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Executive Summary

One of the most difficult tasks in micro and nano technologies is to agree on a consistent use of terms. Indeed, a common vocabulary is often the first step in developing norms or standards in an industry. This is even true for the terms that describe the field, MEMS, microsystems, and micromachines, since they are defined differently depending on which continent one works. This is further complicated in the microsystems arena since our devices function in many differing energy and environmental domains and some symbols are used differently and mean different things in those domains, requiring a higher level of sophisticated understanding for those involved in the field. These differences at this basic level reflect in turn differing industry scopes.

Difference in microsystems nomenclature can cause wide variation in understanding of a topic. This is very evident when marketing research is being conducted where outcomes based

on differing understandings of nomenclature create factor differences in the forecasts. MEMS is generally used to mean the device-level product and is popular in North America. Market studies derived from this definition of the field are typified by the two SPC reports. Microsystems is often defined as the smallest purchasable subsystem that includes a MEMS device and is popular in Europe. Market studies developed from this definition of the field are typified by the Nexus market studies. Micromachine is popular in Asia and is even more elemental than the term MEMS when used to define the field. Many of the Japanese market studies are derived from this definition of the field. All of these efforts are excellent, but they measure different things and the resultant market studies can therefore be very different. Differences in understanding terms is equally important but sometimes much more subtle in microsystems technological arenas.

The Glossary in this roadmap is designed to provide a comprehensive definitional effort of terms used in this emerging industry. We have provided operational terms, definitions used in differing application spaces, processing jargon, regional terms, management terminology, statistical terms, test, packaging and reliability terminology and many others. The following provides nearly 1400 commonly used terms, some of which may be rudimentary depending on your area of expertise and educational background. Professionals and students from many companies and educational facilities helped to compile this glossary. This is especially true for students from UNM, NJIT, University of Twente, Sandia National Laboratory's MESA Institute and many other universities around the world who compiled this chapter.

Terms and Definitions

A-C

A, C, T and G Adenine, Cytosine, Thymine and Guanine, which are complex chemical compounds that make up nucleotides, the building blocks of nucleic acids. A given sequence of pairs of A-T and G-C forms a DNA strand.

Ablation The process of removing material by cutting, grinding, or evaporating.

AC See Alternating Current.

Accelerometers Instruments that measure an acceleration or gravitational force capable of imparting acceleration. Accelerometers are also used for detecting and measuring vibrations.

Acceptable Process Tolerances Permissible deviation from a specified value of a structural dimension, often expressed as a percent, at each manufacturing process step.

Acceptor Impurities, like boron ions, that can make a semiconductor a p-type by causing the absence of electrons in the conduction band (called “holes”). These “holes” are carriers of positive charge. See also Donor.

Accuracy Deviation between the result of a measurement and the value of the measurand. Using the term “precision” for “accuracy” should be avoided.

Activate Dopants Impurities, ranging from 1 to 1000 ppm, purposely introduced into a semiconductor material to increase its conductivity. They must reside on a substitutional lattice site within the semiconductor for them to be “activated” and donate charged particles (electron or hole) and thereby increase conductivity.

Active Area Region of thin oxide on a wafer in which transistors and other circuits reside.

Active Component Non-mechanical circuit component that has gained or switched current flow, such as a diode, transistor, etc.

Active Device Device requiring a source of energy for its operation and has an output that is a function of present and past input signals. Exam-

ples include controlled power supplies, transistors, LEDs, amplifiers, and transmitters.

Active layer A layer of a microelectronic device in which both electrons and holes are active. In MOSFETs, bulk, silicon is the active layer. In thin-film transistors, a thin silicon film is the active layer.

Active Mask A mask that defines areas where transistors are fabricated.

Actuator A device that converts energy (electric, chemical, etc.) into mechanical work.

ADC See Analog-to-Digital Converter.

Adjustment Operation intended to bring a measuring instrument into a state of performance and freedom from bias suitable for its use.

Admixture The act of mixing; a product of mixing.

Adsorption Formation of molecules of a gas similar to a thin film that binds on the surface of a solid. Unlike absorption, the binding to the surface in adsorption is usually weak and reversible. Adsorption is a method for separating mixtures and purifying fluids.

AF See Atrial fibrillation.

AFM (Atomic Force Microscope) A microscope that visualizes features on an atomic scale.

Agency Costs Transaction costs that arise when a party acting as an agent has differing incentives than the party performing as a principal.

Aging Behavior Models Accelerated aging methods are often used to predict the lifetime of materials under their ambient aging condition by following degradation under several accelerated environmental conditions, modeling the accelerated results, and then extrapolating the model to ambient conditions.

ALD See atomic layer deposition.

Aldehyde A family of highly reactive compounds characterized by the CHO group.

Alias Error A phenomenon whereby equally spaced sampling of high-frequency signals, such as noise, appear as lower-frequency signals and are thus indistinguishable from data frequencies.

Aliasing A process whereby two or more frequencies, integral multiples of each other, cannot be distinguished from each other when sampled in an analog-to-digital converter.

Aligner An optical system used in transferring a mask or reticle image to a wafer.

Alignment Mark A reference mark used in the alignment of the several photomask layers required for a single device or circuit.

Alignment Arrangement of a mask and wafer in correct positions with respect to each other. After alignment, light-sensitive photoresist on the wafer is exposed by light passing through the non-opaque areas of the mask.

Alloy Local heating that increases the bond between silicon and contact metal like tungsten.

Alternating Current (AC) Electrical current, that reverses (or alternates) at regular intervals.

Aluminum A conductive metal used in wafer fabrication to connect the various parts of the circuit.

Ambient The state of surrounding conditions of a device, like pressure and temperature.

Amino Acid The fundamental chemical building block of proteins that determine genetic code. There are 20 common amino acids.

Ammonia (NH₃) A toxic gas used to create a silicon-nitride passivation layer by a CVD process.

Amorphous Material lacking a crystalline orientation and consisting of extremely fine grains, each a few nanometers in size.

Amplification A process of producing a large number of matching copies of DNA material. In electronics, it refers to the increase in magnitude of electrical current or voltage.

Ampoule A hermetically sealed small bulbous glass vessel that is used to hold a solution for hypodermic injection.

Analog A continuous, non-digital representation of phenomena. An analog voltage, for example, may take any value, unlike digital that is limited to 0 and 1.

Analog Circuit An electronic circuit in which voltages and currents vary with the intensity of an external quantity (e.g., sound level).

Analog-To-Digital Converter A device that samples an analog signal at discrete, steady-rate time intervals, converts the sampled data points to a form of binary numbers, and passes the sampled data to a computer for processing.

Anchor A location where a section of the MEMS device is held to the substrate to prevent it from moving.

AND Gate A gate whose output is ON only if all input gates are ON.

Aneurysm An abnormal blood-filled dilatation of a blood vessel and especially of an artery resulting from disease of the vessel wall.

Angioplasty A balloon procedure to open an obstruction or narrowing of a blood vessel, or percutaneous transluminal angioplasty (PTA). Also known as percutaneous transluminal coronary angioplasty (PTCA).

Angioscopy The visualization with a microscope of the passage of substances through blood capillaries after intravenous injection.

Angstrom A unit of length that is 1/10,000 of a micrometer, i.e. 10^{-4} μm .

Anisotropic Etching Etching that involves different etch rates in different directions in the material.

Anisotropy Different material or processing properties in different directions.

Annealing The process of heating and then cooling a metal, alloy, or glass, usually for removing internal stresses and making the material less brittle. Also, cooling slowly, usually in a furnace.

Anodic Bonding A method of hermetically and permanently joining glass to silicon without the use of adhesives. The silicon and glass wafers

are heated to a temperature (typically in the range of 300-500°C depending on the glass type) at which the alkali-metal ions in the glass become mobile. The components are brought into contact and a high voltage applied across them.

Antimony An n-type dopant often used to form the buried layer in a bipolar structure.

APCVD Atmospheric Pressure CVD. It refers to CVD systems that operate at or near atmospheric pressure. Not as popular as Low-Pressure CVD (LPCVD) due to inferior film quality and a lack of conformality. It has higher deposition rates than LPCVD and is not sensitive to temperature variations.

Aperture The time required for an analog-to-digital converter to establish the digital representation of the unknown analog signal.

Application-Specific Integrated Circuit See ASIC.

Aqueous A solution having water as the solvent

ARDE (Aspect Ratio Dependent Etching) A defect associated with dry etching caused by differing plasma etch rates due to topography variation of surfaces. Due to ARDE, channels with larger widths or shallow depths are etched faster than channels that are deeper or less wide. ARDE occurs when the majority of ion species fail to reach the bottom of high-aspect-ratio structures because of its increasing interaction with the sidewalls of the channels.

Area Array A compact packaging technique developed in the 1990s where solder bumps are placed on a grid across the chip surface.

Argon An inert gas typically used in deposition systems.

Array An IC fabrication technology in which the final metal interconnect layers of an otherwise pre-fabricated wafer are patterned in accordance with user-supplied design data.

Arsenic A chemical element typically used as an N-type dopant in various doping, deposition, and ion-implant processes. Arsenic is used often to form the buried layer in a bipolar structure and also as an implant source in both bipolar and MOS processing.

Arsine (AsH₃) A toxic, highly inflammable gas used as a source for arsenic during ion implantation.

Artificial Neural Network An interconnected network of processing-element neurons, which makes it possible to model sensor signals to predict sample properties such as its constituents or concentration.

Artificial Silicon Retina™ (ASR™) Artificial retinas from Optobionics and made from silicon microchips 2-mm in diameter and one-thousandth of an inch thick. The chip replaces damaged photoreceptors, the “light-sensing” cells of the eye, which normally convert light into electrical signals within the retina.

Ashing A method of stripping photoresist using plasma (an electromagnetically excited reactant gas).

ASIC Application-Specific Integrated Circuit. A chip specially designed for a certain customer and application.

Aspect Ratio The ratio of structural height to width. If a structure has 10 µm height and 2 µm of width, the aspect ratio is 5:1 or 5. A “high aspect ratio” refers to an aspect ratio greater than 10.

Aspect-Ratio-Dependent Etching See ARDE.

ASR™ See Artificial Silicon Retina.™

Assembly The final stage in semiconductor manufacturing in which the device is encased in a plastic, ceramic, or other package. Also referred to as “packaging,” and is considered a part of the BEOL (Back-end-of-line) process.

Asynchronous Transfer Mode See ATM.

ATE (Automatic Test Equipment) Computer-controlled equipment used in the production testing of packaged ICs. Test-voltage sequences (test patterns) are applied and responses compared to data on file or to a known-to-be-good IC.

Atherosclerosis A condition where fatty materials tend to accumulate beneath the inner lining of an arterial wall.

ATM 1. Asynchronous Transfer Mode 2. Atmosphere (1 atm = 760 mm Hg)

ATM (Asynchronous Transfer Mode) A switching technology that organizes digital data into 53-byte cell units and transmits them over a physical medium using digital signals. Each cell is processed individually without any time dependency relative to other related cells and is queued before being multiplexed over the transmission path.

Atomic Force Microscope See AFM.

Atomic Layer Deposition (ALD) A technique that deposits atoms or molecules on a wafer a single layer at a time. It is used to make nucleation or barrier films.

Atria The two chambers of the heart that receive blood from the veins.

Atrial Fibrillation (AF) The irregular and very rapid beating of the heart's atrial chambers and resulting when the normal electrical conduction system of the atria malfunctions, leading to an irregular and chaotic electrical signal.

Attribute A measurable parameter or function.

Autodesk Drawing Exchange Format See DXF.

Automatic Test Equipment See ATE.

Average Cost Per Unit The total costs divided by the total number of units produced. It is a function of a weighted measure of both fixed and variable costs.

Back-End Design Design activities starting with either a netlist (a list of components and connections between them) or a hardware-description-language version of a chip design and ending with the layout (physical design) of the chip.

Back-end-of-line See BEOL.

Back-End Processing Operations performed on the wafer from first level of metallization that connects the transistor on the surface of the chip until packaging.

Backside Patterning Patterning the backside of the wafer using masks. A silicon-nitride layer, which is used as a passivation, masking, or insu-

lating layer, can be etched by adopting backside patterning.

Baked A term used to characterize films (such as paint) that have been heated to speed the evaporation of thinners (in the case of paint) and/or to promote the reaction of binder components so as to form a hard film.

Ball Grid Array See BGA.

Balloon Catheter A tube used for gaining access to the arteries with a tiny balloon on its tip. The balloon is gently inflated after the catheter is in position.

Bandpass Filter A filter that allows the transmission of frequencies only within a prescribed band range.

Bandwidth The width of the range of frequencies that an electronic signal uses in a given transmission medium. All digital and analog signals have a bandwidth.

Barrier A physical layer designed to prevent the transfer of a layer above and below the barrier layer.

Barriers To Entry Conditions blocking competing firms from entering a field. Barriers include high initial investments, intellectual property rights, etc.

Base The control portion of a bipolar transistor. In an npn transistor, the p-type material forms the base.

Base Diffusion The diffusion during which the base regions of transistors are formed.

Base Process A particular processing service offered by the MEMS exchange on behalf of its affiliated fabs. A base process is classified by its location in the process hierarchy, or generic process. It is further identified by the specific fab and piece of equipment where the service is offered and by the material of interest.

Base Units The units of measurement of the seven base quantities like length, mass, time, voltage etc., in a given system of quantities. In SI units, the base units for mass, time, voltages are kilogram, meter, and second, respectively. Derived quantities like capacitance, frequency, etc.

and their units are derived from base quantities and their units.

Baseline Process The basic process providing the steps/procedures, measurements, and calculations that are used as bases for comparison.

Batch Production of many components at the same time.

BAW Sensor See Bulk Acoustic Wave Sensor.

Bead-Based Arrays Arrays in which reactions take place on the surface of spherical miniature beads. These arrays can contain millions of individual probes, making them perhaps the most promising technology for fields such as drug discovery.

Beam Leads Thick, strong leads deposited directly on an integrated circuit chip and used for interconnecting the circuit into the system.

Beamline A vacuum line extending in from the source of synchrotron radiation that captures a portion of the radiation and transfers it where the radiation (like X-rays) are required.

Beam Tape Polyimide tape supporting copper foil shaped into beam leads for TAB bonding. Specifically designed for an in-line automation of IC package.

Behavioral Model An efficient reduced-order model characterizing the response of a device or system to a range of input excitations.

Behind-The-Ear See BTE.

Bimetallic Actuation The bending movement occurring when a pile of two materials having different coefficients of thermal expansion are heated. The extent of bending is related to the temperature of the materials that are exposed and used to sense temperature rise and protect circuits from excess current flow.

BEOL (Back-end-of-line) The processes required after the wafer fabrication for a surface micromachine, or integrated microsystem assembly. In semiconductor manufacturing, it refers to the package assembly and test stages of production. It includes burn-in and environmental test functions.

BGA (Ball Grid Array) A style of chip package that uses an array of solder balls to achieve very high interconnect densities.

Bias Error The inherent bias (offset) of a measurement process or (of) one of its components. See also Systematic Error.

Bias-Enhanced Nucleation Process The agglomeration of proteins around a starting nucleus in a liquid that has dissolved proteins and is subjected to an electric field.

BiCMOS (Bipolar Complementary Metal Oxide Semiconductor) The combination of bipolar and CMOS technologies.

Biliary Stent Stents, made of metal or plastic tubes, designed to overcome obstruction of bile ducts.

Binary A system of numbers using 2 as a base, in contrast to the decimal system, which uses 10 as a base. The binary system requires only two symbols, 0 and 1. The language understood by microprocessors and computers.

BioFilms Populations or communities of microorganisms adhering to environmental surfaces. A major concern for implants like catheters, lens, and other prostheses are biofilms growing on them and shielding bacteria and other disease-causing organisms. Control of infections gets difficult due to the presence of biofilms since it increases the concentration of antibiotics required by 100 to 1000 times the normal dose.

BioFlip 1. A biological chip 2. A BioMEMS chip packaged using Flip-Chip technology.

Bioinformatics The discipline of storing, retrieving, analyzing, and integrating biological data.

BioMEMS Biological MicroElectro Mechanical Systems are MEMS systems with applications for the biological/analytical chemistry market. Areas of interest include, but are not limited to, micro- and nanotechnology for drug delivery, tissue engineering, harvesting, manipulation, amplification, and sequencing of nucleic acids, proteomics, microfluidics and miniaturized total analysis systems (microTASs), biosensors, molecular assembly, nanoscale imaging, and integrated systems.

Biomimetics The study relating to the adoption of good designs seen in living beings. For example, researchers in robotics intend to implement the principles of human and bird muscles in next-generation robotics.

Bionanotechnology Molecular motors, biomaterials, single-molecule manipulation technologies, biochip technologies, etc. [Source: Asia Pacific Nachnology Initiatives].

Biophotonics The study of light given out by biological tissue. Biophotonics is used to identify diseases.

Bipolar Transistors Transistors formed with two (n-type and p-type) semiconductor types. Such transistors are generally termed npn or pnp types.

Bipolar Junction Transistor See BJT.

Bipolar Process Bipolar devices are semiconductor devices in which both electrons and holes participate in the conduction process. In a typical bipolar transistor, silicon serves as a substrate and two closely coupled p-n junctions serve as contacts.

Bird's Beak The expansion of the SiO₂ layer beneath the SiN₃ layer during local oxidation of the silicon wafer. The SiO₂ forms a structure similar to a bird's beak.

BIST (Built-In Self Test) The ability of an IC to internally generate the sequence of test voltages required to verify its functionality.

Bit A binary digit, the smallest unit of storage in a digital computer. It is used to represent one of the two states in the binary number system.

BJT (Bipolar Junction Transistor) A transistor in which current is controlled by the voltage impressed across a crystal interface between p-and n-type semiconductors.

Blanket Deposition A deposition technique on the entire surface of the wafer.

Boat A wafer holder made from quartz or polycrystalline silicon for use in furnace operations of semiconductor fabrication. It also may be made of Teflon for transporting wafers between processing locations.

BOE See Buffered Oxide Etch.

Bolus A large dose of medication given intravenously so that the desired therapeutic concentration in the blood is reached rapidly.

Bond Pads Comparatively large metallization areas usually placed around the perimeter of the integrated circuit die to which wires or other interconnecting contacts are made.

Bond Wire The joining of metal bond pads on an integrated circuit to a metal lead frame by using fine wires, usually of aluminum or gold.

Bonded Wafer Technology A process in which two semiconductor wafers are bonded to form a substrate having precise features. This technology offers a high-quality, low-cost Silicon-On-Insulator (SOI) substrate capability and also a range of pre-bond processing options. The latter allows the manufacturer to optimize the total process by increasing performance while reducing cost.

Bonding The process of connecting wires from the package leads to the chip (or die) bonding pads. Alternately, it is the process of securing a semiconductor die to a lead frame or package.

Bonding, Ball A thermal compression-bonding technique used with gold wire. The wire end is melted to form a ball, which provides a larger area of contact than otherwise possible.

Bonding, Die The attaching of the semiconductor die to the package substrate, with epoxy adhesives, gold eutectic or solder alloy. Also called die attachment.

Bonding, Wedge A form of thermal compression of ultrasonic bonding used for microelectronic assembly, so named because a heated wedge is used to form the bond.

Bonding, Wire The joining of metal bonding pads on an IC to a metal leadframe, using fine wires, usually of aluminum or gold.

Bonding Aligners A tool which first precisely aligns patterns on two (or more) substrates, typically followed by bonding of the substrates while the patterns remain aligned.

Bonding Pads Comparatively large metallization areas usually placed around the perimeter of

the integrated circuit die to which wires or other interconnecting contacts are made.

Boolean Algebra A logical calculus named for mathematician George Boole, using alphabetic symbols to stand for logical variables, and 0 and 1 to represent states. AND, OR, and NOT are the three basic logic operations in this algebra. NAND and NOR are combinations of the three operations.

Boron An element used as a p-type dopant in crystal growing and in various fabrication processes, commonly used for the isolation and base diffusion in standard bipolar npn IC processing, and source/drain regions in PMOS transistors.

Boro Silicate Glass See BSG.

Bosch Process A silicon surface-micromachining technique developed by Robert Bosch GmbH. The process in brief: Deposit and pattern a sacrificial layer that is present on top of the surface. Polysilicon is deposited on the patterned sacrificial layer, which is then removed to form structures similar to cantilevers. Advantages include large maximum feature size (>1 mm) due to of low stress and strain gradient.

Boule A large cylindrical silicon ingot drawn from a molten silicon melt.

Bradycardia A medical term used to describe a slower-than-normal heart rate.

Brazing The process of joining two or more metals by partial fusion with a layer of hard-solder alloy at high temperatures.

Breakdown A condition when a critical level of voltage is exceeded in an insulator or semiconductor and current starts to flow.

BSG (BoroSilicate Glass) Glass doped with boron that improves step coverage.

BTAB See Bumped Tape Automated Bonding.

BTE (Behind-The-Ear) A hearing instrument that fits over the ear and is coupled to the ear via an earmold. These types of hearing instruments are not popular at present.

Buffered Refers to an acid or base solution to which a substance capable of neutralizing the acid or base has been added.

Buffered Oxide Etch (BOE) A wet-etching technique that uses an etching solution containing hydrofluoric acid, and ammonium-fluoride. The hydrofluoric acid etches silicon-dioxide and the ammonium-fluoride raises the solution pH and protects the photoresist.

Built-In Self Test See BIST.

Bulk Acoustic Wave (BAW) sensor A device used in electronic nose technology. It comprises a quartz crystal coated with a chemically selective film. The crystal is configured in an oscillator circuit and typically has a base frequency of 10 MHz. When vapors from the sample interact with the coating film, some are absorbed, causing an increase in the mass of the film. This in turn leads to a decrease in the frequency of the sensor and is measured as the response.

Bulk Micromachining The tailoring of structures by machining a wafer's interior using wet chemical techniques and differential etching rates of different crystallographic planes.

Bumped Chip A chip from a wafer that has been processed with buffer metal(s) over the I/O pads, followed by an addition of solder or gold "bumps" to provide reflow or thermocompression bonding areas for copper-beam attachment. See TAB.

Bumped Die A die that has solder or gold bumps formed on the bond pads.

Bumped Tape Automated Bonding (BTAB) A bonding process where bumped dies are attached to metal leads mounted on a tape carrier. See tape automated bonding.

Bumping The process of forming solder or gold bumps on the bond pads of a die. Electroplating or evaporation may form the bumps.

Buried Layer A low-resistivity, diffused region placed under collector of a bipolar transistor to reduce its series resistance, commonly employed with an epitaxial structure.

Burn-In An electrical test performed over time wherein a semiconductor device is subjected to a voltage at high temperatures. This test is an accelerated aging of devices to screen out infant mortalities. It is used on new products until

yield-enhancement efforts have achieved the required yield.

C2D™ (Chrysler's Collision Detection)

A multiplexing network that reduces enormously the number of wires and connections required in Chrysler's automobiles.

CAD (Computer Aided Design) Any computer program that allows the user to draw or simulate device designs (such as AutoCAD, MEMCAD, Ansys, etc.)

CAE (Computer-Aided Engineering) A design tool similar to CAD. Traditionally, CAE has been used to describe the electrical design rather than the physical design, which was the realm of CAD, although these distinctions have blurred.

Calibration The set of operations that establish, under specified conditions, the relationship between values indicated by a measuring instrument or system, or between values represented by a material measure and the corresponding known (or accepted) values of a measurand.

Calibration Factor A term or set of terms, calculated through calibration, by which the instrument values are related to the corresponding known standard values. Sometimes expressed as a calibration factor, calibration coefficient, or as a series of calibration factors in the form of a calibration curve.

Calorimetric Sensor Module An array of thermopiles that measure heat generated during absorption or the adsorption of volatile materials by the sensitive coating.

Caltech Intermediate Format See CIF.

CAM (Computer-Aided Manufacturing) The use of algorithms for planning and controlling fabrication processes. It is a form of automation where computers communicate fabrication instructions to the machinery.

CAN (Controller Area Network) A 250-kbit/s interface system designed to interconnect smart devices and build intelligent systems. A CAN network is used to connect different electronic control units in cars.

Cannula A small tube for insertion into a body cavity, duct, or vessel.

Cantilever A lever beam held down at one end, with some support near the middle, and that supports a load on the other end. Diving boards and drawbridges are cantilevers.

Capabilities A term utilized to define the managerial assets of a firm or device and is specifically centered on husbanding the technological competencies of a firm or device.

Capacitance The capability of storing electrical charge. It is the ratio of the charge on one of the two conductors of a capacitor to the potential difference between the conductors. Its SI Unit is a Farad (F).

Capacitance Voltage Test See CV test.

Capacitor A device that consists of two conductors (such as parallel metal plates) insulated from each other by a dielectric. A capacitor introduces capacitance into a circuit, stores electrical energy, blocks the flow of direct current, and permits the flow of alternating current.

Capacitor Microphone A microphone, which is based on the conversion of sound energy to electricity by changing the capacitance of a deflecting membrane.

Carbon Nanotubes Tiny tubes about 10,000 times thinner than a human hair and consisting of rolled up sheets of carbon hexagons. Discovered in 1991 by researchers at NEC, they have the potential for use as minuscule wires or in ultra-small electronic devices. They can be "grown" directly by chemical vapor deposition (CVD). [IBM Research Nanology "Carbon nanotubes" 2001].

CARG See Compound Annual Rate of Growth.

Carriers Holes or electrons available in a semiconducting device for conduction of electric current.

Cascade Molecule See Dendrimer .

Cassette A vessel with slots used to hold wafers for cleaning, transporting, or processing through the fabrication processes. It is usually made of Teflon and holds up to 25 wafers. Cassettes are used to transport wafers just prior to cutting them into individual dies.

Catheter A tube used for gaining access to one of the body's cavities. In angioplasty, a catheter provides access to the heart's arteries.

Catheterization A procedure that involves passing a tube (catheter) through blood vessels and injecting dye to detect blockages.

Cathode The negative electrode in an electrochemical cell at which electrons can be received from an external circuit.

CCD (Charge-Coupled Device) A device utilizing a technique in which information is stored and transported by means of packets of minute electrical charges.

CD (Compatibility Definition) The interface features, between a part or assembly and its next assembly that defines their capability to exist or function in the same system or environment without mutual interference.

CD See Critical Dimension.

CD-SEM See Critical Dimension Scanning Electron Microscope.

Cell Library A set of computer data files which contain all the information needed to model, simulate, and layout pre-designed integrated circuit modules that can then be automatically interconnected.

CERDIP (CERamic Dual In-line Package) A package assembled with the lead-frame sandwiched between two ceramic layers and sealed by firing a glass frit.

CERPACK (CERamic PACKage) A CERDIP-like package with the leadframe extending out to all four sides, typically in surface-mounting format. Also known as CERPAC or CERPAK.

CERQUAD (Ceramic Quad-Flat Pack) A packaging solution similar to CERDIP but has pins on all sides on its periphery.

Cervical Cancer A cancer of the lowest portion of the uterus.

Channel The conducting charge layer between source and drain of an MOS transistor that is induced by an applied gate voltage.

Characterization The measurement of the typical behavior of instrument properties that may

affect the accuracy or quality of its response or derived data products. The results of a characterization may or may not be directly used in the calibration of the instrument response, but may be used to determine its performance.

Characterization (of an IC) The process of collecting measured electrical data about the operation of an integrated circuit component or module to enable it to be accurately modeled in a computer simulation.

Charged-Coupled Device See CCD.

Check Valve A valve that allows fluid to flow in only one direction.

ChemFET (Chemical Field-Effect Transistor) A transistor with the gate electrode coated with a selective coating that absorbs volatile molecules, which changes conductivity across the transistor's gate.

Chemical Mechanical Planarization (CMP) (also called Chemical Mechanical Polishing) The use of chemical slurry to polish a wafer's surface to eliminate topological layer effects at specific steps of the process flow in the manufacturing of semiconductors. It is an important process in BEOL. CMP technology was originally developed as a planarization tool for the manufacture of multi-level metal interconnects used in high-density integrated circuits. CMP is a critical component of the SUMMiT process enabling planar deposition in multiple-layer micro-machining processes.

Chemical Vapor Deposition (CVD) The growth of thin solid films on a substrate as the result of thermochemical vapor-phase reactions. Also defined as a SEMICON process used to deposit material onto a wafer using chemical reactions on the wafer surface to modify the material during processing. Materials that can be deposited by CVD include polysilicon, silicon oxide, and silicon nitride.

Chip A piece of semiconductor material, usually a section of a wafer, upon which a component or an integrated circuit is fabricated. Also called a die.

Chip Carrier A square (or rectangular) IC package with I/O connections on four sides; connections may be leadless or leaded.

Chip Lead The fine metallic tracks laid down on the surface of a semiconductor chip that helps it communicate with other chips.

Chip Size Packaging An IC packaging technique that allows a single chip, irrespective of size, to be protected from handling, moisture and contaminants. The chip-sized packaged device can be used as a chip carrier and directly soldered on a printed-circuit board. CSPs are used in products where portability is important, like camcorders, hand phones, and book computers and have recently been used to package MEMS accelerometers.

Chromatography A range of techniques for the separation of complex mixtures that rely on the differential affinities of substances for a gas or liquid mobile medium and for a stationary adsorbing medium through which the mixture passes, such as paper or gelatin.

CIC (Completely-In-the-Canal) A hearing instrument, the smallest amplification device available, extending inwards from 1 mm to 3 mm inside the opening of the ear canal, which allows greater gain with less power due to the proximity of the receiver to the eardrum (the tympanic membrane).

CIF (Caltech Intermediate Format) A common output format of designs drawn using a CAD program. These drawings eventually become masks used in photolithography.

Circuit A combination of electrical elements connected to perform a specific function.

Circuit Layout A tool used to convert a schematic diagram to the pattern that will be transferred to a wafer by photolithography. After verification that the circuit is complete, the schematic diagram is converted to a circuit layout based on a set of design rules for the photolithography process.

Cladding The material surrounding the core of an optical fiber. The cladding has a lower refractive index (faster speed) to keep the light in the core. The cladding and the core make up an optical waveguide.

Clean Room A confined area in which the humidity, temperature, and particulate matter are precisely controlled within specified units. The "class" of the clean room defines the maximum

number of particles of 0.3- μm size or larger that may exist in one cubic foot of space anywhere in the designated area. For example, in a Class 1 clean room, only one particle of any kind may exist in one cubic foot of space. Newer clean rooms are typically Class 1-10, and are needed for manufacturing ICs and surface micromachines with feature sizes close to 1 μm .

Closed-Loop Feedback An automatic control system for an operation or process in which feedback in a closed path or group of paths acts to maintain output at a desired level.

Cluster Tool Equipment that utilizes a robot to feed a set of process chambers. They are used to perform multiple process steps on a single piece of equipment and improve process control and reduce cycle time.

CMOS Complimentary Metal Oxide Semiconductor refers to an IC or its fabrication process that uses both p-mos and n-mos transistor technology. CMOS is finding many applications in MEMS fabrication.

CMP (Chemical Mechanical Polishing) See Chemical Mechanical Planarization.

CNC Computerized Numerical Control.

Cochlear Implant A device designed to help severe to profoundly deaf individuals who gain little or no benefit from hearing aids. Cochlear implants convert acoustic sound waves into weak electric currents, which are delivered to the immediate vicinity of the auditory nerve in the inner ear or cochlea.

Cocktail Party Effect The ability to focus on a specific voice from a variety of noises in the background. A silicon biomimetic microphone is being developed by the Cornell Nanofabrication Facility to achieve this.

Coefficient Of Diffusion The rate at which a diffusant will diffuse into bulk material at a given temperature; measured in cm^2/s .

Coefficient of Thermal Expansion (CTE) A material property pertaining to the change in lateral dimensions of a material with respect to temperature change. $\text{CTE} = (\text{Change in length/original length}) / \text{Change in temperature}$; Units = $^{\circ}\text{C}^{-1}$).

Collector The region of a bipolar transistor that “collects” the emitted electrons and then passes them on through a conductor, completing the electrical circuit.

Collimated Beams Light beams that are parallel.

Colloidal A substance that consists of minute particles, which are too tiny to view through a simple microscope, dispersed throughout another substance and is unable to pass through a semi-permeable membrane.

Comb Drive An electrostatic actuated MEMS device composed of inter-digitated fingers comparable to a comb. The comb has two halves, a fixed and a movable part. A potential difference applied across the two parts results in an attractive electrostatic force that pulls the combs together. Comb drives form the basis of inertial sensors and RF resonators.

Commercialization The process that a firm designs to exploit an invention, discovery, or product for profit.

Commodity An item that is available from multiple sources with no discernable differences in function or quality.

Compatibility Dimension See CD.

Compatibility Drawings Drawings of the interface features between a part or an assembly and its next assembly.

Competency The term utilized to define the technological product and know-how assets of a firm.

Compound Annual Growth Rate (CAGR) The year over year growth rate of an investment or market over a multiple-year period. The arithmetic definition is as follows: $CAGR = (\text{value at end of period/beginning value})^{(1/\text{No. of years})} - 1$.

Compressive Strain A decrease in a dimension (length, width, etc.) of a body when it is subjected to an external compressive force.

Compound Semiconductor A semiconductor formed by the combination of Group III and Group V elements such as GaAs, GaInP, etc.

Computer Aided Design See CAD.

Computer Aided Engineering See CAE.

Computer Aided Manufacturing See CAM.

Computer Modeling The process of providing to a computer, usually in the form of mathematical equations, a precise and unambiguous description of the system under study, including the relationships between system inputs and outputs. This description is used to simulate or model the described system.

Concentration (Impurity) The level of impurity materials as compared to “pure” semiconductor materials within the structure. The net concentration establishes the characteristic conduction pattern and other characteristics of the material.

Conditioned-Based Maintenance A proactive equipment maintenance that is able to predict failures at an early stage. Portable inspection equipment or embedded sensors are used to derive real-time information about changes in equipment condition or operating parameters and then define the maintenance actions needed. Unlike preventive maintenance, it is not scheduled and hence reduces costs.

Conducting Polymer Polymers in which adsorption of volatile components modulate the electrical conduction mechanism of the polymer and brings about changes in resistance.

Conductor, Electrical A material capable of carrying (conducting) electricity. Gold is the best electrical conductor. Copper and aluminum are also popular conductors. Aluminum is the conductor most commonly used in IC fabrication.

Confidence Ranges A confidence interval that provides a range of values around an estimate to show how precise the estimate is. The confidence level associated with the interval, usually 90%, 95%, or 99%, is the percentage of times in repeated sampling that the intervals will contain then true value of the unknown parameter.

Configuration Management A process for managing physical configurations and physical processes through documents, records, and data.

Conformal A property of films like photoresists, deposited metal etc. that are coated on a wafer. If the thickness of the film is the same throughout the surface irrespective of the contour, the film is said to be conformal.

Contact Aligner An optical system that uses contact printing to expose a wafer.

Contact Printing Exposure of a wafer by passing light through a mask that is in direct contact with the photoresist coated wafer. Chrome working plates are most commonly used due to their longer life, but emulsion-working plates can be used to prevent damage to the wafer.

Contacts The regions of exposed silicon that are covered during the metallization process to provide electrical access to individual devices.

Contamination A general term used to describe unwanted material or foreign matter that adversely affects the electrical characteristics of a semiconductor wafer.

Continuous Innovation Incremental product improvements that occur within the existing milieu. These innovations utilize existing knowledge in existing markets and extend current technology product platform schemas.

Continuum Modeling The modeling of components based on continuum materials properties such as Young's Modulus, hardness, ductility, etc.

Contour Maps Plots of measured data related to a wafer on a screen depicting resistance per square deviations with respect to a mean value.

Contrast The degree of sharpness of the transition of exposed to non-exposed parts in photoresists.

Controller Area Network See CAN.

Control Parameter Metrics A control parameter is a measurement taken for controlling an in-line process or as a test on a product.

Core The central region of an optical fiber through which light is transmitted. It has a refractive index different from the surrounding cladding.

Core Competence A term that has become ubiquitous and can mean many things. They include what a firm does best, what an individual does best, the industry standard technology bundles required, and many others. Here, we utilize the term to mean a unique set of technology know-how and production skills that enables a firm to be ahead of its competitors.

Cores A complex, pre-designed functional module (e. g. a digital signal processor) that is integrated within a larger chip.

Coriolis Effect The noticeable deflection of moving objects on the surface of a rotating body such as the Earth. The deflection is rightward in the northern hemisphere and leftward in the southern hemisphere.

Coronary Arteries Arteries that supply freshly oxygenated blood to the heart. Insufficient oxygen reaching the heart muscle via the coronary arteries may cause angina, heart attack (myocardial infarction), or even death.

Coronary Artery Disease Arteriosclerosis of the coronary arteries.

Coronary Stent A stent used to open up a blocked coronary artery (a blood vessel that carries blood from the heart to the rest of the body). After implantation, the coronary stent becomes a permanent implant to hold the artery open and prevent it from closing back down.

Correction The value which, when added algebraically to the uncorrected result of a measurement, compensates for an assumed systematic error. The correction is equal to the assumed systematic error, but of opposite sign. Since the systematic error cannot be known exactly, the correction value is subject to uncertainty.

Cost Leadership Strategy A strategy of producing a product of average function and quality, produced at a lower-than-industry average cost.

Cost Structure The mix of variable and fixed costs faced by a firm in producing a product.

Coulomb [C] A measure of electrical charge. One Coulomb is the electric charge equal to the quantity of electricity transferred by a current of one ampere in one second.

Covalent Bond A chemical bond between atoms such that they share electrons.

Creative Destruction Creative destruction occurs in an industry when a new technology or product paradigm replaces the old. The industry becomes redefined and uses a new technology trajectory. This has occurred in microsystems when MEMS-based accelerometers eclipsed the

mini-electro-mechanical systems developed for air-bag exploders in passenger cars.

Critical Dimension (CD) The smallest width or space of fabricated devices on a wafer (usually width of the gate). Critical dimensions are measured on some or all wafers following any photolithography or etching process.

Critical Dimension Scanning Electron Microscope (CD-SEM) A device that measures the critical dimension of an IC or MEMS device.

Cross-Calibration The process of assessing the relative accuracy and precision of response of two or more instruments. A cross-calibration would provide the calibration and/or correction factors necessary to compare data from different instruments looking at the same target. Ideally, simultaneous viewing of the same working standards or target would do this.

Cross-Connect Switching An optical switching technique that permits light signals to be differentiated by wavelength and routed across the network to a destination, as light, and not to be converted to electrical signals. Using a cross-connect switch, vast amounts of traffic data can be bundled and sent over pre-set routes.

Crosstalk Signal interference between adjacent channels that carry current usually due to coupling between them in some element, e.g., ICs, power supplies, adjacent cables, and adjacent telemetry channels.

Crystal Orientation The relationship of wafer surface to the crystal facets at which the crystal is sliced. Each crystal orientation has a direct effect on device characteristics.

Crystal Structure The style in which atoms or ions are arranged. It is defined in terms of the atom positions within the unit cell.

Crystallography The science and classification of crystals, particularly the semiconductor material employed to fabricate transistors and integrated circuits.

CTE See Coefficient of Thermal Expansion.

Current The flow of electrons. Usually measured in Amperes (amp or A).

Cutoff. Condition in a diode, transistor, or an electrical circuit in which there's no current flow.

CV Test Capacitance Voltage test. A technique used to characterize the amount of active defects and mobile contaminants in a gate oxide. It's also used to find the dopant profile of a pn junction.

CVD See Chemical Vapor Deposition.

Cyclization A chemical reaction that causes parts of a molecule to join so that a ring of atoms is formed within the molecule.

Czochralski Method The most common single-crystalline silicon growth technique used by industry. It uses a seed crystal introduced into a container of molten silicon liquid, which is pulled to form a solid single-crystalline silicon ingot.

D-F

Damascene A processing technique used in semiconductor processing to achieve copper interconnects. By this process, a metal conductor pattern is entrenched in an etched dielectric film on a silicon substrate and a planar interconnect layer is obtained.

Darkfield Mask A lithographic mask where clear glass will define electrical components like transistors on wafers. Most of the mask is covered with chrome.

DARPA (Defense Advanced Research Projects Agency) A research and development organization that is a part of the U.S. Govt.'s Department of Defense (DoD). It funded MEMS research when microsystems/MEMS was in its infancy. DARPA looks at research both from a military and commercial perspective though it concentrates on the former.

DC (Direct Current) The external, constant-voltage, single-polarity electrical power supplied to an IC.

DCA (Direct Chip Attach) An IC packaging technique where the chip is attached upside down directly on a substrate through epoxy attach and wirebonding.

Dead Band The range through which a stimulus can be varied without producing a change in the response of a measuring instrument. The inherent dead band is sometimes deliberately increased to reduce unwanted change in the response for small changes in the stimulus.

Decibel (dB) Defined as 20 times the logarithm (base 10) of the intensity ratio between two signals. It is a unit to express a comparative difference in intensity of electrical or acoustical signals, usually the latter. E.g., 60 dB refers to an intensity ratio of 1000 between the two signals.

Decimation The process of eliminating data frequencies in digital data used with digital filtering to minimize aliasing.

Decision Risk The probability of making an incorrect decision.

Deep Reactive Ion Etching See DRIE.

Deep Sub-Micron See DSM.

Deep Ultra Violet (DUV) Electromagnetic waves with a wavelength between 100 to 300 nanometers ($100\text{-}300 \times 10^{-9}$ m). The IC industry is using DUV lasers to obtain the 0.13- μm technology node.

Defect An imperfection in the surface or substrate of a silicon wafer, which causes one or more chips to malfunction. A defect in a silicon crystal refers to the presence of a break in the periodicity of arrangement of atoms in the crystal lattice.

Defect Density The number of defects per unit area of wafer surface.

Defense Advance Research Projects Agency See DARPA.

Degree of Planarity (DP) The flatness of the wafer surface at a particular step height location relative to the initial step height.

Deionized Water Water from which the majority of ions and particle contamination have been removed, which is ideal for semiconductor fabrication. This term is replaced by the term Ultra Pure Water (UPW).

Demultiplex To separate a multiplexed signal into its component parts. See multiplex.

Dendrimer A synthetically constructed strand of molecules built with nanoscale precision. It is similar to a polymer except that it is not randomly ordered. Chemicals can be attached to it to detect and cure diseases.

Dendritic A structure that branches repeatedly, i.e. tree-like.

Dense Wavelength-Division Multiplexing See DWDM.

Density A property of a material defined as the ratio of mass to volume of a sample.

Deoxyribonucleic acid (DNA) A nucleic acid that carries genetic information in the cell. DNA consists of two long chains of nucleotides warped into a double helix and coupled by hydrogen bonds. The sequence of nucleotides in the DNA determines individual hereditary characteristics. DNA is responsible for all protein synthesis and handling genetic information in living beings.

Depletion Device A type of MOSFET, which is "on" when no input signal is present.

Depletion-Mode Transistor A MOSFET that is on even though there is no external exciting voltage. Depleting the channel of carriers turns it off.

Depletion Region That area at a p-n junction which, when reverse-biased, is swept clear of free charges.

Deposition The procedure in which materials are deposited onto a substrate. Usually refers to thin conducting or insulating films used to form MOS gates, capacitors, thin-film resistors, and the interconnect system for an IC. Electro-deposition is used in the LIGA process to deposit metal plating onto the wafer substrate.

Depth Of Focus (DOF) The range of distances between a lens and image plane for which the image formed by the lens at a given setting is clearly focused. In current IC processing technology, the depth of focus offered by high-resolution lithographic tools is limited to around 1 μm . Due to depth-of-focus limitations, planarization techniques have to be adopted if the mask pattern is to be accurately transferred to the silicon wafer.

Derived Units Units expressed algebraically in terms of base units (of a system of measure) by the mathematical symbols of multiplication and division. Because the system is coherent, the product or quotient of any two quantities is the unit of the resulting quantity.

Descum A plasma etch operation following development that removes photoresist from areas of the wafer exposed to light.

Design For Manufacturing See DFM.

Design For Test (DFT) Design strategies adopted in early chip design that considers the testability of the device after production. The designer will have to sacrifice device compactness and allow the incorporation of new structures to make failure analysis and testing easier. This could include adding special circuits as part of an IC to aid in testing fabricated chips.

Design Intent The information and knowledge, which collectively forms the technical basis of a product's design. Fundamentally it consists of design input, constraints, concepts, and requirements, which are required to ensure that customer requirements are satisfied.

Design Kit A collection of technical information, software, and computer data files that enable the designer to model, simulate, and layout ICs using a specific technology (e. g. 0.8- μm CMOS).

Design Layout and Validation The determination by review of quality evidence that a particular design layout has met specified requirements.

Design Rule Check Commonly referred to as DRC, it is the process of checking for violations of the design rules (width, spacing, overlap of geometry, materials) for a specific technology. Rules are established through repeated part fabrication. It is an operation carried out by a CAD tool, which compares the dimensions, separations, overlaps, etc. of a chip layout to the minimum and maximum dimensions specified by the design rules for a particular process.

Design Rules Rules for design of a device, established by repeated part fabrication, or materials testing, and includes minimum feature widths, minimum feature spacing, feature over-

lap dimensions, etch release hole spacing, material characteristics, etc.

Design Space The boundaries that constrain a design.

Desorption The discharge of by-products due to reactions on the wafer.

Detector A device or substance that indicates the presence of a particular quantity without necessarily providing its value. In some cases, an indication may be produced only when the value of the quantity reaches a given threshold. e.g. halogen leak detector, temperature-sensitive paint.

Develop The third step in the photolithography process, during which chemicals are applied on coated and aligned wafers to remove areas of exposed photo resist, leaving the wafer with a photo resist pattern.

Devitrification. The process in which a non-crystalline material (glass) changes to a crystalline solid.

DFM (Design For Manufacturability) Statistical information on manufacturing process characteristics used to ensure that the device design falls within the parameters of normal manufacturing variances for each process element. This allows the designer to center the design for maximum performance and enhances yields, thereby reducing cost.

DFT See Design For Test.

Diborane (B_2H_6) A highly toxic and combustible gas used as a boron source for ion implantation and CVD.

Die Array or Matrix The grid pattern that appears on the wafer surface due to marking of die patterns on the wafer.

Die Attach The attachment of the die to the lead-frame or substrate, usually by epoxy.

Die Bonding See Bonding, Die.

Die Yield The ratio of the number of good die by the number of dies tested. Measured on a per-wafer or per-lot basis.

Die Chip cut from a larger wafer before it is packaged.

Die-by-Die Alignment An alignment method used by photolithography steppers that align each die on the wafer to the reticle, one die at a time.

Dielectric A material typically used as an insulator that contains few (if any) free electrons, has low electrical conductivity and supports electrostatic stresses.

Differentiation Strategy A strategy of producing a high-function and quality product at approximately industry average cost.

Diffraction The phenomenon of light that occurs when light passing through a narrow aperture bends when it passes around an edge.

Diffusant See Dopant.

Diffusion A high-temperature process by which selected chemicals (dopants) enter the crystalline structure of semiconductor materials to change the electrical characteristics at desired locations. This process takes place in a diffusion furnace.

Digital A method of representing information in an electrical circuit by switching the current on or off.

Digital Circuit A circuit that operates like a switch and can form logical functions. It's used in computers or similar logic-based equipment.

Digital Cross-Connect See DXC.

Digital Light Processor (DLP) A technology developed by Texas Instruments that enables analog-digital conversion necessary to connect a computer to video devices. DLP projectors are based on the combination of the DMD and the processing techniques to make extremely bright and sharp pictures. An electrostatic driven MEMS mirror represents each image pixel in a large array. DLP technology is widely licensed to conference display projector manufacturers such as Proxima and InFocus.

Digital Micromirror Device See DMD.

Digital Signal Processing See DSP.

Diluent An inert gas like argon, used along with reactant gases to maintain the preferred reaction rate.

Dimple A small feature or bump, typically a raised square on the surface of a MEMS device. Dimples can be used as mechanical stops. e.g. to control the touchdown in a high-aspect-ratio device.

Diode A two-terminal device that allows current to flow only in one direction. A diode is present at the intersection (junction) of a p-type and an n-type semiconductor.

DIP (Dual In-Line Package). A common type of IC package; circuit leads or pins extend symmetrically outward and downward from opposite sides of the rectangular package body.

Dipole An electric field created by two opposite charges of equal magnitude that are separated by a small distance.

Direct Chip Approach See DCA.

Direct Current (DC) The flow of electrons that only goes in one direction.

Direct Method of Measurement A method of measurement in which the value of the measurand is obtained directly, rather than by the measurement of other quantities functionally related to the measurand. e.g. measurement of a length using a graduated rule.

Direct Simulation Monte Carlo See DSMC.

Direct Wafer Bonding Bonding wafers not using an intermediate adhesive material.

Discontinuous Innovation Fundamental and far-reaching product changes that require the users or producers to change. Often discontinuous innovations are first used in an industry setting by lead user groups that are not being satisfied by the industries' current product offerings. Established companies often find it harder to cope with discontinuous innovations than with continuous innovations.

Discrete Device A semiconductor device containing only one active element, such as a transistor or a diode.

Discrimination See Resolution

Discrimination Threshold The smallest change in a stimulus that produces a perceptible change

in the response of a measuring instrument. The discrimination threshold may depend on, for example, noise (internal or external), friction, damping, inertia, or quantization. E.g., if the smallest change in a load that produces a perceptible displacement of the pointer of a balance is 90 mg, then the discrimination threshold of the balance is 90 mg.

Disklike Liquid Crystal See DLC.

Disruptive Technology Those technologies that have redefined the technology/product paradigm in an existing application area and have created the basis for a new industry. They are only acknowledged in hindsight and are often called typhoon technologies, creative destroyers or by other such anachronisms. We often use the term nascent disruptive technologies to identify technologies that have this potential not yet realized.

Dislocation A crystal defect due to a discontinuity in the crystal lattice structure.

Dissolution Rate The rate at which a developer dissolves the photoresist. It depends on developer concentration and the device feature size being patterned.

Dissolved Wafer Process A wet bulk micro-machining process developed by the University of Michigan that can be used to create MEMS inertial devices and sensors. It involves an anodic bond of a silicon sensor to a glass substrate.

DLC (Disklike Liquid Crystal) Disk-shaped molecules stacked like coins over a sensor's surface. The sensor's interaction with gas molecules disrupts the stacks resulting in change in resistance.

DLP See Digital Light Processing.

DMD™ (Digital Micromirror Device) Thousands of microscopic mirrors fabricated on hinges on top of an SRAM. Each mirror is able to switch or move into two states, "on" or "off," and controls an individual pixel of light.

DMOS Double-Diffused MOS. Also called VMOS (differing from V-groove MOS), for its vertical flow of current through the substrate.

DNA See Deoxyribonucleic acid.

Donor An impurity that can make a semiconductor n-type by donating extra "free" electrons to the conductive band. The free electrons are carriers of negative charges. See also Acceptor.

Dopant (also Diffusant) Dopants are the materials used to change the characteristics of a semiconductor crystal.

Dopant Profile A plot showing the amount of dopants added or distributed in a wafer at various depths.

Doping Atoms with one less electron than silicon (such as boron), or one more electron than silicon (such as phosphorous), introduced into the area exposed by the etch process to alter the electrical character of the silicon. These areas are called p-type (boron) or n-type (phosphorous) to reflect their conducting characteristics.

Dose (Q) The number of ions of an ion-implantation beam per unit area of wafer surface. Units are ions/cm².

Double-Diffused Devices Transistors in which two p-n junctions are formed in the semiconductor wafer by gaseous diffusion of both p-type and n-type impurities. See also planar devices for definitions of p- and n-type semiconductors.

Double-Diffused MOS See DMOS.

Downstream Reactor A reactor that ensures reduction of damage to the wafer surface by ion bombardment during dry plasma etching, by locating the wafer away from the plasma source.

Downtime The time a piece of equipment is not available for use in production, since it is broken or undergoing maintenance.

DP See Degree of Planarity.

Drain The working current terminal (at one end of the channel in an FET) that is the drain for holes or free electrons from the channel. It corresponds to the collector of a bipolar transistor.

DRAM (Dynamic Random Access Memory) Memory circuits that require regular refreshing of the data stored in each memory cell. The circuits are more compact than static RAM but do not retain data when the refresh signal (clock) or power is turned off.

DRC See Design Rules Check.

DRIE (Deep Reactive Ion Etching) An etching technique that uses plasma to obtain high-aspect-ratio structures or deep features.

Drift The slow variation with time of a metrological characteristic of a measuring instrument.

Drive-In The second part of a two-part diffusion. It is the part of the operation in which the diffusant deposited during predeposition is diffused further into the wafer to achieve the desired impurity profile.

Dry Etching Processes based on chemically aggressive gases (e.g. RIE), plasma, and particle-bombardment.

Dry-In/Dry-Out: A chemical mechanical planarization approach that eliminates the generation of liquid vapors. Room-temperature processing methods achieve dry-in/dry-out.

Dry Strip A post ion-implantation dry photoresist removal process that turns photoresist chemicals into ash. The dry removal process is accomplished using a fluorine-based gas, which forms a microwave-generated plasma that converts the photoresist into ash.

DSM (Deep Sub-Micron) Fabrication processes using dimensions less than 0.5 μm or 0.35 μm are often described as DSM. Any activities aimed at using these processes are deemed DSM, for example, a DSM digital design flow.

DSMC (Direct Simulation Monte Carlo) A numerical technique for modeling gas flows. Every set of particles is given a position, velocity, an internal energy, etc.

DSP (Digital Signal Processing) The manipulation of information that has been numerically coded using a digital circuit. Analog data (signals) are first converted to digital form by an analog-to-digital converter (ADC), then processed using digital circuits, then converted back to analog form by a digital to analog converter (DAC).

Dual-In-Line Package See DIP.

Ductility A measure of a material's ability to be drawn into wire or hammered thin, before it gets fractured.

DUV See Deep Ultra Violet.

DWDM (Dense Wavelength Division Multiplexing) A technology that enables data from different sources to be put together on a single optical fiber. Each signal is carried simultaneously on its own distinct wavelength. Using DWDM, up to 80 or more separate wavelengths or channels of data can be transmitted on a single optical fiber which would be able to deliver 200 billion bits a second.

DXC (Digital Cross-Connect) A telecommunication network device that is used to arrange lower-level digital signals among higher-level digital bit streams.

DXF (AutoDEsk Drawing eXchange Format) A drawing format commonly used to transfer layout information between EDA tools and by the foundry to generate fabrications masks.

Dynamic Measurement The determination of the instantaneous value of a quantity and, where appropriate, its variation with time. The qualifier "dynamic" applies to the measurand and not to the method of measurement.

Dynamic RAM (Random Access Memory) See DRAM.

e-beam (or Electron Beam) Refers to a machine that produces a stream of electrons (electron beams) that can be used to expose resists sensitive to such beams. It can be used to expose photosensitive film in the production of IC masks (photo-masks), or the circuit elements themselves.

Echelette Grating A coarse diffraction grating of 100-200 lines/mm (used to separate light of different wavelength) that enables resolutions of 1-2 Angstroms.

ECL (Emitter-Coupled Logic) A form of current-mode logic in which the output is available from an emitter-follower output stage.

Economies of Scale A decrease in per-unit costs as production volume increases. This effect is driven by fixed costs.

ECR (Electron Cyclotron Resonance) Providing energy to electrons by the use of RF energy at the electron cyclotron resonance frequency.

EDA (Electronic Design Automation) A term used for activities or facilities that involve software design aids used in chip design, or the industry sector making the aids.

EDM (Electro Discharge Machining) Milling using electric sparks.

EDP (Ethylene Diamine Pyrocatechol) A silicon etchant, like KOH or TMAH, but highly toxic.

EEPROM or E²PROM (Electrically-Erasable PROM) Similar to ROM, but with the capability of selective erasure through special electrical stimulus. Sometimes termed EEROM.

Elastic Modulus See Young's Modulus.

Elastomers Polymers having the elastic properties of rubber.

Electrical Breakdown See breakdown.

Electrically-Erasable PROM See EEPROM.

Electrical Overstress See EOS.

Electro-Static Discharge See ESD.

Electrochemical Etch-Stop A microfabrication wet-etching technique that enables the manufacture of single-crystalline silicon micro diaphragms. The process in brief: A wafer with a known doping profile is ion-implanted to form a well-designed p-n junction at the boundary between the varyingly doped areas of a silicon wafer. The wafer is put in a potassium-hydroxide etchant bath and a potential is applied to the p-n junction. The process is designed such that the silicon is etched until the formation of oxide that inhibits further etching when it reaches the p-n junction.

Electro Discharge Machining See EDM.

Electroluminescence The emission of visible light by a p-n junction when a forward-biased voltage is applied across it. It also refers to the emission of light caused by an electric discharge in a gas.

Electrolyte A substance that when dissolved in a suitable solvent or when fused can conduct electricity.

Electromagnetic Interference (EMI) External electromagnetic waves affecting the performance of electronic devices. The most common source is solar flares. Sensitive electronic devices have to be designed considering EMI effects.

Electromechanical Pertaining to a mechanical device, system, or process that is electrostatically or electromagnetically actuated or controlled.

Electromigration The movement of atoms in a metal interconnect line due to collisions by conduction electrons. The metal atoms migrate in the direction of current flow and can create voids in interconnect metal lines leading to failure of the IC. The addition of copper to aluminum reduces electromigration.

Electron An elementary charged atomic particle that carries a negative charge of electricity.

Electron Beam See e-beam.

Electron Cyclotron Resonance See ECR.

Electron Design Automation See EDA.

Electrophoresis The migration of oppositely charged colloidal particles or molecules in opposite directions through a solution under the influence of an external electric field. This process can be used to separate molecules composed of ions of opposite charges. The rate of movement of these molecules reflects its composition.

Electroplate Deposition of metals using an electric current and an electrolyte solution.

Electro Static Discharge See ESD.

Electrostatic Force Mechanical force caused by a voltage between two electrodes.

EM Electro-Magnetic.

Embolization The process or state in which a blood vessel or organ is obstructed by the lodging of a material mass (as an embolus).

Embolus An abnormal particle like an air bubble, circulating in the blood. Embolic coils can be released using a microgripper into the brain during aneurysms.

EMI See Electromagnetic Interference.

Emitter-Coupled Logic See ECL.

Emitter Diffusion The diffusion during which the emitters of the transistors are formed.

Emitter The region of a bipolar transistor that serves as a source or input end for carriers.

Emulsion A photoplate covered with a suspension of a salt of silver in gelatin or collodion, which is exposed and developed to produce a photomask.

End-Effector A tool or instrument connected to the tip of a robot arm. Every end-effector has its own structure and is programmed according to the required task(s).

Engineering Units A set of defined units commonly used by an engineer in a specific field to express a measurand. The units should be expressed in terms of a recognized system of units, preferably SI units.

Enhancement Device A type of MOSFET that requires a control signal input to turn on the device. The device is “off” when no input signal is present.

Environmental Variables Variable physical properties in the environment of the instrument or target (such as temperature, particulate and electromagnetic radiation, vacuum, and vibration) that may affect the result of a measurement. The sensor does not measure an environmental variable; it measures an observable.

Enzymes Molecules found in nature or man-made, which speed up chemical reactions.

EOS (Electrical Overstress) A transient or steady state electrical condition that exceeds the specifications and/or capabilities of a device. Both the magnitude and duration of an EOS event can vary. Examples of mild EOSs are oxide ruptures and junction damage with signs of visual stress. Severe EOS may include massive vaporization of bond wires or aluminum interconnects and carbonizing of plastic packages.

Epi Short for epitaxy. The controlled growth, atom by atom, of a layer of crystalline semiconductor material on a suitable substrate.

Epipoly Epitaxially deposited polysilicon.

Epitaxial Layer, Epitaxy See Epi.

Epon SU-8 See SU-8.

Epoxy A family of thermosetting resins used in the packaging of semiconductor devices. Epoxies form a chemical bond to many metal surfaces.

EPROM (Erasable Programmable Read-Only Memory) Similar to ROM, but enables the user to erase stored information. Normally refers to a memory device whose contents may be erased by exposure to ultraviolet light.

Error The difference between the result of a measurement and the value of the measurand.

ESD (Electro Static Discharge) A static buildup of electrons that is then discharged. The magnitude of ESD can vary widely, but the duration of a pulse is usually very short. An ESD event can result in junction failure, contact damage, filamentation, oxide thermal damage, oxide breakdown, charge injection and fusing (opening) of interconnects.

EST See Expressed Sequence Tags.

Etching The removal of portions of a layer of conductive material from a usually insulating etching base through chemical or electrolytic means. In wet etching, the material is dissolved when immersed in a chemical solution. In dry etching, the material is sputtered or dissolved using reactive ions or a vapor-phase etchant.

Etch Pit Microscopic cavities that can be formed on the surface of a crystal if discontinuities in the normal lattice structure intersects its surface. Etch pits will form if atomic impurities in the crystal get concentrated at these discontinuities due to thermal treatment, and the crystal specimen is subsequently chemically etched.

Etch Profile A representation that illustrates the shape of the sidewall of the etched structure.

Etch Stop A technique of stopping the etching at well-defined locations, e.g. at silicon-insulator interfaces or p-n junctions in semiconductors.

Etchback Planarization A technique that involves bulk removal of raised material during a planarization process. A surface of SiO₂ can be made planar, by an etchback planarization proc-

ess by spinning a thick photoresist on the SiO₂ and etching both the photoresist and SiO₂ until the required thickness of SiO₂ is obtained. This technique is used to fill voids and low areas on the surface.

Ethylene Diamine Pyrocatechol See EDP.

Eutectic A particular composition of the alloy having the lowest melting point and is lower than the melting point of its constituents. Its applications include high-quality soldering in surface-mount chips since eutectic alloys have a fixed melting point unlike other alloys, which have a range of melting-point temperatures.

Eutectic Attach An obsolete method of connecting a chip to a lead-frame by depositing gold on the backside of the chip to alloy to the substrate.

Eutectic Bonding A wafer-level packaging technique involving the deposition of intermediate metallic and glass films prior to the bond. The wafer is heated to the eutectic point, which is the lowest melting temperature in a two-component phase diagram where there is little or no solid solubility between the components. An alloy is then formed by solid-liquid interdiffusion at their contact interface and is followed by solidification upon cooling.

Evaporation A method for depositing metal on wafers by heating a material until it vaporizes and deposits on the wafers.

Excimer laser A laser that uses chemicals like ArF and KrF (called excimers or excited dimers) that generates light having wavelengths of less than 200 nm. Used as a common source of ultraviolet rays in semiconductor lithographic tools.

Exposure Subjecting a sensitive chemical to light or other electromagnetic energy.

Expressed Sequence Tags (EST) Genetic sequences that are expressed as mRNA but have no known identity or function. ESTs do not represent genes.

Fab The informal name for a chip manufacturer's fabrication plant where ICs or MEMS devices are made. SEMICON industry term for a foundry.

Fabless A characteristic of certain semiconductor companies that contract with outsource foundries for their wafer fabrication requirements.

Fabrication The process of creating ICs on the surface of wafers. It refers to only the front-end processing of devices in semiconductor wafers and does not include the back-end processing like assembly and packaging.

Face-Centered Cubic (FCC) The crystal structure associated with semiconductors (Si, Ge, GaAs) and metals. In FCC, atoms are found at all 8 corners of a cube and at the center of each face.

Failure Analysis An orderly procedure for determining that a device has failed. The results are frequently useful for enhancing the reliability of subsequent products.

Failure In Time See FIT.

Failure Rate A rate of failure per unit time, for example, 3 failures per 164 hours or 1 failure per day, etc. Semiconductors are usually measured in failures per 1000 hours.

Farad The unit of capacitance. It is equal to the capacitance of a capacitor between whose plates there appears a potential of one volt when it is charged by one coulomb of electricity.

Fault Models Software rules to identify different types of failures during electrical testing.

Fault Tree The relationship between a "top event" (a critical functional failure in the system operation) and a combination of component faults.

FCC See Face-Centered Cubic.

FEA (Finite-Element Analysis) A simulation procedure for analyzing multiphysics behavior.

Feature Size See Critical Dimension.

FED (Field-Emission Display) A display technology using electron emitters, placed in a grid, and individually controlled by cathodes. It consumes less power than conventional cathode-ray tubes and improves image quality.

FEM (Finite-Element Method) A method of computationally analyzing mechanical components.

Femto A prefix meaning one-quadrillionth (1×10^{-15}). Its symbol is f.

Ferroelectric A property of a particular material that determines its polarization in one direction or the other, or reversed, if a positive or negative electric field is applied, e.g. lead zirconate titanate (PZT).

FEOL See Front End Of Line

FIB (Focused Ion Beam) A finely focused ion beam (often Ga^+) used for imaging and milling. The most-used tool in failure analysis.

Fiber Bragg Grating An optical fiber that has periodic variations in the index of refraction lengthwise along the fiber. The period of the index modulation can be designed to cause deflection of light at a specific wavelength, and functions as an optical filter.

Fiber-Optic (FO) Sensor Conventional optical fiber layered with fluorescent coating that interacts with odorant molecules. The coating adsorbs an optical pulse.

Fiber Optics The conduction of light waves through certain materials across long distances. It demonstrates total internal reflection by combining like materials of differing indices of refraction.

Field-Effect Transistor (FET) A solid-state device in which current is controlled between the source and drain terminals by voltage applied to a non-conducting gate terminal.

Field-Emission Display See FED.

Field Oxide A relatively thick layer of silicon dioxide (on the order of μms) that covers the surface of an IC between active components and acts as an insulating layer. This oxide is porous and prevents induced charge in the wafer surface. See also Gate Oxide.

Field-Programmable Gate Array See FPGA.

Filter A circuit that inhibits the transmission of frequencies. A low-pass filter allows the transmission of low frequencies, while a high-pass

filter allows the transmission of high frequencies.

Final Assembly and Packaging The assembly and packaging of the IC chip. Also known as first-level packaging.

Finite-Element Analysis, Finite-Element Method See FEA, FEM.

First Interlayer Dielectric (TLD-I) The dielectric between the wafer and the first interconnect metal layer.

First-Level Packaging The assembly and packaging of the IC chip. Also known as final assembly and packaging.

First Production The period when the manufacture of a product according to product specifications is initiated and quality control and inspection procedures are implemented. This culminates in an authorization that releases material for specified uses.

FIT (Failure In Time) A measure of failure rate in 10^9 device hours; e.g. 1 FIT = 1 failure in 10^9 device hours.

Fixed Cost A cost that does not vary with the level of output. The fixed cost per unit decreases as production levels increase.

Fixed-Fixed Beam A beam that is supported at both of its ends.

FL (Fuzzy Logic) A method to mathematically represent uncertainty and ambiguity and provide formalized tools to deal with data whose boundaries are not sharply defined (i.e. are fuzzy). Some PalmTops use fuzzy logic to recognize handwriting.

Flat Pack A ceramic surface-mounted hermetic package. Very popular for military applications because of its small size, but characterized by lead and package seal fragility, poor structural strength, excessive gold, and loose-particle problems.

Flats The flat portion on the periphery of a circular wafer that identifies the crystal orientation.

Flip Chip A packaging technique introduced by IBM, where the chip is attached to the plastic or ceramic substrate facedown without using the

cumbersome peripheral wire bonding. A grid of solder balls on the surface of the active area of the die is joined directly to a corresponding set of solder pads on the substrate. An IC designed for facedown mounting, is attached by controlled-collapse solder pillars on I/O pads of the device.

Flip-Flop An electrical circuit having two stable states of on or off. A basic logic circuit component.

Float-Zone Crystal Growth A crystal-growth method that produces a single-crystalline silicon ingot that has lower oxygen content and is of higher purity than Czochralski growth. It is obtained by selectively heating the silicon ingot. This technique is not adopted due to difficulty in obtaining accurate doping concentrations.

Fluorosilicate Glass (FSG) Glass (SiO_2) in which fluorine is added to reduce the dielectric constant of glass. It is used in multilevel metallization.

Focal Length The distance from the center of the lens to the focal point.

Focal Point A point along the axis of the lens where light rays refract and converge.

Focus A condition where most of the individual rays of radiated energy are made to converge together into a single point.

Focused Ion Beam See FIB.

Footprint Floor space area occupied by certain equipment in the cleanroom.

Forward Bias A p-n junction is said to be under forward bias if an external voltage is applied across a junction such that the p side is positive with respect to the n side and current flows from the p side to the n side.

Foundry Semiconductor fabrication facilities, which house a given set of equipment to prototype or manufacture IC wafers and chips or MEMS devices. It's usually owned by private contractors who are not associated with any individual company. Foundries specialize in certain devices or processes.

FOUP See Front-Opening Unified Pod.

Four-Point Probe A metrology tool used to measure sheet resistance. It forces a current through the two probes and measures the resulting voltage drop across the other two probes.

FPGA (Field-Programmable Gate Array) An IC fabrication technology in which pre-fabricated circuit modules are electrically configured by the user to meet specific design requirements on a chip-by-chip basis.

Frenkel Defect A defect found when an atom leaves its crystal lattice site and takes up position in between two layers of atoms. It can migrate across the crystal.

Frequency The number of occurrences of an event in a given time period (usually one second). With respect to electromagnetic waves, it is the number of waves (cycles) per second that pass a given point in space.

Frequency (electrical) The number of times per second an alternating current goes through a complete cycle. Formerly expressed in cycles per second. Now expressed in Hertz (Hz).

Frequency Degeneracy This occurs when a number of identical oscillators are coupled with each other and their frequencies become degenerate, i.e. having two or more levels.

Frequency Response The ability of a device to handle the frequencies applied to it. Frequency response is quantified as the ratio of the range of the output signal to the range of the input signal.

Fresnel Diffraction (or Near-Field Diffraction) The condition when the light source or screen, or both, are at a finite distance to the aperture. This type of diffraction occurs when a short distance separates the mask and the wafer. It leads to error during mask exposure at mask edges and is the limiting factor for proximity aligners.

Front End In semiconductor manufacturing, it refers to the set of fabrication processes that enable transistors to be formed on the wafer.

Front-End Of Line (FEOL) Operations performed on the wafer starting from transistor manufacturing until first-level metallization.

Front-End Processing Operations performed on the wafer device during manufacturing and before the first level of metallization.

Front-Opening Unified Pod (FOUP) A wafer-handling system that combines wafer cassette and tool insert/removal functions. It is a critical factor for the transition from hand delivery to mechanized transportation of material.

Fullerene A new allotrope of carbon (composed of at least 60 atoms of carbon) characterized by a closed-cage structure consisting of an even number of three coordinate carbon atoms devoid of hydrogen atoms. This class was originally limited to closed-cage structures with twelve isolated five-membered rings, the rest being six-membered rings. It can be used as a nachnology material and is considered an excellent material for future MEMS and nanotechnology applications. [IUPAC Provisional Recommendations for the Nomenclature for the C₆₀-Ih and C₇₀-D_{5h}(6) Fullerenes, 2001].

Functional Genomics A branch of genetics that deals with the functions of specific genes and discovers how genes influence medical conditions.

Functional Tests Electrical tests to verify whether or not a chip meets specifications.

Fused Silica Non-crystalline (amorphous) quartz.

Fusion Bonding Bonding two silicon wafers together to simplify the fabrication of micromechanical devices such as sensors and actuators by allowing intricate channels, reservoirs, and other structures to be etched separately into each wafer before being bonded together.

Fuzzy Logic See FL.

G-J

GaAs (Gallium Arsenide) A compound semiconductor considered to be an alternative to silicon and electronically faster, but more expensive and difficult to work with. GaAs has higher carrier mobility than silicon, and can thus be used to produce higher-speed devices. Currently its most popular application is in cell-phone technology and it's beginning to be used in MEMS applications.

GaAs FET A discrete device used to amplify higher-frequency radio signals.

Gain The ratio of output over input amplitudes.

Galvanic Cell A chemical reaction that produces electricity.

Ganglion and Bipolar Cells Cells that form a link between the rod and cone cells (present in the eye to absorb light) and the optic nerves.

Gap Fill The filling of narrow openings with material.

Gas-Phase Nucleation A process where reactant molecules attach to each other to form larger molecules. An undesirable event in CVD that creates particles impurities.

Gas Purge A method of flushing unwanted gases from a container or a gas-delivery system. Usually done by introducing an inert gas like nitrogen.

Gate Array An IC consisting of a regular arrangement of gates that are interconnected to provide custom functions. Sometimes called an uncommitted logic array (ULA).

Gate Equivalent The basic unit of measure for digital circuit complexity, based on the number of individual logic gates that would have to be interconnected to perform the same circuit function.

Gate Oxide The insulating very thin oxide layer that separates the gate and the underlying silicon in a MOSFET. It's usually in the order of nanometers and is grown to precise thickness.

Gate 1. The basic digital logic element where the binary value of the output depends on the values of inputs. 2. The primary control terminal of an FET.

GDSII Like CIF, a common output format of designs drawn using a CAD program. These drawings eventually become masks used in photolithography.

Gene Expression Profiling The process of determining which genes are active in a specific cell or group of cells and is accomplished by measuring messenger ribonucleic acid (mRNA). Variations in gene expression profiles in normal

tissue, compared to diseased tissue, or in the presence of or absence of a drug, can act as an important indicator of disease or predisposition to a disease.

Generic Process Any node in the process hierarchy. For example, “deposition”, “deposition/CVD”, and “deposition/CVD/LPCVD” are three different (but related) generic processes.

Germanium A brittle, grayish-white metallic element having semiconductor properties. It’s widely used in crystal diodes and early transistors.

Gettering The trapping of impurities away from the semiconductor surface towards the bottom.

Giga Prefix meaning one billion (1×10^9). Its symbol is G.

Glassivation Passivation using silicon-dioxide (glass).

Global Planarization refers to surface planarization across the entire wafer.

GLV (Grating Light Valve) A MEMS display technology developed by a Stanford researcher and licensed to Sony that allows pixels to be formed on the face of a silicon chip and project it onto a huge screen, PDA etc. A GLV consists of reflective ribbons 10^{-13} m long mounted on a silicon chip. A voltage applied bends a set of ribbons towards the chip and represents a pixel of the image. The shape of a ribbon and hence a pixel can be changed 20 billion times a second.

Grain An individual crystal in a polycrystalline metal or semiconductor.

Grain Boundary The boundary between grains in polycrystalline materials.

Grain Growth The increase in average grain size of a polycrystalline material for most materials. An elevated-temperature heat treatment is necessary.

Ground The connection point in a transistor that makes an electrical connection to a voltage of 0 Volts.

H See Henry.

Haptic Glove A glove based on the sense of touch, used for surgical techniques.

Hard Bake A bake performed on photoresist after development. It is performed at a higher temperature than a soft bake to stabilize the photoresist prior to subsequent processing. It removes solvents and moisture, and enhances adhesion during an etch or implant process.

Hard Surface A photoplate coated with a relatively hard, non-emulsion coating, which may be selectively etched to produce a photomask. Popular hard-surface materials are chromium, chromium-oxide and iron-oxide.

Hardness The measure of a material’s resistance to deformation by surface loads or scratching.

Hardware The actual IC chips and interconnections in a system as opposed to the computer programs and data (software) that may be stored in memory (which is itself hardware).

HARM (High Aspect Ratio Micromachining) Micromachining techniques for manufacturing microstructures of aspect ratios >10 . DRIE, LIGA, or laser micromachining etc. come under HARM.

HDL-A/MS HDL applied to analog/mixed - signal systems. Also referred to as VHDL-A/MS. The V prefix stands for VLSI.

Heat Sink An assembly that serves to dissipate, carry away, or radiate into the surrounding atmosphere heat, which is generated by an active electronic device.

Henry (H) A unit of inductance equal to the self-inductance of a circuit or the mutual inductance of two circuits in which one volt is produced when the electric current in the circuit varies uniformly at the rate of 1 ampere per second.

HEPA (High-Efficiency Particle Air) An air filter that removes 99.97% of particles greater than $0.3 \mu\text{m}$ in diameter.

Heteroepitaxy A type of epitaxy where one type of material is epitaxially deposited on another like Si on Al_2O_3 .

Hexamethyl Disilazene See HMDS.

HF See Hydrofluoric Acid.

High Aspect Ratio Micromachining See HARM.

High-Density Plasma Etch Low-reactor-pressure dry-etching technique suitable for high-aspect ratio structures, which have a high density of active species in the plasma.

High-Efficiency Particle Air See HEPA.

High-Performance MOS See HMOS.

High-Q Factors A quality factor for high frequency applications.

High-Resonant Q Factor The quality (Q) factor of a circuit is the ratio of its reactance to its resistance. Q-factor of a resonant circuit measures the circuit's peak response at the resonant frequency and also its bandwidth. The greater the value of Q, the higher the peak response and the narrower the bandwidth.

Hillock Protrusions that form on a thin interconnect film due to electromigration.

HMDS (Hexamethyl Disilazane) What is used to prime the wafer surface to enable better adhesion of photoresist on a wafer.

HMOS (High-Performance MOS) A scaled nMOS structure.

HNO(3) See Nitric Acid.

Hole The absence of a valence electron in a semi-conductor crystal. The movement of a hole is equivalent to the movement of a positive charge.

Holy Grail (non biblical) A device obtained after extensive research and development and has features that far exceed competing devices in the same category.

Homoepitaxy An epitaxial deposition wherein both the deposited material and the substrate are the same type.

Horizontal Furnace A furnace where the quartz tube that is used to handle wafers is in the horizontal position during batch furnace processing.

Hot Electrons Electrons created in semiconductor regions subjected to high electric fields. They

destroy transistors and are a major reliability problem.

Hot Lot A set of wafers that is given priority and processed straight away upon reaching each fabrication step.

HVAC Heating, Ventilation, and Air Conditioning.

Hybrid Circuit A microelectronic device consisting of both film circuits and semiconductor elements.

Hybrid-Integration Packaging Platform A technique developed by Axsun Inc. that integrates nearly any combination of optical devices. It claims a 10x reduction in photonic subsystems in comparison to those developed by conventional integration techniques.

Hybridization A process that occurs when two complementary DNA strands complement each other.

Hydrazine An anisotropic silicon etchant that is highly toxic and also used as a missile fuel. If a MEMS sensor is to be added to CMOS circuitry in a single chip, hydrazine is one of the few etching solutions available that is selective to aluminum, the metallization material used in most CMOS devices.

Hydrofluoric Acid (HF) An acid (in various dilutions) commonly used to etch oxide in many MEMS fabrication processes, such as a sacrificial oxide release process. It is also used as an ingredient in etchants to attack SiO₂ (including quartz).

Hydrophilic A type of material that has affinity for water.

Hydrophobic A type of material that has no affinity for water.

Hysteresis The property of a measuring instrument whereby its response to a given stimulus depends on the sequence of preceding stimuli. It is also defined as the lagging in the values of resulting magnetization in a ferromagnetic material due to a varying magnetizing force. This results in irreversible loss of energy through heat dissipation.

IC See Integrated Circuit.

IEEE 1451.2 A specification of a digital interface to access a data sheet, read sensors, and set actuators.

III Integrated Injection Logic. A bipolar structure characterized by an integrated PNP load device and inverted operation of the NPN logic transistor.

ILD See Interlayer Dielectric.

IMEMS (Integrated MicroElectroMechanical Systems) A fabrication process that enables both CMOS circuitry and MEMS to be created on the same chip. Developed by Sandia National Laboratories.

Impedance The opposition in an electrical circuit to the flow of an alternating current that is equivalent to the electrical resistance to a direct current.

Index of Refraction (n) The ratio of the velocity of light in a vacuum to the velocity of light in a given medium.

Indirect Method of Measurement A method of measurement in which the value of a measurand is obtained by the measurement of other quantities functionally related to the measurand. E.g. (a) measurement of a pressure by measuring the height of a column of liquid; (b) measurement of a temperature using a resistance thermometer.

Inductance The property of an electric circuit by which an electromotive force is induced in it as the result of a change in the inducing current

Inductively Coupled Plasma Plasma etch systems that uses RF energy in combination with low-pressure gas by an inductive coil. Like RIE, it is a low-pressure process but has higher ion densities.

Inductor An energy storage circuit component that introduces an inductance into a circuit.

Industrial Pull The drive to produce commercially exploitable products and processes to meet new requirements.

Inertial Sensors Accelerometers that detect a change in inertia (resistance to change in momentum) of the mass or body to which they are attached and convert this change into a useful input signal for an information-gathering system.

Infrared Electromagnetic radiation having a wavelength between 700 nanometers and 1 millimeter. Thus it has a longer wavelength, and lower frequency, than visible red light.

Infrared Interference A nondestructive and relatively fast technique for measuring dopant concentrations of lightly doped layers based on optical reflectance.

Innovation In a commercial sense, it is closely aligned with utilization of a new product or a new service. In a technological sense, it is closely aligned with technological change. It is important for the users or reader of this term to understand the context in which it is used.

Insertion Loss The loss in power between source and load caused by inserting a device. Its units are in decibels.

Insulator A material that is a poor conductor of electricity used to separate conductors from each other or to protect personnel from active electrical devices.

Integrated Circuit (IC) An interconnected array of active and passive elements integrated with a single semiconductor substrate or deposited on the substrate by a continuous series of compatible processes, and capable of performing at least one complete electronic circuit function. Also known as chip or integrated semiconductor.

Integrated Micro-Electro-Mechanical Systems
See IMEMS.

Interconnect The metal and silicon patterns on an IC that interconnect electrically components (e. g. transistors) and supply power and distribute electrical data throughout the circuit.

Interconnect Delay A delay in the propagation of electrical signals due to time delay caused by the resistance and capacitance of the interconnect. As transistor dimensions reduce, this is a major stumbling block to increasing the speed of ICs.

Interlayer Dielectric (ILD) The insulator material in ICs, between each metal layer or between the tungsten via and silicon wafer surface. Lower-k materials have to be adopted to avoid crosstalk between adjacent metal layers. Same as interlevel dielectric.

Interlevel Planarization Planarization after each metal or dielectric layer deposition during the integrated chip fabrication process. As transistor sizes reduce, flat surfaces and hence planarization at every step or level are required to ensure the accuracy of the lithographic process that defines a new layer of metal or interconnect built above a layer.

Internal Stresses Stress systems within solids that are not dependent on external forces. Also known as residual stresses.

Internet Protocol (IP) A telecommunication standard for transmitting blocks of data between computers, which function as sources and destinations and identified by unique addresses.

Interstitial A defect where an atom is located in between lattice atoms.

Interstitial diffusion The movement of an atom from a typical lattice position to an empty space between the lattice atoms called an interstitial site. The atom that diffuses has to be much smaller than the lattice atoms. See Vacancy Diffusion.

Intrathecal space The space where fluid flows around the spinal cord.

Intrinsic Error (of a measuring instrument) Errors inherent in a measuring instrument. E.g. nonlinearity, gain accuracy, noise, offset, and hysteresis.

Intrinsic A pure semiconductor whose electrical conductivity depends only on ambient temperature and the band gap energy and not on external dopants.

In-vitro Fertilization A technique for conception of a human embryo outside the mother's body. Eggs, from the female are placed in a special container and sperm from the male is introduced to achieve fertilization. The fertilized egg is then introduced in the same or a different female's body.

Ion An atom or group of atoms that has either gained or lost an electron, thus being positively or negatively charged.

Ion Analyzer An ion implanter subsystem that separates the desired dopant ions from the rest of the ions in the beam.

Ion-Beam Etching An etching process that uses ions to bombard a material and physically knock out molecules from the substrate.

Ion-Beam Milling A process of physically removing unwanted (unprotected) material from a semiconductor surface by ion bombardment.

Ion Implantation A means for adding dopants to a semiconductor material. Charged atoms (ions) are accelerated in an electric field into the semiconductor material. It is especially useful for thin doped areas. This process is much more precise than the diffusion method of doping.

Ionic Bond A bond that exists between two adjacent and oppositely charged ions.

Ionized Metal Plasma PVD A sputtering process where metal is ionized in RF plasma and the metal ion flows in a highly directional path to achieve conformal coverage of high-aspect-ratio structures.

IP See Internet Protocol.

IR See Infrared.

ISFET Ion-Sensitive Field-Effect Transistor.

Isolation An electrical separation between areas of an IC.

Isolation Diffusion A method of achieving isolation by diffusing in such a manner that p-n junctions surround the areas to be isolated from one another.

Isothermal A process occurring at a constant temperature. In an isothermal process heat is, if necessary, supplied or removed from the system at just the right rate to maintain a constant temperature.

Isotropic Etch The process through which a substrate or layers are etched at the same rate in every direction.

Isotropic A property of a material that has the same values when measured along axes in all directions.

JFET (Junction Field-Effect Transistor) A solid-state device in which current is controlled between source and drain regions by voltage applied to a conduction or junction gate terminal.

Junction (p-n) The line of demarcation where the number of p-type and n-type carriers are exactly equal with a surplus of p-type on one side and n-type on the other.

Junction Depth The precise depth in a wafer where the p-type doped region meets the n-type doped region.

Junction Spiking Microalloying by diffusion of the contact metal into the silicon.

Junctions Regions of transition between two different semiconducting regions in a semiconductor device (such as a p-n junction), or between a metal and a semiconductor

K-M

Kerf The width of a channel cut by a saw.

Killer Apps The applications that make a sustaining market for a promising but under-utilized technology. A particular application first introduces a new application type and creates a lot of consumer interest that starts accepting products, which in turn offer similar application. The Lotus 1-2-3 spreadsheet was the killer app for the IBM PC product.

Killer Defect A defect that can destroy an IC.

Kilo Prefix meaning a multiple of 1000 (1×10^3). Its symbol is k.

KOH The formula for potassium-hydroxide. The most common etchant for wet etching of silicon.

KrF An excimer laser that uses krypton and fluorine gases to produce a light source of 248 nanometers. Used in 0.18- μm technology.

Lab-On-CD A CD-ROM having microfluidic structures to achieve automation of an entire testing procedure.

Lab-On-chip MEMS technology applied to analytical instrumentation. The apparatus required to conduct in-depth chemical analysis is miniaturized in size such that it fits onto a credit-card-sized chip.

Lambda Router (also Wavelength Router or Optical Cross-Connect, OXC) A device that takes in a single wavelength of light from a specific fiber-optic strand and recombines it into another strand that is set on a different path.

Laminar Flow Streamlined flow with no turbulence. It is a filtration system used through virtually all clean-room processing operations to control airflow and velocity at workstations within the fab. The “path” the airflow takes is optimized to keep airborne particles from coming in contact with the wafers.

Lapping A mechanical operation to remove damage due to wafer slicing and achieve a high-quality flat surface on the wafer.

Large-Scale Integration (LSI) ICs having between 1,000 and 100,000 transistors. LSI ICs have 100 to 5,000 gate equivalents (number of primitive gates, generally 2-input NANDs), or 1,000 to 16,000 bits of memory.

Laser-Assisted CVD See LCVD.

Laser Tweezers are used for the manipulation of specialized cellular parts like mitochondria, DNA, RNA etc. DNA can be uncoiled to study gene structure and DNA replication, by optical tweezers. Laser tweezers have helped in increased manipulation of DNA.

Lateral Diffusion The diffusion of dopants parallel to the surface of the substrate.

Layout The physical location of the components and interconnections, which make up an IC. The layout data include the geometrical patterns on each of the masks required during processing.

LCC (Leaded Chip Carrier) A chip package having pin connectors on each side.

LDD See Lightly Doped Drain.

LLCC (Leadless Chip Carrier) is a chip package with flat contacts, instead of pin connectors, on each side. They are more compact, lightweight and easier to install than LCCs and are usually made of ceramic material.

LCVD (Laser-Assisted CVD) Similar to conventional chemical-vapor deposition except that deposition is localized using a laser source that allows localized heating.

Leadframe A stamped or etched metal frame that provides external electrical connections for a packaged electrical device.

Leakage Current Undesirable carrier movement in a semiconductor device that consumes battery power and disrupts normal functions of the device.

Learning Cycle The analysis-corrective action formulation-corrective action implementation cycle needed to fix a yield problem.

LED (Light-Emitting Diode) A compound semiconductor device that emits light whenever current passes through it.

LI See Local Interconnect.

Liftoff A method to pattern a deposited thin metal layer. The process is as follows: A silicon wafer with an oxide layer above it is coated with photoresist. The photoresist is patterned by photo lithography, exposing the oxide below it, which is wet-etched, followed by metal deposition to leave a fine metal layer where the oxide was present. The rest of the photoresist and the metal film over the areas covered by the photoresist is removed using acetone or any solvent that can seep through the thin metal film.

LIGA A German acronym for Lithographie Galvanoformung Abformung (a process based on lithography, electroplating, and molding). High-aspect-ratio EMS structures and devices are made using LIGA. MEMS structures made out of plastic, nickel and other non-silicon materials can be made using LIGA.

Light Scattering A particle inspection method that uses reflected light to detect from particles on the wafer surface.

Lightfield Mask A lithographic mask where chrome will define electrical components like transistors on wafers. Most of the mask is covered with clear glass.

Lightly Doped Drain (LDD) A low-energy p-type or n-type dopant implant to form shallow source and drain junctions.

Line Width The length of the gate terminal of a transistor. It is the most critical parameter used to describe IC technology generations and usually represents the technology node as described in the SEMI Roadmap for Semiconductors.

Linear Circuit A circuit whose output is an amplified version of its input or whose output is a predetermined variation of its input.

Linear Device An amplifying-type (or analog) device, as opposed to a digital device.

Liquid Crystal Considered to be the fourth “state” that certain kinds of matter can exist under the right conditions. Liquid crystals exist between the solid and the liquid phase, since liquid-crystal molecules do not show any positional order like liquids, but they do possess a certain degree of mutual orientation order like solids. Applications include optical computing, display mechanisms in wristwatches, calculators, and portable computers.

Liquidus Temperature In a mixture of materials, it is the temperature above the point at which the mixture starts to liquefy completely, and above the point at which it cannot solidify. In a phase diagram, it is the line between the liquid state and the intermediary state between solid and liquid.

Lithography Copying a mask pattern onto a surface, e.g. using light or X-ray. Photolithography refers to the use of light that is used to achieve the transfer.

Loaded Brush The cleaning brush that is embedded with particles during CMP.

Loading Effects The difference in etch-rate time requirements for wafers with more surface area versus wafers with smaller surface areas.

Loadlock A vacuumed location where wafers are placed prior to entering the process chamber.

Local Interconnect (LI) The interconnect layer used to connect transistors and contacts at the substrate level.

LOCOS (Local Oxidation Of Silicon) The selective oxidation of silicon at openings not covered by a silicon-nitride layer. It is not used in the modern IC manufacturing technology.

Logic Gate A circuit module that performs a common logical function such as inversion or logical AND, OR operations.

Lorentz Force The mechanical force on a electric charge ‘q’ moving with a velocity ‘v’

through an external magnetic field of intensity 'B'. The Lorentz force $F = QvB$.

Low Thermal Budget Low thermal-energy requirements during a manufacturing process of a device. If the chip is exposed to sufficiently high temperatures (much greater than 450°C), the metal lines (made of aluminum or copper) will either melt or diffuse significantly into the silicon, resulting in non-functional circuits. Unfortunately, high temperatures are often necessary to make high-performance MEMS. See also Thermal Budget.

Low-k Material A material with a dielectric constant less than the dielectric constant of silicon dioxide of $k < 4$. Low-k dielectric materials reduce capacitance and propagation delay.

LPCVD (Low-Pressure CVD) refers to CVD systems that operate below atmospheric pressure. The films formed are thinner than APCVD and are of better quality. They are more sensitive to temperature variations than APCVD.

LSI See Large-Scale Integration.

Latchup An effect observed when parasitic transistors are turned on in the CMOS device.

Luminescence The emission of light at a low temperature due to a chemical process for a very brief period of time.

Lumped Parameters Simple parameters describing a device such as a mass, spring constant, or damping factor that can be used as an analytical representation of the real device.

M3S (Modular Monolithic MEMS) A fabrication process that enables both CMOS circuitry and MEMS to be created on the same chip.

Macroarrays Arrays on which gene-specific probes are present on a nylon membrane substrate. Macroarrays have lower probe density and use radio isotopic detection methods unlike microarrays.

Magnetic-Field Strength An expression of the force that a magnetic field exerts on a theoretical unit magnetic pole in free space. See also Henry.

Magnetoscriptive A material that changes in shape under a magnetic field.

Magnification The ratio of the optical image size by the object size.

Major Component See MC.

Majority Carrier The mobile carrier type in extrinsic semiconductors, either holes or electrons that will be present in much higher concentration in one over the other (holes or electrons). The carrier with the higher concentration is called the majority carrier.

Makeup Air Outside air used to replace exhaust air in a semiconductor facility. In clean rooms, makeup air is brought into the clean room at a higher rate than exhaust air is removed to ensure that contaminants are pushed out of the room.

Manifold Absolute Pressure (MAP) An air-pressure sensor used to sense fuel-injection inlet air pressures. Changes in engine operation and speed affect the readings of the MAP sensor.

Marangoni Dryer A dryer that uses a solvent film to displace water from a wafer surface to ensure low particle wafer drying.

Marginal Cost The incremental cost of producing one more unit. It is driven by variable costs.

Marginal Revenue The sales revenue derived from selling an incremental unit of production.

Market Pull A situation where the market demands a product or service, and producers respond by producing and delivering that product. The customer educates the producer in market pull. Many firms also refer to a term called technology pull, which is closely related to this term.

Martensitic A solid solution of iron having nearly one percent of carbon. Martensite is the chief constituent of steel and is responsible for its hardness, but it also reduces its toughness and makes it brittle.

Mass Transfer In a mixture consisting of two or more components whose concentrations vary from point to point, there would be a natural tendency for the transport of different species from regions of high concentration to those of low concentration. This process of transfer of mass as a result of species-concentration difference in a mixture is called mass transfer.

Mask Used to protect one area of the wafer while working on another. This process is referred to as photolithography or photo-masking. A transparent (glass or quartz) plate covered with an array of patterns used in making ICs, silicon surface micromachined structures, or LIGA parts. Each pattern consists of opaque and transparent areas that define the size and shape of all circuit and device elements. The mask is used to expose selected areas of photoresist, which defines areas to be etched. Masks may use emulsion, chrome, iron-oxide, silicon or other materials to produce the opaque areas.

Mask Trimmer A device that uses bursts of laser energy to vaporize and remove unwanted opaque areas or spots on a photomask or reticle.

Mass Spectrometry An analysis technique that separates matter according to atomic and molecular mass and is often used in the analysis of organic compounds. It is used to measure and analyze the molecules contained in microarray spots. It is based on the principle that the mass/charge ratio of compounds and elements give information about its composition.

Master Plate An original photomask generated by a step-and-repeat camera or an e-beam system and used to print submaster or working plates.

Matching of Revenue and Expenses Proper allocation of revenue and costs to give a true picture of profitability in a period.

Material Any element or compound that is incorporated into a wafer (e.g. through doping, deposition, diffusion, or growth), removed from a wafer, or present in the processing environment. We use qualified terms such as deposited material or etched material to describe the material of primary interest in a given processing operation.

MBE See Molecular Beam Epitaxy.

MC (Major Component) A designation applied to a major component, a part, or a subsystem designed to perform a special operational function in a weapon. The designation is formed of the letters MC followed by a four digit number, e.g. MC3828.

MCM See Multi-Chip Module.

MCNC Microelectronics Center of North Carolina.

Mean A statistic that measures the center of a set of numbers by adding all of them and dividing by the number of data points.

Mean-Free Path The average length traveled by an electron in between two collisions in a semiconductor lattice.

Mean Time Between Failure See MTBF.

Mean Time To Repair See MTTR.

Measurand A specific quantity subjected to measurement.

Measurement The set of operations having the object of determining the value of a quantity.

Measurement Reliability The probability that a measurement attribute (parameter) of an item of equipment is in conformance with performance specifications.

Median The median of a set of numbers is the value that divides the set of numbers in half. Numerically, half of the set of numbers will have values that are equal to or larger than the median, and half will have values that are equal to or smaller than the median.

Medium-Scale Integration See MSI.

Mega Prefix meaning a multiple of one million (1×10^6). Its symbol is M.

Megasonic Cleaning A wafer-cleaning technique using ultrasonic energy (frequency around 1 MHz) to remove particles at low temperatures. Particle sizes of 200-1000 nm can be removed using megasonics. A very useful wafer-cleaning method as device dimensions shrink and particles of smaller size have to be removed.

MEMCAD (MicroElectroMechanical Computer-Aided Design) A design program under development at the Massachusetts Institute of Technology.

Memory A general term for computer hardware that holds information in electrical or magnetic form.

MEMS (MicroElectroMechanical Systems) Miniature devices that contain both electronic circuits and microscopic machines such as force transducers, valves, and motors. MEMS are also popularly referred to as micromachines, nanomachines, or transducers characterized by being less than a square millimeter in size. In the most general form, MEMS consist of mechanical microstructures, microsensors, microactuators, and electronics, all integrated onto the same chip.

MEMS Exchange A network of fabrication and design centers organized and connected such that a user company can draft a process sequence and send it to a fab through the Internet or any other high-speed communication facilities. It is supported by DARPA and coordinates a virtual fab for customers in the U.S. (URL: www.mems-exchange.com)

MEMS Pro A PC-based MEMS layout, design and simulation package marketed by MEMSCAP, originally developed by Tanner EDA.

MESA Microsystems and Engineering Sciences Applications program at Sandia National Laboratories, Albuquerque, N.M.

Mesoscale Machining Manufacturing processes that bridge the gap between silicon micro machining and conventional miniature machining.

Messenger RNA See mRNA.

Metal-Nitride-Oxide Semiconductor See MNOS.

Metal-Oxide Semiconductor See MOS. See also MOSET.

Metal-Oxide Sensor Array Tin-oxide sensors, each of which exhibits different selectivity and receptivity. The functionality is based on a change in conductivity. Best suited for oxidizing and reducing gases.

Metal-Gate CMOS MOS devices with a metal layer deposited to form the gate elements.

Metallization The Tanner EDA process of depositing a thin film of conductive metal onto a substrate and patterning it to form the desired interconnection arrangement.

Metastable A process characterized by only a slight margin of stability.

Metrology The field of knowledge concerned with measurement. Metrology includes all aspects, both theoretical and practical, with reference to measurements, whatever their level of accuracy, and in whatever fields of science or technology they occur.

Micro A prefix meaning one-millionth (1×10^{-6}). Its symbol is μ .

Microarrays Similar to macroarrays, except that they have a higher density of probes and use fluorescent detection techniques.

Micro-Cavity Technology Microcavities form the basis for a line of fully integrated optic components now being tested for wave-division multiplexing (WDM) and dense wave-division multiplexing (DWDM) applications. It is the cornerstone for photonic computing, since photons held in a microcavity "well" determine logic outcomes at the level of individual photons in a photonic circuit.

MicrocheMistry The study of chemical reactions, using small quantities of materials, frequently less than 1 milligram or 1 milliliter, and often requiring special small apparatus and microscopical observation. It can also be defined as the application of chemical tests to minute objects or portions of matter, magnified by the use of microscopy; distinguished from macrochemistry. [OMD].

Microchip or chip. See Integrated Circuit.

Microcomputer A microprocessor, complete with stored program memory (ROM), random-access memory (RAM), and input/output (I/O) logic. Microcomputers are capable of performing useful work without additional supporting logic. If all functions are on the same chip, this is sometimes called a microcontroller.

Microelectromechanical Computer-Aided Design See MEMCAD.

Microelectronic Arrays Microarrays made by techniques similar to IC fabrication. Very small electric currents are used to draw chemical probes and reagents to precise locations on the chip.

Microelectronics This technology includes techniques used to manufacture ICs, discrete microelectronic devices, MEMS devices such as sensors and actuators, and various electro-optic devices.

Micro Electro-Optical Mechanical Systems
See MOEMS.

Microendoscopes Ultra-thin endoscopes and the main approach for developing minimally invasive surgery.

Microfabrication A manufacturing technology for making microscopic devices, such as ICs or MEMS. Microfabrication is usually based on specialized batch-processing technologies developed for the semiconductor industry. Typical microfabrication processes include photolithography, deposition, and etching.

Microfluidics The science of designing, manufacturing, and formulating devices and processes that deal with nanoliter or picoliter volumes of fluids, i.e. (10^{-9} or 10^{-12} liters). Microfluidic studies include nozzles, pumps, reservoirs, mixers, valves, etc., that can be used for a variety of applications including drug dispensing, ink-jet printing, and general transport of liquids, gases and, their mixtures. Advantages of microfluidics compared to conventional fluidic systems are low fabrication cost, enhancement of analytical performance, a low power budget, and low consumption of chemicals.

MicroFlumes (Micro Fluidic Molecular Systems) Micro/chip-scale systems based on fluid-based protocols and operations, such as chemical/biochemical reaction, transport, synthesis, and engineering. Instead of relying on pumps, valves, filters, mixers, and tubes as system components in the standard sense, a MicroFlume channel network may pump, mix, heat, separately, or perform other functions within the channel network itself. The key here is that control functionality is totally integrated in the channel itself.

Microgripper Used for remote manipulation of catheters in small areas via access through small holes or catheters.

Microinjection The insertion of a substance into a cell through a microelectrode. Typical applications include drug injection, histochemical markers (such as horseradish peroxidase or lucifer

yellow), and RNA or DNA in molecular biological studies. To extrude the substances through the very fine electrode tips, either hydrostatic pressure (pressure injection) or electric currents (ionophoresis) is employed. [OMD]. A technique for introducing a solution of DNA, protein, or other soluble material into a cell using a fine microcapillary pipet. [Life Sciences Dictionary].

Micromachine A structure or a mechanical feature with microscopic dimensions.

Micromachining Processes for microstructure fabrication. Originating from the semiconductor industry's processes.

Micromanipulation Manipulation of individual cells like mitochondria, ribosomes, etc., using laser tweezers, optical tweezers, etc.

Micrometer One-millionth (1×10^{-6}) of a meter. About 40 millionths of an inch. Synonymous with micrometer. Its symbol is μm .

Microphone An instrument whereby sound waves are generated or modulated by an electric current. Used in hearing aids and sound recorders.

Microphysiometer A system that detects functional responses from living cells in minutes and offers novel information on cell signaling, unobtainable with other assay methods.

Microprocessor The basic arithmetic logic of a computer based on an IC. Also called MPU for microprocessor unit.

Microspectrometer A miniaturized instrument that finds chemical composition and concentration based on light scattering.

Microstructure A physical structure having dimensions of small geometries (sub- μm to mm). Often fabricated using micromachining.

Microstructure (of a material) Information about grain size, shape etc.

Microsystem A system including one or more microstructures, assembled using microtechnology.

Micro-System Technology See MST.

MicroTAS (MicroTotal Analysis Systems, μ TAS) The integration of all steps in a chemical analysis from sampling to detection and data treatment, into a miniature instrument. The advantages of a MicroTAS include improved analytical performance, a reduced reagent, parallel analysis, and greater accuracy. Applications include medical diagnostics and biochemical analysis.

MicroTip A single, field-emission tip used in field-emission display (FED) technology and fast cold-cathode vacuum electronics. Derived from the tip used in a scanning-tunneling electron microscope.

Mil One-thousandth of an inch (10^{-3} inches). Equal to 25.4 μ m.

Miller Indices The reciprocals of the fractional intercepts the plane makes with the crystallographic axes. It is a figurative vector representation for the orientation of an atomic plane in a crystal lattice, which consists of 3 integers.

Milli Prefix meaning one-thousandth (1×10^{-3}). Its symbol is m.

Miniaturization Desirable for many technologies for overall cost reduction (including reduction in the amount of reagents and analytes). It is important to remember that building space is often the least available and most expensive component of an overall laboratory budget.

Mini-Environment A restricted clean environment created around a tool. Wafers are moved from one mini-environment-equipped tool to the next one in sealed containers and only exposed to the atmosphere inside the tool.

Minimum Geometry The smallest line width or spacing between lines or features of a semiconductor die. May be defined "as drawn" or "as printed."

Minority Carrier The non-predominant mobile charge carrier in a semiconductor.

MLE (Molecular Layer Epitaxy) The controlled crystal monolayer growth of semiconductors.

MMC The Micromachine Center (Japan).

MMIC (Monolithic Microwave IC) An analog IC with on-chip inductors and capacitors designed to work at microwave frequencies.

MNOS (Metal-Nitride Oxide Semiconductor) The dielectric between metal and semiconductor that's fabricated from silicon-nitride. This technology is commonly used to make EEPROMs.

Mobility (of a hole or an electron) The rate at which a carrier (majority or minority) moves within the material under the influence of an electric field.

Modeling The capture of the electrical and functional behavior of a circuit within a computer program that is then used to test the response of the circuit to various input data without fabricating the chip.

Modular Integration Modular means in modules or in sections. It refers to fabricating the electronics first, and then the MEMS devices and putting both electronic and mechanical parts on the same silicon wafer substrate. Integration improves system performance because it eliminates the resistance and capacitance associated with connections between separate electronics and MEMS chips. It can potentially lower manufacturing cost because the total chip area is reduced, so that more chips can be made on a silicon wafer.

Modular Monolithic MEMS See M3S.

Modulator A device that imposes an optical signal on the sinusoidal component of a carrier wave.

Module An interconnected subsystem of IC components, usually designed to act as a building block for more complex circuits.

Modulus of Elasticity (E) The ratio of stress to strain of a material during its elastic state. See also Young's modulus.

MOEMS (Micro electro-optical mechanical systems) MEMS devices that have applications in optical telecommunications. Also known as optical MEMS.

Molecular-Beam Epitaxy (MBE) An evaporative deposition process under high vacuum and capable of manufacturing extremely high-quality semiconductor epitaxial surfaces.

Molecular Electronics Seeks to use individual molecules to perform functions in electronic circuitry now performed by semiconductor devices. Individual molecules are hundreds of times smaller than the smallest features conceivably attainable by semiconductor technology.

Molecular-Layer Epitaxy See MLE.

Molecular Nanoscience An emerging interdisciplinary field that combines the study of molecular/ biomolecular systems with the science and technology of nanoscale structures. The potential applications are very broad and include such possibilities as the use of biomolecules and cellular systems to self-assemble nanoelectronic circuitry and other nanoscale structures.

Molecular Nachnology See molecular nanoscience, nachnology.

Molecule An aggregate of two or more atoms of a substance that exists as a unit.

Monitor Wafers Unpatterned wafers used to test process performance.

Monochromatic Light Radiation in the form of a very narrow band of wavelengths.

Monocrystal Single-crystalline material.

Monolithic Device A device whose circuitry is completely contained on a single die or chip.

Monolithic 1. Formed from a single crystal, such as a monolithic silicon chip. 2. A monolithic IC (MIC) is an IC having all elements formed in place on or within a semiconductor substrate, with at least one element being formed within the substrate. See also Substrate and Integrated Circuit.

Monolithic Microwave IC See MMIC.

Monomer Any chemical compound that can be linked repeatedly to form polymers.

Moore's law The number of transistors the industry would be able to place on a IC chip would double every 18 months. The IC industry has been able to keep pace with this law to date and strives to achieve the same in the future. Named after the co-founder of Intel, Gordon Moore.

MOS (Metal-Oxide Semiconductor) A type of IC fabrication process based on insulated-gate field-effect transistors. The process layers from top to bottom are metal (or polysilicon), insulating oxide, and semiconductor. The fabrication technology which is used to produce silicon field-effect transistors in which the flow of current is controlled by the strength of the electric field between the gate and the conducting channel, which are separated by an insulating layer of silicon-dioxide.

MOSFET (Metal-Oxide Semiconductor Field-Effect Transistor) A type of field-effect transistor. See MOS.

MOSIS A low-cost prototyping and small-volume foundry service for VLSI circuit development.

Moving Mask Lithography Process An X-ray lithography process that ensures sidewall inclination of a PMMA microstructure by moving an X-ray mask in parallel with a PMMA substrate during X-ray exposure.

MPU (MicroProcessor Unit) Used synonymously with the word microprocessor.

MPW (Multi Project Wafer) Several projects that share the space and cost of a wafer.

MRNA (Messenger RNA) An intermediary between DNA sequences and the production of protein. It is a copy of the information carried by a gene on the DNA and is deciphered by transfer RNA (tRNA) and amino acids to build a protein.

MSA See Multi Source Agreements.

MSI (Medium-Scale Integration) A term generally applied to IC chips containing ten or more gate equivalents, but less than 100. Also applies to memory devices with less than 1000 bits of memory.

MST (Micro-System-Technology) A more general statement of MEMS including optical and fluidic systems. MST is a more common term than MEMS in Europe and Japan. Similar to MEMS with or without the electronic circuitry (e. g. optical, mechanical or fluidic structures).

MTBF (Mean Time Between Failure) The average time between failures for a particular piece of equipment or equipment set.

MTTR (Mean Time To Repair) The average time required to repair a given piece of equipment or equipment set.

Multi-Level Metal A processing technology that has more than one layer of metal interconnect.

Multi-Chip Module (MCM) An assembly of two or more dies on a substrate by any bonding technology, i.e. a package that has more than one IC chip.

Multicore Fibers An ultra-thin fiber-optic media that is used to manufacture endoscopes having a diameter of less than 1 mm. The flexibility of endoscopes depends on the number of such fibers and their density. Also used in lasers.

Multiplex A system that transmits several messages, programs, or signals simultaneously on the same circuit or RF channel. It also refers to sending (messages or signals) by a multiplex system. The two or more combined signals can be individually recovered.

Multiplexer A device that enables transmitting several signals concurrently on the same circuit or channel.

Multi Project Wafer See MPW.

Multi-Source Agreements (MSAs) Agreements between groups of suppliers that have fixed standard physical and electrical parameters for a component. These multi-vendor alliances drive the development of both new standards and devices.

MUMPS A multi-user MEMS process developed by MCNC and funded by DARPA. A process used for 3-layer polysilicon surface micro-machine prototyping.

Murphy's Model A popular wafer-yield prediction model that presumes defect density varies across the wafer and from wafer to wafer.

N-P

Nachnology The technology arising from efforts to exploit the novel and improved properties that phenomena and processes exhibit at the scale between single atoms/ molecules and bulk be-

havior (approximately 10^{-9} to 10^{-7} meters). [National Science Foundation, US NSF].

NAND Gate (NOT-AND gate) One that is an AND gate followed by an inverter. The output of the AND gate is inverted to the opposite value.

Nano A prefix meaning one-billionth (1×10^{-9}). Its symbol is n.

Nanobiology Many fundamental biological functions are carried out by molecular machineries that have the sizes of 1^{-100} nm. You find many examples in molecular biology and cell biology single enzymes, transcription complexes, ribosomes, transport complexes, and nuclear pores.

Nanocomputer A computer whose fundamental components measure only a few nanometers in size. State-of-the-art current computer components are no smaller than about 350 nm.

Nanocrystals Crystals that have a diameter between 1 and 10 nm and may contain 100-50000 atoms.

Nanodevices Devices that may lead to computer chips with billions of transistors, instead of millions, which is the typical range in today's semiconductor technology. The more transistors crammed on a chip, the more powerful it is.

Nano Electro Mechanical Systems See NEMS.

Nanomachines Nanomachines somewhat similar to those envisaged by molecular nachnology already exist. They are biomacromolecules, which are nanoengines acting both as thermal engines and as informational engines like the so-called "assemblers" (cf. Molecular Nachnology). The latter are not "self-programmed" like nanobiomachines.

Nanometer (nm) A unit of measurement equal to one billionth of a meter.

Nanoparticles Both synthetic (bottom-up) and transformative (top-down) fabrication rely on the availability of building-block materials and artifacts such as quantum dots, nanotubes and nanofibers, ultrathin films, and nanocrystals. These also include their assemblies in coatings, dispersions, colloids, aerogels and nanoporous structures, as well as organic dendrimers, block co-

polymers and nanocomposites, and also biomolecules such as proteins, nucleic acids, etc.

Nanosatellites Very small lightweight [under 20 kg (44 lbs)] satellites containing MEMS electronic equipment, components, and payloads.

Nanoscale 1 to 100 billionths of a meter. At the nanoscale level, physics, chemistry, biology, materials science, and engineering converge toward the same principles and tools. The nanoscale is not just another step toward miniaturization, but a qualitatively new scale.

Native Oxide A very thin oxide layer that forms on a silicon wafer if exposed either to air at room temperature or ultra-pure water.

Nebulizers Similar to metered dose inhalers but are more effective and are mostly aqueous solutions of medicine.

Negative-Channel Metal-Oxide Semiconductor See NMOS.

Negative Lithography Transferring a pattern on the wafer surface that is opposite to the pattern in the mask.

Negative Resist A photoresist that remains in areas that are not protected from exposure by the opaque regions of a mask. A negative image of the mask remains following the development procedure.

NCAP (Network-Capable Application Processor) A module between the STIM and a network that supports IEEE 1451.2. It employs a specific network protocol and contains application-specific firmware. The TEDS is interpreted, written, and used by a NCAP. The NCAP's primary purpose is to mediate between the STIM and a specific network.

NEMS (Nano ElectroMechanical Systems) Machines, sensors, computers and electronics that are on the nanoscale level. The potential payoffs are likely to be enormous and could benefit a diverse range of fields, from medicine and biotechnology to the foundations of quantum mechanics. [Michael Roukes "Nanoelectromechanical systems face the future," *Physics World* 14 (2) Feb. 2001].

NETD (Noise-Equivalent Temperature Difference) A metric that describes the capability to resolve between temperature differences.

Netlist A computer file listing all of the components together with the details of how they are interconnected to form the overall circuit.

Network-Capable Application Processor See NCAP.

Neuron (with reference to an Electronic Nose) Basic unit of an artificial neural network. Each neuron receives a number of inputs, multiplies them by specific weights, and transforms them through a mathematical function to derive an output signal.

Nitinol (Nickel Titanium Alloy) An alloy with both superelastic and shaped-memory properties and is thus used in minimally invasive surgical instrumentation like endoscopes. It is also very corrosion-resistant and biocompatible.

Nitric Acid (HNO₃) A liquid corrosive oxidizer used to clean silicon wafers and wet-etch metals.

Nitride The combination of silane and nitrogen in a CVD process to form an insulating thin film.

Nitrogen A colorless, odorless gas used in a variety of fabrication processes: etching, deposition, and annealing.

Nitrous Oxide (N₂O) A nontoxic, nonflammable gas used in combination with silane for CVD of silicon nitride layers.

NMOS (Negative-Channel Metal-Oxide Semiconductor) A type of IC using n-doped semiconductors negatively charged so that transistors function by the movement of electrons. In contrast, PMOS (positive-channel MOS) works by moving electron vacancies (holes). NMOS is faster than PMOS, but also more expensive to produce.

Noise Any extraneous or unwanted signal that contaminates the measurement. For measurement systems, noise consists of random noise (thermal processes within conductors), white noise (thermal processes within resistors), and systematic noise (such as line frequency, power-supply ripple, and EMI).

Noise-Equivalent Temperature Difference See NETD.

Nonlinearity The deviation of the output of a device from a straight line where the straight line may be defined using end points, terminal points, or best fit.

Non-Recoverable Engineering (NRE) Costs Development costs incurred before production begins. These costs are a fixed cost in the cost structure like salaries of employees, failed contract bids, etc. Chips made for a particular contract have huge NRE costs.

Nonvolatile Memory Semiconductor memory that stores digital data in the form of electrical charge, even after power is turned off.

NOR Gate (NOT-OR gate) An OR gate followed by an inverter. The output of the OR gate is inverted to the opposite value.

NOT Gate The output is just the opposite from the single input.

Notch A deliberately created dent on the wafer edge oriented so that the diameter passing through the center of the notch is parallel to a specific crystal direction.

Novolak An amorphous polymer used in molding and bonding materials and electrical insulation. The polymer of most G-line and I-line positive photoresists.

npn An npn bipolar transistor has a p-type base silicon sandwiched between an n-type emitter and a collector.

NRE Costs See Non-Recoverable Engineering Costs.

N-Type Semiconductor A semiconductor crystal containing a small amount of “dopant” atoms that have one more outer electron than the other atoms. These extra negative electrons can find no unoccupied bonds to bind them, so they are free to wander and constitute electric current. Common n-type dopants for silicon are phosphorus and arsenic.

Nuclear Safety Callouts The nuclear safety features are the product design attributes and the production operation elements determined to be critical to satisfying a weapon’s nuclear safety theme.

Nuclear Stopping During ion implantation, ions are stopped in the silicon crystal by collisions between atoms, causing a displacement of silicon atoms.

Nucleation Layer A thin layer of film that helps the growth of the films on top of it.

Nucleation The stage where clusters of stable nuclei are formed in a thin-film growth.

Nucleotide Complex chemical compounds that make up deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). There are four types of nucleotide: viz., adenine (A), cytosine (C), guanine (G), or thymine, the sequence of which defines genetic information.

Numerical Aperture A measure of the light-gathering capacity of the lens system. It determines its resolving power and depth of field. It is the sine of one-half the angular aperture times the refractive index of the medium. The higher the numerical aperture, the smaller devices can be made on a chip, but the depth of field of the lens system will also decrease.

n-well A local n-type doped region on which PMOS devices are built.

OADM See Optical Add/Drop Multiplexer.

Objective The system of lenses in an optical microscope that magnifies the object being viewed.

Occlusion Effect Hollowness in sound quality

OEE (Overall Equipment Effectiveness) The actual output of a tool divided by the potential output of a tool assuming 100% utilization and 100% uptime.

OEIS (OptoElectronic Integrated Systems) Research is currently focused on the development of methodologies for self-assembly of micron-scale objects with the objective of fabricating optoelectronic-integrated systems (OEISs) [RP25].

OEMs (Original Equipment Manufacturers) Companies that sell products after buying individual components from a variety of other manufacturers.

O-E-O The conversion of optical to electrical to optical signals in switches that are not completely optical.

Ohm A unit of electric resistance equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

Ohmic Contact A metal semiconductor contact that is of low resistance and independent of applied voltage. It obeys Ohm's law, i.e. Voltage = Resistance x Current.

One-Chip Solution A sensor element and its electronics integrated on one chip.

Op-Amp (Operational Amplifier) An amplifier having a large voltage gain, very high input impedance and low output impedance. Its output is dependent on the instantaneous differences between the two input waveforms.

Opaquing The applying of minute droplets of opaquing ink to fill pinholes and correct geometric areas on masks or reticles.

OPC See Optical Proximity Correction.

Operation A designer-specified process capability that is the actual product that designers order from the MEMS Exchange. Process capabilities can have a number of parameters, some of which may be specified by the designer. For instance, a deposition process would require knowledge of the thickness of the deposition, an etch knowledge of the etch depth, etc. When a designer specifies values for all the parameters that require a value, an operation is created.

Optical Add/Drop Multiplexer (OADM) A device that adds or drops individual wavelengths from a DWDM system.

Optical Attenuator A passive device for reducing the amplitude of a signal without appreciably distorting the waveform.

Optical Backplanes A novel optoelectronic device that eliminates the need for "electrical to optical and optical to electrical" conversions and achieves 10 Gbit/s speeds and beyond, in optical telecommunications. Backplanes refer to the bus or matrix that is at the back of a modular networking product, and into which the modules are plugged.

Optical Cross-Connect A network device used by telecom carriers to switch high-speed optical signals (OC-12, OC-48, etc.). It differs from digital cross-connects in that it deals with multiple high-speed signals that are switched in their entirety and not multiplexed together. Optical cross-connects work entirely at the optical layer and may be able to operate without having to convert to electrical form and back again.

Optical Dispersion The cause of bandwidth limitations in a fiber. Dispersion causes the spreading or broadening of light pulses as they travel through a fiber. The three major types are modal dispersion, chromatic dispersion, and waveguide dispersion.

Optical Fabrics An optical switch fabric enables telecom service providers to switch any type of data traffic.

Optical Interconnect Devices The linkage used to join two or more communications units, such as systems, networks, links, nodes, equipment, circuits, and devices.

Optical Lithography The use of lenses and light to precisely project and expose a mask pattern onto a resist-coated wafer.

Optical MEMS See MOEMS.

Optical Proximity Correction (OPC) A photolithography procedure that introduces selective image size alterations into the reticle pattern to compensate for light diffraction and interference between closely spaced features.

Optical Pyrometer A contactless temperature-sensing device based on measuring the infrared radiation given out by a heated body.

Optical Ring Protection The most robust protection scheme employed to achieve optical restoration, i.e. to avoid the implications when a single fiber gets cut, affecting a large number of optical networks connected to the cut fiber. Optical ring protection requires more numbers of fibers than other restoration techniques but it is the most sophisticated.

Optical Switch A switch that allows signals in optical fibers to be selectively switched from one circuit to another. It could either be through mechanical means or electrical and magnetic means.

Optoceramic Materials A class of proprietary materials having high electro-optic coefficients manufactured using chemical-vapor-deposition techniques that can be used to reduce the size of optical devices

Optoelectronic Integrated Systems See OEIS.

Optoelectronics ICs and systems, which combine optical elements (e.g. lasers and photo detectors) with microelectronic circuits, often as part of a single chip.

OR Gate The output is “yes” if at least one of the inputs is a “yes.”

Organic Compound A chemical compound of carbon, hydrogen, and one or more other elements, like oxygen or nitrogen.

Original Equipment Manufacturers See OEMs.

Osmosis The flow of fluid through a semi-permeable membrane from a solution with a higher concentration to a solution with a lower concentration until there is an equal concentration of fluid on both sides of the membrane. Unlike diffusion, in osmosis, chemical equilibrium between two adjacent solutions is achieved by a flow of solvent rather than a flow of solute.

Outgassing The release of absorbed gases or vapors from materials usually accelerated by heating or using vacuum.

Overall Equipment Effectiveness See OEE.

Overflow Rinser The flowing of de-ionized water through and around wafers, sometimes with a nitrogen bubbler to aid flow at the wafer surface.

Overlay In lithography it refers to the superposition of a mask’s pattern on a pattern already present on a wafer.

Overlay Budget In photolithography, the maximum allowable relative displacement between a new patterned layer and the earlier defined layer.

Oxidation The elimination of one or more electrons from an atom, ion, or molecule. It also refers to the formation of oxides of chemical elements.

Oxide-Trapped Charge A charge trapped in the bulk gate oxide far away from the oxide-semiconductor interface.

Oxide Common reference for silicon-dioxide.

Oxygen A gas used in semiconductor fabrication to oxidize silicon or to form vapor-deposited oxide.

p+ A silicon region doped heavily with acceptor ions, e.g. boron, to achieve concentration levels of 10^{20} cm.⁻³

Package The protective container or housing for an electronic component or die, with external terminals to provide electrical access to the components inside. Packages provide power and signal distribution, power dissipation, electrical connection and physical and chemical protection of the circuits.

PAG See Photo-Acid Generator.

Parallel Testing Electrical test techniques that permit simultaneous testing of different areas of a chip to increase test throughput.

Parameter A numerical value relating to a characteristic of a process or device.

Parametric Tests Tests that measure DC conditions, functionality, yield, and beam characteristics of a chip or surfacemicromachined device, such as maximum current, leakage, and output drive.

Parasitic Capacitance The undesirable, inherent capacitance of an electrical component.

Parasitic A parasitic is an undesirable stray capacitance, inductive coupling, or resistance leakage, as well as undesired transistor actions. The first and last are most serious in monolithic ICs.

Partial Pressure of a Gas System The pressure each gas in the system will have if all of the other gases were entirely eliminated from the system.

Passivation Usually a silicon-dioxide or silicon-nitride layer deposited last to seal the circuit to protect it from moisture and/or contamination. The passivation layer is patterned and etched to open it up to the bonding pads.

Passive Component An electrical component without “gain” or current-switching capability. Commonly used when referring to resistors, capacitors, or inductors.

Passive Device Any device that does not require a source of energy for its operation. Examples include electrical resistors or capacitors, diodes, optical fibers, glass, lenses, and filters.

PAT Packaging, Assembly and Testing.

Pattern Generator A system that takes CAD information and generates mask patterns. The system typically has a light source, a reduction lens system, a variable aperture, and a stepping apparatus.

Pattern Wafers Wafers that have an image of a die matrix formed into a layer of photoresist or a permanent pattern that has been etched into the substrate.

Patterned Etching An etch process that uses a masking layer to define a pattern on the wafer surface to remove only selected portions of the wafer surface material.

Patterning The passing on of an image from a reticle or mask to the photoresist coating on top of the wafer.

PCA See Principal Component Analysis.

PCB (Printed-Circuit Board) An insulating card with one or more layers of copper interconnections onto which are soldered IC packages and other electronic components. PCBs are usually plugged into sockets that may be interconnected through a wire bus. A substrate on which a predetermined pattern of printed wiring and printed elements has been formed. Also called a printed-wiring board.

P-Channel MOSFET See PMOS.

PCR See Polymerase Chain Reaction.

pdf See Probability Density Function.

PECVD (Plasma Enhanced CVD) A single-wafer process where plasma is generated in the reactor to increase the energy available for the chemical reaction that deposits thin films on the wafer surface.

PEL See Permissible Exposure Limit.

Pellicle A thin, transparent membrane which seals off the mask or reticle surface from airborne contamination.

Percutaneous An operation performed through a small opening in the skin.

Perimeter Array Conventional packaging with wire bonding that has bonding pads on the die boundaries to reduce the number of input/output pins in the package.

Permissible Exposure Limit (PEL) An exposure limit averaged over a given period or a maximum allowable exposure limit for employees.

PGA See Pin Grid Array.

PH(3) See Phosphine.

pH scale A scale that specifies the strength or weakness of an acid (0 to 7) or base (7 to 14).

pH value The negative logarithm of hydrogen-ion activity denoting the degree of acidity or baseness of a solution, at room temperature.

Phase A portion of a material system whose properties and composition are homogeneous and which is physically distinct from other parts of the system. Any of the forms or states, solid, liquid, gas, or plasma, in which matter can exist, depending on temperature and pressure.

Pharmacogenomics The study of how an individual’s genetic makeup affects the body’s response to drugs. Its goal is to manufacture drugs that are tailor-made for individuals and are adapted to each person’s own genetic composition.

Phase Shift The alteration in the angular phase of a sinusoidal quantity with respect to a reference angle or another sinusoidal quantity of the same frequency. In lithography, it increases resolution of pattern transfers by destructive interference, preventing resist exposure in the regions in which it should not be exposed. It is directly proportional to the refractive index of the material. It is also defined as the lag between the input and output signals.

Phase-Shift Mask (PSM) A mask that defines regions for phase shifting to realize the shrunken

features by changing the phase of the exposing light. It has a layer of material of a refractive index that shifts the phase of light passing through transparent portion of the mask. It improves the resolution of optical systems.

Phonon A single quantum of vibrational or elastic energy.

Phosphine (PH₃) A toxic gas that is a source of phosphorus in CVD, ion implantation, and epitaxial growth.

Phosphorescence Luminescence that occurs for a perceptible time after the incident radiation has stopped without sensible heat.

Phosphorus The n-type dopant commonly used for the buried-layer contact and emitter diffusions in standard bipolar IC technology, and the source/drain regions in NMOS.

Phosphorus Oxychloride See POCl₃.

Photo-Resist Stripping A general term that describes removal of die resist with either wet stripping or dry methods.

Photo-Acid Generator (PAG) A chemical used in deep ultraviolet (DUV) resists that boosts the resist's sensitivity to DUV light by producing a catalyst upon irradiation that weakens the linkages of the photoresist. E.g. di(tbutylphenyl) iodonium triflate.

Photodiode A semiconductor diode that produces current when exposed to light.

Photolithography Lithographic techniques involving light as the pattern-transfer medium. See also Lithography.

Photo-Mask The photographic film (glass plate) that contains the masking pattern required for a particular wafer-processing step.

Photons Very small increments or parcels of electromagnetic radiation like light.

Photonic Band-Gap Structures Materials with periodic changes in the dielectric constant that hinder propagation of electromagnetic waves in certain frequency ranges. They are used in lasers, antennas, millimeter-wave devices, solar cells, etc. Photonic band-gap structures can be used to trap and manipulate light, sending it down specific routes.

Photoplate The term used for a mask before images have been formed on its chrome-coated surface.

Photopolymerization A reaction that converts monomers into polymers by the exposure of a combination of monomers to ordinary or man-made light, with or without a catalyst.

Photo resist A substance used to protect areas not to be etched. This process patterns via lithography followed by removal (etching) of exposed (or unexposed) areas. A light-sensitive material that is used to form selectively protective masking layers during wafer processing. A photo-mask is used to define the areas of photoresist exposed to light, which are subsequently removed by a solvent, leaving the required pattern on the wafer surface.

Physical Vapor Deposition This is primarily a physical rather than a chemical process to deposit a material by physically dislodging atoms from the surface of a solid target. Also referred to as sputtering.

Pico A prefix meaning a trillionth or one-millionth of one-millionth (1×10^{-12}). Its symbol is p.

Piezoactuator An actuator typically producing a force or displacement in response to an electrical input signal.

Piezoelectric The ability to generate a voltage when mechanical force is applied, or to produce a mechanical force when a voltage is applied to a material.

Piezoelectricity Mechanical stress generated by an electric field/charge, and vice versa. Present in strongly anisotropic dielectrics, e.g. quartz.

Piezoresistive Effect The change in the electrical resistivity of a metal or semiconductor that is produced by mechanical stress.

Piezoresistors Resistors that undergo a change in resistivity when undergoing mechanical stress. See also Resistors.

Pin-Grid Array (PGA) Also called area array. It is a package with pins distributed over much or the entire bottom surface of the package.

Pinhole An unwanted minute void formed in a material, especially in a metallic product such as an electroplated coating or a foil. Pinholes include defects caused by thermal contraction in oxides.

Pinout A representation (i.e. diagram or table) that describes the function of each pin in a chip, or each wire in a network cable.

PLA (Programmable Logic Array) A general-purpose logic circuit containing an array of logic gates, which can be connected (programmed) to perform various functions.

Planar Devices Semiconductor devices having planar electrodes in parallel planes, made by alternate diffusion of p- and n-type impurities into a substrate. P-type semiconductors have electron hole densities exceeding their conduction-electron densities. N-type semiconductors have conduction-electron densities exceeding their hole densities.

Planar Lightwave Circuit (PLC) A device that incorporates a waveguide fabricated in a flat material such as a thin film.

Planar Process A fabrication process for forming IC and semiconductor components. It's based on the use of a single surface for referencing each successive operation. The planar process depends on the repeated use of silicon-dioxide (SiO_2) from one surface to control the location of impurities.

Planar Existing essentially in a single plane; a process in which all P-N junctions intersect the top surface of the semiconductor materials, such that these intersections are permanently protected by the masking oxide, and all contacts to the device can be made to the top surface. Also refers to a process that is on a two-dimensional flat surface.

Plasma An electrically conductive gas composed of ionized particles, which are used to etch unwanted material through a chemical or physical bombardment process. Plasma etching takes place in a reactor, which may be of the barrel type or the planar type.

Plasma Enhanced CVD See PECVD.

Plasma-Induced Damage The damage to IC devices on the wafer due to plasma during DRIE. It causes trapped charges to be formed in the gate

oxide under the gate electrode, causing a breakdown of the thin gate oxide.

Plasma Vapor Deposition See PVD.

Plastic Deformation A permanent deformation accompanied by permanent atomic displacement.

PLCC (Plastic Leaded Chip Carrier) A leaded quad package—a replacement for the plastic DIP in surface-mounting organic printed-circuit boards.

PMMA (Poly Methyl Methacrylate) An electron-beam and X-ray-sensitive positive resist.

PMOS (P-channel MOSFET) A MOS device where the primary current carriers are positively charged “holes”.

P-N Junction The interface region on a doped silicon crystal in which the silicon changes from p-type to n-type silicon.

POCl_3 (Phosphorus Oxychloride) A colorless fuming liquid used in semiconductor processing as a source of phosphorus, and an n-type dopant in silicon. Liquid POCl_3 is vaporized at temperatures above 106°C and transferred to a furnace where the wafer is doped.

Point Defects Defects occurring in a crystal at a specific lattice site as opposed to affecting a large area.

Poisson's Ratio (ν) A measure of the simultaneous change in elongation and in cross-sectional area within the elastic range during a tensile or compressive test. During a tensile test, the reduction in cross-sectional area is proportional to the increase in length in the elastic range by a dimensionless factor, Poisson's ratio.

Polarized Light Electromagnetic radiation in which the electric component of the waves is confined to a single plane.

Polyimide A compound characterized by more than one inorganic compound, which is derived from ammonia by replacement of an atom of hydrogen with another element (like a metal).

Polycide Formed when a refractory metal reacts with polysilicon. It is a low-resistance material.

Polycrystalline Si Silicon that is composed of aggregates of individual Si crystals.

Polyimides Polymeric compounds containing multiple amides, i.e., NH (nitrogen-hydrogen) groups derived from ammonia (NH₃) by the replacement of two hydrogen atoms by metals or equivalents of acid groups. Used in semiconductor processing as a dielectric and a protective coating layer on wafers since it has excellent thermal stability and a low coefficient of thermal expansion.

Polymer A chain of numerous monomers. For example, cellulose is a polymer that is formed from the monomer glucose.

Polymerase Chain Reaction (PCR) An incubation process for creating billions copies of a DNA fragment. Applications include DNA fingerprinting and genetic research.

Poly Methyl Methacrylate See PMMA.

Polymorphisms Variations in the DNA sequence that may be associated with certain genetic diseases.

Polysilicon Silicon consisting of crystalline grains and used as the structural material for many MEMS devices. Sometimes called “poly.” The form of silicon made of many small randomly oriented crystals. Doped poly is a conductor of electricity and is often used as an alternative to metal in interconnecting devices on ICs. Polysilicon is often deposited via CVD or PVD.

Positive Resist Photoresist that is removed in areas that were not protected from exposure by the opaque regions of a mask-while remaining in regions that were protected by the mask. The positive image of the mask remains following the development.

Potassium Hydroxide See KOH.

Potential Therapeutics A new branch of medical science dealing with the application of remedies to diseases based on protein identification.

Power The rate at which work is done, expressed as the amount of work per unit time and commonly measured in units like watts. In electronics, it is the product of voltage and current in a component.

PQ See Qualification Plan.

Preamorphization Implantation of a wafer with an electrically inactive species, like silicon (Si), to amorphize a thin layer of the wafer to reduce channeling during ion implantation. It also reduces transient-enhanced diffusion and lower-leakage junctions can be made

Precision The closeness of the agreement between the results of successive measurements of the same measurand carried out subject to the same conditions. See Repeatability.

Predeposition The first part of a two-part diffusion. In this part, a high concentration is diffused shallowly into the surface. This acts as a source for the second or drive-in portion of the process.

Preforms, Solder Formed pieces of solder material for closing microcircuit packages. Additionally used in some applications to attach a die or chip to a package.

Preventive Maintenance Maintenance on equipment to prevent future random failures of the equipment or cleaning to improve the quality of the equipment yield. It is performed on a scheduled basis, based on elapsed time, the number of runs, or the number of wafers processed.

Principal Component Analysis (PCA) A mathematical procedure that transforms a number of correlated variables into a smaller number of uncorrelated variables. Used in electronic nose technology as a method to analyze the data obtained from the sensors used.

Printed-Circuit Board See PCB.

Printed-Wiring Board (PWB) A platform upon which electronic components such as IC chips and capacitors are mounted. A PWB also provides electrical interconnection between components. It consists of a fiberglass substrate on which electrical circuits are built. A bare PCB, i.e. a PCB without any components, is a PWB.

Probability Density Function (pdf) A mathematical expression describing the functional relationship between a specific value of an attribute or variable and the probability of obtaining that value.

Probability Distribution A list of probabilities, which can have a finite number of values, asso-

ciated with each of a variable's possible values. It is also called the probability function or the probability mass function.

Probability The ratio of a number of outcomes corresponding to an event to the total number of outcomes. For example, the probability of an even number occurring when a dice is thrown is $3/6 = 0.5$

Probe Card The interface between an automatic tester and the device being tested. It is usually a printed-circuit board that has probes to make electrical contact to the device being tested.

Probing A term used to describe testing techniques of individual IC dies by using very finely tipped probes to temporarily connect each to a test computer, thus verifying proper operation. A bad die will usually be marked with a spot of ink.

Process Capability A comparison of the actual variability of a process to the process specification.

Process Design Rules Specifications that ensure that size, spacing, and overlap of geometry are correct for a manufacturing process.

Process Hierarchy A tree that organizes abstract descriptions of everything that can be done to a semiconductor wafer in transforming it into a collection of finished devices including inspection and testing. Briefly, one node in the process hierarchy might be "deposition/CVD/LPCVD," meaning that "LPCVD" is a kind of "CVD," which in turn is a kind of "deposition."

Process Integration The optimization of each process step to be compatible with previous and succeeding steps in a chronological process flow.

Process Latitude The ability of a process that has varying parameters to manufacture products that meet specifications. A robust process must have large process latitude to allow for variations in its parameters and ensure correct operation.

Process Module A bundle of commonly associated processing services (such as base processes) made available by a particular fab in a set sequence, often for a special price. Every process module is identified by a generic process or a location in the process hierarchy. For example, a

"deposition" module might include a cleaning, the actual deposition, and an inspection.

Product Definition A set of models, drawings, specifications, and other information that describes a product and product's performance specifications and defines product identification elements. The product definition may include additional design and production requirements to ensure that the required design is achieved.

PROM (Programmable Read-Only Memory) A read-only memory, which can be programmed after manufacture by external equipment. Typically, PROMs utilize fuseable links, which may be burned open to produce a logic bit in a specific location.

Proof Mass A predetermined test mass in a measuring device or machine, such as in acceleration measurement equipment, which serves as the reference mass for the quantity to be measured.

Propellant Gas A compressed inert gas (such as a fluorocarbon) that acts as a vehicle for discharging the contents of an aerosol container.

Protein Chips Arrays that consist of proteins themselves (e.g., for studies of protein, protein interactions or protein/small-molecule binding) or of probes for capturing proteins (so that protein levels in a sample can be gauged).

Proteomics The study of cellular proteins and their interactions.

Proximity Aligner An optical system that uses a mask that is very close to the wafer.

Proximity Printing The exposure of a wafer by passing light through a mask that is very close to, but not in contact with, the photoresist-coated wafer. Collimated light is required to ensure minimum image resolution.

PSM See Phase-shift Mask.

PSTN (Public Switched Telephone Network) The worldwide interconnected public-telephone network, both private and government-owned.

P-Type Semiconductor A semiconductor crystal containing a small amount of "dopant" atoms that have one less outer electron than the other atoms. Each "dopant" atom causes one unoccu-

pied spot, called a “hole,” among the electrons that are bound in their orbits. The holes are positively charged and can move to constitute electric current. Boron is a commonly used P-type dopant for silicon.

Public Switched Telephone Network See PSTN.

Puddle Develop A resist development process that applies a small puddle of photoresist to form a meniscus over the entire wafer to minimize required developer volume.

Punchthrough A condition that occurs when depletion regions of the drain and source meet, causing a channel current to flow irrespective of gate voltage, which causes device failure. Punch-through occurs due to the presence of small channel length and high electric fields at the drain end of the channel. Thinner oxides, larger substrate doping, shallower junctions and longer channels can circumvent this.

Purge A cleaning procedure that uses an inert gas to remove undesirable gases from a process chamber.

PVD (Plasma Vapor Deposition) A SEMICON process used to deposit material onto a wafer by ionizing gas plasma (typically via microwave radiation). In PVD, chemical reactions occur in the gas/plasma phase, as opposed to on the surface of the wafer in CVD.

PWD See Printed-Wiring Board.

Pyrex Also called borosilicate glass. A type of glass resistant to heat, chemicals, and electricity. Used in chemical apparatus, industrial equipment, and thermometers.

Pyrolytic A chemical reaction induced by external heat.

Pyrophoric Materials that ignite in air at or below 54.4°C.

PZT (Lead Zirconate Titanate) A family of ceramics that has low electrical losses and high values for the piezoelectric charge coefficient, electromechanical coupling coefficient, and dielectric constant. Used extensively in ultrasound transducers.

Q-S

QC-1 (Quality Criteria-1) The basic quality principles and requirements for nuclear weapons research, design, development, procurement, production, dismantlement, maintenance, stockpile evaluation, and disassembly/disposal.

Q Factor (Quality Factor) A measure of the sharpness of resonance of an electronic/electromechanical resonator component. A device with a high Q factor has a sharp, large magnitude, and well-defined resonance. It is defined as the ratio of the reactance to the effective series resistance of a component.

QFP (Quad Flat Pack) A common package for ICs with high pin count. It has many leads on all 4 sides of the package. QFP is losing popularity in the IC industry.

QMA See Quadrupole Mass Analyzer.

Quadrature A phenomenon when two periodic signals of the same frequency are out of phase by 90° (360°/4).

Quadrupole Analyzer An analyzer in which, during each short time interval, ions of a particular mass are allowed to pass through the analyzer and are counted by the detector. This is repeated for other types of ions that have different masses. Thus the analyzer scans through a large range of masses. Used in electronic noses

Quadrupole Mass Analyzer (QMA) A mass analyzer that separates the ions generated in the ion source according to their mass-to-charge ratio and is controlled by a combination of RF and DC potentials. Only ions of a specific mass can pass through a given set of oscillating RF and DC fields developed through four cylindrical rods.

Quad Flat Pack See QFP.

Qualification The process of assuring that a product and all associated processes are capable of meeting customer requirements.

Qualification Plan (PQ) The qualification plan documents the engineering evaluation objectives, the engineering evaluation results, and performance metrics for prescribed attributes. A control

number for callout in an application shall identify each PQ.

Quality Criteria-1 See QC-1.

Quality Factor See Q Factor.

Quantum Physics Describes fundamental electronic and optical properties of matter at microscopic levels and wave and interference phenomena in particular. Quantum electronics, quantum optics and optoelectronics are important areas of application—including atomic clocks and lasers.

Quartz Micro Balance Sensor Module An array of quartz oscillators, each layered with different polymers (polysiloxanes, etc.). Volatile molecules are adsorbed by the sensitive coating, which results in nanometric changes in coating mass and frequency. Best suited for detecting large molecules.

Quartz (Crystalline SiO₂) An inert, highly stable, and piezoelectric material.

Queue Time The highest amount of time allowed between two sequential operations.

Rad-Hard Technology Parts Radiation-hardened ICs manufactured with special devices and isolation techniques such that when exposed to heavy radiation they remain operational. Conventional circuits will short out under such conditions because the radiation generates electrical currents inside the semiconductor material.

Radical A reactive atom or group of atoms created when an energetic electron bombards a neutral gas molecule.

Radio Frequency See RF.

RAM (Random-Access Memory) The basic (read/write) storage element in a computer. It stores digital information temporarily and can be changed as required.

Random Error A component of the error of measurement, which in the course of a number of measurements of the same measurand varies in an unpredictable way. It is not possible to correct for random error.

Random Numbers Numbers that have no order or any relation to each other. Sophisticated computer programs generate random numbers.

Range The set of values that equals the highest number minus the number score. It gives a measure of the scatter or variability in a set of values.

Range (Ion Implantation) The depth an ion travels in the silicon substrate during ion implantation.

Rapid Thermal Processing (RTP) A process that rapidly increases the temperature of a wafer by placing it in a heated oven for a very short period of time. A halogen quartz lamp that provides the heat and temperatures during RTP can reach as high as 800°C.

RCA Clean A wet cleaning technique that has three distinct steps: removal of organic contaminants from the wafer surface using a 5:1:1 H₂O:H₂O₂:NH₄OH solution; removal of any oxide layer that may have built up using a 50:1 H₂O:HF solution; and removal of ionic or heavy metal contaminants using a solution of 6:1:1 H₂O:H₂O₂:HCl. Named after the now defunct Radio Corporation of America, the company for which the inventor of the RCA clean formula worked.

Reactance The component of the impedance of an AC circuit that is due to capacitance or inductance or both. Its units are ohms.

Reactivity The ability of a chemical to undergo chemical reactions and release energy.

Reaction-Rate Limited During CVD at lower pressures, the arrival rate of reactants surpasses the rate at which they are consumed by the chemical reaction process at the wafer surface.

Reactive Ion Etching See RIE.

Reactor A process chamber in which chemical reactions occur to deposit specific materials in layers during semiconductor manufacturing.

Read-Only Memory See ROM.

Recrystallization A process where materials crystallize repeatedly due to an annealing heat treatment. Recrystallization is the most common

method employed for the purification of an impure solid. It is a process that relies on the use of the relative solubilities of the desired compound, and the impurities present, in the solvent chosen for use.

Rectifier A device for converting AC into DC. Semiconductor rectifiers are diodes made large enough to disperse the heat caused by current flow.

Redistribution The modification of dopant concentration due to silicon oxidation. It occurs during diffusion.

Reflective Notching is a critical problem in making ICs in which the wafer typography reflects light into unexposed areas. This light may cause notching if it concentrates light in dark features that results in linewidth or transistor gate length contraction. It can be avoided by using anti-reflective coatings.

Reflow A high-temperature process that makes the corners of an oxide insulating layer flow to other areas to improve step coverage.

Refraction The bending of light rays as they pass through a transmission medium of one refractive index into a medium with a different refractive index.

Refractive Index The ratio of the velocity of light in a vacuum to the velocity of light in a specific material. Using 1.0 as the base reference, the higher the number, the slower the speed of the lightwaves in the material.

Refractory Metals Metals that can withstand very high temperatures without melting. Tungsten, tantalum, titanium, and molybdenum are the refractory metals.

Refractory A material that is very resistant to high temperature processes. The refractory metals in the periodic table include titanium, tungsten, tantalum, and molybdenum. The first three metals or their compounds are used in semiconductor processing extensively.

Registration Overlay The accuracy of the position of all patterns with respect to previous patterns that form other layers of a semiconductor wafer.

Release Etch The process step in which all of the sacrificial material is removed to free the structural layers and achieve movable microstructures.

Released Layers The patterned layers containing free-standing mechanical structures left behind by the removal of the sacrificial layer in surface micromachining.

Reliability Analysis The probability of losing a required function as a result of component failures. Reliability analysis typically uses physical component models characterized by failure-rate statistics. The goal of the analysis is to calculate system-level failure rates for selected functionalities.

Reliability Base Events The lowest-level faults on the reliability fault tree are considered base events.

Reliability Fault Tree The fault tree represents the logical relationship between a top event and fault modes in the form of an AND-OR tree, based on the probability of losing a required function as a result of component failures.

Repeatability The ability of an instrument to give, under specific conditions of use, closely similar responses for repeated applications of the same stimulus.

Replication Duplication of an original using casting, embossing, or molding.

Reproducibility (of measurements) The closeness of the agreement between the results of measurements of the same measurand, where the individual measurements are carried out, changing conditions like (a) the method of measurement; (b) the observer; (c) the measuring instrument; (d) the location; (e) conditions of use; (f) time.

Requirement A translation of the needs into a set of individual quantified or descriptive specifications for the characteristics of an entity to enable its realization and examination.

Residual Stress Stresses in a material that is free of external forces or temperature gradients and depends on the interactions between the defects within the component and the stresses to which it is exposed. These stresses are a combination of

those applied in service and those that developed during manufacture and processing.

Resin A semi-solid transparent flammable natural organic substance used in varnishes, printing inks, plastics etc.

Resistance The property of a body whereby it opposes and limits the passage through it of a steady electric current. Its units are ohms.

Resistive Loading The reduction in the voltage at the point being probed. This is caused when a probe is introduced into a circuit. Some of the current that was flowing in the circuit will now flow into the probe.

Resistivity (ρ) The longitudinal electrical resistance of a uniform rod of unit length and the unit cross-sectional area of the reciprocal of conductivity. The reciprocal of electrical conductivity and a measure of a material's resistance to passing electric current. Its units are ohm-cm, ohm-micron, etc.

Resistors Devices designed to have definite amounts of electrical resistance and are used in circuits to limit current flow or to provide voltage drops.

Resolution (of an indicating device) A quantitative expression of the ability of an indicating device to distinguish meaningfully between closely adjacent devices.

Resolution The smallest image that can be clearly discerned.

Resonant Circuit A circuit that contains both inductance and capacitance elements to achieve resonance at a frequency that can be manipulated by altering the value of the inductance or capacitance.

Resonant Frequency In an electrical circuit, the frequency that exists when the inductive reactance and the capacitive reactance are of equal magnitude, causing electrical energy to oscillate between the magnetic field of the inductor and the electric field of the capacitor. At this frequency, the circuit has a maximum output for a given input. Resonance frequency =

$$1/(2\pi\sqrt{LC})$$

Resonator A mechanical structure that vibrates, sometimes at a resonance frequency.

Response Characteristic The relationship between a stimulus and the corresponding response.

Response Time The time interval between the instant when a stimulus is subjected to a specified abrupt change and the instant when the response reaches and remains within specified limits of its final steady value.

Reticle A mask used in a stepper.

Return On Assets Net income divided by net assets. This measure of profitability is considered to be broader than a return on equity because it takes into account both equity and debt financing.

Return On Investment At the firm level, it is often defined as net income divided by a shareholder's equity.

Reverse Bias. If an external voltage is applied across a p-n junction with a polarity that p-type material is negative with respect to the n-type material, the junction is under reverse bias.

Reverse Engineering The process of determining the actual circuit by study of the geometrical layout of a fabricated chip.

RF (Radio Frequency) Alternating voltages and currents having wavelengths between 22 km (lowest energy) and 1mm (highest energy). The AC current is input to an antenna and an electromagnetic (EM) field is generated suitable for wireless broadcasting.

RF Sputtering A sputtering system with a cathode and anode configuration and an RF source that can sputter metal or insulator thin films in inert or reactive atmospheres in which DC methods cannot.

RHEED Reflection High Energy Electron Diffraction.

Rheology The study of the ability of matter to flow or deform. Studies for the successful operation of sensors.

RIE (Reactive Ion Etching) Dry etching by plasma having chemically active gas ions.

Rinse The use of ultra-pure water to neutralize and remove pollutants from a wafer.

Riser A cavity that contains molten metal provided to compensate for the contraction of the metal in a casting as it solidifies.

RMS (Root Mean-Square) The square root of the arithmetic average of a set of squared instantaneous values. It refers to the most common mathematical method of defining the effective voltage or current of an AC wave.

ROM (Read-Only Memory) A device that permanently stores information repeatedly used—such as tables of data, characters for electronic displays, etc. Unlike a RAM, a ROM cannot be altered.

Root Mean-Square See RMS.

Roughing Pumps Pumps used to achieve a vacuum of not greater than 10^{-8} torr. They can be used to evacuate chambers in a cluster tool.

Router A device or software that determines the next network point to which data should be forwarded on the way to its final destination.

RTP See Rapid Thermal Processing.

Run A process sequence together with a description of the tangibles to be used in processing (masks, wafers) and all the logistical minutiae required to make it actually happen—process approval, scheduling, tracking, billing, etc.

Run Card A form (paper or electronic) summarizing some work that needs to be done to move a run forward. Like a process sequence, a run card might describe the whole run from start to finish, or some subset of it. Common subsets include the work to be done at just one fab, or the work to be done at one fab plus the work done at all previous fabs involved in that run.

Sacrificial-Layer Etching Removal of a buried fast-etching layer used, e.g. to create freely movable structures.

Sampling Interval The size of the samples used to measure something, e.g. in imaging sampling, it refers to pixel size. In spectroscopy, sampling refers to the smallest spectral bandwidth used to measure something. Sampling, as applied to an analog-to-digital converter, is the process that transforms a continuous function into a series of discreet values at a linear time rate.

SAW See Surface Acoustic Wave.

SC1 (Standard Clean 1) The first cleaning step of the RCA clean. SC1 is done in a megasonic bath containing ammonium-hydroxide and hydrogen-peroxide. This step removes organic residues and particles.

SC2 (Standard Clean 2) The second cleaning step in the RCA clean. SC2 is a heated mixture of hydrochloric-acid and hydrogen-peroxide and removes metal contaminants.

Scaling A technique of reducing the size of an existing IC die by selective shrinking of the X and/or Y dimensions.

Scanning-Electron Microscopy See SEM.

Scanning Projection Aligner An aligner that scans light through a slit across a mask to produce an image on a wafer. Since scanning is done through a slit, a relatively small lens can be used. The technique allows larger areas to be imaged without requiring huge optical systems.

Schottky Contact A contact created when metal is directly in contact with a semiconductor. It does not allow current both ways and metal silicides like $TiSi_2$, to ensure that current flows freely both sides. The properties of the Schottky contact are determined by the properties of the majority carriers in the semiconductor and are used as rectifiers in the form of a Schottky diode.

Schottky Defect The presence of a missing atom in a crystal lattice. Also known as vacancy.

Schottky Diode Possesses a lower voltage drop than conventional diodes and is an order of magnitude faster than the conventional PN diodes and hence used in RF applications. A normal diode has between 0.7-1.7 volt drops, while a Schottky diode voltage drop is between approximately 0.5-0.45 volts, which accounts for higher system efficiency.

Schottky TTL A form of TTL logic in which Schottky diodes are used to clamp the transistors out of saturation, effectively eliminating the storage of charge within the transistor—allowing increased switching speeds.

SCREAM Single Crystal Reactive Ion Etching and Metallization.

Scribe Line The partition between neighboring die on the wafer. It is used as the cutting area in sawing a wafer into the individual die. Also referred to as saw lane or street.

Second-Level Packaging The assembly of the packaged IC component into the next level, such as a printed-circuit board (PCB). During second-level packaging, through-hole components like PGAs account for more than 50% of the IC packaging on a PCB.

SED See Silicon Electron Devices.

Seeds Model A probability model for converting defect density to predicted yield.

Selective Etching The etching of one material without removing any other material.

Selectivity The difference in removal rates between two materials during an etching.

SEM (Scanning Electron Microscopy) Allows features, too small for optical microscopy to resolve, to be visible by scanning the sample with an electron beam.

Semiconductor Material whose conductivity, due to charges of both signs, is normally in the range between that of metals and insulators and in which the electric charge-carrier density can be changed by external means. [IUPAC Compendium]. International Technology Roadmap for Semiconductors, International SEMATECH.

Semiconductor Optical Amplifier See SOA.

Sensitivity The minimum input signal required to produce a measurable output signal having a specified signal-to-noise ratio. The amount of change in a sensor's output in response to a change at a sensor's input over the sensor's entire range.

Sensor A device that responds to the absolute value of, or change in, a physical stimulus (heat, light, sound, magnetism, pressure, or particular motion) and produces a corresponding signal. It may react also to other stimuli, e.g. temperature. A sensor can be an entire instrument or the part of it that measures a phenomenon.

Separation By Implantation of Oxygen See SIMOX.

SEU (Single-Event Upset) An IC failure mechanism that occurs when ICs are exposed to cosmic rays. A single cosmic ray can bring about latch-up in a CMOS structure by activating a parasitic transistor.

Shaped-Memory Alloy Alloys that can be deformed by up to 8% strain. They will stay in the deformed shape until heated to above the transformation temperature of the specific alloy and then will return to their predeformed shapes. Increases the degrees of freedom of movement in endoscopes used for minimally invasive surgery.

Shape Of Crystal The atoms in a crystal occupy positions with definite geometrical relationships to each other. This structural arrangement of its atoms is uniquely defined by the chemistry of the substance and determines the shape of the crystal.

Sheet Resistance A characteristic of material that is formed in such a way so that its resistivity varies as a function of its cross-sectional structure. Sheet resistance is expressed as RS in terms of ohms per square, where the square refers to surface area but has no absolute dimensions.

Shim A thin tapered piece of material used to fill fissures or make a structure flat.

SI Units The international system of units derived from the modern metric system of measurement.

Single-Event Upset See SEU.

Sintering The process of heating the material to a temperature below the melting temperature but high enough to allow bonding or fusion of individual particles.

Si/Pyrex Sandwich An anodic bonding technique used to create novel MEMS devices and also as a batch-compatible packaging process.

Side-Brazed Ceramic Package A multilayer ceramic dual in-line package (DIP) with external leads brazed on the sides of the package.

Signal-Conditioning Electronics Electronics that interface a wide range of sensors and transmitters that carry information regarding temperature, humidity, or pressure, to data storage devices.

Signal-To-Noise Ratio (S/N or SNR) A measure of signal strength relative to background noise. The ratio is usually measured in decibels (dBs). Communications engineers always strive to maximize the S/N ratio.

Silane (SiH₄) A toxic gas used to deposit silicon films in CVD processes.

Silica Waveguides Waveguides made out of SiO₂.

Silica-On-Silicon Waveguide Technology A technology used to fabricate advanced photonic devices on a small chip using a technique similar to fabricating IC chips.

Silicide A compound of metal and silicon. Silicides may be easily formed by thermally reacting a variety of metals with silicon and are widely used as contacts to silicon and conductors.

Silicon A pure crystalline element (Si) that is the most commonly used semiconductor material for the fabrication of ICs. Since silicon is the only semiconductor that allows growth of its oxide easily, silicon is used in the IC industry and not germanium, which has better semiconductor properties than silicon.

Silicon-Dioxide (SiO₂) An insulator with a dielectric constant of 3.9.

Silicon Fusion Bonding High-temperature hermetic bonding. Its atomic nature means high-quality bond interfaces.

Silicon Nitride (Si₃N₄) An insulator with a dielectric constant of 7.5 and is used as a barrier material on the sides of the gate as protection against contaminants.

Silicon On Insulator See SOI.

Silicon On Sapphire See SOS.

Silicon-Gate MOS MOS devices with a polycrystalline silicon layer deposited to form the gate elements.

Silicon Sculpting The act of “etching” bulk silicon. It is one of the basic technologies utilized in traditional bulk micromachining processes.

SIMOX (Separation by Implantation Of Oxygen) A popular technique used to fabricate sili-

con-on-insulator (SOI) substrates by implanting oxygen ions at extremely high temperatures in silicon wafers to form oxide layers. Developed by IBM, the relatively perfect silicon oxide allows direct bonding to the pure crystalline silicon substrate.

SIMS Secondary Ion Mass Spectroscopy.

Simulation The use of a CAD tool that mimics the behavior of the actual circuit through a collection of sub-circuit models and so enables designers to test and debug circuits before layout and fabrication.

Simulation Program for Integrated Circuits Emphasis See SPICE.

Single Crystal A piece of material having a continuous, regular crystalline lattice structure and having no internal grain boundaries.

Single-Crystal Silicon Silicon having a continuous, regular crystalline lattice structure and having no internal grain boundaries.

Single-Electron Device (SED) A nanoscale device that controls the movement of individual electrons. One day, it may be possible for ICs to have as many as 10 billion electronic devices in a square centimeter, a density 1000 times greater than that believed feasible for single-electron transistors.

Single-Mode Fiber-Optical Switch An optical switch in which only the lowest-order bound mode can propagate at the wavelength of interest. The bound mode refers to a mode that has a field intensity that decays monotonically in the transverse direction, everywhere external to the core. A mode is one of the various possible patterns of propagating or standing electromagnetic fields, which is characterized by wavelength, frequency, and electric and magnetic field strengths.

Single-Mode Fiber An optical fiber in which the signal travels in one mode. It typically has an 8-10-mm core within a 125-mm cladding.

Single Nucleotide Polymorphism See SNP.

Single-Point Prediction A forecast in the form of a single value for a given market and for a given period of time. It is usually obtained by taking the average of a series of expert opinions.

Sintering The process of heating the material to a temperature below the melting temperature but high enough to allow bonding or fusion of individual particles.

SIP (Single In-Line Packaging) Packaging with a single row of pins (in picket-fence style) and is usually mounted in the vertical plane.

Slice Another term for a wafer.

SMA See Shaped-Memory Alloy.

Small-Outline/Small-Outline IC See SO/SOIC.

Small-Scale Integration See SSI.

Smart Sensor The electronics associated with a sensor that processes the output and are partially or completely integrated on a single chip.

Smart Switches Optical switches that can provide multiple functions such as switching, power regulation and dynamic broadcast. The integration of power regulation and switching reduces complexity of optical-network control and management.

Smart Transducer Interface Model See STIM.

SMD (Surface-Mount Device) A sophisticated microelectronic packaging technology in which packages are small enough to be soldered using eutectic alloys on the surface of a printed-circuit board.

SME (Small and Medium Enterprise) A business organization can be considered small or medium scale based on satisfying the following criteria: a) the number of employees, b) the percentage owned by a single entity, and also one of the following criteria: c) turnover and d) balance-sheet total. See the table at the end of this glossary.

SMM See Surface Micromachining.

SMT See Surface-Mount Technology.

SNP (Single Nucleotide Polymorphism) Polymorphism differing in a single base pair (AT or GC).

SNP Genotyping A method of determining variations in genetic sequences that cause diseases. SNP is pronounced as “snip.”

SO/SOIC (Small-Outline/Small-Outline IC)

A plastic dual in-line package with “gull wing” feet designed for surface mounting. Most versions have lead spacing compatible with that of PLCC packages. Another version, SOT (Small Outline Transistor) has been popular in hybrid use for several years.

SOA (Semiconductor Optical Amplifier) It is similar to regular lasers, but with an optical signal being amplified by stimulating light emission. It is manufactured by coating an optical cavity that stores light, by coating it with anti-reflection coatings and angle cleaving its facets. An SOA provides high-speed switching capability as well as gain.

Soft Bake A bake performed after photoresist coating and before exposure. This step dries the photoresist film and improves photoresist adhesion to the wafer. It is performed at a temperature lower than a hard bake.

SOG See Spin-on-glass.

SOI (Silicon On Insulator) An oxide layer sandwiched between two silicon layers, used in etching, as an etch stop barrier and sacrificial layer.

Solid State Refers to electronic devices, like transistors, that conduct and control the movement of electrons in solid materials (instead of in a vacuum).

Solidus Temperature In a mixture of materials, it is the temperature below where the mixture starts to solidify completely and below where it cannot liquefy. In a phase diagram it is the line between the solid state and the intermediary state between solid and liquid.

SONET (Synchronous Optical Network)

Communication between different networks requires complicated multiplexing/demultiplexing and coding/decoding processes to convert a signal from one format to another. The SONET communication protocol allows these different types of formats to be transmitted on one line. SONET allows the addition and elimination of signals with a single multiplexer.

SOS (Silicon-On-Sapphire) A fast MOS technology in which silicon is epitaxially grown on a sapphire wafer, and etched away between tran-

sistors. Each device is thus isolated by air or oxide from other devices.

Sound Power Level (dB) Equal to $10 \times \log_{10}$ (sound power of the source / a reference sound power). Sound power values are used to find out whether sound levels are not hazardously high.

Source The working-current terminal of an FET that is a source for holes (P-channel) or free electrons (N-channel) flowing in the channel. C It corresponds to the emitter of bipolar transistors.

Span The modulus of the difference between the two limits of a nominal range of a measuring instrument. E.g., a nominal range -10 volts to +10 volts spans 20 volts.

Spark Erosion A method for producing fine powders of metals, alloys, and semiconductors by maintaining cyclic spark discharges near material immersed in a dielectric liquid. The spark discharge creates localized vaporization of the material in the dielectric, which freezes into powder. Spark erosion is an electro-discharge machining technique used to remove material during the manufacture of tools and dies.

Special Cause Variation A variation in output for a process because a component of the process changed.

Specific Heat The heat capacity per unit mass of a given material. It is the heat required to raise the temperature of one gram of a substance one degree Celsius.

SPICE (Simulation Program for Integrated Circuits Emphasis) An Electronic Circuit simulator used to verify circuit designs and predict the circuit behavior.

Spider Bonding A method of connecting an IC die to its package leads. A preformed leadframe is placed over the chip and all contacts are made by just one operation of a bonding surface. Tape automated bonding (TAB) uses this approach for interconnection.

Spin-On-Glass (SOG) A thin layer of liquid glass spin-coated on a surface that solidifies to form a dielectric.

Spreading-Resistance Probe (SRP) A metrology technique to measure electrically active

dopant levels. A semiconductor is ground down at an angle through the area to be measured and four tiny needles are pushed down measuring resistance as they go.

Sprue And Runner System A type of mold system used in metallurgy. A sprue is the vertical channel from the top of the mold to the mold cavity where the metal has to reach. The runner is a cylindrical tube that connects the sprue with the riser.

Sputtering 1. The ejection of atoms or groups of atoms from the surface of the cathode (negative electrode) of a vacuum tube as the result of heavy-ion impact. 2. The use of this process to deposit a thin layer of metal on a glass, plastic, metal, or other surface in a vacuum.

SRAM (Static Random-Access Memory) Memory circuits that permit the storage and retrieval of data from any desired memory cell. The data remain stored as long as power is applied. It does not require periodic refresh cycles, as does dynamic RAM.

SRP See Spreading Resistance Probe.

SSI (Small-Scale Integration) ICs containing fewer than ten logic gates.

Stability The ability of an instrument to maintain its metrological characteristics within specified limits.

Standard Atmospheric Pressure A unit of pressure equal to the earth's normal air pressure at an altitude of sea level, i.e. 1.01325×10^5 Newton per square meter.

Standard Cell A pre-designed IC module that implements a specific function. The data required to use the cell as part of a more complex circuit are contained in a computer file that can be accessed by other CAD tools. Standard cells are designed to be interconnected by simple abutment with other cells from the same cell library.

Standard Clean 1, Standard Clean 2 See SC1, SC2.

Standard Deviation The standard deviation for a series of n measurements characterizes the dispersion among them and is given by the formula

$$\text{s.d.} = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

where x_i is the result of the i th measurement and \bar{x} is the arithmetic mean of the n results considered.

Standing waves A problem associated with optical lithography and created when two sine-wave-shaped waves having the same frequency and the same amplitude are traveling in opposite directions. Standing waves are created when incoming light waves of the optical system can interfere with the light reflected due to the different refractive indices of photoresist and substrate material. Standing waves create line-width variations and degenerate image quality. Antireflective coatings are used to eliminate it.

Static RAM See SRAM.

Statistical Process Control (SPC) A method to control product quality by observing a process during its operation while the products are being produced, rather than depending on inspection. This identifies the causes of variation in product quality.

Stator A motionless part in a machine about which a rotor revolves.

Stent An expandable, metallic (tubular shaped) device that provides structural support for a vessel.

Step And Repeat A lithographic system that exposes a wafer by exposing an area of the wafer and then stepping to the next adjacent area of the wafer to perform the next exposure. The system steps and exposes repeatedly until the whole wafer is covered with patterns. This system utilizes reticles to create patterns.

Step-And-Repeat Camera An optical system that reduces the 10X reticle image to 1X on a master plate. After each exposure, the master plate is stepped to a new position and the exposure process is repeated.

Step Coverage If a layer of material is to be deposited on top of a thin strip of material, it is the ratio of film thickness along the walls of the step to the film thickness at the bottom of the

step. LPCVD and PECVD offer excellent step coverage.

Step Response The response of a system to an instantaneous jump in the input signal.

Stepper A resist exposure tool based on projection lithography and step-and-repeat wafer exposure procedures. The same as Stepping Aligner.

Stepping Aligner An optical system that projects (usually 5X or 10X) reticle images on a portion of the photoresist-coated wafer. After exposure, the wafer is stepped to a new position and the exposure process is repeated.

Stiction Undesired adhesion of movable solids in very close proximity, caused by forces such as Van der Waals, capillary, and hydrogen

STIM (Smart Transducer Interface Module) A module that contains the TEDS logic to implement the transducer interface, the transducers and signal conversion or conditioning units. It contains analog-to-digital or digital-to-analog converters and activating mechanisms.

STM Scanning Tunneling Microscope.

Stoichiometry The quantitative relationship between chemical elements in a chemical substance.

Strain The alteration of relations between the parts of a structure by applying an external force.

Strain Gauges Instruments for measuring the strain, or response to stress, on a structure. The stress is essentially the load on the structure. The load may be dynamic or static.

Stress Concentration High localized stress intensity at a geometric discontinuity of a body, as in the vicinity of a notch or hole or at a change in the diameter of a shaft.

Stripping The process of completely removing a coating such as photoresist.

Structural Material Used to make the parts that move in a MEMS device, as opposed to the sacrificial material, which is the material that is etched away to free the structural material.

SU-8 (Epon SU-8) A photodefinable epoxy used to make high-aspect-ratio features. This material

is commonly used in electroplating or polymer casting.

Substrate The material on which a microelectronic device is built. Such material may be active, like silicon, or passive, like alumina ceramic.

Sublimation A phase change of a material directly from the solid to the gaseous state without becoming liquid.

Substitutional Atom An extraneous atom replacing an atom of a crystal and occupying its position in the crystal lattice.

SUMMiT (Sandia Ultra Planar, Multi-level MEMS Technology) A Sandia MEMS fabrication process, consisting of a four-level polycrystalline silicon surface-micromachining process: one ground plane/electrical interconnect and three mechanical layers. There is also a 5-layer version called SUMMiT V.

Super Critical Drying A drying technique that avoids the sudden change in densities caused by a fluid's transition from liquid to gas during typical air-drying. Super critical drying is usually performed after release of bulk or surface micromachined devices to achieve stictionless movement by avoiding distortion due to thermal expansion.

Superelastics Those materials that can be deformed to eight percent strain. However, it will immediately return to its original shape upon unloading.

Surety A level of confidence that a system will operate exactly as planned under both expected and unexpected circumstances. Surety attributes include reliability in normal environments, safety of people and surroundings in abnormal environments, and security and use control in malevolent environments.

Surface Acoustic Wave (SAW) sensors Similar to bulk acoustic wave sensors but operating at a higher frequency of oscillation. The resonators in SAW sensors oscillate usually at 260 MHz.

Surface Micromachining An additive fabrication technique that involves the building of a device on the top surface of a supporting substrate. This technique is relatively independent of substrate; therefore, it can be easily mixed with

other fabrication techniques that modify the substrate first.

Surface-Mount Device See SMD.

Surface-Mount technology (SMT) A sophisticated microelectronic packaging technology in which packages are small enough to be soldered using eutectic alloys on the surface of a printed-circuit board.

Surface Passivation The rendering of electric bonds or contacts ineffective by chemical methods, especially oxidation. It is of critical importance to MEMS reliability.

Surface Roughness A characteristic of a surface that is found by measuring deviations of the actual surface from its intended shape. The surface roughness of a wafer is the difference between the highest and the deepest surface feature.

Susceptor A platen on which semiconductor wafers are heated during thermal processes such as epitaxy and chemical-vapor deposition (CVD).

Sustaining Technology A technology associated with a developed market. It is the current stable technology product platform in an industry or firm setting. In well-managed companies that supply this technology, the products advance as rapidly as improvements in science and engineering allow. Managers carefully determine the desires of their customers and plan new engineering projects to satisfy those needs quickly and cost-effectively.

Synchronous Optical Network See SONET.

Synchrotron A large device that imparts extremely high velocity to charged particles by combining a high-frequency electric field and a low-frequency magnetic field. Used as a source for X-rays.

Synthesis The CAD operation of automatically generating an IC layout from a high-level description (e.g. using a hardware description language) of the desired circuit function and behavior.

Systematic Error A component of the error of measurement, which, in the course of a number of measurements of the same measurand, remains constant or varies in a predictable way.

Systematic errors and their causes may be known or unknown. See also Bias Error.

T-V

T²L See TTL.

Tape-Automated Bonding (TAB) A bonding technique using a transparent flexible polyester tape that has tracks on which unpackaged ICs are attached and stored in a reel. Silver epoxy is screen-printed onto the pads of the tape to which the device's leads are to be connected. The tape is fed through an automatic machine, which pushes the device, and the TAB leads into the epoxy. On curing, the silver-loaded epoxy forms electrical connections between the TAB leads and the pads on the substrate.

Target The metal source for a sputtering process. Targets are mostly round, thick metal pieces larger in diameter than the wafers on which the metal will be deposited. Targets are specially shaped to optimize deposition uniformity.

Taxonomy A general method for classification. An example of a MEMS taxonomy is that proposed by P. McWhorter, which classifies MEMS applications according to the following categories: (1) non-moving components, (2) moving components that do not touch each other, (3) components that move and impact each other, and (4) components that move and rub against each other.

μTAS See microTAS.

TC See Thermo-Compression.

TCAD Technology Computer-Aided Design

TCE (Thermal-Coefficient-of Expansion) Defined as the rate at which a material expands and contracts as a temperature rises or falls. It is measured as change in length per change in temperature. The TCE of adjacent thin films in semiconductor microfabrication have to be similar to avoid failure-causing stresses induced at room temperature.

TCR See Temperature Coefficient of Resistance.

TCS See Trichlorosilane.

Technology File A software file used to design the fabrication process steps necessary to achieve a MEMS or IC component.

Technology Node Also called minimum feature sizes of a device. It refers to the line width of a transistor and gives an insight into the sophistication of a semiconductor fabrication process. The technology complexity of an IC product is represented by a technology node. E.g. a 0.13-μm (130-nm), 0.15-μm (150-nm), etc., technology node. The smaller the technology node the more the number of transistors can be put on a single die. At present, most MEMS devices are in the 1-μm technology node while IC processing technology has reached 0.09 μm.

Technology/Product Paradigm The technology a company utilizes to form a "core product" that acts as a platform from which many application-specific products can be developed. It is a matrix describing the relationship between the various technologies and products of a company.

Technology Push Often referred to as the domain of a market visionary. Technology push occurs when a firm introduces a new product that they think will be beneficial and of interest to a consumer before the consumer is even aware of it. Technology push is more risky than market pull. The producer has to educate the consumer of the product's benefits.

Technology/Product Paradigm The technology that a company utilizes to form a "core product" that acts as a platform from which many application-specific products can be developed. It is a matrix describing the relationship between the various technologies and products of a company.

TED See Transient Enhanced Diffusion.

TEDS See Transducer Electronic Data Sheet.

Telecalibration The use of information technology to offer remote calibration services for metrology equipment using a communication network.

TEM See Transmission Electron Microscope.

Temperature Coefficient of Resistance (TCR) The rate of change of resistance due to temperature variation. Mathematically, $TCR = (\Delta R/R) / \Delta T$, where Δ refers to a change.

Tensile Strain An increase in a dimension (length, width, etc.) of a body when it is subjected to an external tensile (stretching) force.

Tensile Strength The maximum stress encountered when a material undergoes stretching without it tearing apart.

Tensile Pertaining to the stress (i.e., tension) resulting from the elongation of an elastic body.

TEOS (TetraEthylOrthoSilicate) A chemical used in CVD deposition of SiO₂. It is commonly used in the industry since the film achieved is conformal.

Tetra-Methyl-Ammonium-Hydroxide (TMAH) A chemical used to develop photoresist after the photo resist-coated wafer is exposed to light through a mask.

Thin-Film Transistor (TFT) A transistor whose active, current-carrying layer is a thin film of silicon that is on top of a glass substrate. TFTs are used in flat-panel display since light is able to pass through a transparent glass to be visible to a viewer. They're cheaper than conventional transistors since they don't require lot of clean room time and use inexpensive equipment for manufacture.

Thermal Actuator An electro-thermally actuated MEMS device. A current passed through the device causes Joule (I^2R) heating resulting in differential thermal expansion of the device, which can be used to extract a relatively large mechanical deformation.

Thermal Budget The amount of thermal energy transmitted to a wafer. It is proportional to the product of temperature and time of the heating process.

Thermal Coefficient of Expansion See TCE.

Thermal Compression Bonding A method of direct bonding that does not use an intermediary metal or melting, but rather the plastic flow of materials resulting from the combination of heat and pressure. It's used to bond beam-lead devices to packaging substrates.

Thermal Conductivity (λ) A measure of the effectiveness of a material as a thermal insulator. A substance with a large thermal conductivity value is a good conductor of heat; one with a small thermal conductivity value is a poor heat

conductor, i.e. a good insulator. Its units are W/mK.

Thermal Diffusion A phenomenon in which a temperature gradient in a mixture of fluids gives rise to a flow of one constituent relative to the mixture as a whole. Also known as thermodiffusion.

Thermal Stress A residual stress introduced inside a body due to a change in ambient temperature.

Thermistor A thermally sensitive resistor. It's manufactured using barium-titanate or the oxides of transition metals—manganese, cobalt, copper and nickel. Thermistors are used in measurement and control and temperature compensation.

Thermo-Compression (TC) bonding An IC bonding process between a gold wire and a gold metallized substrate using a wedge-shaped tool under accurate and precise combination of heat, force and mechanical vibration.

Thermocouple A device for measuring temperature. It consists of a pair of wires of electrochemically different metals like copper and iron. The free ends of the wires are connected to a voltmeter, which measures the difference in potential created at the junction of the two metals.

Thermoplastic Plastics that soften or fuse when heated and harden again when cooled.

Thermoplastic Polymer Polymers that soften and flow when heated. These polymers can be heated and reformed since polymer chains are not crosslinked or connected.

Thermoset Polymer Polymers that will not flow when heated since they are crosslinked or connected together, like a net. They're used in automobiles, furniture, ski boots, etc. They also used in electrical insulation, carpet fibers, microwave containers, etc.

Thermosonic Bonding Similar to Thermo-compression bonding except for the addition of high-frequency ultrasonic vibration to the tip during bonding. The interface temperature is around 100-150°C and thus avoids the high-temperature effects of thermo-compression bonding that needs a temperature >300°C.

Thick-Film Process 1. A hybrid microelectronic process where conductors, insulators, and passive components are screened from special pastes onto a substrate. This process is less expensive than the thin-film process that uses photolithographic techniques to define conductors, etc. 2. The use of deposited films of conductive or insulation material, which may be patterned via photolithographic techniques to form electronic components and conductors on a substrate, or used as insulation material between successive layers of components.

Three-D Geometry Simulator 3D geometric model of a MEMS device built by simulating the manufacturing process using a mask set and a process-definition file. The resulting solid model is in a standard commercial file format that can be used for visualization, analysis, dynamic modeling, rapid prototyping, etc.—e.g. SUM-MiT 3D Modeler from Sandia National Labs (USA).

Three-D Modeler See 3D Geometry Simulator.

Three-D Three-dimensional. The visual display that exhibits width, height, and thickness or depth. Standard 2D computer images and television displays create a flat image with only height and width.

Threshold The smallest input signal that will cause a readable change in the output signal.

Through-Hole Components Components with lead that need insertion through holes in the PCB and are soldered on the opposite side of the PCB. They're more labor-intensive than surface-mount technology (SMT) parts and are losing popularity.

Throughput The number of wafers per hour through a semiconductor equipment tool, a production stage, or the factory, assuming 100% equipment uptime at its maximum capacity. It is adjusted for any idle time under certain circumstances.

Throughput Time The ratio of the amount of time taken to complete a production run and the number of acceptable work pieces produced. If it takes 1000 minutes to make 100 pieces then throughput time is 10 minutes.

Through-Wafer Vias An interconnect technology used to make 3D MEMS structures. It solves

the problem of wafer front-side space shortage and enables high-density packaging.

Time Constant The time it takes for the output change to reach 63% of its final value.

TiSi₂ (Titanium Silicide) A compound of titanium and silicon that is coated by CVD. It is used to reduce the resistance of the metal contact on the silicon.

TO See Transistor Outline Package.

Tolerance The total permissible variation of a quantity from a designated value.

Top Down Nanosystems These systems utilize metaphors such as “chip” (large scale integrated nanosystems) or a “cell” (small complex nanosystems that function in larger quantities) that are revolutionary in nature and require a much longer term to develop. They utilize MEMS based manufacturing technologies.

Top-Down Nanotechnology Engineers taking existing devices, such as transistors, and making them smaller. Top-down or mechanical nanotechnology will have the greatest impact on our everyday lives in the near future. [Noah Robischon “Nanotechnology and the battle to build smaller,” Discovery Channel 1998].

Topography Refers to the contour or shape of a surface. The various semiconductor manufacturing processes like CVD, epitaxial growth, etching, etc. have an effect on the topography of a silicon wafer.

Torque A force that produces rotation. It is also the measure of the value of a force and is the product of the force and the perpendicular distance from the line of action of the force to the axis of rotation. The SI unit is Newton-meter.

Torr A unit of pressure. It is equivalent to a pressure exerted by a column of 1 mm of Hg (mercury). One atmospheric pressure = 760 torr. $1 - 10^{-3}$ Torr is low vacuum and $10^{-3} - 10^{-9}$ torr is high vacuum.

Torsional Micromirrors A micromirror that changes its position on the application of a potential. Increasing the driving voltage results in larger rotation angles. Its applications include digital projection displays, printers, and optical communications equipment.

Total Internal Reflection The reflection that occurs when light, in a higher refractive-index medium, strikes an interface, with a lower-refractive index medium, at an angle of incidence greater than an angle specific to the two media.

Toughness The amount of energy absorbed by a material as it fractures. It is found by calculating the total area under the material's tensile stress-strain curve.

Transceiver A transmitter and receiver combined in one device.

Transducer A measuring device that provides an output quantity having a given relationship to the input quantity. E.g., (a) thermocouple; (b) current transformer; (c) electropneumatic converter.

Transducer Electronic Data Sheet (TEDS) A set of electronic data needed by software for mapping between transducers and describe itself to the network. A TEDS is a persistent memory that specifies one or more transducers (sensors, actuators, or digital input or output devices) and their triggering, signal conditioning, and signal conversion. The TEDS is part of a STIM.

Transduction Conversion of energy from one form into a more readable form.

Transformation A statistical technique to modify all the values of a variable by using a mathematical operation. For example, a transformation of a group of numbers occurs by multiplying by a constant or taking the natural logarithm or similar operations. The data can now be viewed in a different perspective to find new information that was previously not noticeable.

Transient Enhanced Diffusion (TED) The diffusion of dopant ions due to the interaction of defects, like silicon interstitials and vacancies, with dopants during annealing after ion implantation. The dopant diffusivities are enhanced by many orders of magnitude but the increase is transient since the defects ultimately diffuse into the bulk or get destroyed at the surface.

Transient Response The response of the sensor to a unit change in the quantity being measured.

Transistor An active semiconductor device with three electrodes that may be used either as an amplifier or a switch.

Transistor Outline (TO) Package. Standard mechanical packages used primarily for discrete transistors and low-pin-count ICs.

Transistor-Transistor Logic See TTL.

Translation Uniform motion of a body in a straight line.

Transmission Electron Microscope (TEM) A microscope that creates images by using electron beams to pass through a specimen. Only black and white images are formed and the specimen has to be made very thin.

Trench An etched region filled with oxide or doped silicon that acts as an isolation region between adjacent devices. It is also used to fabricate capacitors.

Tribology A study that deals with the design, friction, wear, and lubrication of interacting surfaces in relative motion.

Trichlorosilane (TCS) stands for SiHCl_3 , which is a liquid used in epitaxial silicon growth or polysilicon.

T-Spice A version of SPICE developed by Tanner Research Labs and is part of MEMS Pro.

TTL (or T²L) Transistor-Transistor Logic. A bipolar technology where a transistor output is connected directly (rather than through a resistor or diode) to a transistor input of the next stage.

Tungsten Hexafluoride (WF₆) A toxic liquid used in CVD of tungsten interconnects. The contact holes in ICs are filled with tungsten using WF₆.

Turnaround Time Completion time to manufacture a product.

Twin Well A process where both a p-type region and an n-type region are made adjacent to enable the fabrication of pmos and nmos devices in the n-well and p-well, respectively.

Twinning A defect in which the crystal grows in two different directions from a plane.

Type II Diabetes A disease that affects the body's ability to use sugars, starches, fats and proteins and is not genetically transmitted as Type I diabetes. With Type II diabetes, too much insulin is produced in the body that prohibits glucose from entering the muscle cells. In turn, glucose rises to abnormal levels in the blood. Type-II diabetics are non-insulin dependent.

ULPA Filter (Ultra-Low-Particle Air filter) An air filter that removes 99.999% of particles that are 0.1 μm or larger. Only 1 particle 0.1 μm in size out of 100,000 ones passes through the ULPA filter.

ULSI (Ultra Large Scale Integration) The placing more than one million circuit elements on a single chip. The same as VLSI and used more often in Japan.

Ultrasonic Bonding A bonding technique that utilizes ultrasonic energy and pressure to form bonds.

Unipolar FET devices where current passes only through one type of semiconductor material (P or N) as it flows from input to output.

UV (Ultraviolet Rays) Radiation that has a wavelength between 4 nm and 480 nm. Most lithographic equipment for IC and MEMS fabrication use UV radiation.

Vacancy Diffusion The migration of an atom from a typical lattice position to a vacancy lattice site. The migrating atom has to be of the same size or has to be a substitutional atom. See also Interstitial Diffusion.

Van der Pauw Method A way of measuring the sheet resistance of a wafer using a four-probe system.

Vapor Plating A vacuum process, usually less than 10^{-10} Torr (mm of Hg), where metal(s) are vaporized through thermal agitation, then recrystallized on cooler surfaces, generally the material to be coated. It's also referred to as evaporation.

Vapor Pressure The pressure in the space above a liquid in a closed container. Compounds with high vapor pressures are volatile. The boiling point of a liquid is the temperature at which the vapor pressure of the liquid equals the external pressure.

Vapor Priming A process of exposing wafers to a vapor of HMDS to prime the wafer surface prior to photo-resist coating. It improves photo-resist adhesion, consuming less HMDS since a monolayer of HMDS is formed.

Variable Cost A cost that increases or decreases in proportion to the level of output. The variable cost per unit may remain level over different production volumes.

Variance The square of the standard deviation. See Standard Deviation.

Vascular Graft An implant of a new vessel in the vascular system.

Vascular System The heart, blood, and network of blood vessels that lead to and from the heart.

VCSEL Vertical-Cavity Surface-Emitting Laser.

Ventricular Tachycardia A condition that occurs when ventricles (a pair chambers in the heart) beat at such an abnormally rapid rate that they are unable to fill completely with blood, impairing the ventricles' ability to pump oxygenated blood throughout the body.

Verification Tests and analyses to be performed during the design, development, assembly, integration, and operational phases of a measurement system to assure that specified requirements have been met. It includes all subsystem and system tests done at the functional level.

Verification Process The determination, by review of quality evidence, that the results from a given project activity satisfy conditions imposed at the start of that activity. The act of confirming, substantiating, and assuring that an activity or condition has been implemented in conformance with specified requirements.

Vernier Resolution The measuring capacity of the smallest measuring instrument in a measuring device.

Vertical Foundries Foundries that include all elements needed to produce finished products. Example companies include Standard MEMS and TMP.

Vertical Integration The degree to which a single firm controls the production and distribution

process from initial resources to the end customer. It also refers to the combination of two or more stages in a production chain.

Very Large Scale Integration See VLSI.

VHDL (Very high-speed integrated-circuit Hardware Description Language) It is a standardized example of a hardware description language that has the capability of specifying function and behavior of circuits.

Via A path filled with conducting material between two metallic layers in an IC.

Viscosity The property of resistance to flow in a fluid (a gas or liquid).

VLSI (Very Large Scale Integration) The fabrication technology for concentrating many thousands of semiconductor devices into a single IC. Strictly speaking, VLSI is in the range of >10,000 transistors but less than 1,000,000.

VMOS See DMOS.

VOC (Volatile Organic Compound) Any compound of carbon (excluding carbon-monoxide), carbon-dioxide, carbonic acid, metallic carbides or carbonates, and ammonium-carbonate, that participates in atmospheric photochemical reactions. These compounds have the potential as refrigerants, aerosol propellants, fire extinguishers, blowing agents, and solvents. (Source: United States Environment and Protection Agency).

Volatile The relative inclination of a substance to become a gas from a liquid or solid form.

Voltage Regulator Device A chip that controls voltage delivered to a load.

Voltage Electron potential in an electrical wire or circuit. Usually expressed in volts (V).

VXI VME (Versa Module Eurocard) bus extensions for instrumentation. An industry standard in test instrumentation.

W-Z

Wafer A round disc of semiconductor material used to manufacture semiconductor devices in wafer fabrication, and available in a variety of diameters, e.g. 75 mm (3 in.), 100 mm, 125 mm,

150 mm (6 in.), 200 mm, and 300 mm (12 in.). A wafer contains several hundred die.

Wafer Boat A quartz or Teflon container used to transport wafers from fabrication facilities to a clean room. Most boats have 25 or 50 slots.

Wafer Fabrication The process of creating ICs on the surface of wafers.

Wafer Sort The primary wafer-level electrical test to verify that each die functions properly at the completion of wafer fabrication.

Wafer Yield The ratio of the number of wafers that have successfully completed the wafer fabrication process by the number of wafers initially put through the wafer fabrication process.

Water Deionization A process of removing the ions using ion-exchange resins to obtain deionized water that is used in semiconductor fabs.

Waveguide A material medium that confines and guides a propagating electromagnetic wave. In optical telecommunication, a waveguide is an elongated transmission line that consists of a solid dielectric filament, usually circular in cross section. E.g., an optical fiber.

Wavelength Routing A concept developed by Cisco Systems where at each intermediate node between the end nodes, light coming in on one port at a given wavelength gets routed out of one and only one port. It allows carriers to leverage their core network technologies to support the massive growth of data services. It avoids wasting transmitted power, by channeling the energy transmitted by each node along a restricted path instead of letting it spread over the entire network.

Wavelength The length of one complete cycle of a wave. The shorter the wavelength, the greater the energy of the wave.

WDM In optical-fiber communications, a technique by which two or more optical signals having different wavelengths may be simultaneously transmitted in the same direction over one fiber, and then be separated according to wavelength at the output end.

WDM Source Laser A laser that tests power and spectral sensitivity of active components,

passive components, and other WDM building blocks.

WEDG Wire Electric Discharge Grinding.

Wedge Bonding See Bonding, Wedge.

Weight Percent (wt%) A way of expressing the concentration of a substance on the basis of weight (or mass) of the dissolved substance in the solution. Weight percent = weight of solute/weight of solution x 100.

Welding The joining of two or more pieces of metal by fusing them together.

Wet Etching A process of removing material during semiconductor fabrication using wet-chemical agents. Dry etching is preferred to wet etching in the semiconductor industry.

Wet oxidation The introduction of water vapor during oxidation to increase the growth rate. The oxide grown is not electrically stable.

WF(6) See Tungsten Hexafluoride.

Wheatstone Bridge A bridge for measuring electrical resistances that consists of a conductor joining two branches in parallel, each branch having two resistors connected in series. The resistance of one of the four resistors can be found by this arrangement.

WIDNU See Within-Die Non-Uniformity.

WIP See Work In Progress.

Wire Bonding A method to make electrical connections between aluminum bonding pads on the surface of the chip to the package lead terminals.

Wiring The electrical circuitry on a wafer. Also called interconnect.

Within Wafer Non-Uniformity (WIWNU) A measure of the amount of film thickness variation across the entire wafer. It is used to evaluate equipment performance and compare different processes. WIWNU increases as wafer size increases.

Within-Die Non-Uniformity (WIDNU) The average amount of film thickness variation across a die. Overall film thickness variation of a film coated on top of a wafer is the sum of

within-die non-uniformity (WIDNU) and within-wafer non-uniformity (WIWNU).

Wobble Motors A low-cost alternative to electric motors. These motors use rotors with diameters between 120 and 500 μm , are robust, require no lubrication, have higher torque-to-weight ratios than conventional motors, and are inexpensive. Thus they can be used in miniature medical devices. Manufactured by Sarcos Inc., Utah.

Work In Process (WIP) The input materials still in a manufacturing process. In the semiconductor industry, it is the wafers still being subjected to various manufacturing processes until final packaging. It is measured in units of wafer or in dollar terms.

Working Plates Masks printed from master plates that are used for the production exposure of wafers. As these plates are subject to wear, they must be replaced periodically.

X-ray Electromagnetic radiation with a wavelength greater than 10×10^{-9} m and less than 10×10^{-12} m. It has a smaller wavelength than an ultra-violet ray but more than a gamma ray.

X-ray Fluorescence (XRF) A non-destructive technique to find material composition and measurement of film thickness, based on an X-ray spectrum emitted by a sample.

X-ray Lithography A recent lithographic technology that uses X-rays to pattern an image on a photo-resist-coated wafer.

Yellow Room The room in which wafers are exposed to ultraviolet light in an aligner. Fluorescent lights in the room have yellow filter tubes around them to block unwanted ultraviolet light from that source.

Yield Model A mathematical probability model used to convert defect density to a projected yield.

Yield The percentage of the total number of die available on a wafer that function to specifications.

Young's Modulus (or modulus of elasticity) In a given material, it is the ratio of stress placed on the material to elastic strain. It is a measure of the stiffness or hardness of a material.

Zener Diode A P-N junction two-terminal, semiconductor device reverse-biased into the breakdown region. It offers high impedance when a voltage less than the breakdown voltage is applied. Current increases dramatically at voltages over the breakdown voltage and hence it is used as a voltage regulator.

Zephyr A common term used to describe lightweight fabrics.

Zero Offset The output of a sensor at zero input for a specified supply voltage or current.

Zeta Potential A positive or negative electrical charge that can build up around particles in a colloid.

ZIF (Zero-Inspection-Force) Socket A socket in which package leads are readily accepted by the socket, and then firmly connected through cam action.

Zone Refining. A metallurgical process for obtaining a highly pure metal that depends on continuously melting the impure material and recrystallizing the pure metal.

Table. Criteria for defining small and medium enterprises (SMEs)

Criterion	Small	Medium
Maximum number of employees	49	249
Maximum annual turnover	7 million Euros	40 million Euros
Maximum annual balance sheet total	5 million Euros	27 million Euros
Maximum % owned by one, or jointly by several entities	25%	25%

(Source: Department of Trade and Industry, United Kingdom)