BS EN 62047-1:2016

BSI Standards Publication

Semiconductor devices — Micro-electromechanical devices

Part 1: Terms and definitions

National foreword

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Dispositifs à semi-conducteurs - Dispositifs microélectromécaniques - Partie 1: Termes et définitions (IEC 62047-1:2016)

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European foreword

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 1: Terms and definitions

FOREWORD

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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.

A list of all parts in the IEC 62047 series, published under the general title *Semiconductor devices – Micro-electromechanical devices*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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"

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.

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

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.

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 $V_{\mathrm{rot}} = V_{\mathrm{rev}} \times (L_{\mathrm{stat}} - L_{\mathrm{rot}})/ L_{\mathrm{rot}}$, 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

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.

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.

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

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

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.

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

2.4.28

photoelectric transducer

transducer that generates an electric output corresponding to the incident light

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

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.

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.

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

2.5.9
photolithography
technique that transfers a fine pattern onto a substrate by the use of light

Note 1 to entry: In photolithography, a glass plate on which a desired pattern has been drawn is used as a mask. The mask is placed onto the substrate on which a thin film of photosensitive material (called the photoresist) has been coated, to expose part of the substrate to visible or ultraviolet rays through the mask. Since the solubility of the photoresist to the developer solution is altered by the exposure to the light, the pattern drawn on the mask is transferred to the photoresist thin film in the development process. Photolithography is indispensable to the silicon process. In the semiconductor industry, the required resolutions of horizontal patterns have reached the submicrometre level, bringing light of shorter wavelengths into use.

2.5.10
photomask
partially transparent film or glass plate or quartz that is used to transform its transparent pattern by optical projection

Note 1 to entry: In the integrated circuit process, the designed circuit pattern is drawn on an enlarged scale, from several tens to nearly a hundred times, and reduced onto film or glass plate as a photomask. This original mask is directly used for exposure, copying to the wafer, or to produce a working version with the same pattern as the original to be used for production purposes. The material of the plate depends on the wavelength of the rays used in the projection process.

2.5.11
photoresist, <micro-electromechanical devices>
photosensitive material used in photolithography

Note 1 to entry: Photoresists consist of macromolecular compounds with photosensitive functional molecules. There are water soluble and organic solvent soluble types. To form a pattern, the sample is coated with photoresist, then prebaked, exposed, developed, and postbaked. Photoresists include positive photoresists that lose their exposed section by development, and negative photoresists whose exposed section remains. To form submicrometre fine patterns, various photoresists such as electronic beam and X-ray photoresists are provided for exposure to beams with different wavelengths.

2.5.12
electron beam lithography
technique that generates a fine pattern onto a substrate by the use of an electron beam

Note 1 to entry: Pattern resolution depends on the wavelength of the rays. Electron beam lithography improves the resolution by the use of an electron beam. Therefore, combining electron beam lithography with a computer-aided design (CAD) system makes the lithography process flexible without a mask. However, it takes more exposure time compared to batch exposure because the electron beam has to be scanned in a raster or vector pattern.

2.5.13
LIGA process
process of creating microstructures by using deep lithography based on X-rays (synchrotron radiation) and electroforming which can be used as a mould

Note 1 to entry: LIGA is an acronym for Lithographie, Galvanoformung und Abformung, the German for lithography, electroforming, and moulding. Characteristics of the LIGA process include the ability to mass-produce high-aspect ratio microstructures with a line width of 1 μm to 10 μm and a height of several hundreds of micrometres, to allow the use of a wide range of materials including plastics, metals, and ceramics, and to be combined with silicon semiconductor elements, etc.

2.5.14
UV-LIGA
extension of the LIGA process in which X-rays are replaced with ultraviolet rays

2.5.15
X-ray lithography

technique that transfers a fine pattern onto a substrate by the use of X-rays

Note 1 to entry: Lithography technology at first used visible radiation, but with the increase in the degree of pattern integration, ultraviolet rays or shorter wave excimer lasers began to be used. Moreover, although batch exposure is difficult, lithography sometimes uses electron beams or ion beams. X-rays have a much shorter wavelength than the excimer laser and are therefore considered to be suited to higher integration. However, the optical systems have many problems; for example, an efficient and accurate lens for X-rays is difficult to produce.

2.5.16
beam processing

machining process using high-density energy beams

Note 1 to entry: High-density energy beams used in micromachining include laser beams, electron beams, ion beams (a typical ion beam is a focused ion beam, i.e. FIB), and molecular or atomic beams. Micromachining based on laser beams either is performed through a micro-pattern mask or uses a focused laser beam. In the case of the mask method, the machining accuracy is determined by the accuracy of the mask and aberration of the lens. In the case of a focused laser beam, the machining accuracy is determined by the wavelength of the laser beam and the focal length of the lens. Ion beam processing is used in finishing acute profiles.

2.5.17
sputtering, <removal process>

removal of atoms from a plasma source by energetic ion bombardment and their subsequent deposition as a thin film on a base material

Note 1 to entry: Sputtering by inert or reactive ions can be applied to various types of processing for either removing as etching or depositing the ejected atoms as thin film formation.

[SOURCE: IEC 60050-521:2002, 521-03-17, modified – Sputtering is often used as a removal process as well as a deposition process]

2.5.18
focused ion beam machining

FIB-machining

technique that removes a microscopic portion of material from the surface by means of sputtering with accelerated and focused ions

Note 1 to entry: The use of a focused ion beam of a diameter of about 0,1 μm makes it possible to bore microscopic holes at high accuracy, to sharpen various types of probe, and to process and modify aspheric surface lenses. By measuring the changes in intensity of secondary ions or secondary electrons ejected from the material, the depth of processing can also be controlled accurately. One drawback is the slow process speed, and another drawback is that relatively complex equipment is necessary to obtain the required high vacuum.

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

2.5.19
laser dicing

wafer cutting technology using a laser light that is irradiated and scanned along dicing lines on a substrate

Note 1 to entry: In a cutting process where blade dicing is difficult to use, the laser dicing method is widely used where a laser light is focused inside the substrate and modified layers are formed beneath the scribe lines, and finally the wafer is diced by a mechanical expansion.

2.5.20
etching process, <micro-electromechanical devices>

material removal process by means of chemical corrosion

Note 1 to entry: Etching, either isotropic etching or anisotropic etching, removes part of a material in a corrosive environment of either gas or liquid phase, sometimes assisted with electric energy (electrochemical etching). In the field of micromachining technology, anisotropic etching is popular. Examples are the application of potassium hydroxide (KOH) or ethylene diamine pyrocatechol (EDP) to single-crystal silicon, where the crystal plane of Miller index (111) is etched away slower than other crystal planes, leaving a three-dimensional structure consisting of the (111) crystal plane.

2.5.21
wet etching

etching process in liquid phase by a reactive chemical solution

Note 1 to entry: To apply wet etching, the region to be left unetched is covered with a mask in advance whereas the rest is left exposed, and then the material is dipped into the reactive solution. Etching processes are classified into isotropic etching that is independent of the crystalline structure of the material, and anisotropic etching that is dependent on it. In an isotropic etching process, corrosion progresses in all directions at a uniform speed from an unmasked region on the surface resulting in a round-shape cross-section. On the other hand, in an anisotropic etching process, the etching rate varies at different crystalline directions of the material, leaving the plane of the slowest etching rate unetched thus determining the final shape.

2.5.22
dry etching

etching process in vapour phase by the physical, or chemical, or physical and chemical, reaction of the reactive gas or reactive plasma

Note 1 to entry: A reactive gas generated by electric energy reacts with the substrate and removes the material to form the desired shape or dimension. Etching methods are divided into plasma etching, which is an isotropic etching based on a chemical reaction, and ion etching, which is a directional etching that uses a physical reaction (sputtering). Dry etching, which uses one of these methods or both together, is extensively used in current large-scale large scale integrated circuit (LSI) manufacturing processes.

2.5.23
isotropic etching

etching process in which the etching rate does not vary with the crystallographic orientation or direction of the energy beams

Note 1 to entry: A typical isotropic etchant for silicon is $HF/HNO_3/CH_3COOH$ (HNA) solution.

2.5.24
anisotropic etching

etching process in which the etching rate differs depending on the crystallographic orientation or direction of the energy beams

Note 1 to entry: A typical anisotropic etchant for silicon is potassium hydroxide (KOH). It is widely used in various bulk micromachining.

2.5.25
etch stop

technique that terminates the etching process at a controlled depth where a very low etch rate layer is formed

Note 1 to entry: An etch stop is sometimes used as the termination layer of the etching process. There are two basic types of etch stop that are used in micromachining: dopant etch stop and electrochemical etch stop.

2.5.26
sacrificial etching

micromachining in which an intermediate layer sandwiched between two layers of a different material is preferentially (sacrificially) etched and selectively removed

Note 1 to entry: Usually, the etch selectivity is high between the intermediate layer and the two sandwich layers. The purpose of the sacrificial layer is to mechanically release one or both of the sandwich layers. Silicon oxide is a commonly used sacrificial layer.

2.5.27
supercritical drying

drying method using supercritical fluid

Note 1 to entry: The supercritical fluid is highly diffusible and resolvable without the attraction due to surface tension. Through the use of supercritical drying, it is possible to dry delicate materials whilst maintaining their structure, whereas conventional drying methods cause extensive deformation and deterioration in structure. Carbon dioxide is often used as the supercritical fluid. This is because that it is possible to take out a dried-sample from cleaning liquid since the supercritical carbon dioxide can resolve various materials and vaporizes below the critical point. It is used for the drying process without stiction in MEMS device fabrication.

2.5.28
reactive ion etching
RIE

technique that combines etching with corrosive gas and sputtering with ions

Note 1 to entry: Under reactive ion etching, material is removed selectively in the vertical direction under the mask by both chemical reaction and physical bombardment (sputtering) with ions and radicals produced in plasma. Unlike in anisotropic etching wherein the direction of erosion depends on the crystal orientation of the material, in reactive ion etching the direction of removal is determined by the direction of the ion stream. Reactive ion etching results in less undercut erosion from the edge beneath the mask than does wet etching.

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

2.5.29
deep reactive ion etching
DRIE

variation of reactive ion etching (RIE), which can produce high aspect-ratio structures with vertical sidewalls

Note 1 to entry: For example, high aspect-ratio structures can be produced by introducing alternately an etching gas and a protective-film-forming gas in reactive ion etching equipment.

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

2.5.30
inductively coupled plasma
ICP

high density plasma generated by inductive coupling

Note 1 to entry: Inductively coupled plasma is used in etching processes such as deep reactive ion etching.

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

2.5.31
vapour deposition

technology that deposits a substance from a vapour onto a solid surface

Note 1 to entry: Vapour deposition is a technique of forming a thin film by vaporizing a solid substance, typically a metal placed in vacuum, by means of heating or irradiation with electron beams, and exposing the substrate to the vapour to be deposited. The purity of the film depends on the pressure in the chamber. The adhesive strength of the film is relatively weak, and the crystalline structure may be imperfect because the film sticks through the force of simple adhesion. Therefore, the substrate is sometimes preheated to induce a chemical reaction after deposition, to strengthen the adhesion and to improve the crystalline structure.

2.5.32
atomic layer deposition
ALD
thin film deposition technique at atomic level resolution thickness

Note 1 to entry: By changing the precursor gases sequentially, a chemical deposition process can be controlled down to the atomic or molecular scale. In the molecular beam epitaxy process, one of the related techniques, the deposited layer has the same crystal structure as that of the mono-crystalline substrate.

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

2.5.33
physical vapour deposition process, <micro-electromechanical devices>
PVD process
production process of a thin film mainly by using physical evaporation

Note 1 to entry: The physical vapour deposition process mainly constitutes a thin film by using vacuum evaporation of atomic species or sputter deposition using single or multiple targets in inert or reactive atmospheres (e.g. RF-magnetron sputtering, ion beam sputtering, molecular beam epitaxy, laser ablation).

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

[SOURCE: IEC 60050-815:2015, 815-14-13, modified – The target material is not limited to superconductive materials but various materials can be deposited.]

2.5.34
self-assembled monolayer
SAM
self-organized monolayer of molecules that are chemisorbed on a surface due to the specific affinity of the molecule

Note 1 to entry: In a self-assembled monolayer, molecules are typically bonded to the substrate strongly with chemical bonding while molecules in Langmuir-Blodgett films are bonded weakly with physisorption such as electrostatic force.

2.5.35
electroforming
production or reproduction of articles by electrodeposition upon a mandrel or former or mould which is subsequently separated from the deposit

Note 1 to entry: A resin or other matrix is made conductive by electroless plating, and it is used as a cathode to electrodeposit a desired metal thickly and rapidly. The product is obtained by releasing the metal from the matrix. The electroforming method is used in the manufacture of stampers for compact discs and laser discs because the shape and surface roughness of the matrix is precisely replicated.

2.5.36
micro-electrodischarge machining
micromachining using the discharge between micro-electrodes and the material

Note 1 to entry: While micro-electrodischarge machining uses the same principle as conventional electro-discharge machining, micro-energy discharge technology and micro-electrode production technology differ: the floating capacitance between the electrode and the material being processed must be reduced and the electrode must be miniaturized by methods such as wire electro-discharge grinding (WEDG). With the WEDG method, electrodes with a diameter of 2,5 μm can be prepared and microholes can be processed with this electrode.

2.5.37
nanoimprint
moulding process to replicate nanometre-scale structures

Note 1 to entry: Nanoimprint is classified into two types according to the difference in moulding method. Thermoplastic nanoimprint utilizes temperature and pressure controls with thermoplastic materials. Photo nanoimprint utilizes light irradiation with photo-curable materials. The hot-embossing process, a conventional technique, is a similar fabrication process to the thermoplastic nanoimprint. In some cases, hot-embossing and nanoimprint are distinguished through the moulding processes to form bulk film materials and thin-film materials on a substrate, respectively.

2.5.38
micromoulding
process for obtaining the desired shape of microscopic components after pouring a liquefied material into a mould

Note 1 to entry: Micromoulding is a microforming process that uses such means as compression, transfer, injection, and blowing to form a desired shape in a metallic mould. Microshapes are created by feeding raw materials such as polymers and ceramics into a mould. In the LIGA process, plastics are formed in a metallic mould using precision moulding technology. In a typical example, a low-viscosity plastic is degassed and fed into the vacuum mould under high pressure to prevent bubbling and to fill small gaps completely. Heat treatment is performed at high temperature under high pressure to cure the plastics, to release the stress, and to compensate for shrinkage. The plastics structures made with this reaction injection moulding technology can be plated and used themselves as moulds to produce metallic structures.

2.5.39
STM machining
atomic and molecular level surface processing (atomic manipulation) using a scanning tunnelling microscope (STM)

Note 1 to entry: STM machining, an example of which uses atoms to write characters, is well known and can be used to perform processing at the molecular and atomic levels. This technology is extremely sensitive to vibration, which makes it application difficult.

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

2.6 Terms and definitions relating to bonding and assembling technology

2.6.1
bonding
uniting technique of one material to another

EXAMPLE Typical examples include anodic bonding, diffusion bonding, silicon fusion bonding, and ultrasonic wire bonding. In these examples, the materials are bonded without adhesive materials.

2.6.2
adhesive bonding
technique that binds two materials using polymeric materials as an adhesive

2.6.3
anodic bonding
technique of bonding a glass substrate, which contains movable ions, and a substrate of silicon, metal, and so on, where the substrates are softened by heat, and bonded by the electrostatic attraction of an electric double layer produced by applying a high voltage across the substrates with glass side as cathode

Note 1 to entry: High precision bonding is achieved due to the bonding process in the substrates' solid state. The bonding strength largely depends on the flatness of the surfaces, although this is not as critical as for silicon fusion bonding. Bonding silicon wafers with materials such as borosilicate or tempered glass enables structures with internal cavities, such as capacitive pressure sensors and micropumps, to be fabricated. When bonding two silicon wafers or a silicon wafer and a metal wafer, a thin glass film is formed on the contacting surface of the wafers, or the surface of the silicon wafer is oxidized. The problem with the use of thin films is that at high bonding temperatures, the dielectric breakdown voltage of the films is lowered to the point that sufficient voltage cannot be applied. To reduce the process temperature to room temperature, attempts are being made to form a glass film with a low melting point by sputtering. This solves problems such as the strain and deformation caused by thermal stress, and introduces benefits such as the improvement in precision and the wide choice of materials.

2.6.4
diffusion bonding

technique of bonding materials by heating them to below their melting points and pressing them together to achieve solid state adherence by the mutual diffusion of their atoms

Note 1 to entry: As the materials are bonded in a solid state, far more accurate bonding is possible than with fusion bonding. Diffusion bonding is mainly used for bonding metals or bonding a ceramic to a metal. After bonding dissimilar materials, thermal stress occurs during cooling because of the difference in the coefficients of the thermal expansion of the materials. To avoid cracking caused by this stress, most diffusion bonding research is concerned with ways of reducing thermal stress. Methods of achieving this include sandwiching either a third material with a coefficient of thermal expansion roughly halfway between that of the two bonding materials, or a readily deformable material between them. Much research is being done into the insertion of a material whose coefficient of thermal expansion changes gradually across its thickness (functionally gradient material, i.e. FGM).

2.6.5
surface activated bonding
SAB

process for bonding two substrates directly by increasing the surface energy of each substrate using ion beam or plasma irradiation

Note 1 to entry: Surface activated bonding is effective in reducing thermal stress because the temperature in the bonding process is comparably low. In MEMS devices, surface activated bonding is expected to be applied to the substrate bonding such as hermetic sealing.

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

2.6.6
silicon fusion bonding

technique of bonding hydrophilized substrates made of silicon, oxidized silicon, and so on by primary hydrogen bonds between the surfaces, and then by Si-O-Si bonds after annealing at high temperature

Note 1 to entry: Silicon fusion bonding is used to form impurity diffusion layers or insulation layers inside a wafer by bonding two silicon wafers, one or both of which may be oxidized. The technology is also used to bond wafers that contain impurities of different species or concentrations, as an alternative process to in-depth impurity diffusion or epitaxial growth where high temperatures and long process time are required. The main problem with silicon fusion bonding is its high process temperature; all lower-temperature processes should take place after the bonding. Studies are ongoing to lower the process temperature by the application of plasma oxidation treatment before bonding, and to apply the technology to bond non-silicon materials. By bonding oxidized wafers, the silicon on insulator (SOI) structure can be obtained, in which an insulation layer is sandwiched by two silicon layers. The SOI structure is used to separate integrated element components by oxide and other dielectric materials to improve performance; for example, to manufacture photodiode arrays and so on. Another application of the technology is bonding wafers that have been bored or cut with grooves, to obtain precise structures made inside a wafer. This technique is used to make pressure sensors, and heat exchangers for laser diodes with internal cooling structure, and so on.

2.6.7
micromanipulator

mechanism to manipulate microscopic objects such as genes, cells, microcomponents, and microtools

Note 1 to entry: Micromanipulators can be driven by mechanical, pneumatic, hydraulic (oil or water), electromagnetic, or piezoelectric actuators as well as by electric motors. Micromanipulators for cell manipulation generally combine two separate drives: one for fine movement and one for coarse movement. Most micromanipulators are manually controlled by visual information received through microscopes or cameras to adjust their microposition. The future development of micromanipulators with force control mechanisms is expected for assembling microscopic objects using microforce and for realizing micro-teleoperation systems.

2.6.8
non-contact handling

grasping and moving objects without contact

Note 1 to entry: For example, it is general practice in cell manipulation to suck up cells with a glass micropipette and to handle them mechanically, but this contact damages the sample or changes the physical and chemical conditions, or both. One method of non-contact handling is laser trapping. With this method, the pressure of the light on the object (radiation pressure) manipulates the object without contact or damage. According to electromagnetic theory, the force generated by a 1 mW laser beam is 7 pN.

2.6.9
packaging

process of mounting components on a container that has external terminals for protecting the components

Note 1 to entry: The purpose of packaging is to minimize external chemical and physical damage to the components. As the device is miniaturized, strain due to the packaging stress is possibly troublesome. To prevent this, amongst other things, the bonding technology that joins microcomponents and so on to a silicon chip is important. In the field of sensor systems, a hybrid integration technology is necessary so that special packaging techniques are being studied.

2.6.10
wafer level packaging

process to complete packaging before dicing the wafer

2.6.11
through-silicon via

TSV

perpendicularly penetrating electro interconnection between both surfaces of a silicon substrate

Note 1 to entry: Through-silicon-vias are mainly applied to three-dimensionally stacked packaging of semiconductor devices. In the MEMS fields, the through-silicon-vias are applied to wafer level packaging technology. Some through-silicon-vias consist of through-via, insulator and electrode material. Solder, copper, doped-poly-silicon and so on are used as electrode materials.

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

2.7 Terms and definitions relating to measurement technology

2.7.1
scanning probe microscope

SPM

microscope that uses a probe with a tip of atomic scale and scans it in a raster pattern close to the specimen for measuring physical quantities between the probe and the surface to obtain an image

Note 1 to entry: By approaching a sharply pointed probe tip to the surface of the specimen, various physical forces that work between the probe and the specimen can be measured at the resolution of an atomic scale. In general, the probe is moved over the surface of the specimen in a raster pattern while keeping the measured physical quantity to a constant level, and the displacement of the probe in doing so is used as the data for drawing a fine image of the specimen. This is the common principle of different types of scanning probe microscope, i.e. the scanning tunnel microscope, atomic force microscope, electrostatic force microscope, scanning ion microscope, scanning magnetic field microscope, scanning temperature microscope, and scanning friction force microscope.

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

2.7.2

atomic force microscope

AFM

microscope that measures microscopic geometry by monitoring the displacement of a cantilever caused by the atomic force between the cantilever tip and the specimen while scanning the cantilever in a raster pattern

Note 1 to entry: The optical lever method is useful for monitoring the displacement of the cantilever. The displacement of the cantilever is measured by detecting the reflected light from the cantilever. There are three types of cantilever movement in the measurements: 1) the method wherein the cantilever contacts the specimen, 2) the method that monitors the amplitude change of the vibrating cantilever with cyclic contact (tapping mode), 3) the method that monitors the frequency change of the vibrating cantilever without contact between the cantilever and the specimen.

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

2.7.3

scanning tunnelling microscope

STM

microscope that measures microscopic geometry by keeping the tunnelling current between the probe and the specimen constant while scanning the probe in a raster pattern

Note 1 to entry: When an extremely sharpened probe approaches the surface of a solid material at a distance of 1 nm to 2 nm and applies a voltage, a tunneling current is produced between them. By controlling the probe position so as to keep the tunneling current constant while the probe is moved in the horizontal direction, the surface profile at an atomic scale can be determined.

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

2.7.4

near-field microscope

scanning near-field microscope

microscope that measures the intensity of electromagnetic or supersonic radiation through a nanometre-sized waveguide extremely close to the specimen while scanning the waveguide in a raster pattern to obtain high resolution images

Note 1 to entry: With ordinary microscopes, the resolution is limited to half of the wavelength of the electromagnetic waves or sonic waves used for observation. However, the resolution can be increased by making the aperture angle wide. If observation is made extremely close to the specimen through a nanometre-sized waveguide while moving the waveguide in a raster pattern, the resolution of the image is determined not by the wavelength but by the diameter of the waveguide alone. The near-field microscope obtains an image on the basis of this principle. However, the reduction in the diameter of the waveguide weakens the signal intensity, and so highly sensitive receivers are required to achieve a better resolution. The near-field supersonic microscope, laser scanning microscope, and fluorescent microscope are being developed.

2.7.5

spectroscopic ellipsometry

optical measurement method where the sample is successively irradiated with several-wavelength monochromatic light and both the thickness and the refractive index of the layers can be obtained simultaneously from the polarized reflection

Note 1 to entry: Monochromatic light from a spectroscope is linear-polarized using a polarizer. Then the light is irradiated on the thin film, and the reflected light intensity of the polarized components is measured. The thickness and the complex refractive index can be calculated from the measurement results.

2.7.6

aspect ratio, <micro-electromechanical devices>

ratio of the vertical dimension (height) to the horizontal dimension (width) of a three-dimensional structure, used as an index of the relative thickness of the structure

Note 1 to entry: It is accepted that the silicon process is not appropriate to form three-dimensional structures of much depth, because it is difficult to manufacture structures having an aspect ratio over 10:1. By the use of anisotropic etching or the LIGA process, deep holes, grooves and so on having an aspect ratio of 100:1 or greater can be obtained.

2.8 Terms and definitions relating to application technology

2.8.1

bio-MEMS
biomedical MEMS
application of MEMS technology in the field of biology, biomedical sciences or both

2.8.2

RF MEMS
radio frequency MEMS
application of MEMS technology in the field of wireless communication using radio frequency bands

2.8.3

MOEMS
micro-optical-electromechanical systems
application of MEMS technology in the field of optics

Note 1 to entry: This note applies to the French language only.

2.8.4

power MEMS
application of MEMS technology in the field of power generation and energy conversion

Note 1 to entry: Power MEMS include micro-thrusters for propulsion, micro-thermodynamic machines, micro fuel cells, energy harvesting devices and energy scavenging devices.

2.8.5

energy harvesting
power harvesting
energy scavenging
technology by which electric energy is derived from environmental sources and stored in the storage device

Note 1 to entry: MEMS technology is often used for typical energy conversion devices. Examples of environmental energies are solar energy, thermal energy, wind energy and mechanical vibration energy. Typical storage devices are a capacitor, super capacitor, and battery. The important applications of energy harvesting are the environmental monitoring system in the wide area or remote area, the security system, the building maintenance system, and the factory maintenance system.

2.8.6

lab-on-a-chip
system for a chemical, biochemical or biotechnological process that is installed on a microchip

Note 1 to entry: Lab-on-a-chip is a chip including systems for metering, measuring, and mixing microscopic liquid samples with reagents, moving the mixtures to an integrated temperature-controlled reaction chamber, and separating and determining the results with an on-board detector. Lab-on-a-chip can be used both for analysis and for synthesis.

2.8.7
micro TAS
integrated miniaturized chemical, biochemical or biotechnological analysis systems

Note 1 to entry: Micro TAS is an abbreviated term standing for Micro Total Analysis Systems.

2.8.8
microreactor
device for a chemical reaction process, which is on the micrometre scale

Note 1 to entry: A microreactor, which has a chamber-like shape and is on the micrometre scale, can be one of the processing units in a chemical process. The feature of microreactors is that temperature-, pressure- and concentration-gradients increase as scale is diminished, which increases thermal conductivity, mass transport and diffusion. For instance, when the size is reduced to 1/100, molecular diffusion time drops to 1/10 000. Other potential advantages of a microreactor include better control of reaction conditions, improved safety, and improved portability. The better control results from the precise controllability of the temperature due to the high surface-to-volume ratio of the reactor. The manufacturing processes, materials and shapes of the microreactor vary with the applications.

2.8.9
microscopic surgery
microsurgery, JP
surgical operation performed under a microscope view

Note 1 to entry: One attractive technique today is surgery performed under a stereoscope. While the technical term for this is microscopic surgery, in Japan it is called microsurgery. Microscopic surgery is practiced in otolaryngology, ophthalmology, neurosurgery, vascular surgery, plastic surgery, and other areas. Currently, surgery of the smallest scale is performed in suturing arteries, veins, and nerves with a diameter of around 800 μm using a needle and a thread with a diameter of around 20 μm. However, because surgeons must manipulate the needle holder, forceps and scalpel by hand, and perform the same actions as in ordinary surgery, these sizes of blood vessels and nerves are considered to be the limit. Therefore micro-teleoperation and other micromachine technology hold considerable promise for the future.

2.8.10
active catheter
catheter that can reach its destination by bending freely with a mounted microactuator in response to external control signals received

Note 1 to entry: If a catheter could bend freely and reliably inside winding tubular organs with internal passageways in response to external manipulation, diagnostic or therapeutic tools could be easily inserted into parts of the body through blood vessels. To realize the active catheter, various microactuators and micromechanisms will have to be developed.

2.8.11
fibre endoscope
tool that transfers images using a bundle of optical fibres, used for inside observation of the body which is impossible from the outside directly

Note 1 to entry: Compared with a rigid endoscope consisting of lenses alone, a fibre endoscope is flexible and can be easily bent because thin fibres are bundled, and therefore it is used to see the inside of tubular organs such as digestive tracts and blood vessels. Fibre endoscopes are also used for industrial purposes such as inspection of the inside of pipes and jet engines. With microsurgical tools loaded on the inside of endoscopes, a doctor can perform a surgical operation while observing the diseased part. Research and development for making microsurgical tools is also in progress.

2.8.12
smart pill
robot that performs measurement and drug delivery inside the body

EXAMPLE A commonly proposed example of a smart pill is the gastrointestinal tract smart pill. This smart pill includes a sampling device that takes samples for measuring, a drug reservoir and releasing system, and an intelligent sensor circuit and a controller fabricated on a silicon wafer as well as a micropower supply.

2.8.13
bio-chip
device consisting of miniaturized test sites arranged on a solid substrate that permits various biological reactions to be performed in a short time response

2.8.14
DNA chip
device consisting of a high density array of short DNA fragments bound to a solid surface which facilitates high throughput analysis of thousands of genes simultaneously

Note 1 to entry: DNA is the abbreviation for deoxyribonucleic acid.

2.8.15
protein chip
device consisting of a high density array of substances with a strong affinity for various proteins, such as antibodies, which facilitates high throughput analysis of thousands of proteins simultaneously

2.8.16
cell handling
manipulation or treatment of cells

Note 1 to entry: In the field of biotechnology, various manipulations are made to cells while holding them. One example is pricking a cell nucleus with a glass capillary tube and implanting foreign genes. For this kind of manipulation, apparatuses such as an optical microscope, micromanipulators, microstages, and micropipettes are used. Since most of these conventional types of equipment require dexterity and experience in manipulation, the development of automated systems is expected. Major themes of development are remote operation, manipulators having multi-degree of freedom, automated tracking systems, microactuators, and so on.

2.8.17
cell fusion
fusion of two adjacent cells into one cell with disappearance of the septum in between

Note 1 to entry: Through the artificial fusion of cells, a hybrid cell that retains the genetic information of both original cells, which can be of either the same or different species, is obtained. Cell fusion is a fundamental technique in biotechnology, as well as in gene manipulation. The fusion of cells is possible by using viruses or polyethylene glycol, and also by applying electric pulses. One example is implemented by a cell fusion apparatus, in which cells are suspended in liquid and aligned by applying alternating electric field, and then DC pulses are given to fuse the contacting septa. By application of micromachine technology, a system that can process a large quantity of cells at one time can be produced, in which multiple units of this apparatus are connected in parallel.

2.8.18
polymerase chain reaction, <micro-electromechanical devices>
PCR
amplification process for synthesizing billions of identical replicas of a DNA fragment

Note 1 to entry: This note applies to the French language only.

2.8.19
microfactory
small manufacturing system comparable in scale with the small products on which it is used

Note 1 to entry: Small equipment such as watches, cameras, and cassette recorders contain many components of a few millimetres in size. So far, such miniature components have been processed and assembled by metre-order machine tools or assembly robots. Accordingly, in the processing of microcomponents and assembling by such metre-order manufacturing systems, the power required for the movement of the machine tools and assembly robots themselves is much higher than that required for the processing and assembly of the small equipment. In addition, compared to the size of the components and products, extremely large amounts of space and resources are required for metre-order manufacturing systems.

Annex A
(informative)

Standpoint and criteria in editing this glossary

A.1 Guidelines for selecting terms

Attention was paid to the selection of terms for the glossary so as not to be partial to any specific field and to be helpful for the people in diverse fields, since micro-electromechanical devices relate to a wide variety of fields. To achieve this, Table B.1 was prepared dividing the terms into categories in order to confirm that there was no partiality to any field and that no important field had been left out. Further considerations were made for hierarchical relationships and for separating abstract and concrete terms in the table.

A.2 Guidelines for writing the definitions

As for the terms already defined in some field, definitions were followed to those. However, the definitions have been expressed as simply as possible to account for the fact that micro-electromechanical devices relate with various fields.

A.3 Guidelines for writing the notes

In addition to the general explanations, issues particular to micro-electromechanical devices are also described in the notes. Concrete numerical values and examples are cited in some terms. However, due to the possibility of future unforeseen developments, expressions that would limit the range of numerical values in applications have been avoided.

Annex B
(informative)

Clause cross-references of IEC 62047-1:2005 and IEC 62047-1:2015

Table B.1 presents the changes from the previous edition as well as showing the difference in the categories of terms.

Table B.1 – Clause cross-reference of IEC 62047-1: 2005 and IEC 62047-1:2015

Ed.2: 2015	Ed.1: 2005	Heading of the first edition or new heading	Change contents
2	2	Terms and definitions	
2.1	2.1	General terms	
2.1.1	2.1.1	micro-electromechanical device	definition, note
	2.1.2	MEMS	omitted term
2.1.2	2.1.3	MST	
2.1.3	2.1.4	Micromachine	note
2.1.3.1		Micromachine <device>	new term
2.1.3.2		Micromachine <system>	new term
	2.1.5	micromachine technology	omitted term
2.2	2.2	Terms relating to science and engineering	
2.2.1	2.2.1	micro-science and engineering	definition
2.2.2	2.2.2	scale effect	definition
	2.2.3	mesotribology	omitted term
2.2.3	2.2.4	microtribology	
2.2.4	2.2.5	biomimetics	
	2.2.6	ciliary motion	omitted term
2.2.5	2.2.7	self-organization	
2.2.6		electro wetting on dielectric, EWOD	new term
2.2.7		stiction	new term
2.3	2.3	Terms relating to material science	
	2.3.1	shape memory polymer	omitted term
	2.3.2	modification	omitted term
2.3.1		silicon-on-insulator, SOI	new term (clause change)
2.4	2.4	Terms relating to functional element	
2.4.1	2.4.1	actuator	definition, note
2.4.2	2.4.2	microactuator	note
2.4.3	2.4.3	light-driven actuator	
2.4.4	2.4.4	piezoelectric actuator	
2.4.5	2.4.5	shape-memory alloy actuator	
2.4.6	2.4.6	sol-gel conversion actuator	
2.4.7	2.4.7	electrostatic actuator	
2.4.8	2.4.8	comb-drive actuator	
2.4.9	2.4.9	wobble motor	
2.4.10	2.4.10	microsensor	

Ed.2: 2015	Ed.1: 2005	Heading of the first edition or new heading	Change contents
2.4.11	2.4.11	biosensor	
2.4.12	2.4.12	integrated microprobe	
2.4.13	2.4.13	ion sensitive field effect transistor, ISFET	
2.4.14	2.4.14	accelerometer	
2.4.15	2.4.15	microgyroscope	
2.4.16	2.4.16	diaphragm structure	
2.4.17	2.4.17	microcantilever	
2.4.18	2.4.18	microchannel	
2.4.19	2.4.19	micromirror	
2.4.20	2.4.20	scanning mirror	
2.4.21	2.4.21	microswitch	
2.4.22	2.4.22	optical switch	
2.4.23	2.4.23	microgripper	
2.4.24	2.4.24	micropump	
2.4.25	2.4.25	microvalve	
	2.4.26	integrated mass flow controller	omitted term
2.4.26		CMOS MEMS	new term
2.4.27	2.4.27	micro fuel cell	
2.4.28	2.4.28	photoelectric transducer	
2.5	2.5	Terms relating to machining technology	
2.5.1	2.5.1	micromachining	definition, note
2.5.2	2.5.2	silicon process	
2.5.3	2.5.3	thick film technology	
2.5.4	2.5.4	thin film technology	
2.5.5	2.5.5	bulk micromachining	
2.5.6	2.5.6	surface micromachining	
2.5.7		surface modification	new term
2.5.8		chemical mechanical polishing, CMP	new term
2.5.9	2.5.7	photolithography	
2.5.10	2.5.8	photomask	
2.5.11	2.5.9	photoresist	
2.5.12	2.5.10	electron beam lithography	
	2.5.11	silicon-on-insulator, SOI	omitted term (clause change)
2.5.13	2.5.12	LIGA process	
2.5.14	2.5.13	UV-LIGA	
2.5.15	2.5.14	X-ray lithography	
2.5.16	2.5.15	beam processing	
2.5.17	2.5.16	sputtering	
2.5.18	2.5.17	focused ion beam machining, FIB- machining	term
2.5.19		laser dicing	new term
2.5.20	2.5.18	etching process	
2.5.21	2.5.19	wet etching	
2.5.22	2.5.20	dry etching	
2.5.23	2.5.21	isotropic etching	

Ed.2: 2015	Ed.1: 2005	Heading of the first edition or new heading	Change contents
2.5.24	2.5.22	anisotropic etching	
2.5.25	2.5.23	etch stop	definition, note
	2.5.24	lost wafer process	omitted term
2.5.26	2.5.25	sacrificial etching	
2.5.27		supercritical drying	new term
2.5.28	2.5.26	reactive ion etching,RIE	
2.5.29	2.5.27	DRIE, deep reactive ion etching	definition, note
2.5.30	2.5.28	ICP, inductivity coupled plasma	note
2.5.31	2.5.29	vapour deposition	
2.5.32		atomic layer deposition, ALD	new term
2.5.33	2.5.30	physical vapour deposition process, PVD process	
2.5.34		self-assembled monolayer, SAM	new term
2.5.35	2.5.31	electroforming	
2.5.36	2.5.32	micro-electrodischarge machining	
	2.5.33	hot embossing process	omitted term
2.5.37		nanoimprint	new term
2.5.38	2.5.34	micromoulding	
2.5.39	2.5.35	STM machining	
2.6	2.6	Terms relating to bonding and assembling technology	
2.6.1	2.6.1	bonding	
2.6.2	2.6.2	adhesive bonding	
2.6.3	2.6.3	anodic bonding	
2.6.4	2.6.4	diffusion bonding	
2.6.5		surface activated bonding, SAB	new term
2.6.6	2.6.5	silicon fusion bonding	
2.6.7	2.6.6	micromanipulator	
2.6.8	2.6.7	non-contact handling	
2.6.9	2.6.8	packaging	
2.6.10	2.6.9	wafer level packaging	
2.6.11		through-silicon via, TSV	new term
2.7	2.7	Terms relating to mesurement technology	term
2.7.1	2.7.1	scanning probe microscope, SPM	
2.7.2	2.7.2	atomic force microscope, AFM	
2.7.3	2.7.3	scanning tunnelling microscope, STM	
2.7.4	2.7.4	near-field microscope, scanning near-field microscope	definition, note
2.7.5		spectroscopic ellipsometry	new term
2.7.6	2.7.5	aspect ratio	
	2.7.6	power-to-weight ratio	omitted term
2.8	2.8	Terms relating to application technology	
2.8.1	2.8.1	bio-MEMS, biomedical MEMS	note
2.8.2	2.8.2	RF MEMS, radio frequency MEMS	note
2.8.3	2.8.3	MOEMS, micro-optical-electromechanical systems	note
2.8.4		power MEMS	new term
2.8.5		energy harvesting, power harvesting, energy scavenging	new term

Ed.2: 2015	**Ed.1: 2005**	**Heading of the first edition or new heading**	**Change contents**
2.8.6	2.8.4	lab-on-a-chip	
2.8.7	2.8.5	micro TAS	
2.8.8	2.8.6	microreactor	
2.8.9	2.8.7	microscopic surgery, microsurgery	
2.8.10	2.8.8	active catheter	
2.8.11	2.8.9	fibre endoscope	
2.8.12	2.8.10	smart pill	
2.8.13	2.8.11	bio-chip	
2.8.14	2.8.12	DNA chip	
2.8.15	2.8.13	protein chip	
2.8.16	2.8.14	cell handling	
2.8.17	2.8.15	cell fusion	
2.8.18	2.8.16	polymerase chain reaction, PCR	
2.8.19	2.8.17	microfactory	

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[1] To be published.

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