTS to the investigation of Quantum dots and determined strain barrier of interface and the dual growth mode, the photoluminescence characteristics of their 1.3μm quantum dot material is one of the best one at that time. His colleagues and he won first grade Awards for Natural Science of Chinese Academy of Sciences and second grade National Awards for Natural Science, he won also Shanghai Peony Awards for Natural Science. Since 2001, He was transferred to Shanghai Institute of metallurgy by Chinese Academy of Sciences (Actually Shanghai Institute of Microsystem and Information technology), and he start to lead the research of wireless sensor network and nano-devices, several wireless sensor network system for different application have been developed and installed since then. His group won first grade Shanghai Awards for Science and Technology Progress. He has published more then 120 papers in international journals and won several national and ministerial natural science prices. He is expert member of several national scientific bodies a principle investigator of the projects.