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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Micro-electromechanical devices –
Part 1: Terms and definitions

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques –
Partie 1: Termes et définitions

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 1: Terms and definitions

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International Standard IEC 62047-1 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition published in 2005. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) removal of ten terms;
b) revision of twelve terms;
c) addition of sixteen new terms.

The text of this standard is based on the following documents:

FDIS	Report on voting
47F/232/FDIS	47F/238/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 1: Terms and definitions

1 Scope

This part of IEC 62047 defines terms for micro-electromechanical devices including the process of production of such devices.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1 General terms and definitions

2.1.1
micro-electromechanical device
microsized device, in which sensors, actuators, transducers, resonators, oscillators, mechanical components and/or electric circuits are integrated

Note 1 to entry: Related technologies are extremely diverse from fundamental technologies such as design, material, processing, functional element, system control, energy supply, bonding and assembly, electric circuit, and evaluation to basic science such as micro-science and engineering as well as thermodynamics and tribology in a micro-scale. If the devices constitute a system, it is sometimes called as MEMS which is an acronym standing for "micro-electromechanical systems"

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2.1.2
MST
microsystem technology
technology to realize microelectrical, optical and machinery systems and even their components by using micromachining

Note 1 to entry: The term MST is mostly used in Europe.

Note 2 to entry: This note applies to the French language only.

2.1.3
micromachine

2.1.3.1
micromachine, <device>
miniaturized device, the components of which are several millimetres or smaller in size

Note 1 to entry: Various functional device (such as a sensor that utilizes the micromachine technology) is included.

2.1.3.2
micromachine, <system>
microsystem that consists of an integration of micromachine devices

Note 1 to entry: A molecular machine called a nanomachine is included.

2.2 Terms and definitions relating to science and engineering

2.2.1

micro-science and engineering

science and engineering for the microscopic world of MEMS

Note 1 to entry: When mechanical systems are miniaturized, various physical parameters change. Two cases prevail: 1) these changes can be predicted by extrapolating the changes of the macro-world, and 2) the peculiarity of the microscopic world becomes apparent and extrapolation is not possible. In the latter case, it is necessary to establish new theoretical and empirical equations for the explanation of phenomena in the microscopic world. Moreover, new methods of analysis and synthesis to deal with engineering problems must be developed. Materials science, fluid dynamics, thermodynamics, tribology, control engineering, and kinematics can be systematized as micro-sciences and engineering supporting micromechatronics.

2.2.2

scale effect

change in effect on the object's behaviour or properties caused by the change in the object's dimension

Note 1 to entry: The volume of an object is proportional to the third power of its dimension, while the surface area is proportional to the second power. As a result, the effect of surface force becomes larger than that of the body force in the microscopic world. For example, the dominant force in the motion of a microscopic object is not the inertial force but the electrostatic force or viscous force. Material properties of microscopic objects are also affected by the internal material structure and surface, and, as a result, characteristic values are sometimes different from those of bulks. Frictional properties in the microscopic world also differ from those in the macroscopic world. Therefore, those effects must be considered carefully while designing a micromachine.

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2.2.3

microtribology

tribology for the microscopic world

Note 1 to entry: Tribology deals with friction and wear in the macroscopic world. On the other hand, when the dimensions of components such as those in micromachines become extremely small, surface force and viscous force become dominant instead of gravity and inertial force. According to Coulomb's law of friction, frictional force is proportional to the normal load. In the micromachine environment, because of the reaction between surface forces, a large frictional force occurs that would be inconceivable in an ordinary scale environment. Also a very small quantity of abrasion that would not be a problem in an ordinary scale environment can fatally damage a micromachine. Microtribology research seeks to reduce frictional forces and to discover conditions that are free of friction, even on an atomic level. In this research, observation is made of phenomena that occur with friction surfaces or solid surfaces at from angstrom to nanometer resolution, and analysis of interaction on an atomic level is performed. These approaches are expected to be applied in solving problems in tribology for the ordinary scale environment as well as for the micromachine environment.

2.2.4

biomimetics

creating functions that imitate the motions or the mechanisms of organisms

Note 1 to entry: In devising microscopic mechanisms suitable for micromachines, the mechanisms and structures of organisms that have survived severe natural selection may serve as good examples to imitate. One example is the microscopic three-dimensional structures that were modelled on the exoskeletons and elastic coupling systems of insects. In exoskeletons, a hard epidermis is coupled with an elastic body, and all movable parts use the deformation of the elastic body to move. The use of elastic deformation would be advantageous in the microscopic world to avoid friction. Also, the exoskeleton structure equates to a closed link mechanism in kinematics and has the characteristic that some actuator movement can be transmitted to multiple links.

2.2.5

self-organization

organization of a system without any external manipulation or control, where a nonequilibrium structure emerges spontaneously due to the collective interactions among a number of simple microscopic objects or phenomena

2.2.6
electro wetting on dielectric
EWOD
wetting of a substrate controlled by the voltage between a droplet and the substrate covered with a dielectric film

Note 1 to entry: The contact angle of a liquid droplet, typically an electrolyte, on a substrate can be electrically controlled because the solid-liquid surface interfacial tension can be controlled with the energy stored in the electric double layer which works as capacitor. Covering the electrode with a dielectric material of determined thickness, the capacitance can be determined with ease. Electro wetting on dielectric is used typically in microfluidic devices.

Note 2 to entry: This note applies to the French language only.

2.2.7
stiction
phenomenon that a moving microstructure is stuck to another structure or substrate by adhesion forces

Note 1 to entry: When structures become smaller, stiction appears significant due to the scale effect that surface forces predominate over body forces. Stiction frequently occurs in the MEMS fabrication process when small structures are released during wet etching processes due to the surface tension of liquid. Representative adhesion forces to cause stiction are van der Waals force, electrostatic force, and surface tension of liquid between structures.

2.3 Terms and definitions relating to materials science

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2.3.1
silicon-on-insulator
SOI
structure composed of an insulator and a thin layer of silicon on it

Note 1 to entry: Sapphire (as in SOS), glass (as in SOG), silicon dioxide, silicon nitride, or even an insulating form of silicon itself is used as an insulator.

Note 2 to entry: This note applies to the French language only.

2.4 Terms and definitions relating to functional element

2.4.1
actuator, <micro-electromechanical devices>
mechanical device that converts non-kinetic energy into kinetic energy to perform mechanical work

2.4.2
microactuator
actuator produced by micromachining

Note 1 to entry: For a micromachine to perform mechanical work, the microactuator is indispensable as a basic component. Major examples are the electrostatic actuator prepared by silicon process, the piezoelectric actuator that utilizes functional materials like lead zirconate titanate (PZT), the pneumatic rubber-actuator, and so on. Many other actuators based on various energy conversion principles have been investigated and developed. However, the energy conversion efficiency of all these actuators deteriorates as their size is reduced. Therefore, the motion mechanisms of organisms such as the deformation of protein molecules, the flagellar movement of bacteria, and muscle contraction are being utilized to develop special new actuators for micromachines.

Note 2 to entry: Micro-electrostatic actuators are actuated by a micro-electrostatic field, magnetic microactuators are driven by a micromagnetic field, and piezoelectric microactuators depend on a microstress field to convey motion and power.

2.4.3
light-driven actuator
actuator that uses light as a control signal or an energy source or both

Note 1 to entry: Since the development of photostrictive materials, various light driven actuators have been proposed. These actuators have simple structures and can be driven by wireless means. A motor is proposed that utilizes the spin realignment effect, in which a magnetic material absorbs light and the resulting heat changes the direction of magnetization reversibly. Actuators utilizing thermal expansion, and exploiting polymer photochemical reactions, are also being studied.

2.4.4
piezoelectric actuator
actuator that uses piezoelectric material

Note 1 to entry: Piezoelectric actuators are classified into the single-plate, bimorph, and stacked types, and the popular material is lead zirconate titanate (PZT). The features are: 1) quick response, 2) large output force per volume, 3) ease of miniaturization because of the simple structure, 4) narrow displacement range for easier microdisplacement control, and 5) high efficiency of energy conversion. Piezoelectric actuators are used for the actuators for micromachines, such as ultrasonic motor, and vibrator. An applied example is a piezoelectric actuator for a travelling mechanism which moves by the resonance vibration of a piezoelectric bimorph, and a micropositioner piezoelectric actuator which amplifies the displacements of a stacked piezoelectric device by a lever.

2.4.5
shape-memory alloy actuator
actuator that uses shape memory alloy

Note 1 to entry: Shape-memory alloy actuators are compact, light, and produce large forces. These actuators can be driven repeatedly in a heat cycle or can be controlled arbitrarily by switching the electric current through the actuator itself. Lately, attempts have been made to use the alloys to build a servosystem that has an appropriate feedback mechanism and a cooling system, intended for applications where quick response is not necessary Application examples under development are microgrippers for cell manipulation, microvalves for regulating very small amounts of flow and active endoscopes for medical use.

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2.4.6
sol-gel conversion actuator
actuator that uses the transition between the sol (liquid) state and the gel (solid) state

Note 1 to entry: A sol-gel conversion actuator can work in a similar way to living things. For example, if electrodes are put on a small particle of sodium polyacrylate gel in an electrolytic solution and a voltage is applied, the particle repeatedly changes its shape. Sol-gel conversion actuators can be connected in series, sealed in a thin pipe and fitted with multiple legs, to make a microrobot that moves in one direction and that looks like a centipede. Another application being conceived is a crawler microrobot that automatically moves through a thin pipe.

2.4.7
electrostatic actuator
actuator that uses electrostatic force

Note 1 to entry: Since the electrostatic actuator has a simple structure and its output force per weight is increased as the size is reduced, much research is ongoing to apply these characteristics to the actuators of micromachines. Application examples developed so far on an experimental basis include a wobble motor and a film electrostatic actuator.

2.4.8
comb-drive actuator
electrostatic actuator, consisting of a series of parallel fingers, fixed in position, engaged and interleaved with a second, movable set of fingers

Note 1 to entry: The application of an electrostatic charge to the first set of fingers attracts the fingers of the second set, such that they become more fully engaged in the interdigit spaces of the first set. Then the static charge is removed and drained, and the second set of fingers is returned to its home position by micromachined spring tension.

2.4.9

wobble motor

harmonic electrostatic motors

variable-gap electrostatic motor that generates a rolling motion of the rotor on an eccentric stator without slip

Note 1 to entry: Wobble motors consist of a rotor, a stator with electrodes for the generation of electrostatic force, and an insulation film on the rotor or stator surface. The rotor rotates in a reverse direction to the revolution.

The rotation speed, V_{rot} , is given as $V_{rot} = V_{rev} \times (L_{stat} - L_{rot})/ L_{rot}$, where V_{rev} is the revolution speed, L_{stat} is the stator circumference, and L_{rot} is the rotor circumference.

Characteristics of the wobble motor include 1) the ability to easily provide low speed and high torque when the rotor circumference is very close to the stator circumference, 2) no problems of friction or wear because there are no sliding parts, 3) the possibility to be fabricated using diverse materials, and 4) an easily increasable aspect ratio. On the other hand, the revolution of the rotor can cause unnecessary vibration. Production examples include a wobble motor that supports a rotor by a flexible coupling, and a wobble motor fabricated by the integrated circuit process and whose rotor rolls at the fulcrum.

2.4.10

microsensor

device, produced for example by micromachining, and which is used for measuring a physical or chemical quantity by converting it to an electric output

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Note 1 to entry: In micromachines, the first field to be developed and realized was that of the microsensor. Microsensors include mechanical quantity sensors (measuring pressure, acceleration, tactile senses, displacement, etc.), chemical quantity sensors (measuring ions, oxygen, etc.), electric quantity sensors (measuring magnetism, current, etc.), biosensors, and optical sensors. In many microsensors, the detecting section containing the mechanism is integrated with the electronic circuits. The advantages of microsensors are: 1) minimal environmental disruption, 2) the ability to measure local states of small areas, 3) the integration with circuits, and 4) minimal operating power.

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2.4.11

biosensor

sensor that uses organic substances in the device, that is intended for measurement of organism-related subsystems, or that mimics an organism

Note 1 to entry: A typical biosensor consists of a biologically originated specific material such as an enzyme or an antibody that identifies the object of measurement and the device that measures a physical or chemical quantity change related to the identifying reaction. A semiconductor sensor or any of various types of electrode (e.g. ISFET, micro-oxygen electrode, and fluorescence detection optical sensor) prepared by silicon micromachining technology can be used as this device. Biosensors are used for blood analysis systems, glucose sensors, microrobots, and so on.

2.4.12

integrated microprobe

one-piece probe combining a microprobe and a signal processing circuit

Note 1 to entry: The smaller the sensitive part of the sensor, 1) the less interference to the measuring object, 2) the higher the signal-to-noise ratio in the measurement, and 3) the more small-area local data can be obtained. An integrated microprobe is a device consisting of a microprobe prepared by micromachining silicon to an ultra-microscopic needle and incorporating a signal processing circuit. Integrated microprobes made by machining silicon needles to a diameter of from several nanometers to several micrometers and combining them with an impedance conversion circuit, etc., are in actual use as microscopic electrodes for organisms, scanning tunneling microscopes (STMs), and atomic force microscopes (AFMs).

2.4.13

ISFET

ion-sensitive field-effect transistor

semiconductor sensor integrating an ion-sensitive electrode with a field-effect transistor (FET)

Note 1 to entry: In the ion-sensitive electrode section, the membrane voltage changes according to fluctuations in pH or carbon dioxide partial pressure in the blood, for example. As the voltage amplifier, the ISFET uses a FET, a transistor controlling the conductance of the current path (channels) formed by the majority carriers using an electric field perpendicular to the carrier flow. The ISFET is based on silicon micromachining technology integrating a detector and amplifier on a silicon substrate. In addition, an ISFET with mechanical components such as a valve has been developed. The ISFET is used in such fields as medical analysis and environmental instrumentation.

Note 2 to entry: This note applies to the French language only.

2.4.14

accelerometer

measurement transducer that converts an input acceleration to an output (usually an electric signal) that is proportional to the input acceleration

Note 1 to entry: The accelerometer, based on silicon micromachining technology, is typically composed of a soft spring and a mass. The accelerometer senses the displacement of the spring caused by the inertia of the accelerated mass, or detects acceleration from the measurement of the force required to cancel this displacement. Among today's silicon-made sensors, accelerometers hold particular promise as a next-generation product. There are many types of accelerometer such as semiconductor strain gauges, capacitance detectors, electromagnetic servosystems, and electrostatic servosystems. In addition, vibration detection-type accelerometers, which detect changes in resonance frequencies, and piezoelectric effect-type accelerometers, which use the piezoelectric effect, are also under development. Continuing development is aimed at applications in a wide variety of fields, including automobiles, robots, and the space industry.

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[SOURCE: ISO 2041:2009, 4.10, modified – Note 1 to entry has been added.]

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2.4.15

microgyroscope

microscopic sensor for measuring angular velocity

Note 1 to entry: Microgyroscopes are expected to be applied as microrobot attitude sensors. Rotational and vibrational gyroscopes are based on the Coriolis force. Ring laser gyroscopes and optical fibre gyroscopes are based on the Sagnac effect. Among these types of gyroscope, vibrational gyroscopes (the tuning fork- and resonant piece-types) are suitable for miniaturization and are being developed for miniaturized applications.

2.4.16

diaphragm structure

flexible membrane structure that separates space

Note 1 to entry: In a microscopic region, materials such as single-crystal silicon, polysilicon, and so on are used for the diaphragm structure. The structure is commonly fabricated by anisotropic etching. The thickness of the structure can be controlled from several micrometres to several tens of micrometres depending on the application. The structure can be used to detect pressure changes, or to cause displacement. For example, it is used in the pressure-sensitive part of a pressure sensor for automobile engines and silicon microphones. Also, it is used as a membrane to change pressure in microvalves and micropumps.

2.4.17

microcantilever

cantilever produced by micromachining

Note 1 to entry: Microcantilevers are often used in high-resolution microscopes such as the Atomic Force Microscope (AFM).

2.4.18
microchannel

channel produced by micromachining

Note 1 to entry: Microchannels are often used in fluidic devices such as a lab-on-a-chip. The flow in a microchannel is different from that in a macroscopic one, and the formulation of the flow is one of the key issues in micro-science and engineering. A microchannel can be used as an acoustic guide.

2.4.19
micromirror

microsized reflecting mirror that can be actuated to control its reflection angle

2.4.20
scanning mirror

mirror that scans a light beam

Note 1 to entry: Scanning mirrors are developed for laser printers, the scanning parts of optical sensors, the heads for optical disks, displays and so on. An array of scanning mirrors can be fabricated on a silicon wafer with an actuator by micromachining technology. The scanning mirror is expected to be one of the practical applications of micromachine technology.

2.4.21
microswitch

mechanical switch produced by micromachining

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Note 1 to entry: The term “microswitch” is already used in commercially available switches that are produced using conventional techniques.

Note 2 to entry: The main application of a microswitch is that of a microrelay.

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2.4.22
optical switch

optical element to switch optical signals without conversion into electric signals

2.4.23
microgripper

mechanical device that grasps microscopic objects

Note 1 to entry: Microgrippers have two roles. They can be used as tools to assemble micromachines or as the hands of microrobots, etc. In either case, the microgripper has fingers to grasp objects and an actuator to handle them. Compared to a microrobot hand, microgrippers are structurally large but require precise control. As the function of a microgripper is simply to grasp an object, multi-degrees of freedom handling requires the combination of suitable manipulators. Compared to non-contact-type handling using a laser beam, contact-type handling based on a microgripper or similar device gives better attitude control of the object. However, if the object to be handled is below several tens of micrometres in size, the attractive forces between the surfaces of the microgripper fingers and the object handled make manipulation difficult.

2.4.24
micropump

mechanical device that pressurizes and thus transports a small amount of fluid

Note 1 to entry: There are many examples of micropumps mainly fabricated on silicon or glass, for instance, and using micromachining technology to form a diaphragm together with an actuator. Application examples include a diaphragm-type pump with a microscopic check valve driven by a piezoelectric element, and an integrated pump using a thermal expansion actuator along with a microheater. Pumps discharging and sucking fluids by deforming a diaphragm actuated by a stacked piezoelectric actuator can control the rate by changing the frequency of the actuator drive. In addition, pulsation-damping pumps can control the fluid flow with a high accuracy by using a dual pump along with a synchronous buffer pump.

2.4.25
microvalve

mechanical device that controls the flow of fluid in a microscopic channel

Note 1 to entry: Microvalves, which are composed of such components as actuators and diaphragms, made of silicon, etc., control the flow in microscopic channels (narrower than several micrometres). For example, a gas flow control valve is composed of a stacked piezoelectric actuator and a diaphragm. To control high-viscosity fluids such as blood, it is necessary to enlarge the channel and increase the stroke of the valve drive. A mechanism using a shape-memory alloy coil and a bias spring has been developed experimentally for this purpose, as well as a mechanism that alters the channel by an electrostatic, magnetic, or piezoelectric actuator.

2.4.26
CMOS MEMS

integrated MEMS device, in which complementary metal–oxide–semiconductor (CMOS) signal-processing circuits and MEMS elements are formed on the same silicon substrate

Note 1 to entry: CMOS MEMS is one form of the MEMS device that integrates CMOS signal-processing circuits and MEMS elements. Usually, the CMOS MEMS is fabricated by performing a MEMS process on the CMOS preformed wafer, and therefore it is necessary that the MEMS process does not damage the CMOS circuit.

2.4.27
micro fuel cell

micromachined device converting the chemical energy of a fuel directly into electricity by an electrochemical process

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2.4.28
photoelectric transducer

transducer that generates an electric output corresponding to the incident light

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Note 1 to entry: Photoelectric transducers are divided into two groups according to their applications: 1) a photodetector that handles light signals, and 2) a photovoltaic power system such as a solar battery that responds to light energy. In the former case, sensitivity and response speed are important, while in the latter case, energy conversion efficiency is important. Classified by their operating principles, photoelectric transducers can be divided into a photo-conductive type, typified by photo-conductive cells and image pick-up tubes, and a photovoltaic type, typified by photodiodes and solar batteries.

2.5 Terms and definitions relating to machining technology

2.5.1
micromachining

machining process used to realize microscopic structures

Note 1 to entry: Micromachining is a general term including wide-ranging machining technologies for microscopic structures. Depending on the contexts, however, the term can be used with more specific meanings, as follows:

a) machining processes derived from the semiconductor manufacturing technologies, used to realize microscopic structures for the production of micromachines or MEMS,

b) machining processes used to realize microscopic structures of micromachines or MEMS, applying conventional machining technologies such as cutting and grinding.

2.5.2
silicon process

processing technologies for silicon

Note 1 to entry: While the silicon process is broadly divided into surface micromachining and bulk micromachining, most of the technologies involved are the same. The silicon process starts with layer work and continues to a patterning process, microassembly, annealing, and packaging. Many technologies such as deposition, diffusion, chemical corrosion, and lithography are combined as working technologies. A feature of the silicon process is the ability to use batch processing on large wafers for the mass-fabrication of components.

2.5.3

thick film technology

technology that forms thick films on a substrate

Note 1 to entry: A thick film is a film of a thickness of about 5 µm or greater formed by ink-paste coating or spray-printing and subsequent baking. These films are applied in the manufacture of piezoelectric or magnetic actuators.

2.5.4

thin film technology

technology that forms thin films on a substrate

Note 1 to entry: A thin film is a film formed on a substrate by means of vacuum deposition or ion sputtering, or any other processes. The film thickness ranges from a layer of single atoms or molecules, to 5 µm thickness. Usually the term refers to films of a thickness of 1 µm or less. A thin film can change properties such as colour, reflectivity, and friction coefficient of the substrate, while the shape of the substrate is left practically unchanged. Phenomena such as optical interference and surface diffusion are noticeably affected by the formation of thin films. Thin film formations usually take a nonequilibrium, heterogeneous nuclear formation step, which brings on structural properties different from those of bulk materials produced under ordinary equilibrium conditions. In one application, thin film technology combined with etching improved the degree of integration of a thermal printer head that was conventionally manufactured by thick film technology.

2.5.5

bulk micromachining

micromachining that removes a part of the substrate

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Note 1 to entry: An example of bulk micromachining is a processing method based on etching by a chemical solution to remove unnecessary parts of a substrate. Covering the areas to be preserved with a mask of SiO_2 or Si_3N_4 ensures that etching cannot progress below the surface. Also, a boron-doped layer can stop the etching of the part below the surface layer. Recently, silicon fusion bonding has been used to fabricate still more complex structures.

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2.5.6

surface micromachining

micromachining that forms various substances in various microshapes on the substrate surface

Note 1 to entry: Surface micromachining is a processing technique that applies for example chemical vapour deposition (CVD) to form various thin films on the substrate and uses a mask to perform selective removal of the substrate surface to produce movable parts and other structures. The dissolved layer that was deposited initially is called the sacrificial layer. A typical sacrificial layer material is phosphosilicate glass (PSG). This technology is applied to the fabrication of micro-beams, bearings, and links, etc.

2.5.7

surface modification

process that modifies physical, chemical, or biochemical properties of the material surface

Note 1 to entry: Surface modification processes include doping for electric applications, deposition of materials for mechanical/chemical applications, and molecular modification for biochemical applications.

2.5.8

chemical mechanical polishing

CMP

planarization process for a substrate by a combination of mechanical polishing and chemical etching

Note 1 to entry: Chemical mechanical polishing is applied mainly to planarize steps on a substrate due to the semiconductor manufacturing process. Because the steps are composed of a plurality of materials such as substrates, dielectrics and metals, various slurries are used to selectively remove each material. In MEMS devices, chemical mechanical polishing is used to planarize the bonding surfaces in the wafer level packaging process.