

# IC KNOWLEDGE LLC

## IC Knowledge – Glossary of Semiconductor Terminology

IC Knowledge LLC, PO Box 20, Georgetown, MA 01833

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### A

- Ab Initio - from first principles. An ab initio calculation is a calculation derived from first principles.
- Aberrations - failure of a mirror or lens to produce an exact point-to-point correspondence between an object and an image of the object.
- Acceptor - group three elements in the periodic table such as boron, B, aluminum, Al, gallium, Ga, or indium, In, have one less electron in the outer most energy level than silicon, Si. When these atoms are introduced into silicon, an impurity level is created near the valence band. At zero degrees kelvin the impurity level is empty, at room temperature sufficient energy is available to excite electrons from the valence band into the impurity level. Because these Elements introduce impurity levels that accept electrons, they are referred to as acceptors. See also donor.
- Acetic Acid - chemical formula  $\text{CH}_3\text{COOH}$ , a carboxylic acid, acetic acid is a relatively weak acid mainly used as a pH buffer. Acetic acid is commonly sold as a 100% solution and has a density of 1.05Kg/L.
- Acetone - chemical formula  $\text{CH}_3\text{COCH}_3$ , acetone is a flammable solvent used primarily to clean-up positive photoresist. Acetone is commonly sold as a 100% solution and has a density of 0.79Kg/L. Skin contact and breathing acetone vapor should be avoided.
- Acid - substance that ionizes in water to produce  $\text{H}^+$  ions. Acid solutions have  $\text{H}^+$  concentrations  $>1 \times 10^{-7}$  ( $\text{pH} < 7$ ). See also alkali or base.
- Acoustic Streaming - localized high velocity streams of fluid created by high frequency sound in a liquid.
- Actinic - relating to or exhibiting actinism.
- Actinism - property of radiant energy that produces chemical changes, particularly in the visible and ultraviolet spectrum.
- Active Component - circuit element that switches the flow of current or has gain. Example are: transistors, diodes, vacuum tubes, etc.
- Air Change - volume of air recirculating through a cleanroom per minute divided by the volume of the room. Generally the lower the cleanroom class the higher the air changes. A class 1000, class 100, class 10 and class 1, Cleanroom should have 5-6, 7, 7-10, and 10 air changes per minute respectively.
- ALD - see Atomic Layer Deposition.
- Algorithm - technique or method of performing a mathematical calculation. An algorithm will typically have a finite number of steps that are repeated to perform a calculation.



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- Aligner - type of semiconductor manufacturing equipment used to transfer patterns onto wafers through the use of photolithography and exposure. Aligners can "align" a new pattern on a reticle or mask to patterns already on the wafer, hence the name aligner. See also Contact Aligner, Proximity Aligner, Projection Aligner, Step and Repeat and Step and Scan.
- Alignment - act of moving a mask or reticle to match up alignment marks. Alignment insures that a new pattern being added to a wafer is aligned to the previous pattern or patterns on the wafer.
- Alignment Mark - mark or target on a reticle or mask that is used to achieve alignment. For example, a wafer might have a cross printed on it from a previous layer, and a reticle might have a cross designed to fit inside the cross already on the wafer. When the smaller cross fits within the larger cross, the reticle is aligned to the wafer.
- Alkali - acid neutralizing substance. A soluble salt with base properties.
- Alkali Metal - family of group IA metals in the periodic table made up of, lithium, Li, sodium, Na, potassium, K, rubidium, Rb, cesium, Cs, and francium, Fr, all group IA elements except hydrogen, H. The oxides and hydroxides of these metals are strong bases. See also, alkali.
- Alkaline - having the properties of an alkali, specifically acting as a base.
- Alkaline Earth - family of group IIA elements, beryllium, Be, magnesium, Mg, calcium, Ca, strontium, Sr, barium, Ba, and radium, Ra. The oxides and hydroxides of these elements are strong bases. See also, alkaline.
- Alloy - process of "alloying" two or more substances together. An alloy is a combination of two or more elements where at least one element is a metal.
- ALSTTL - Advanced LSTTL. A fast bipolar IC process with power dissipation approximately one half of LSTTL.
- Alternating Current - electrical current that reverses direction at regular intervals, for example 60 Hertz in the U.S.
- Aluminum - atomic symbol, Al, aluminum is the 13th element in the periodic table (atomic number 13) with an atomic weight of 26.98, aluminum is a metal, an excellent conductor with a resistivity of approximately 2.8 $\mu$ ohm-cm, and is commonly used as an interconnect in integrated circuits and sometimes as a P-type dopant due to its high diffusivity in silicon. Aluminum is commonly deposited by evaporation or sputtering.
- Aluminum Etch - etching solution used to etch aluminum. Typically aluminum etches are based on phosphoric acid. A common aluminum etch formula would be phosphoric acid, H<sub>3</sub>PO<sub>4</sub>, 80ml, nitric acid, HNO<sub>3</sub>, 5ml, and water, H<sub>2</sub>O, 15ml acetic acid, CH<sub>3</sub>COOH, will sometimes be added as a buffer. Aluminum etches evolve hydrogen bubbles that may cling to the aluminum layer being etched locally preventing etching, and leaving behind aluminum residue, "snow". Some

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mechanism such as agitation or low pressure must be supplied to remove hydrogen bubbles. Surfactants may also be used to enhance wetting.

- Ammonia - chemical formula  $\text{NH}_3$ , ammonia is a toxic gas with a TLV of 25ppm, and is combustible in the range of 12-28%. Ammonia has a strong pungent odor and is irritating to lungs, skin and eyes. Ammonia is commonly used as a deposition gas for silicon nitride,  $\text{Si}_3\text{N}_4$  and may also be used to anneal titanium, Ti, to form titanium nitride, TiN or to anneal gate oxides to form oxynitride,  $\text{Si}_x\text{O}_y\text{N}_z$ .
- Ammonium Fluoride - chemical Formula  $\text{NH}_3\text{F}$ , ammonium fluoride is a toxic, corrosive chemical used to buffer hydrofluoric acid, HF, in buffered oxide etch, BOE. Fluorine is not only toxic but may be absorbed through the skin without immediate evidence of irritation and later react with the calcium in bones and or poison the person exposed to the chemical. Ammonium fluoride is commonly sold as a 40% solution with a density of 1.11Kg/L.
- Ammonium Hydroxide - chemical formula  $\text{NH}_4\text{OH}$ , ammonium hydroxide is a corrosive chemical with a strong ammonia odor. Ammonium hydroxide fumes are irritating to lungs, skin and eyes. Ammonium hydroxide is used in SC1 cleaning solutions and is commonly sold as a 30% solution with a density of 0.90Kg/L.
- Amorphous - a material state where the atoms making up the material are randomly oriented relative to each other. See also crystalline, polycrystalline.
- Ampere - a measure of electric current flow. The ampere is defined as the transfer of one coulomb per second.
- Amplifier - a device that increases the amplitude of a signal. Ideally an amplifier will increase amplitude without changing any other aspects of the signal being amplified.
- Amplify - to increase the amplitude.
- Amplitude - the maximum departure of a time varying signal or oscillation from the average value.
- Analog - a signal in an electrical circuit that can have a continuous range of values. See also, digital.
- AND - a flash memory architecture that uses Fowler Nordheim tunneling to achieve low power programming.
- AND Gate - a basic logic gate that outputs a 1 only if both inputs are a 1, otherwise outputs a 0. See also, NAND, NOR and OR.
- Angle of Incidence - the angle between a ray of light incident on a surface and a line drawn normal to the surface.
- Angle of Reflection - the angle between a ray of light reflected from a surface and a line drawn normal to the surface. From Snell's law the angle of incidence is equal to the angle of reflection.
- Angstrom -  $1 \times 10^{-10}$  meters, 1/10 nanometer.



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- Anion - a negatively charged ion, i.e., an ion that migrates to the anode in an electrolyzed solution.
- Anisotropic - different in one direction than in another direction or directions. An anisotropic etch process is an etch process that has a higher etch rate in one direction than other directions, or an anisotropic medium is a medium where some property or properties depend on the direction in which the medium is measured. See also, isotropic.
- Anneal - a heating and cooling process designed to reduce stress.
- Annular Illumination - a technique utilized in certain steppers (see step and repeat and step and scan) whereby illumination is provided by a ring centered around the optical axis. Annular or off-axis illumination can increase resolution by allowing more diffraction orders into the lens system.
- Anode - the positive terminal of an electrolytic cell. See also, cathode.
- Antimony - atomic symbol, Sb, antimony is the 51st element in the periodic table (atomic number 51) with an atomic weight of 121.8. Antimony is a group V element making it a donor in silicon, i.e., makes silicon N-type. Antimony is a large atom with a low diffusivity in silicon and is commonly used as a buried layer dopant where low outgassing and up-diffusion are desired.
- APCVD - see Atmospheric Pressure Chemical Vapor Deposition.
- Application Specific Integrated Circuit (ASIC) - a proprietary integrated circuit designed to meet a particular customers specific application requirements.
- Application Specific Standard Product (ASSP) - typically an ASIC that has been converted into a standard product. See also, application specific integrated circuit.
- ArF - Argon Fluoride. See also, argon fluoride laser.
- Argon - atomic symbol, Ar, argon is the 18th element in the periodic table (atomic number 18) with an atomic weight of 39.95. Argon is a group 0 element and is inert. Argon is used as inert gas for annealing and as a background gas in sputtering due to its relatively high ionization cross section. Argon is an asphyxiant.
- Argon Fluoride Laser - in the semiconductor industry, generally used to refer to an excimer laser that uses argon and fluorine gases to produce an output of 193 nanometers. Expected to be the light source of choice for critical levels at 90nm and 65nm minimum linewidths.
- Array - a group of items that are arranged in rows and columns. For example a memory array would be a group of memory cells arranged in rows and columns.
- Arsenic - atomic symbol, As, arsenic is the 33rd element in the periodic table (atomic number 33) with an atomic weight of 74.9. Arsenic is a group V element making it a donor in silicon, i.e., makes silicon N-type. Arsenic has the same atomic diameter as silicon and so introduces very little strain into a silicon crystal lattice. Arsenic has a relatively low diffusivity and is widely used to create shallow doped junctions such as source/drains. Arsenic is toxic and carcinogenic.



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- Arsine - chemical formula AsH<sub>3</sub>, arsine is a highly toxic gas with a garlic like odor and a TLV of 0.05ppm. Arsine is flammable in the range of 4.5 - 78%. Arsine is so toxic that it has been used as a chemical warfare agent. Arsine is used as a dopant gas during various CVD reactions and to create As<sup>+</sup> ions for ion implantation.
- Ashing - the process of removing photoresist using an oxygen plasma or ultraviolet light generated ozone. Ashing produces no chemical waste, photoresist is volatilized into N<sub>2</sub>, O<sub>2</sub>, CO and CO<sub>2</sub> gases.
- ASIC - see Application Specific Integrated Circuit.
- Aspect Ratio - the depth or height of a feature divided by the width of the feature. A high aspect ratio indicates a feature is narrow relative to its height or depth. Example high aspect ratio features would be, contacts that are narrow relative to their depth, trenches that are narrow relative to their depth or metal lines that are tall relative to their width.
- Aspheric Surface - a lens or mirror surface that has been altered from spherical in order to reduce optical aberrations.
- Asphyxiant - a gas that causes unconsciousness or death through lack of oxygen (suffocation).
- Assembly - the process of packaging semiconductor die.
- ASSP - see Applications Specific Standard Product.
- Atom - the smallest particle that can exist and still exhibit the properties of an element.
- Atomic Layer Deposition (ALD) - a deposition technique whereby pulses of gaseous reactants are used to deposit a film one layer at a time. See tech brief on Atomic Layer Deposition.
- Atomic Number - the number of protons and electrons in an atom of a specific element in the ground state.
- Atomic Percent - the number of atoms of an element per unit volume divided by the number of atoms per unit volume of the substance containing the element.
- Atomic Symbol - a standard chemical abbreviation used to indicate a specific element.
- Atomic Weight - the weight of an atom of a specific element where one atomic weight unit is defined as the weight of 1/12 of a carbon 12 Atom.
- Atmospheric Oxidation - see oxidation.
- Atmospheric Pressure - the pressure exerted by the weight of air. The standard atmospheric pressure on earth is 14.7 pounds per square inch (PSI) or 1 kilogram (Kg) per square centimeter (cm<sup>2</sup>). Actual pressure at any point and time on the face of the earth depends on altitude and atmospheric conditions.
- Atmospheric Pressure Chemical Vapor Deposition (APCVD) - Chemical Vapor Deposition performed at atmospheric pressure.



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- Autodoping - dopant atoms out-gas from a wafer and are absorbed either at another location on the same wafer or on an adjacent wafer. The key concept is that autodoping is a form of contamination, doping results in undesired locations.
- Automation - making a process automatic eliminating the need for human intervention.

## B

- Background Impurity - the concentration of impurity present in a wafer prior to some or all processing. Most wafers as manufactured have a uniform concentration of a dopant already in the wafer. Alternately the background concentration might be set by a relatively deep diffusion or epitaxial deposition step that another dopant was later introduced into.
- Bake - a process where wafers are heated above room temperature but below 200°C.
- Ball Bond - when a bond wire is attached to a die or leadframe one technique is to use mechanical and or thermal energy to bond the wire down by forming an intermetallic. Because the end of the wire is heated and or compressed down, a ball forms on the end of the wire at the bond. See also, wire bonder.
- Ball Bonding - the process of forming a ball bond.
- Ball Grid Array - a newer type of package for IC's with very high pin counts. Replaces pin with small solder balls.
- Band Gap - a region between the valence band and the conduction band devoid of allowed energy states.
- Bandwidth - a range of wavelengths or frequencies. For example, the bandwidth of a light source would be the range of wavelengths produced by the light source. Alternately, the bandwidth of an amplifier would be the range of frequencies the amplifier would amplify.
- Barrier Metal - a metal layer designed to stop other layers from interacting. The most common barrier metals is titanium nitride, TiN, titanium tungsten, TiW was widely used at one time, chromium, Cr, has seen some use, tantalum, Ta, and tantalum nitride, TaN, are seeing increased use with copper metalization processes and tungsten nitride, WN, is a relatively new barrier metal.
- Base - chemical definition - a substance that ionizes in water to produce OH<sup>-</sup> ions. Base solutions have OH<sup>-</sup> densities >1E<sup>-7</sup> (pH > 7). See also, acid, alkali. Electrical definition - the base is a middle region in a bipolar transistor of one semiconductor type, separating the emitter and collector of the bipolar transistor that are of opposite semiconductor type. For example an NPN transistor would have a P base region separating the N emitter and N collector.
- Base – electrical definition a region in a bipolar transistor that separates the emitter and collectors regions and is of opposite type to the emitter and collector. For example in an NPN



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bipolar transistor the N-type emitter and collector regions are separated by a P-type base region.

- Base Diffusion - the base region of a transistor formed by diffusion.
- Batch Process - some semiconductor processes are performed on several wafers simultaneously, multiple wafers processed simultaneously as a group is referred to as batch processing.
- Bath Tub Curve - failures rates over time fall into three distinct regions. The first region is referred to as infant mortality, or parts that fail at some relatively higher rate over a short period of time, due to manufacturing defects. Once the infant mortality is removed from the population, the useful life period is reached with a relatively lower failure rate. During the useful life failures are random in time. The final stage is wear out, the parts begin to wear out and fail at some relatively higher rate. If the failure rate of the parts versus time is plotted on a curve, the high failure rates initially and at end of life with relatively low failure rates during the middle period results in a bath tub shaped curve.
- Beam Leads - rectangular shaped leads that attach to bond pads on one end and a carrier tape on the other end for tape automated bonding (TAB).
- BGA - see Ball Grid Array.
- BiCDMOS - a semiconductor technology combining bipolar, CMOS and DMOS devices on one integrated circuit.
- BiCMOS - a semiconductor technology combining bipolar and CMOS devices on one integrated circuit.
- Binary - the base 2 numbers system. All numbers are represented as a string of ones and zeros. The number system used by digital computers. A one is represented by a voltage and a zero by the absence of a voltage. In 4 bit binary the numbers 0, 1, 2, 3, 4, 5, would be represented by 0000, 0001, 0010, 0011, 0100, 0101 respectively.
- Bipolar - a semiconductor device that uses both holes and electrons for conduction simultaneously.
- Bipolar Transistor - a transistor that uses both holes and electrons for conduction. A bipolar transistor has an emitter of one semiconductor type that emits carriers into a base region of opposite semiconductor type, and a collector region of same semiconductor type separated from the emitter by the base, the collector collects electrons that transit the base region. Modulating the current injected into the base terminal of a bipolar transistor will modulate the current flowing through the base from the emitter to the collector. Properly biased a signal injected into the base will result in an amplified signal appearing at the collector terminal.
- Bit - a single digit of a binary number. A bit is either a one represented by a voltage or a zero represented by no voltage. The number 5 represented in 4 and 8 bit binary would be 0101 and 0000101 respectively.

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- Boat - a carrier made to hold wafers. Most commonly a boat has 25 slots and is made of quartz, polysilicon or silicon carbide for use in a furnace, polypropylene for general wafer transport or Teflon for use in a wet process. Some furnace boats have 50 slots.
- Boat Puller - a mechanical piece of equipment designed to automatically push-in or pull-out boats from a furnace.
- BOE - see Buffered Oxide Etch.
- Bond Pads - metal pads on semiconductor die where wire bonds can be attached to connect the die to the outside world.
- Bonding Wire - tiny gold, copper or less commonly aluminum wires that form connections from bond pads to lead frames. Common gold bond wire is 1 to 3 thousands of an inch in diameter, aluminum bond wire is used for thicker wires such as 5 or 7 thousands of an inch. Recently copper has been replacing gold for cost reasons due to the high price of gold.
- Boolean Algebra - a logical calculus named for mathematician George Boole, where alphabetic symbols are used to represent logical variable, 1 and 0 are states, and, AND, OR, and NOT are the basic logical operations. NAND and NOR can be represented by combinations of AND, OR and NOT.
- Boron - atomic symbol, B, boron is the 5th element in the periodic table (atomic number 5) with an atomic weight of 10.81. A group III element boron is an acceptor in silicon, i.e., makes silicon P-type. Boron is the most commonly used P-type dopant and has a relatively high diffusivity compared to arsenic and antimony, common N-type dopants, and a diffusivity and similar to phosphorus, another common N-type dopant.
- Boron Tribromide - chemical formula  $BBr_3$ , boron tribromide is a liquid at room temperature and was at one time widely used as a source of boron during pre deposition processes. During the pre deposition process, Nitrogen gas is bubbled through heated boron tribromide liquid. The nitrogen gas leaves the bubbler carrying vapor of boron tribromide into the per deposition furnace. Boron tribromide's vapor pressure ranges from approximately 15mm of Hg at 0°C, 63mm of Hg at 25°C to 170mm of Hg at 50°C. Boron Trichloride - chemical formula  $BCl_3$ , boron trichloride is a corrosive toxic gas with a TLV of 5ppm. Boron trichloride has a pungent irritating odor and is a corrosive. Boron trichloride is most commonly used as an etch gas for aluminum, but may also be used as a Boron Source for Doping.
- Boron Trifluoride - chemical formula  $BF_3$ , boron trifluoride is a corrosive toxic gas with a TLV of 1ppm. Boron trifluoride is pungent and suffocating. Boron trifluoride is primarily used as a feed gas to create boron species in ion implanters.
- Bosch Process - a patented plasma etch process whereby the etcher chemistry is switched every few seconds back and forth between etching and polymerizing chemistries. The Bosch process is commonly used to produce high rate anisotropic trench etching of silicon. During the etch



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chemistry step, rapid isotropic etching of the silicon occurs. During the polymerizing chemistry portion of the process all exposed surfaces of the substrate are coated with polymer. During the next etch chemistry portion of the process, ion bombardment removes the polymer from the bottom of the trench normal to the direction of ion motion, and a isotropically etched cavity is then created. The Bosch process results in microscopic "scallop" on the trench sidewalls being etched. The degree of sidewall scalloping may be controlled by varying the length of each etch - polymer deposition cycle. See also, inductively coupled plasma.

- **Boule** - in order to grow wafers, a large ingot is drawn from a molten silicon melt. The ingot is also referred to as a boule.
- **Breakdown** - when a critical field is exceeded in an insulator or semiconductor, the material breaks-down electrically allowing current to flow.
- **Breakdown Voltage** - the voltage at which breakdown occurs.
- **BTAB** - see Bumped Tape Automated Bonding.
- **Bubbler** - a Pyrex glass or quartz container with an inlet tube that extends down to near the bottom of the vessel and an outlet tube located near the top of the vessel. When filled with liquid, a gas may be introduced through the inlet tube and the gas will bubble through the liquid and exit through the outlet tube. Bubblers are used to introduce vapor from a liquid source into a gas.
- **Buffered Oxide Etch (BOE)** - an etching solution containing hydrofluoric acid, HF, and ammonium fluoride,  $\text{NH}_4\text{F}$ . The hydrofluoric acid etches silicon dioxide and the ammonium fluoride raises the solution pH reducing the attack rate of the solution on photoresist.
- **Bumped Die** - die that have had tiny solder or gold bumps formed on the bond pads.
- **Bumped Tape Automated Bonding (BTAB)** - a process where bumped die are attached to metal leads mounted on a tape carrier. See also, tape automated bonding.
- **Bumping** - the process of forming solder or gold bumps on bond pads of a die. The bumps may be formed by electroplating or evaporation.
- **Burn-In** - the use of elevated temperature and or electrical stress to cause infant mortality failures so they may be removed prior to shipping product to a customer. Burn-In is common on new products until yield enhancement efforts have increased yield and decreased defect density.
- **Buried Layer** - a low resistivity - doped layer underneath the surface of a semiconductor. Buried layers may be formed by pre deposition - diffusion followed by epitaxial growth, ion implantation and diffusion followed by epitaxial growth or by high energy ion implantation.
- **Butyl Acetate** - chemical formula  $\text{CH}_3\text{COO}(\text{CH}_2)_3\text{CH}_3$ , butyl acetate is a flammable solvent used primarily as a negative photoresist post develop rinse. Butyl acetate is commonly sold as a 100%

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solution and has a density of 0.88Kg/L. Skin contact and breathing of butyl acetate vapor should be avoided.

- Byte - a unit of computer memory, typically 8 bits in length. The smallest addressable unit of memory and most commonly represents a single character such as a letter.

## C

- CAD - see Computer Aided Drafting.
- Cantilever Loader - a piece of equipment that suspends boats of wafers in the air for insertion into and removal from furnaces. The cantilever is a long stiff bar held at one end and the wafer boats are placed on the cantilever. The cantilever is inserted into the furnace by a computer controlled - motorized mechanism that rides along a track in front of the furnace. The end of the cantilever that is held, is held outside of the furnace and the rest of the cantilever is suspended in such a way that the cantilever does not touch the sides of the furnace. Cantilever loading reduces rubbing against the furnace walls and dramatically reduces particle generation versus older wheeled sleds.
- C-V Plot - see Capacitance Voltage Plot.
- Capacitance - the capability of a material or system of materials to store charge. The measure of capacitance is the farad.
- Capacitance Voltage Plot - a technique used to characterize the amount of electrically active defects and mobile contaminants in a dielectric. Oxide fixed charge, oxide trapped charge, interface trapped charges, number of interface traps and mobile charge may all be measured. The technique may also be used to measure the profile of impurities in silicon.
- Capital - items with a useful life of greater than one year and with a cost above some threshold value. Capital items are written off over a set period (Depreciation) related to the useful life of the item and accounting rules.
- Carbon Dioxide - chemical formula CO<sub>2</sub>, carbon dioxide is an asphyxiant with a TLV of 5,000ppm. Carbon dioxide is used in cleaning equipment and is a byproduct of photoresist stripping operations.
- Carbon Monoxide - chemical formula CO, carbon monoxide is poisonous - odorless gas with a TLV of 35ppm. Carbon monoxide is a byproduct of photoresist stripping operations.
- Carboxylic acid - Acids containing a carboxyl group, COOH.
- Carcinogenic - cancer causing.
- Carrier Gas - an inert gas used to carry some other substance into a process For example a carrier gas would be bubbled through a bubbler to carry vapor into a process. The carrier gas is inert to the extent that it does not take part in the process reaction.

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- Carriers - holes or electrons carrying electric current in a semiconductor.
- Cassette - a Teflon or polypropylene wafer holder. Cassettes commonly hold up to 25 wafers.
- Cathode - the negative terminal of an electrolytic cell. See also, anode.
- Tes
- Cavitation - the rapid formation and collapse of bubbles in a liquid.
- CD - see Critical Dimensions.
- CD Tool - a piece of equipment used to measure critical dimensions.
- CD SEM - a scanning electron microscope used to measure critical dimensions.
- Cells - individual devices or circuits that may be reused as blocks in designs.
- CERDIP - Ceramic Dual In-Line Package, see also, DIP.
- Channel - the region of a field effect transistor that conducts or blocks the flow of current when the device switches on and off respectively. See also, Metal Oxide Semiconductor.
- Charged Coupled Device (CCD) - a device that takes input light or electric charge and converts the intensity of the input into an output electronic signal. Charged coupled devices are designed as a group of pixels, where each pixel will trap electrons in proportion to the input stimuli. Each pixel may be read in sequence to determine the input stimuli level. Charged coupled devices are widely used in scientific instruments and digital cameras to capture images. Charged coupled devices are however more difficult to make than more common processes such as CMOS, although they do have better imaging performance. Due to easier fabrication, CMOS sensors are making inroads into traditional charged coupled device applications in the low-end, and CMOS sensor quality is rapidly improving as well.
- Chemical Etching - the process of removing material-etching, through the use of chemical activity.
- Chemical Mechanical Planarization (CMP) - a process whereby a chemical reaction increases the mechanical removal rate of a material. CMP is commonly used to polish off high spots on wafers or films deposited on wafers, flattening the film or wafer, referred to as planarization. The chemical reaction that increases the mechanical removal rate is commonly tailored to provide a higher removal rate of one material versus another material. The chemical action in CMP helps to achieve higher selectivity's of one material to another than a strictly mechanical process would provide.
- Chemical Mechanical Polishing (CMP) - an older terminology for Chemical Mechanical Planarization.
- Chemical Vapor Deposition (CVD) - a process whereby a film is deposited by reacting chemicals together in the gaseous or vapor phase to form a film. The gases or vapors utilized for CVD are compounds that contain the element to be deposited and that may be induced to react with a substrate or other gas(es) to deposit a film. The CVD reaction may be thermally activated,



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plasma induced, plasma enhanced CVD or activated by light in photon induced CVD. See also, Atmospheric Chemical Vapor Deposition, Low Pressure Chemical Vapor Deposition, Metal Organic Chemical Vapor Deposition, Photo Enhanced Chemical Vapor Deposition.

- Chemically Amplified Photoresist - a type of photoresist where the exposure reaction initiates a chain reaction of chemical events. Chemically amplified photoresist are more sensitive than standard photoresist and are widely used for DUV exposure.
- Chill Plate - a plate held at or below room temperature used to return wafers to room temperature following bakes.
- Chip - a layman's term for a semiconductor die.
- Chlorine - chemical formula Cl, chlorine is a corrosive - toxic gas with a TLV of 0.5ppm. Chlorine has a strong pungent odor and is irritating to lungs, skin and eyes. Chlorine is primarily used as an etch gas although it has seen some use as a furnace cleaning and oxidation additive.
- Chrome - see Chromium.
- Chromium - atomic symbol, Cr, chromium is the 24th element in the periodic table (atomic number 24) with an atomic weight of 52.00. A group VI metal, chromium has seen some use as a barrier metal in backside metal and under solder bumps. IBM in particular has made a large number of solder bumps with chromium barrier metal.
- Circuit - a combination of electrical elements connected together to perform a specific function.
- Circuit Layout - a schematic diagram converted to the pattern that will be transferred to a wafer by photolithography. Once a schematic of a circuit is complete and has been simulated, the schematic is converted to a circuit layout based on a set of design rules for the process being used. Certain elements of the layout may exist as cells that are connected together to make the circuit.
- Cleanroom - a room combining the use of air filters and continuous air circulation to produce levels of air borne particles that are lower, and typically much lower than normal atmospheric dust levels. Outdoor atmospheric dust levels are on the order of 400,000 particles/ft<sup>3</sup> >0.5µm in size. Cleanroom cleanliness levels generally are agreed to begin at 100,000 particles/ft<sup>3</sup> and extend down to 0.01 particles/ft<sup>3</sup> or less! See also, Cleanroom Class.
- Cleanroom Class - a standard method for characterizing the cleanliness level of a cleanroom, originally developed by the U.S. government and released as the 209 standard. For example, a class 1 cleanroom has less than 1 particle and a class 100 cleanroom has less than 100 particles >0.5µm in size per ft<sup>3</sup> of air respectively. Generally speaking a class 1000, class 100, class 10 and class 1, class 0.1 cleanroom will support production down to approximately, 4µms, 1.25µms, 0.7µms, 0.3µms and <0.1µms respectively.

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- Cluster Tool - a piece of equipment that utilizes a central robot to feed multiple process chambers. Cluster tools are commonly used to perform multiple process steps on a single piece of equipment and may improve process control and cycle time.
- CMOS - see, Complimentary Metal Oxide Semiconductor.
- CMP - see Chemical Mechanical Planarization.
- Coater - a piece of semiconductor process equipment utilized to perform the coating process. Coaters typically provide an input and output elevator that can hold wafer cassettes, have a shuttle system to transport wafers from the input to the spin head, and transport wafers from the spin head to the output. Coaters may also include hotplates to bake wafers before or after coating and chill plates to return the wafer temperature to room temperature following baking.
- Coating - the process of applying photoresist to a wafer, generally by dispensing a small amount of photoresist in the center of a wafer and then spinning the wafer at a high rate to spread and dry the photoresist.
- Coherence Length - the wavelength of a light source divided by the bandwidth of light of the light source.
- Coherent Light - coherence refers to the state or property of being together. Coherent light may be broken down into temporal coherence and spatial coherence.
- Collector - the area of a bipolar transistor that collects carriers that have transitioned across the base region. See also, emitter.
- Collimated Light - light that has parallel rays.
- Collimated Sputtering - a sputtering process where the arrival of metal is at an angle normal to the wafer surface. The metal may be collimated by a thick honeycomb grid that blocks off angle metal atoms or by ionizing the metal atoms and attracting them towards the wafer. Collimated sputtering improves filling of high aspect ratio contacts.
- Colloidal Matter - particles with sizes of 1 to 200 nanometers in size.
- Combustible - a material that will burn.
- Common Cause Variation - the normal random variation in output for a process.
- Complimentary Metal Oxide Semiconductor (CMOS) - a circuit that combines PMOS and NMOS devices in pairs. CMOS circuits only consume power when they are switching state. See also, NMOS and PMOS.
- Compound - a substance made up of two or more elements.
- Compound Semiconductor - a semiconductor made up of two or more elements, for example GaAs, InP, SiC are commonly used compound semiconductors.
- Computer Aided Drafting (CAD) - the design of products using a computer.
- Concentration - the amount of a substance per unit area or volume. Concentration is commonly used to refer to the amount of dopant in a semiconductor as atoms per area or volume, or to



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refer to elements added to materials to change the material properties, etc. May be in weight or atomic percent or number per unit area or volume.

- Condenser Lens - a lens or mirror used to concentrate light.
- Conduction - the flow of electric current.
- Conduction Band - a group of energy states that are empty at zero degrees kelvin and are available to support the movement of electrons that gain sufficient energy to jump from the valence band to empty levels in the conduction band.
- Conductive - a material that is a conductor.
- Conductor - a material which readily supports the flow of electric current. Conductors have overlapping valence and conduction bands or only partially filled bands. See also, Insulator, Semiconductor.
- Contact Aligner - process equipment utilized to align masks to wafers and transfer patterns to the wafers by photolithography. In a contact aligner the wafer is actually brought into contact with the wafer during exposure. The first contact aligner became commercially available in 1963. Contact aligners have largely fallen out of use due to the tendency for the photoresist on the wafer to contaminate the mask during contact.
- Contact Printing - the use of a contact aligner to expose a pattern onto a wafer using photolithography.
- Contacts - openings in an insulating film to allow contact to an underlying electronic device.
- Contamination - any unwanted substance. Contamination of semiconductors may generally be categorized as metals, organic, oxide or particles.
- Corrosive - a material which causes damage to skin, eyes or other parts on the body on contact.
- Coulomb - the quantity of electricity transferred by one ampere in one second. Equivalent to charge on  $6.24 \times 10^{18}$  electrons.
- Critical Dimension (CD) - the width of a line or space that has been identified as critical to the device being fabricated operating properly. Critical dimensions are frequently measured on some or all wafers following any photolithography or etching process in which the dimensions are critical.
- Critical Level - for a given minimum linewidth technology, the layers that have features at the minimum linewidth.
- Cross Section - a view into the inside of a semiconductor made by cutting through the device. Cross sections allow the depth of diffusions into the semiconductor and the thickness of various films and their relationships to be examined.
- Crossovers - areas in an integrated circuit where a conductor crosses over the top of another conductor or conductive region with the two conductors insulated from each other.

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- Crossunders - areas in an integrated circuit where a conductor or conductive region crosses under another conductor with the two conductors insulated from each other.
- Crystal Orientation - the orientation of the wafer surface to the crystal planes.
- Crystal Planes - plane surfaces in a crystal formed by the periodic arrangement of the crystal atoms.
- Crystalline - a material state where the atoms making up the material are arrayed in a consistent repeating pattern.
- Cumulative Yield - the product of all of the individual yields in a process or process flow. For example, the wafer yield is frequently multiplied by the die yield to calculate an overall yield for wafer fabrication. Alternately the wafer yield, die yield, assembly yield and final test yield might be multiplied to get a cumulative yield for a product.
- Current - the flow of electrons through a conductor measured in amperes.
- Curvature of Field - in an ideal lens all points are focused in the same focal plane. Curvature of field results when the points of focus form a curved field.
- Curve Tracer - a piece of equipment utilized to display the relationships between current and voltage for electronic devices.
- CVD - see Chemical Vapor Deposition.
- Cycle Time - the actual time it takes to complete a process or sequence of processes.

## D

- Darlington - a transistor pair where the two transistor's collectors are tied together and the emitter of the first transistor feeds the base of the second transistor. Darlington pairs can provide very high gain since the gain of the two transistors are multiplied together. Days Per Mask Layer - the cycle time in days divided by the number of mask layers in the process. A common metric of cycle time performance.
- DDR – see Double Data Rate DRAM.
- DDR2 – see Double Data Rate DRAM.
- DDR3 – see Double Data Rate DRAM.
- DDR4 – see Double Data Rate DRAM.
- Deal-Grove Oxidation Law - a theory of oxidation formulated by Bruce Deal and Andy Grove describing oxidation of silicon. The theory basically states that initially the oxidant reacts directly with the silicon surface and the reaction rate determines the oxide growth rate, as oxidation proceeds, a layer of oxide forms and at a sufficient thickness the oxidant must diffuse through the oxide to react with silicon, and the diffusion rate controls the rate of oxide growth, i.e., diffusion is slower than the surface reaction rate.

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- Deep Ultraviolet Light (DUV) - electromagnetic waves with a wavelength of 100 to 300 nanometers.
- Defect - an imperfection in a film or pattern.
- Defect Density - the number of killer defects per unit area on a wafer.
- Dehydration Bake - a bake step to drive moisture off of a wafer surface prior to coating.
- Depletion Device - a MOSFET that is on until turned off by depleting the channel of carriers.
- Depletion Region - an area of a semiconductor where all of the mobile carriers have been swept out by an electric field. The depletion region is depleted of carriers hence the name.
- Depreciation - a percentage of the cost of capital equipment is written off each year and is called depreciation. Typically five year for process equipment, ten years for facility systems and thirty years for the bricks and mortar.
- Depth of Focus (DOF) - the distance away from the focal plane that an image may be and still meet a given resolution specification.
- Developer - a solution used to resolve an image after exposure. For a positive photoresist the developer has a higher attack rate on the exposed portion of a photoresist than on an unexposed portion of the photoresist. For a negative photoresist the developer has a high attack rate on the unexposed portion of the photoresist than on the exposed portion of the photoresist.
- Developing - the process of allowing developer to interact with photoresist to form an image. Developing of negative photoresist is most commonly by spraying developer onto the wafer surface, positive photoresist may be developed by immersion or spray. For positive photoresist developing temperature is very critical.
- Deionized Water - water from which the majority of ions have been removed. Tap water has resistivity of <50 kilohms, deionized water may have resistivity as >18 megaohms. The term deionized water has been largely replaced by ultrapure water to indicate that more than just low ions counts are required.
- DI Silicon - see Dielectrically Isolated Silicon.
- DI Water - see deionized water.
- Diborane - chemical formula  $B_2H_6$ , diborane is a highly toxic gas with a TLV of 0.1ppm, and will automatically combust in the range of 0.8-98% in air. Diborane has a repulsive, sickly smell. Diborane is used as a boron source for ion implantation and to a lesser extent for furnace and CVD doping.
- Dichlorosilane - chemical formula  $H_2SiCl_2$ , dichlorosilane is a flammable, corrosive, and is combustible in the range of 4.1-98.8%. Dichlorosilane has a strong pungent odor and is irritating to lungs, skin and eyes. Dichlorosilane is used in epitaxial and silicon nitride deposition.





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- Die - An individual integrated circuit or discrete device. When a wafer is completed through the fabrication process the surface of the wafer contains many individual die, also called chips.
- Die Area - the length of a die multiplied by the width of the die.
- Die Attach - the process of attaching a die onto some type of packaging component or carrier, for example a leadframe.
- Die Bonding - the process of attaching a die down to an underlying substrate, most commonly a leadframe.
- Die Cost - the cost to produce a good die through the wafer fabrication and wafer test steps.
- Die Size - the size of a die. May be expressed as the length time the width or in area.
- Die Sort - the process of sorting out good and bad die on a wafer. See, wafer test.
- Die Yield - the number of good die divided by the number of die tested. Also referred to as the probe yield. Die yield is commonly reported on a per-wafer or per lot basis. On a per wafer basis the die yield would be the number of good die divided by the gross die on the wafer.
- Dielectrically Isolated Silicon - a wafer with silicon tubs that have an insulator, typically silicon dioxide on all four sides and the bottom. Historically dielectrically isolated silicon has been made using a V-Groove technique that was limited to a maximum wafer size of 125mm. Recently SOI with insulator-filled etched-trenches has been used.
- Diffraction - the spreading or bending of light that occurs when light passes around an edge.
- Diffraction Orders - light passing through a slit that is small in comparison to the light wavelength shows a center intensity peak and then a group of peaks on either side of gradually decreasing intensity as the peaks get farther from the center peak. Each peak is a diffraction order, the center peak is order 0 and each peak to the right is numbered +1, +2, +3, etc. in sequence, to the left the peaks are -1, -2, -3, etc. in sequence.
- Diffusant - a substance undergoing diffusion.
- Diffused Layer - a layer formed by diffusion.
- Diffusion - a process whereby a substance redistributes from an area of relatively high concentration to an area of relatively low concentration due to random thermal motion. The larger the concentration gradient the faster diffusion occurs for a given temperature, conversely, the higher the temperature the faster diffusion occurs for a given concentration gradient.
- Diffusivity - the temperature dependent rate that an impurity diffuses.
- Diffusion Depth - the depth at which the concentration of a diffused impurity is equal to the concentration of background impurities in the semiconductor.
- Digital - a signal in an electrical circuit that is limited to certain discrete values.
- Digital Signal Processor (DSP) - special purpose processing unit designed to execute specific algorithms on digitized waveforms, nearly always in real time.

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- Dimer - a compound formed by a union of two simpler compounds or elements.
- Diode - a semiconductor device made up of a single junction between an N-Type and a P-Type area. Diodes allow conduction in only one direction.
- Dip - a brief immersion in an etchant to remove a thin layer or the top surface of a thicker layer.
- DIP – see Dual In-Line Package.
- Direct Current - electrical current that remains of one polarity.
- Direct Labor - the people who directly process the wafers, sometime referred to as "touch labor". Direct labor does not include support people such as equipment and process technicians, engineers, supervisors and managers.
- Direct Step Wafer (DSW) - an older terminology for stepper.
- Discrete - a single semiconductor device per die or packaged product, as opposed to an integrated circuit that is more than one semiconductor device per die.
- Dispersion - the variation in index of refraction of a material versus wavelength of light.
- DMOS - see Double Diffused Metal Oxide Semiconductor.
- Donor - group five elements in the periodic table such as phosphorus, arsenic and antimony have one more electron in the outer most energy level than silicon. When these atoms are introduced into silicon, an impurity level is created very near the conduction band. At zero degrees Kelvin the impurity level is filled, at room temperature sufficient energy is available to excite electrons from the impurity level into the conduction band. Because these elements introduce impurity levels that donate electrons they are referred to as donors.
- Dopant - an Impurity added to a semiconductor to change the number of holes and electrons relative to each other.
- Doping - the process of introducing a dopant. Doping is most commonly accomplished by ion implantation although historically doping was accomplished by pre-deposition.
- Double Data Rate DRAM (DDR) – a type of synchronous DRAM where data is transferred on both the leading and trailing edge of a cycle. A DDR memory transfers 1,600 megabytes per second at a 100Mhz frequency. DDR2 increases the data transfer rate to 2x that of DDR yielding 3,200 megabytes per second at 100Mhz. DDR3 increases data transfer to 2x DDR2 yielding 6,400 megabytes per second at 100Mhz. DDR4 provide higher frequencies and transfer rates at lower voltages than DDR3.
- Double Diffused Metal Oxide Semiconductor (DMOS) - a type of MOS device where the channel is formed by the difference in diffusion depth between two diffused layers. Very commonly used for high voltage and or high power MOS devices.
- Downtime - time that a piece of equipment is not available to production, generally due to the equipment being broken (down unscheduled), undergoing preventive maintenance (down scheduled) or undergoing qualification after maintenance.

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- Drain - the end of a MOSFET that drains carriers that have transited the channel. The MOSFET equivalent of a bipolar collector.
- DRAM - see Dynamic Random Access Memory.
- Drive-In - a diffusion step following pre-deposition. Drive-in increases the diffusion depth of a pre-deposition, pre-depositions are commonly masked by silicon dioxide, if a long diffusion took place during pre-deposition the pre-deposition dopant could penetrate the masking oxide and enter the silicon where it isn't wanted. Following pre-deposition a dip is used to clean off the oxide surface so that it is dopant free prior to drive-in.
- Dry Etch - a process whereby etching is accomplished by a reactive gas as opposed to a liquid. Dry etching techniques include plasma etch, reactive ion etch, magnetically enhanced reactive ion etch, inductively coupled plasma, electron spin resonance, etc.
- Dry Strip - see Ashing.
- Dry Oxidation - oxidation of silicon using dry oxygen.
- DSP - see Digital Signal Processor.
- DSW - see Direct Step Wafer.
- Dual In Line Package - an older style integrated circuit package with two parallel rows of pins designed to be inserted through holes in a printed circuit board. The use of DIPs is declining.
- Dump Rinser - a rinse system where a tank alternately fills up with water and then dumps automatically. Typically 3 to 5 fill and dump cycles are used.
- DUV - See Deep Ultraviolet.
- Dynamic Random Access Memory (DRAM) - a type of semiconductor memory where data may be accessed at random and data must be continuously refreshed. DRAM's will only hold data for a few milliseconds so the data must be read and rewritten every millisecond or so.

## E

- E Beam - see Electron Beam.
- EBR – see Edge Bead Removal.
- ECL - see Emitter Coupled Logic.
- Edge Bead - during photoresist spin coating the photoresist layer is thicker at the edge of the wafer due to surface tension. The thicker area is referred to as the edge bead.
- Edge Bead Removal (EBR) – the process of removing the edge bead. Typically a solvent is dispensed on the edge of the wafer.
- Edge Die - die in the edge exclusion area.



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- Edge Exclusion Area - an area at the edge of a wafer where die are absent or not used if present. Processes have an area at the edge of a wafer where the process does not conform to specification. In order to avoid shipping marginal die an edge exclusion is used.
- EDODRAM - see Extended Data Out Dynamic Random Access Memory.
- EEPROM - see, Electrically Erasable Programmable Read Only Memory.
- Electrical Current - the flow of electrons.
- Electrically Erasable Programmable Read Only Memory (EEPROM) - a type of memory that may be electrically programmed to store data for later retrieval. EEPROMs are nonvolatile. EEPROMs may be electrically erased but all the data is erased at once.
- Electrically Programmable Linear Array - a circuit made up of linear circuit elements which may be electrically programmed into a specific circuit configuration.
- Electromagnetic Spectrum - the range of electromagnetic wave - wavelengths. There is no theoretical limit on the range of wavelengths in the electromagnetic spectrum.
- Electromagnetic Waves - waves propagated through the simultaneous periodic intensity variation of an electric and magnetic fields. Electromagnetic waves propagate through free space without any medium. Electromagnetic waves include radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays and gamma rays.
- Electromigration - the migration of atoms in a metal interconnect line due to momentum transfer from conduction electrons. The metal atoms migrate in the direction of current flow and can lead to failure of the metal line. Electromigration depends on the metal in use with a fairly good correlation to the melting temperature of the metal, higher melting temperatures generally correspond to higher electromigration resistance, temperature, higher is worse, and current density, higher is worse. Electromigration may be due to diffusion in the bulk of the material, the grain boundaries or on the surface. Aluminum electromigration is primarily grain boundary due to the higher grain boundary diffusivity over the bulk diffusivity and the excellent surface passivation effect of aluminum oxide that forms on the aluminum surface when exposed to oxygen. Copper on the other hand, has lower bulk and grain boundary electromigration and primarily exhibits electromigration on the surface due to poor copper oxide passivation properties.
- Electron - a tiny subatomic particle carrying a negative charge equal to  $1.602177 \times 10^{-19}$  Coulombs. An electron is a fundamental unit of electronic charge.
- Electron Beam - a focused stream of electrons.
- Electron Beam Evaporation - the use of an electron beam to heat up a metal to perform evaporation.

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- Electron Beam Exposure - the use of an electron beam to write patterns into a photoresist film. A tightly focused electron beam is deflected by an electromagnetic field under computer control.
- Electronic circuit - a collection of electronic elements that performs a prescribed function.
- Ellipsometer - an optical measurement technique where a polarized laser beam is used to measure thickness and index of refraction for optically transparent films.
- Emitter - the area of a bipolar transistor that emits carriers into the base region.
- Emulsion Mask - a transparent glass plate with light blocking patterns formed on it by silver salts in suspension in a gelatin or colloidal. Emulsion masks are relatively low cost and were widely used when contact aligners were popular. The quality of emulsion masks is not sufficient for sub-micron photolithography and their use largely faded away when projection aligners became popular.
- Emitter Coupled Logic (ECL) - a form of bipolar logic.
- Energy - the capacity for doing work.
- Energy Level - the allowable stable states of energy from quantum mechanical principles.
- Enhancement Device - a MOSFET that is normally off until the channel region is "enhanced" with carriers.
- EPAC - see, Electrically Programmable Linear Array.
- Epi Layer - see, Epitaxial Layer.
- Epitaxial Layer - a single crystal layer formed on top of a single crystal substrate. An epitaxial layer will typically have a different doping level and or type than the substrate upon which the epitaxial layer is formed. In some cases the epitaxial layer may be a completely different type of material than the substrate upon which it is grown. If the substrate and the epitaxial layer are both the same element or compound then the process is homoepitaxy and if the epitaxial layer and the substrate are different elements or compounds then the process is heteroepitaxy. see also, crystalline.
- EPROM - see Erasable Programmable Read Only Memory.
- Erasable Programmable Read Only Memory (EPROM) - a type of memory that may be electrically programmed to store data and erased by exposure to ultraviolet light. EPROM's are nonvolatile and can only be erased by shining a strong ultraviolet light through a window in the device package. During erasure all data is erased at once.
- Etching - the process of removing a material by chemical reaction.
- Ethylene Glycol - chemical formula HOCH<sub>2</sub>CH<sub>2</sub>OH, ethylene glycol is used as an etch activity reducer. Ethylene glycol has a density of 1.11Kg/L. Ethylene glycol is hazardous if ingested.
- EUV - see Extreme Ultraviolet



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- Evaporation - a process technology where metal to be deposited on a wafer is heated in a vacuum chamber to its melting point and the vapor from the metal condenses onto wafers forming a thin film.
- Evaporator - a piece of semiconductor equipment used to perform evaporation.
- Excimer Laser - The term excimer comes from the combination of excited and dimer. The excimer laser was developed in the late seventies and has output in the ultraviolet and near ultraviolet region. In an excimer laser a noble gas such as krypton, Kr, or xenon, Xe, is excited in the presence of a halogen such as fluorine, F, or chlorine, Cl, and neon, Ne, or helium, He, in a resonant cavity. A high voltage pulse dissociates electrons from the noble gas molecules creating a plasma. In the excited state, noble gas atoms combine with the halogen atoms forming a metastable compound such as KrF or ArF with a lifetime of several nanoseconds. When the electrons in the outer shell of the excited compound are stimulated to a lower energy level, ultraviolet light is emitted and the metastable compound disassociates in a few femtoseconds into the original elements.
- Exponential Model - a probability model for converting defect density to projected die yield based on the exponential distribution.
- Exposed - an area of photoresist that has had radiation interact with it during an exposure process.
- Exposure - the process of allowing radiation to interact with some areas of a photoresist layer while blocking the radiation from reaching other areas of photoresist.
- Extended Data Out Dynamic Random Access Memory (EDODRAM) - a type of DRAM with higher data throughput than standard RAM. EDODRAM has now been largely replaced by higher throughput synchronous DRAM.
- Extreme Ultraviolet (EUV) - an electromagnetic wave with a wavelength of 10 to 100 nanometers. Extreme ultraviolet commonly refers to a wavelength of 13 nanometers used for exposure. Extreme ultraviolet wavelength based aligners are a candidate to replace optical lithography for <70 nanometer linewidth photolithography.

## F

- F-RAM – see Ferroelectric Random Access Memory.
- Fab - see Wafer Fabrication.
- Fabless - a semiconductor company that uses foundries for all of its wafer fabrication requirements.
- Fabrication - see Wafer Fabrication.



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- Facilities Costs - the cost to build a facility or alternately the cost of maintaining a facility, i.e., items such as facility system repair costs, insurance, ultrapure water generation, utilities, etc.
- Failure Factor (FF) - utilization multiplied by the mean-time-to-repair a tool divide by the raw process time. Failure factor measures the true impact of downtime on a process.
- Failure in Time (FIT) - the number of failures per one billion devices hours.
- Failure Rate - a rate of failures per unit time.
- Farad - unit of capacitance. One farad is defined as the capacitance between two plates with 1 volt applied and charged by 1 coulomb.
- Feature Size - see Minimum Geometry.
- Femto - a prefix meaning one quadrillionth ( $\times 10^{-15}$ ), symbol f.
- FeRAM – see Ferroelectric Random Access Memory.
- Ferroelectric Random Access Memory (FeRAM) - also known as F-RAM or FRAM. FeRAM stores values by switching and sensing the polarization state of a ferroelectric capacitor.
- FET – see Field Effect Transistor.
- Field Effect Transistor (FET) - a transistor that uses an electric field to accumulate or deplete a channel region to block or allow conduction.
  
- Field Oxide - a thick layer of silicon dioxide that covers the area of an integrated circuit between active components.
- Field Programmable Gate Array (FPGA) - a circuit made up of logic gates where the logic gate connections can be readily programmed into specific configurations.
- Final Test - the test step where finished packaged devices are tested.
- FIT - see Failure in Time.
- Flash - a type of EEPROM where data is erased in blocks. The name Flash comes from the rapid block erase operation. Flash memory requires only one transistor per memory cell versus two transistors per memory cell for EEPROMs making Flash less expensive to produce. Flash is the most popular form of nonvolatile semiconductor memory available today.
- Flat Band Voltage - the voltage that when applied to a MOS Capacitor produces zero net charge in the underlying semiconductor.
- Flat Zone - the region in a furnace where the temperature is controlled within some specific tolerance, for example + or - ½ degree centigrade.
- Flip Flop - a latching register that maintains a consistent state until switched to a different state. The basic building block of SRAM.

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- Flip Chip - another name for a bumped die. Bumped die are flipped over to solder them down, hence the name flip chip.
- Fluorine - atomic symbol, F, fluorine is the 9th element in the periodic table (atomic number 9) with an atomic weight of 18.998. Argon is a group VII element and is highly reactive. Fluorine is used in etching gases and chemicals. Fluorine is toxic.
- Forward Bias - a voltage placed across a junction in the forward direction. When a junction is forward biased to a sufficiently high voltage, current will flow.
- Foundry - a wafer fabrication facility that processes wafers for other companies as a service.
- Four Point Probe - a piece of metrology equipment used to measure sheet resistance. A four point probe forces a current through the two outside probes and measures the resulting voltage drop across two inside probes.
- FPGA - see Field Programmable Gate Array.
- FRAM – see Ferroelectric Random Access Memory.
- Frequency - the number of times an oscillating signal goes through a complete cycle. Typically expressed as hertz.
- Fringe Benefits - benefits provided in addition to salary paid wholly or in part by the employer, such as medical, dental, and or disability insurance, vacation, paid sick leave, 401k matching, pension, etc.
- Fringes - abbreviation for fringe benefits.
- Furnace - a type of semiconductor manufacturing equipment used to heat up groups of wafers to temperatures  $>200^{\circ}\text{C}$  and  $<1,300^{\circ}\text{C}$ , with precise temperature control. Furnaces have quartz tubes sufficiently large to hold a wafer boat and the tube is surrounded by resistance heating elements. The quartz tube has one end connected to a gas controller that allows various gases to flow through the tube, the furnace would also commonly have the ability to change temperatures in a controlled manner and insert and withdraw the wafer boat all under computer control. Computer programs may then insert the wafer boat into a controlled atmosphere, increase the temperature, make changes in the gases flowing and then reduce the temperature and withdraw the wafer boat to accomplish oxidation, diffusion, alloying or annealing. Standard furnace typically ramp-up at  $5\text{-}10^{\circ}\text{C}/\text{min}$ . and ramp-down at  $2\text{-}3^{\circ}\text{C}/\text{min}$ .

## G

- GaAs - see Gallium Arsenide.
- Gallium Arsenide - a semiconductor formed by combining gallium, Ga and arsenic, As. Gallium arsenide has a higher electron mobility, operates at higher temperatures and provides higher frequency performance than silicon. Gallium arsenide use has increased in recent years due to



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cell phones but is still a small fraction of silicon's usage due to difficulties in gallium arsenide fabrication.

- Gamma Delta Model - a probability model for converting defect density to projected die yield.
- Gamma Rays - electromagnetic radiation with a wavelength of <10 picometers.
- Gate - the control terminal of a MOSFET, or alternately a basic digital logic element, for example an AND Gate, See also, OR, NAND, NOR.
- Gate Array - an integrated circuit made up of digital logic gates that are not yet connected. Typically gate arrays are fabricated up to the metal layers and then a custom metal mask is designed for a customer and used to connect the gates into a customer specific circuit.
- Gate Equivalent - the basic unit of measure of a digital logic circuit complexity. Gate equivalent is the number of individual logic gates that would have to be connected to perform the same function.
- Gate Oxide - the insulating layer that separates the gate and the underlying channel of a MOSFET. Historically gate oxide was silicon dioxide, however more recently nitrided silicon dioxide has been used and many people are investigating alternative high-k materials.
- Germanium - atomic symbol, Ge, germanium is the 32nd element in the periodic table (atomic number 32) with an atomic weight of 77.60, germanium is a semiconductor with a energy gap of 0.66eV at 300oK. Germanium has higher electron and hole mobility than silicon but its relatively narrow energy gap makes its high temperature performance poor. Silicon has replaced germanium in virtually all applications due to its higher energy gap and relative ease of fabrication.
- Gettering - the trapping a neutralization of unwanted elements.
- Giga - a prefix meaning one billion ( $\times 10^9$ ), symbol G.
- Glassivation - final passivation using silicon dioxide.
- G-line - the output of a mercury lamp with a wavelength of 435 nanometers. G-line light sources are commonly used in steppers for photolithography with linewidths wider than 800nm.
- Gross Die Per Wafer - the number of whole die on a wafer.

## H

- H-Line - the output of a mercury lamp with a wavelength of 405 nanometers. H-line light sources are not widely used.
- Halocarbon 14 - chemical formula  $CF_4$ , halocarbon 14 is an odorless gas. Halocarbon 14 does not have a formally established TLV but 1,000ppm is recommended. Halocarbon 14 is used as an etch gas.



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- Halocarbon 23 - chemical formula  $\text{CHF}_3$ , halocarbon 23 has a slightly ether like odor. Halocarbon 23 does not have a formally established TLV but 1,000ppm is recommended. Halocarbon 23 is used as an etch gas.
- Halocarbon 116 - chemical formula  $\text{C}_2\text{F}_6$ , halocarbon 116 has a slightly ether like odor. Halocarbon 116 does not have a formally established TLV but 1,000ppm is recommended. Halocarbon 116 is used as an etch gas.
- Hard Bake - a bake performed to photoresist after develop. Hard bake is performed at a higher temperature than soft bake since photoresist photosensitivity is no longer required (exposure and develop are already done and the pattern is formed). Hard bake stabilizes the photoresist prior to subsequent processing.
- HEPA - High Efficiency Particle Air - a type of air filter that removes 99.97% of all particles greater than  $0.3\mu\text{m}$  in diameter.
- Hertz - frequency in cycles per second, 1 hertz equals 1 cycle per second.
- Heteroepitaxy - epitaxial deposition of one type of material on a substrate of another type of material.
- HMDS - Hexamethyldisilazane, a chemical primer used to remove surface moisture and improve photoresist adhesion.
- High Energy Ion Implantation - ion implantation performed at an energy  $>750\text{KeV}$ . High energy ion implantation has become increasingly popular for retrograde well and buried layer formation.
- High Pressure Oxidation - oxidation performed at a pressure greater than atmospheric pressure. High pressure oxidation increases oxidation rate at a given temperature.
- High-k - a dielectric material with a dielectric constant greater than the dielectric constant of silicon dioxide,  $k>4$ . As minimum feature sizes have shrunk it has been necessary to shrink the thickness of gate oxides in proportion. Gate oxides are now becoming so thin that they do not display sufficiently good insulating properties. High-k materials can in theory replace silicon dioxide as a gate insulator, be used at a greater thickness, the higher the dielectric constant the thicker the film that can be used, and still adequately control the channel region.
- Hillock - bumps that form in a thin film during heating and cooling.
- Hole - the absence of an electron. Holes have a net negative charge equal to the charge on an electron. Holes may be mobile and can be treated exactly like they are a positive electron.
- Homoepitaxy - epitaxial deposition of one type of material on a substrate of the same type of material.
- Hot Carrier - carriers that have gained enough energy while transiting the channel region to be injected into the gate oxide. Hot carriers can degrade the reliability of MOS devices.

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- Hot Lot - a lot that is given priority and typically processed immediately upon reaching each step during fabrication. Hot lots move faster than standard lots but at the expense of slowing down all lots due to the disruption.
- Hydrochloric Acid - chemical formula HCl, hydrochloric acid a relatively strong acid primarily used as part of the SC2 Clean. Hydrochloric acid is commonly sold as a 47% solution and has a density of 1.19Kg/L. Hydrochloric acid burns on contact with skin or eyes and the vapors will irritate or burn eyes or lungs.
- Hydrofluoric Acid - chemical formula HF, hydrofluoric acid a relatively strong acid mainly used to etch silicon dioxide. Hydrofluoric acid is commonly sold as a 49% solution and has a density of 1.17Kg/L. Fluorine is not only toxic but may be absorbed through the skin without immediate evidence of irritation and later react with the calcium in bones and or poison the person exposed to the chemical.
- Hydrogen - atomic symbol, H, argon is the 1st element in the periodic table (atomic number 1) with an atomic weight of 1.008. Hydrogen is flammable and or explosive in the range of 4.0-93.9% in air and is an asphyxiant. Hydrogen is used to generate steam in furnaces by reacting with oxygen, as a pre-clean and carrier Gas during epitaxy, and as a constituent of annealing gases.
- Hydrogen Bromide - chemical formula HBr, hydrogen bromide is a toxic, corrosive gas with a TLV of 3ppm. Hydrogen bromide has a strong irritating odor and is irritating to lungs, skin and eyes. Hydrogen bromide is used as an etch gas.
- Hydrogen Chloride - chemical formula HCl, hydrogen chloride is a toxic, corrosive gas with a TLV of 5ppm. Hydrogen chloride has a pungent irritating odor and is irritating to lungs, skin and eyes. Hydrogen chloride is used as a cleaning gas during epitaxial deposition and as a furnace cleaning agent.
- Hydrogen Fluoride - chemical formula HF, hydrogen fluoride is a toxic, corrosive gas with a TLV of 3ppm. Hydrogen fluoride has a sharp irritating odor and is irritating to lungs, skin and eyes. Hydrogen fluoride is used to generate hydrofluoric acid.
- Hydrogen Peroxide - chemical formula H<sub>2</sub>O<sub>2</sub>, hydrogen peroxide is an oxidizer used primarily as part of sulfuric acid peroxide, and SC1 cleans. hydrogen peroxide is commonly sold as a 30% solution and has a density of 1.10Kg/L. Hydrogen peroxide will burn eyes or skin on contact and may react strongly with other chemicals.

## I

- I-Line - the output of a mercury lamp with a wavelength of 365 nanometers. I-Line Steppers were the primary Exposure tool for <800nm to 350nm Minimum Linewidths.

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- IC - see Integrated Circuit.
- ICP - see Inductively Coupled Plasma.
- Ideal Process Time - the time it takes to perform a process if the product being processed does not have to wait for other product to complete the process before being run.
- IGBT – see Insulating Gate Bipolar Transistor.
- I<sup>2</sup>L - integrated injection logic. A form of Bipolar Logic.
- Image - the pattern projected by an Optical System.
- Implanter - see Ion Implanter.
- Impurity - any foreign material incorporated into an Integrated Circuit structure. Impurities can be deliberately added Dopants or unwanted Contamination.
- Impurity Level - an energy level introduced by an impurity.
- Incoherent Light - Light that is not Coherent.
- Indirect Labor - anyone not directly involved in producing parts. Includes, engineering, supervision and technicians.
- Index of Refraction - ratio of the speed of Light in a Vacuum to the speed of Light in a given material. The degree to which a Light Ray entering a material is bent depends on Index of Refraction. Index of Refraction for a given material depends on the Wavelength of the Light due to Dispersion.
- Inductor - a passive electronic component that stores energy as a magnetic field. In its simplest form an inductor is made up of a coil of wire. The inductance measured in henrys, is proportional to the number of turns of wire, the wire loop diameter and the material or core the wire is wound around.
- Inductively Coupled Plasma - inductively coupled plasma systems are plasma etch systems whereby the radio frequency energy is coupled into a low pressure gas by an inductive coil mounted on the outside of a quartz window. ICP etchers run at low pressure similar to RIE but achieve higher ion densities than even MERIE. ICP etchers produce relatively low ion energies and so biasing of the substrate being etched may be used to tailor ion bombardment energies tuning the degree of anisotropy of the resulting etch.
- Infrared Light - Electromagnetic Waves with a Wavelength of 1 millimeter to 700 nanometers.
- Ingot - see Boule. Insulator - a material that resists the flow of electric current. Insulators have Band Gaps of several eV.
- Insulating Gate Bipolar Transistor - a Bipolar Transistor controlled by a MOS Gate electrode.
- Integrated Circuit - an electronic circuit where all the elements of the circuit are integrated together on single semiconductor substrate.
- Interconnect - conductive connections between Active Elements. Inverter - a basic Logic Gate that outputs a 1 if a 0 is input and outputs a 0 if a 1 is input.

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- Ion - an atom that has either gained or lost an Electron making it either positively or negatively Charged.
- Ion Beam Etching - a Process where Ions bombard a material and physically knock Molecules loose, etching the material.
- Ion Beam Milling - see Ion Beam Etching.
- Ion Implantation - a technique where Ions are accelerated to a high Energy and speed and injected into a Semiconductor. The dominant techniques for introducing Dopants into a Semiconductor. See also Ion Implanter.
- Ion Implanter - a type of Semiconductor Equipment that is used to perform Ion Implantation.
- ISL - Integrated Shottky Logic, a type of Bipolar Logic.
- ISO - International Standards Organization.
- Isolation - an electrical separation between areas of an integrated circuit.
- Isolation Diffusion - a Diffusion being used to form an area designed to block the flow of Current. Isolation diffusions are used to form diodes that are then reverse biased to block current flow.
- Isotropic - a Process that proceeds in all directions at the same rate or a medium that exhibits the same properties irrespective of the direction of measurement.

## J

- JFET - Junction Field Effect Transistor, a type of Transistor where Conduction is controlled by modulating the width of a Depletion Region.
- Junction - the line or plane where the level of P-type doping and N-type doping are equal.

## K

- Kilo - a prefix meaning thousands ( $\times 10^3$ ), symbol K.
- Killer Defect - a defect that will "kill" or make nonfunctional an Integrated Circuit.
- KrF - in the semiconductor industry, generally used to refer to an Excimer Laser that uses krypton and fluorine gases to produce an output of 248 nanometers. The light source of choice for critical levels at 250nm, 180nm and 130nm minimum linewidths.

## L

- Large Scale Integration (LSI) - integrated circuits containing >1,000 but <100,000 transistors.



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- Latch Up - a condition that can occur in CMOS where Parasitic NPN and PNP Transistors are both Conducting and remain Conduction once the disturbance that started the Conduction is removed.
- Lateral - a Transistor of any type where Conduction is along the top surface of the Semiconductor. Examples are Lateral PNP, Lateral DMOS, Lateral SCR, etc.
- Leadframe - the Metal frame that Semiconductors are attached to during the Package Assembly process. Typically a Leadframe is a long Metal frame with positions for multiple Chips. After the Chips are attached to the Leadframe tiny wire are used to connect the Chip Bond Pads to the frame and then the positions on the frame where Chips are located are encapsulated in epoxy. After Molding the encapsulated Chips are mechanically broken loose from the frame rails and the parts of the frame protruding from the Package become the Package leads.
- Learning Cycle - a Learning Cycle is the analysis-corrective action formulation-corrective action implementation cycle needed to fix a Yield problem.
- LED - see Light Emitting Diode.
- Light - electromagnetic radiation with a wavelength between 1millimeter and 10nanometers.
- Light Emitting Diode (LED) - a diode junction formed by compound semiconductors that emits light when forward biased.
- Line Yield - see Wafer Yield.
- Linewidth - the width of a line either printed on a wafer or an opaque feature on a mask or reticle.
- Linear Array - an integrated circuit made up of circuit elements that are not yet connected. Typically a linear array is processed up to the metal layers. When a customer places an order, a specific metal mask is generated to connect the circuit elements into the customer's specific circuit.
- Lithography - the transfer of a pattern from medium to another, for example, transferring a pattern from a mask or reticle to a wafer.
- LOCOS – see Local Oxidation of Silicon.
- Local Oxidation of Silicon - oxidation of selected areas of a silicon wafer by masking off the oxidation reaction from other regions. A thin uniform silicon dioxide, SiO<sub>2</sub>, layer is initially formed and then a layer of silicon nitride, Si<sub>3</sub>N<sub>4</sub>, is deposited. The silicon nitride is photolithographically patterned and then a relatively thick silicon dioxide layer is grown in the openings in the silicon nitride. The silicon nitride blocks oxidation wherever silicon nitride is present. Following oxidation the silicon nitride layer is stripped off the wafer. The thin initial silicon dioxide layer is used to prevent stress from direct contact between silicon and silicon nitride. LOCOS is widely used to isolated MOSFETs with minimum linewidths >350nanometers.
- Logic - a set of circuit elements that perform a function.

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- Low-k - a dielectric material with a dielectric constant less than the dielectric constant of silicon dioxide,  $k < 4$ . The propagation delay of a signal through an interconnect layer is related to the resistance and capacitance of the conductor. Low-k dielectric materials surrounding the conductor reduce capacitance and propagation delay.
- Low Pressure Chemical Vapor Deposition (LPCVD) - chemical vapor deposition performed at a pressure below atmospheric pressure.
- LPCVD - see Low Pressure Chemical Vapor Deposition.
- LSI - see Large Scale Integration.

## M

- Magnetic Random Access Memory - a memory technology that stores data as magnetic value. Two ferromagnetic plates that can each hold a magnetic field are separated by an insulating layer. One of the plates is a permanent magnet with a particular polarity and the other plate can have the magnetic field polarity changed to store different values. When the polarities on the two plates match this is considered a 1 and if the polarities are unmatched the value is considered to be 0. Due to the magnetic tunnel effect the electrical resistance of the cell is different for matched and unmatched polarities and it is the resistance that is sensed.
- Magnetically Enhanced Reactive Ion Etching (MERIE) - a type of reactive ion etching where a magnetic field is used to enhance ion generation in the plasma. MERIE has a higher density of ions relative to RIE without magnetic enhancement.
- Magnification - the optical image size divided by the object size.
- Majority Carrier - for a doped semiconductor one type of carrier, either holes or electrons is present in much higher concentration than the other type of carrier, this is called the majority carrier.
- Makeup Air - air brought in from outside of a facility used to replace exhaust air. Typically in cleanroom applications, makeup air is brought into the cleanroom at a higher rate than exhaust air is removed to provide positive pressure insuring that contaminants are pushed out of the room.
- Marangoni Dryer - system that uses a solvent film to displace water from a wafer surface drying the wafer. Marangoni dryers use very little solvent and produce high quality low particle wafer drying.
- Mask - a glass plate with a pattern of transparent and opaque areas used to photolithographically create patterns on wafers. A mask is commonly used to refer to a plate that has a pattern large enough to pattern a whole wafer at one time. See also, reticle.



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- Mask Layer - a method of characterizing the complexity of a process. A mask layer is all of the process steps associated with a particular mask.
- Mass Flow Controller - a device used to measure and control the flow rate of a gas or vapor.
- Master Plate - a mask used to photographically create other masks.
- Material Cost - the cost for the materials that actually make up the product that is shipped. In wafer fabrication, the wafer is the material, in assembly, the leadframe and epoxy are the material. Material costs do not include materials consumed to perform the fabrication process, those materials are included in overhead.
- MCT – see MOS Controlled Thyristor.
- MCU - see Microcontroller.
- Mean Time Between Failure - the average time between failures for a given piece of equipment or equipment set.
- Mean Time To Repair - the average time it takes to repair a given piece of equipment or equipment set.
- Medium Scale Integration (MSI) - an integrated circuit consisting of >30 and <1,000 transistors.
- Mega - a prefix meaning one million, ( $\times 10^6$ ), symbol M.
- Megasonic - the use of 700-1,000 kilohertz sonic energy to aid in particle removal during wet cleans. Megasonic energy creates acoustic streaming, dislodging particles down into the sub-micron range.
- Memory - a device that can store information for later retrieval.
- MERIE - see Magnetically Enhanced Reactive Ion Etching.
- MESFET – see Metal Shottky FET.
- Metal Gate - a type of MOS device that uses metal as the gate electrode.
- Metal Nitride Oxide Semiconductor - the interface between the silicon dioxide and silicon nitride layers may be used to trap charge creating a type of non-volatile memory. The gate of the device is biased during inject or remove electrons into the oxide - nitride interface from the underlying substrate. Commonly used to make EEPROMs.
- Metal Oxide Semiconductor Field Effect Transistor - a type of transistor where a conductive electrode is separated from the semiconductor surface by an insulating layer, typically silicon dioxide. Varying the voltage on the conductive electrode controls the flow of current along the semiconductor surface.
- Metal Oxide Semiconductor (MOS) - a type of semiconductor device fabricated with a conducting layer and a semiconductor layer separated by an insulating layer. MOS semiconductors are unipolar devices that use either holes or electrons for conduction, but not both at once, i.e. they are not bipolar devices.





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- Metal Shottky FET - a field effect transistor that has a metal shottky barrier for a gate. Commonly used for high frequency application on compound semiconductors.
- Metalization - a layer of metal typically utilized to interconnect different devices that make up an integrated circuit.
- Metastable - a state of stability that is barely stable. Metastable states may be easily stimulated to become unstable.
- Metrology - equipment or process used to produce a measurement.
- MICFET – see Minority Injected Carrier Field Effect Transistor.
- Micro - a prefix meaning one millionth ( $\times 10^{-6}$ ), symbol is  $\mu$ .
- Microcontroller - single purpose processing units designed to execute small control programs, sometimes in real time. The program is frequently stored on the microcontroller in an area of nonvolatile memory.
- Microolithography - the process of photographically forming very small patterns.
- Micrometer - one millionth of a meter ( $1 \times 10^{-6}$ ), symbol  $\mu\text{m}$ .
- Micron - an older term for micrometer.
- Microperipheral - chips designed to support microprocessors in personal computers. Microperipherals manage memory and provide various input-output connections, etc.
- Microprocessor - general purpose processing units designed to execute very large and complex programs, usually not in real time.
- Microwave - electromagnetic radiation with a wavelength of 30 centimeters to 1 millimeter. Mid Ultraviolet Light – electromagnetic waves with a wavelength of 300 to 350 nanometers.
- Mil - one thousandth of an inch ( $\times 10^{-3}$  inch), equal to  $25.4 \mu\text{ms}$ .
- Miller Indices - a set of three integers to specify crystal planes.
- Milli - a prefix meaning one thousandth ( $\times 10^{-3}$ ), symbol is m.
- Millimeter - one thousandth of a meter ( $1 \times 10^{-3}$ ), symbol is mm.
- Minienvironment - a localized clean environment created around a tool, or only within a tool where wafers will be exposed to the atmosphere. Wafers are moved from one minienvironment equipped tool to the next minienvironment equipped tool in sealed containers and only exposed to the atmosphere inside of the clean environment created inside the tool.
- Minority Carrier - the carrier type in the minority. For a doped semiconductor, one type of carrier either holes or electrons is present in much smaller concentrations than the other type of carrier, this is called a minority carrier.
- Minority Injected Carrier Field Effect Transistor – a device similar to a MOSFET except minority carriers are also used for conduction increasing the device efficiency.
- MMIC – see Monolithic Microwave IC.



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- MNOS – see Metal Nitride Oxide Semiconductor.
- Mobility - the velocity of a carrier inside a material under the influence of an electric field.
- Molecule - two or more atoms bonded together.
- Monochromatic Light - light of a single wavelength or very narrow bandwidth. Monochromatic light is made up of a single color of light.
- Monolithic Device - a device containing a complete circuit.
- Monolithic Microwave IC - an analog IC with on-chip capacitors and inductors design to work at microwave frequencies.
- MOS – see Metal Oxide Semiconductor.
- MOS Controlled Thyristor - a thyristor controlled by a MOS gate electrode.
- MOS Capacitor - a capacitor created by a metal and a semiconductor separated by an insulator. By performing a CV plot on an MOS capacitor a number of characteristics of the semiconductor and insulator may be measured. An MOS capacitor is the simplest manifestation of the MOS system.
- MOSFET – see Metal Oxide Semiconductor Field Effect Transistor.
- MPR - see Microperipheral.
- MPU - see Microprocessor.
- MRAM – see Magnetic Random Access Memory.
- MSI – see Medium Scale Integration.
- MTBF – see Mean Time Between Failure.
- MTTR – see Mean Time To Repair.
- Multi Level Metal - more than one layer of metal interconnect.
- Murphy Model - one type of probability model for converting defect density to projected yield.

## N

- N-type - a semiconductor with more free electrons than free holes.
- NAND - a type of flash memory commonly used for mass storage application like digital cameras and MP3 players. NAND is a serial memory cell that has 1 less contact per pair of cells than NOR memory making NAND less expensive to produce.
- NAND Gate - a basic logic gate similar to an AND gate but with an inverted output. NAND stands for Not AND. See also AND, and inverter.
- Nano - prefix meaning one billionth ( $\times 10^{-9}$ ), symbol is n.
- Near Ultraviolet Light - electromagnetic waves with a wavelength of 350 to 450 nanometers.
- Negative Photoresist - a type of photoresist that becomes relatively insoluble to developer when exposed to light.

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- Net Die Per Wafer - the number of good die on a wafer after wafer test.
- Nitric Acid - chemical formula  $\text{HNO}_3$ , nitric acid a relatively strong acid primarily used as part of the aluminum etch. Nitric acid is commonly sold as a 70% solution and has a density of 1.42Kg/L. Nitric acid burns on contact with skin or eyes and the vapors will irritate or burn eyes or lungs.
- Nitride - see Silicon Nitride.
- Nitrogen - atomic symbol, N, nitrogen is the 7th element in the periodic table (atomic number 7), with an atomic weight of 14.01. Nitrogen is a group VB element and is relatively inert. Nitrogen is widely used during IC processing as an inert purge gas due to its low cost, but must be used carefully because it will react under certain circumstances. For example, at  $>950^\circ\text{C}$  nitrogen will thermally react with silicon to form silicon nitride in an oxygen starved environment. A small amount of oxygen is commonly added during furnace ramp-up and ramp-down in nitrogen when  $950^\circ\text{C}$  temperatures will be exceeded to suppress silicon nitride formation.
- Nitrogen Trifluoride - chemical formula  $\text{NF}_3$ , nitrogen trifluoride is an oxidizer and toxic gas with a TLV of 10ppm. Nitrogen trifluoride has a mold like odor. Nitrogen trifluoride is used as an etch gas and as a cleaning agent in CVD systems.
- Nitrous Oxide - chemical formula  $\text{N}_2\text{O}$ , nitrous oxide is an oxidizer and a mildly toxic gas with a TLV of 50ppm. Nitrous oxide has a sweet odor. Nitrous oxide is used to nitride silicon dioxide and metals and during silicon oxynitride deposition. NMOS - an MOS device that uses N-type carriers, electrons for conduction in the on-state.
- Non Volatile Memory - memory that maintains data storage when power is removed.
- NOR - a type of flash memory cell widely used to store code, for example personal computers BIOS and cell phone data.
- NOR Gate - a basic logic gate similar to an OR gate but with the output inverted. See also OR and inverter.
- NOT Gate - see Inverter.
- Novalac Resin - the backbone polymer of most G-line and I-line positive photoresists.
- N-type - a semiconductor material that has been doped creating a much larger number of mobile electrons than mobile holes.
- Numerical Aperture (NA) - a measure of the acceptance angle of a lens. Higher numerical aperture means the lens gather more diffraction orders yielding higher resolution but at the expense of depth of focus.

## O

- Objective lens - the lens final lens that forms the image on the wafer.

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- Occupancy Costs - the cost of occupying a building, items such as cafeteria service, waste disposal and cleaning.
- OEE – see Overall Equipment Effectiveness.
- Off Axis Illumination - the use of an aperture to limit the light from an illumination system to only enter a lens system at an angle to the optical axis of the lens system. Off axis illumination is used with advanced exposure systems such as steppers and scanners to improve resolution at a given wavelength.
- Optical Edge Bead Removal - the process of exposing the edge of a wafer to an intense light source to fully expose the edge bead for removal during develop.
- OPTO - an abbreviation for optical semiconductor. OPTO devices react to light in some way or another. OPTO devices may switch on when illuminated or generate electric current when illuminated.
- Optoelectronics - products or systems combining electronics with optical sensitivity.
- OR Gate - a basic logic gate which outputs a 1 if any of the inputs are a 1.
- Outgassing - the release of gases or vapors by a material over time.
- Overall Equipment Effectiveness (OEE) - the actual output of a tool divided by the potential output of a tool assuming 100% utilization and 100% uptime. A measure of equipment effectiveness developed by SEMATECH.
- Overhead Labor - see Indirect Labor.
- Oxidation - the reaction of a material with oxygen to form a compound of the material and oxygen. Commonly oxygen, O<sub>2</sub>, or water vapor, H<sub>2</sub>O, are reacted with silicon, Si, at high temperatures to form silicon dioxide, SiO<sub>2</sub>.
- Oxide - generally refers to silicon dioxide.
- Oxide etching - etching of silicon dioxide.
- Oxidizer - a reactive substance that produces oxygen compounds.
- Oxygen - atomic symbol, O, oxygen is the 8th element in the periodic table (atomic number 8) with an atomic weight of 16.00. Oxygen is a group VIB element and is an oxidizer. Oxygen is used to oxidize silicon and in etching and stripping systems.
- Oxynitride - a compound of silicon, oxygen and nitrogen of the form Si<sub>x</sub>O<sub>y</sub>N<sub>z</sub>. Relatively inert silicon oxynitride is sometimes used as part of a passivation or gate oxide.
- Ozone - chemical formula O<sub>3</sub>, ozone is an oxidizer and a very toxic gas with a TLV of 0.008ppm, and a pungent odor. Ozone is used as an additive to ultrapure water to prevent bacteria growth and in wet strip baths as a hydrogen peroxide replacement.

## P



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- P-Type - a semiconductor material that has been doped so that there is a much larger number of mobile holes than there are mobile electrons.
- PAC - see Photoactive Compound.
- Package - a protective container for electronic components with terminals to provide electrical and or optical access.
- Parameter - a numeric measure of some characteristic of a device.
- Parasitic - an undesired attribute of a device or circuit such as, strap capacitance, leakage, or devices, that reduce the performance of a circuit or device from ideal performance without the parasitic.
- Pareto Diagram - a bar chart that plots failure modes from left to right - largest cause of failure to least cause of failure. A tool for identifying the most significant problems to help prioritize improvement efforts.
- Partial Coherence - the numerical aperture of the condenser lens of and optical system divided by the numerical aperture of the objective lens of the system.
- Parts Per Million (PPM) - one part in a million. Abbreviated ppm and commonly used to express defect levels or concentrations. Passivation - a final layer or layers put on semiconductors to protect them against contaminants and mechanical damage.
- Passive Components - components that do not amplify or switch signals. Examples include capacitors, resistors, transformers, inductors, etc.
- Pattern Generator - a system that takes CAD data and generates patterns. The system typically has a light source, a variable shape aperture, a reduction lens system, a blanking aperture and a stepping mechanism. At one time these systems were widely used to make masks. The systems form various sized shapes by moving a set of blades, the shapes are exposed onto the mask through the reduction optics system, once a shape is exposed the light source is blocked by the blanking aperture and the system steps to a new position. Repeating these actions over and over allows complex patterns to be built up.
- Patterning - creating an image in a photoresist layer. PC Board - Printed Circuit Board - an insulating board with patterned conductive layers on it. Components including ICs are soldered down to a PC board to build up complex electric circuits.
- PCRAM – see Phase Change Memory.
- PECVD – see Plasma Enhanced Chemical Vapor .
- Pellicle - a thin transparent layer stretched over a frame above the surface of a mask or reticle. Pellicles are used to block particles from reaching the mask or reticle surface where the particle would be in the focal plane. Any particles on the pellicle surface are out of the focal plane and should not form and image on the wafer being exposed.
- PGA – see Pin Grid Array.



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- pH - the hydrogen ion concentration in a liquid expressed as a negative logarithm so that a pH of 1 has twice the hydrogen ion concentration of a solution with a pH of 2. A pH of 7 is neutral, less than 7 is acidic and greater than 7 is alkali.
- Phase Change Memory (PCRAM) – also known as PCME, PRAM, Ovonic Unified Memory, Chalcogenide RAM and C-RAM is a type of non-volatile random access memory. PCRAM is based on chalcogenide glass most commonly  $\text{Ge}_2\text{Sb}_2\text{Te}_5$ , or GST, that changes between amorphous and crystalline states when heated. Differences in resistivity between the amorphous and crystalline states can be sensed electrically to differentiate between stored memory values. The device structure has the chalcogenide glass sandwiched between two electrodes in series with a selection transistor or diode in the leakage path. Writing a value to memory requires a short electrical pulse and quench to convert the chalcogenide glass to an amorphous state and then a lower amplitude but longer pulse to convert the chalcogenide to a crystalline state.
- Phosgene - chemical formula  $\text{COCl}_2$ , phosgene is a very toxic gas with a TLV of 0.1ppm. Phosgene has a moldy, hay like odor and is irritating. Phosgene is a reaction product that can form during chlorinated furnace cleans if sufficient oxygen isn't present.
- Phosphine - chemical formula  $\text{PH}_3$ , phosphine is pyrophoric and is a very toxic gas with a TLV of 0.3ppm. Phosphine is combustible in the range of 1.2-98% and has a decaying fish like odor. Phosphine is used as a dopant gas during CVD and as a dopant source for ion implant.
- Phosphoric Acid - chemical formula  $\text{H}_3\text{PO}_4$ , phosphoric acid a relatively strong acid primarily used as part of aluminum etches and to remove silicon nitride. Phosphoric acid is commonly sold as a 85% solution and has a density of 1.70Kg/L. Phosphoric acid burns on contact with skin or eyes and the vapors will irritate or burn eyes or lungs.
- Phosphorus - atomic symbol, P, phosphorus is the 15th element in the periodic table (atomic number 15) with an atomic weight of 30.91. A group V element phosphorus is a donor in silicon, i.e., makes silicon N-type. Phosphorus a commonly used N-type dopant and has a relatively high diffusivity compared to arsenic and antimony, other common N-type dopants, and a diffusivity and similar to boron, the most common P-type dopant.
- Phosphorus Oxychloride - chemical formula  $\text{POCl}_3$ , phosphorus oxychloride is a liquid at room temperature and was at one time widely used as a source of phosphorus during pre-deposition processes. During the pre-deposition process, Nitrogen gas is bubbled through heated phosphorus oxychloride liquid. The nitrogen gas leaves the bubbler carrying vapor of phosphorus oxychloride into the pre-deposition furnace. Phosphorus oxychloride's vapor pressure ranges from approximately 8mm of Hg at  $0^\circ\text{C}$ , 3mm of Hg at  $25^\circ\text{C}$  to 12mm of Hg at  $50^\circ\text{C}$ .
- Phosphorus Pentafluoride - chemical formula  $\text{PF}_5$ , phosphorus pentafluoride is corrosive irritating gas.

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- Photo Active Compound (PAC) - the chemical compound in photoresist that reacts to light and undergoes or initiates a chemical change.
- Photolithography - lithography where the pattern is defined by a photographic process.
- Photomask - see Mask.
- Photoplate - the mask plate prior to a pattern being formed.
- Photoresist - a photo sensitive chemical resistant to acid. Photoresists may be liquids that are spun onto wafers, or solid sheets that are rolled onto printed circuit boards.
- Photoresist Coating - the process of coating a wafer with photoresist. Most commonly photoresist is spun onto a wafer at high speed to form a thin uniform layer.
- Photoresist Developing - a process where an image exposed into photoresist is developed to create a pattern.
- Physical Vapor Deposition (PVD) - a process whereby a film is deposited on a wafer by a physical process, for example, evaporation or sputtering.
- Pico - prefix meaning one trillionth ( $\times 10^{-12}$ ), symbol is p.
- Pin Grid Array (PGA) - a style of integrated circuit package with an array of pins of pins designed to be inserted into a socket on a printed circuit board. PGAs support very high pin counts. The use of PGAs is declining.
- Pinhole - a small undesired hole in a photoresist film, deposited or grown film or opaque area on a photomask.
- PLA – see Programmable Logic Array.
- Plasma Enhanced Chemical Vapor Deposition (PECVD) - a process whereby a plasma is used to accelerate a CVD reaction.
- Planar Process - an IC made in such a way that all of the PN junctions intersect the top surface of the semiconductor. In planar processing photolithography and etching create openings in films on the surface of the wafer and the opening defines diffused and or implanted junctions formed into the wafer.
- Planarize - a process where something is made more flat.
- Plasma - a gas ionized to produce electron - ion pairs and neutral chemically reactive specie.
- Plasma Etch - a technique whereby radio or microwave frequency radiation is coupled into a low pressure gas to ionize the gas producing disassociation of the gas molecules into more reactive specie. Compounds containing halogens such as, fluorine (F), chlorine (Cl) or bromine (Br) are typically used as etch gases. When the compounds disassociate in the plasma, the resulting highly reactive halogen atoms or halogen compounds perform chemical etching in a generally isotropic manner. Typical plasma etching conditions are high pressure, low ionization levels and low ion energies relative to other dry etch techniques.
- PLCC – see Plastic Leadless Chip Carrier.



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- Plastic Leadless Chip Carrier (PLCC) – an older style relatively high pin count package. PLCC usage is declining.
- PM - see Preventive Maintenance.
- PMOS - a MOS device that uses holes as the carrier, holes carry a positive charge hence PMOS.
- PN Junction - an area in a semiconductor where a P type material and an N type material are in direct contact.
- Poly - abbreviation for polysilicon.
- Polycide - a silicide formed over polysilicon. Widely used in DRAMs.
- Polycrystalline - a material made up of grains of crystalline material where the grains are randomly oriented relative to each other. The material has short range but no long range order.
- Polysilicon - silicon with randomly oriented grains where each grain is made up of single crystalline material.
- Positive Photoresist - a type of photoresist that has a higher developer dissolution rate after being exposed to light.
- Post Exposure Bake (PEB) - a bake performed after exposure but prior to develop on chemically amplified photoresists. PEB aids in the exposure induced photo reaction.
- PRAM – see Phase Change Memory.
- Pre-Deposition - a technique whereby a dopant is deposited onto a wafer prior to a diffusion step. In order to perform pre-deposition, a carrier gas is bubbled through a liquid containing the dopant of interest and the carrier gas carries the dopant vapors into a furnace at high temperature. The dopant diffuses into the wafer and also forms a highly doped glass layer on the wafer surface.
- Preventive Maintenance (PM) - maintenance performed on equipment to try to prevent future random failures of the equipment or cleans to improve the quality of the equipment output. Preventive maintenance is performed on a scheduled basis based on elapsed time, number of runs or number of wafers processed.
- Probe Card - a card that hold a number of tiny needles with specific spacing's designed to make contact with bond pads so that die can be tested in wafer form.
- Probe Yield - see Die Yield.
- Prober - a piece of equipment that holds a probe card and under control of an automatic tester, steps the probe card across a wafer touching the probe card needles down on each die. Modern probers accept input and output cassettes of wafers and automatically shuttle the wafers onto the prober chuck, probe the wafers, and then shuttle the wafers back out into the output cassette. The prober may also include an inker to dispense ink on the bad die.
- Probing - the process of probing/testing die in wafer form.
- Process - may be used to refer to a process step or process flow depending on the context.



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- Process Capability - a comparison of the actual variability of a process to the process specification.
- Process Capability Index - the number of standard deviations between the process mean and the closest process specification limit divided by 3, abbreviation Cpk. For example, if there are 6 standard deviations between the mean and the nearest specification limit the process Cpk is 2.0. Generally speaking a Cpk >1.3 is considered capable (4 std deviations) and >2.0 is excellent.
- Process Control Charts - a graphical method for determining whether process variability is special cause or common cause.
- Process Flow - a set of process steps and order for performing the process steps to produce a desired result.
- Process Integration - the act of integrating a set of process steps to create a process flow.
- Process Step - an individual activity that changes the characteristics of a section or surface of a wafer.
- Programmable Logic Array - an array of logic elements that can be programmed to perform various functions.
- Programmable Read Only Memory (PROM) - a type of memory that may be programmed once and then the data can never be changed again.
- Projection Aligner - an alignment system in which a mask and wafer are separated by a significant distance and the mask pattern is focused onto the wafer, aligned and exposed. Projection printing was invented in 1973 and by the mid 1970s had largely replaced contact and proximity aligners.
- Projection Printer - see Projection Aligner.
- PROM – see Programmable Read Only Memory.
- Proximity Aligner - an alignment system in which a mask and wafer are separated by a few microns in distance and the mask pattern is aligned and exposed onto the wafer.
- Proximity Printer - see Proximity Aligner.
- PVD - see Physical Vapor Deposition.
- Pyrophoric - a material that automatically ignites on exposure to oxygen or oxygen containing species.

## Q

- QFP – see Quad Flat Pack.
- Quad Flat Pack - a common package for IC's with higher pin counts. Use of QFPs is declining.
- Quadrupole Illumination - a light source where light is split through four round openings located away from the optical axis of an illumination system. Quadrupole illumination is a type of off axis

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illumination and improves the minimum feature that an exposure system can resolve for a given wavelength.

- Qualification - a set of tests and specifications a product or process must meet before being considered a production process.
- Quartz - a crystalline form of silicon dioxide. Widely used for furnace tubes and boats.

## R

- Radio Waves - Electromagnetic Waves with a Wavelength of approximately 3 kilometers to 30 centimeters.
- RAM – see Random Access Memory.
- RAMBUS - a very high speed proprietary memory interface licensed to memory producers by RAMBUS (the company).
- Random Access Memory - memory devices where any memory cell in a large memory array may be accessed at in any order at random.
- Rapid Thermal Annealer (RTA) - an older terminology for rapid thermal processors.
  
- Rapid Thermal Processor (RTP) - a type of semiconductor manufacturing equipment that can rapidly heat up and cool down semiconductor wafers. RTP is used to very rapidly heat a wafer up to a high temperature for annealing and diffusion processes. RTPs may ramp up at 25-10°C/s ramp down at 30-50°C/s.
- Raw Process Time - the time it takes to perform a process with no waiting. Ignores waiting time, downtime, etc.
- RCA Clean - a type of semiconductor clean first developed at RCA. The RCA clean is the most widely used clean in the semiconductor industry today and utilizes a series of cleaning steps synergistically designed to remove particles, ionic and organic contaminants. See also, SC1, SC2.
- RDRAM - RAMBUS DRAM.
- Reactive Ion Etch (RIE) - a technique whereby radio frequency radiation is coupled into a low pressure gas to ionize the gas producing disassociation of the gas molecules into more reactive specie, and the substrate being etched is biased to induce ion bombardment. Compounds containing carbon (C) and halogens such as, fluorine (F), chlorine (Cl) or Bromine (Br) are typically used as gases. When the compounds disassociate in the plasma, both highly reactive halogen atoms or halogen compounds, and polymers that may deposit on the substrate blocking the highly reactive species are generated. Ions accelerated towards the substrate being etched by the applied or induced bias remove polymers on substrate surfaces oriented normal to the



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direction of ion motion, polymers coat substrate surfaces that are oriented parallel to the ion motion and block etching of those surfaces. Ion bombardment may also activate or accelerate chemical etching reactions. RIE therefore has the capability to etch surfaces normal to the direction of ion motion at a higher relative rate and surfaces parallel to the ion motion at a lower relative rate resulting in anisotropic etching. Typical RIE conditions are low pressure, low ionization levels and high ion energies relative to other dry etch techniques.

- Read Only Memory - a type of memory that is programmed during fabrication and the data can be read but never changed.
- Recirculation air - air that flows into a cleanroom, out to a fan system and back into the cleanroom continuously. Recirculation air typically passes through an air filter immediately before entering the cleanroom so recirculation air provides continuous filtration of the room air.
- Refractory Metals - metals with melting points  $>1,750^{\circ}\text{C}$ , although this definition varies. Some people use  $>1,900^{\circ}\text{C}$  and others use any metal with a melting point above Iron, Fe, Nickel, Ni and Cobalt, Co. Refractory metals include, Tungsten, W, Tantalum, Ta, Molybdenum, Mo, Niobium, Nb, and Zirconium, Zr. Regulators - devices that take a varying input and produce a controlled output. Electronic regulators may for example be, voltage regulators or current regulators, or gas systems may have pressure regulators.
- Resistance (R) - a measure given in ohms of the resistance to the flow of electric current.
- Resistivity - an intrinsic property of a material determining the materials resistance to the flow of current. Resistance in ohms is equal to the resistivity of the material multiplied by the cross sectional area of the material divided by the length of the material. Resistivity is frequently used to specify electrically active doping level and also as a measure of the ionic content of water.
- Resolution - the size of the smallest feature a system can clearly define on a photoresist layer.
- Reticle - a glass plate that contains a pattern of transparent and opaque areas. A reticle contains the pattern for one or more die but is not large enough to transfer a wafer sized pattern all at once.
- Reverse Bias - a voltage placed across a junction in the reverse direction. When a junction is reverse biased, current flow is blocked until the junction breaks down.
- RIE - see Reactive Ion Etch.
- Rinse - the use of ultrapure water to remove chemicals from a wafer surface. Most wet cleaning and etching processes are immediately followed by a rinse.
- Rinser - a piece of equipment used to perform rinsing.
- ROM – see Read Only Memory.
- RPT – see Raw Process Time.
- RTA - see Rapid Thermal Annealer.
- RTP - See Rapid Thermal Processor.

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## S

- Salacide - Self Aligned Silicide - a silicide process where an oxide or nitride layer with opening down to silicon is used to allow silicide to only form in selected areas.
- SC1 - Standard Clean 1, the first cleaning step in the original RCA clean. SC1 is a heated ammonium hydroxide,  $\text{NH}_4\text{OH}$ , hydrogen peroxide  $\text{H}_2\text{O}_2$ , bath used to remove organic residues and particles. Frequently performed in a Megasonic bath to improve particle removal.
- SC2 - Standard Clean 2, the second cleaning step in the original RCA clean. SC2 is a heated hydrochloric acid,  $\text{HCl}$ , hydrogen peroxide,  $\text{H}_2\text{O}_2$ , bath primarily used to remove metal contaminants.
- Scaling - a mathematical set of relationships determining how to shrink an MOS transistor to improve performance while controlling electric fields preventing hot carrier effects.
- Scanning Electron Microscope (SEM) - a microscope that uses a finely focused electron beam scanned across a sample to produce high resolution images. A SEM can resolve much smaller feature than a standard microscope, down to approximately 2 nanometers.
- Scanning Projection Aligner - an aligner that scans light through a slit across a mask to produce an image on a wafer. By scanning through a slit, an exposure area may be scanned by using a relatively small lens. The technique allows larger areas to be imaged without requiring huge optical systems, making optical system design easier.
- Schottky Diode - a diode formed by contact between a metal and a semiconductor.
- Scribe Line - an area between die left empty of circuitry where a saw can pass when sawing die apart. Also referred to as a street.
- SDRAM – see Synchronous Dynamic Random Access Memory.
- Seeds Model - a mathematical probability model for converting defect density to predicted yield.
- Selective Etching - the removal by etching of one material without etching another material.
- Selectivity - the difference in removal rate between two materials during an etching or CMP process.
- SEM - see Scanning Electron Microscope.
- SEMATECH - an industry consortium dedicated to improving semiconductor manufacturing methods.
- Semiconductor - an element with an electrical resistivity in the range between an insulator and a conductor. A material that can conduct or block the flow of electric current depending on processing and applied electrical biases.



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- Semi-custom - an integrated circuit that has been designed either by using existing blocks of design elements or is made on an existing array of gates which are just connected together to form a new circuit. See also Standard Cell and Gate Array.
- Sheet Resistance - the resistance of a film, material or layer measured by a four point probe. The resistance represents the parallel resistance of an infinite number of infinitely thin parallel sheets. Sheet resistance is expressed as ohms per square area and is equal to the average resistivity of a layer multiplied by the junction depth or thickness of the layer.
- Si - the symbol for silicon.
- Si Gate - see Silicon Gate.
- Silane - chemical formula  $\text{SiH}_4$ , silane is a pyrophoric, toxic gas with a TLV of 5ppm, and is combustible in the range of ~1-96%. Silane is widely used to deposit silicon containing films in a variety of CVD reactions.
- Silicide - a compound of metal and silicon. Silicides may be easily formed by thermally reacting a variety of metal with silicon and are widely used as contacts to silicon and conductors.
- Silicon - atomic symbol, Si, silicon is the 14th element in the periodic table (atomic number 14) with an atomic weight of 28.09. Silicon is a group IV element and is a semiconductor at room temperature with an energy gap of 1.11eV. Silicon is far and away the most widely used semiconductor material.
- Silicon Dioxide - chemical formula  $\text{SiO}_2$ , silicon dioxide is an excellent insulator with a dielectric constant of 3.9, a breakdown strength of 107 V/cm, and is thermodynamically stable on silicon up to the silicon melting temperature.
- Silicon Gate - a type of MOS device that uses doped polysilicon as the gate electrode.
- Silicon Nitride - chemical formula  $\text{Si}_3\text{N}_4$ , silicon nitride is a good insulator with a dielectric constant of 7.5, a breakdown strength of 107 V/cm, and is an excellent barrier against moisture and other contaminants. Silicon nitride is highly stressed in direct contact with silicon and so an intervening stress relief layer is typically used.
- Silicon On Insulator (SOI) - a substrate that has a layer of single crystal silicon on top of an insulating layer, on top of additional silicon. SOI is used to reduce stray capacitance for high-speed and or low-power CMOS and may also be used for high voltage applications.
- Silicon Tetrachloride - chemical formula  $\text{SiCl}_4$  silicon tetrachloride is a corrosive, with a pungent, suffocating odor. Silicon tetrachloride is used for CVD deposition of silicon nitride and epitaxial silicon films.
- Silicon Tetrafluoride - chemical formula  $\text{SiF}_4$ , silicon tetrafluoride has a suffocating odor.
- Single Crystal - a material where the atoms form a periodic array.
- SIP – see Single In-Line Package.



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- Single In-Line Package - a package with a single row of pins along one edge, usually mounted up on edge.
- Slice - another term for wafer, most often used during wafer manufacture where wafers are sliced from an ingot.
- Small Outline - a family of package types including SOP, SOJ and TSOP. As of 2012 the most common type of IC packages on a unit basis. SO packages are small surface mount packages.
- Small Outline J Lead Package - a type of SO package with a lead that is bent under the package in what is referred to as a J lead configuration.
- Small Outline Package - another type of SO package with leads that flare out at the bottom.
- Small Scale Integration - ICs with fewer than 30 transistors.
- SO – see Small Outline.
- Sodium Hydroxide - chemical formula NaOH, sodium hydroxide was at one time used to develop positive photoresist but has fallen out of favor due to sodium contamination concerns. Sodium hydroxide is a strong base and is commonly sold as a 50% solution and has a density of 1.53Kg/L. Sodium hydroxide will burn skin or eyes.
- Soft Bake - a bake performed after photoresist coating but prior to exposure. Soft bake dries the photoresist film and improves photoresist adhesion to the wafer.
- SOI - see Silicon On Insulator.
- SOJ – see Small Outline J Lead Package.
- SOP – see Small Outline Package.
- Source/drains - the source in a MOSFET injects carriers into the channel region and the drain collects the carriers.
- Spatial Coherence - the Phase relationship between Photons or Wave Fronts. Point sources of Light produce Wave Fronts that spread out from a single point and are perfectly Spatially Coherent, large area Light Sources produce Spatially incoherent Light.
- Special Cause Variation - a variation in output for a process because something about the process changed, such as, wear-out a setting was changed, something broke in the process equipment, parts were changed, etc. Special cause variation can be desirable or undesirable, for example, if a part on a machine is fixed and the variability in machine output is suddenly decreased, that would be a desirable special cause, alternately, if a part on a machine breaks increasing variability that would be undesirable.
- Spin Coater - see Coater.
- Spreading Resistance Probe (SRP) - a metrology technique for measuring electrically active dopant levels. A semiconductor is ground down at an angle through the area to be measured and four tiny needles are dragged along the bevel measuring resistance as they go. By knowing



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the angle and the speed of travel for the needles the resistance versus depth may be measured. SRP requires an area approximately 0.1mms wide to measure.

- **Sputtering** - a process used to deposit materials where a plasma is used to generate ions, the ions are attracted to a target, the ions impact the target and physically knock loose target atoms, and the atoms knocked loose condense out on wafers placed in the chamber depositing a film. Sputtering is primarily used to deposit metal films. Sputtering is preferred over evaporation because sputtering will transfer a metal alloy from a target to a wafer with roughly the same composition on the wafer as in the target. Evaporation deposits elements at different rates depending on vapor pressure so the film on the wafer may not match the composition of the target. See also, tech brief on Sputtering.
- **SRAM** – see Static Random Access Memory.
- **SRP** - see Spreading Resistance Probe.
- **SSI** – see Small Scale Integration.
- **Standard Cell** - an integrated circuit design where circuit blocks from previous designs are combined to create a new design.
- **Standing Wave** - two superimposed waves of the same frequency traveling in opposite directions.
- **Starting Wafer** - a wafer prior to the fabrication process. Most companies starting wafers or starting wafers with an epitaxial layer on them from third parties.
- **Static Random Access Memory (SRAM)** - a type of semiconductor memory where data may be accessed randomly and data is maintained as long as power is applied, SRAMs do not require refresh like DRAM's. SRAM's typically have faster memory access than DRAMs.
- **Steam Oxidation** - oxidation using steam.
- **Step and Repeat** - a 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. Step and Repeat system utilize reticle to create patterns. Virtually all sub-micron semiconductor exposure is done by some type of stepping exposure system. See also step and scan.
- **Step and Scan** - a step and scan system steps to different locations on a wafer for exposure similar to a step and repeat system, except a step and repeat system exposes a whole area at once and a step and scan system scans light through a slit across the area to be exposed. Difficulties in manufacturing large lens with high resolution limit step and repeat lens systems to approximately 25 x 25mm exposure areas, referred to as fields. Step and scan can produce an approximately 25mm wide field but then scan to a length of approximately 35mms.

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- Step Coverage - the ratio of the thickness of a film over a step edge to the thickness in a flat area. Most metalization processes result in a thinner metal layer over a step than in a flat area. Most people require or at least target >50% step coverage.
- Stepper - see Step and Repeat.
- Street - see Scribe Line.
- Stripping - the process of removing photoresist. Stripping may be accomplished by acid or solvent based wet strippers or by dry ashing.
- Structured ASIC - an IC with predefined blocks that is programmed by customizing the top two to five routing layers. Structured ASICs do not require all layers to be changed the way full custom or cell based ASICs do. Structured ASIC are sometime used to implement designs that are prototyped in FPGAs. The structured ASIC typically saves area and power relative to the FPGA design.
- Sub Atmospheric CVD (SACVD) - CVD performed at a pressure below atmospheric pressure.
- Sub-Micron - dimensions smaller than one micron.
- Substrate - another term for a wafer.
- Sulfur Hexafluoride - chemical formula SF<sub>6</sub>, sulfur hexafluoride has a TLV of 1,000ppm and is used as an etch gas.
- Sulfuric Acid - chemical formula H<sub>2</sub>SO<sub>4</sub>, sulfuric acid is primarily used to strip photoresist as part of a sulfuric acid - hydrogen peroxide mixture. Sulfuric acid will strip photoresist on its own but carbon, C, build up in the bath. The addition of hydrogen peroxide, H<sub>2</sub>O<sub>2</sub>, volatilizes the carbon from the bath as carbon dioxide, CO<sub>2</sub>, and carbon monoxide, CO. Sulfuric acid is commonly sold as a 98% solution and has a density of 1.84Kg/L. Sulfuric acid burns on contact with skin or eyes and the vapors will irritate or burn eyes or lungs.
- Surface Tension - the force that acts on the surfaces of liquids causing them to "bead up" minimizing contact with solid surfaces.
- Surfactant - soap like chemicals added to solutions to reduce surface tension and improve wetting.
- Susceptor - a plate on which wafer may be heated during deposition steps.
- Synchronous Dynamic Random Access Memory (SDRAM) - a newer type of DRAM where data access is synchronized to a clock. Higher speed than standard and EDO DRAM.

## T

- Tape Automated Bonding (TAB) - metal conductors mounted to Mylar tape, bonded to gold bumps on die. The Mylar tape is held on reels and TAB bonded die may be automatically placed onto PC boards very efficiently.





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- Target - the metal source for a sputtering process. Targets are most commonly round-thick pieces of metal larger in diameter than the wafers on which the metal will be deposited. Targets are specially shaped to optimize deposition uniformity.
- TCA - see Trichloroethane.
- TCE - see Trichloroethylene.
- Temporal Coherence - the relationship between the wavelength of a light source and the bandwidth of the light source. Temporal coherence is characterized by the coherence length.
- Test Wafers - wafers that are processed through part or all of a fabrication sequence and then used to measure the results of the processing. Test wafers are discarded or reclaimed after use and not shipped.
- TFT - see Thin Film Transistor.
- Thin Film Transistor - transistors formed in polycrystalline or amorphous silicon layers. Thin film transistors have relatively poor performance compared to transistors fabricated in crystalline silicon. This film transistors are used in certain types of SRAMs.
- Thermal Compression Bonding - bonds formed through a combination of pressure and temperature.
- Thin films - films with thickness less than approximately 100 microns.
- Thin Small Outline Package - a common plastic package for IC's, particularly memory.
- Three-Five Compound - III-V Compound - compound semiconductors made up of group III and group V elements.
- Threshold - the minimum level to effect a change.
- Threshold Limit Value (TLV) - the maximum permissible concentration of a substance typically expressed in ppm that a worker may be exposed to for 8 hours (sometimes 40 hours). TLV is a legally mandated safety limit.
- Threshold Voltage - the voltage required to switch a MOSFET from a blocking state to a conducting state.
- Through Silicon Via (TSV) – a via etched all the way through a silicon die. TSVs are used to make electrical connections between die in die stacking schemes.
- Throughput - the number of units completed through a process per unit time.
- Thyristor - a type of semiconductor device where 4 layers form 3 PN junctions. Thyristors are very efficient devices for switching large AC signals but latch-on until the signal passes through zero making them unsuitable for DC switching.
- Titanium Nitride - a compound of titanium metal and nitrogen gas (TiN), titanium nitride is very inert and serves as an excellent barrier metal. Titanium nitride has a resistivity of  $21.7\mu\text{ohm-cm}$ , a density of  $5.43\text{ g/cm}^3$ , a melting point of  $2,930^\circ\text{C}$ , adheres well to dielectrics, has poor wire bondability and is easy to pattern and etch.



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- TLV - see Threshold Limit Value.
- TO Package – see Transistor Outline Package.
- TOC – see Total Organic Carbon.
- Torr - the pressure exerted by 1mm of mercury, Hg. Standard atmospheric pressure is 760 torr.
- Total Organic Carbon - a measure of organic levels in ultrapure water. High TOC levels have been correlated with lower yields for semiconductors.
- Toxic - a poisonous substance.
- Trans LC - a proprietary and more ozone friendly furnace cleaning chemical used as a replacement for TCA.
- Transistor - a semiconductor device with three terminals where one terminal can be use to control the flow of current through the other two terminals.
- Transistor Outline Package (TO) - a standard package for discrete transistors. There are a variety of different TO packages such as TO3, TO92, TO220, etc.
- Transistor-Transistor Logic (TTL) - a type of bipolar logic.
- Triac - a type of semiconductor device where 5 layers form 3 PN junctions in each of two directions. Triacs are equivalent to two thyristors in anti-parallel.
- Trichloroethane (TCA) - chemical formula  $C_2H_3Cl_3$ , trichloroethane is a liquid at room temperature and was at one time widely used as a source of chlorine for furnace cleans. During the cleaning process, Nitrogen gas is bubbled through heated trichloroethane liquid. The nitrogen gas leaves the bubbler carrying vapor of trichloroethane into the furnace where it disassociates into carbon and chlorine. It is very important that sufficient oxygen is present during the cleaning process to suppress the formation of toxic phosgene gas. Trichloroethane vapor pressure ranges from approximately 30mm of Hg at 0°C, 130mm of Hg at 25°C to >350mm of Hg at 50°C. The use of trichloroethane has now largely ended due to ozone depletion issues.
- Trichloroethylene (TCE) - chemical formula  $C_2HCl_3$ , trichloroethylene is a liquid at room temperature and was at one time widely used as a source of chlorine for furnace cleans. During the cleaning process, Nitrogen gas is bubbled through heated trichloroethylene liquid. The nitrogen gas leaves the bubbler carrying vapor of trichloroethylene into the furnace where it disassociates into carbon and chlorine. It is very important that sufficient oxygen is present during the cleaning process to suppress the formation of toxic phosgene gas. Trichloroethylene vapor pressure ranges from approximately 20mm of Hg at 0°C, 75mm of Hg at 25°C to 200mm of Hg at 50°C. The use of trichloroethylene has essentially ceased due to the carcinogenic nature of trichloroethylene.
- TSOP – see Thin Small Outline Package.
- TSV – see Through Silicon Via.
- TTL – see Transistor-Transistor Logic.

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- Tube - a quartz tube that fits into a furnace. The tube encloses the furnace boats and provides a controlled atmosphere for processing.
- Twin Well - a process where two different types of wells are formed so that different types of devices may be fabricated. Typically one well will be N-type so that PMOS may be formed and one well will be P-type so that NMOS can be formed.
- Two Step Diffusion - a diffusion process where a pre deposition step is followed by a diffusion step. See Pre Deposition and see also Diffusion.
- Type - type refers to whether silicon is N-type, having a majority of negative carriers, or P-type, having a majority of positive carriers.

## U

- ULPA - see Ultra Low Particle Air.
- ULSI – see Ultra Large Scale Integration.
- Ultra Large Scale Integration - integrated circuits containing greater than 10 million transistors.
- Ultra Low Particle Air - a type of air filter that removes 99.999% of particles 0.12µm or larger.
- Ultrapure Chemicals - chemicals low in particles and contaminants.
- Ultrapure Gases - gases low in contaminants such as moisture and other gases.
- Ultrapure Water - highly purified water, low in ions, particles, organic matter and colloids.
- Ultrasonic bonding - a wirebond process using ultrasonic energy to form wirebonds.
- Ultraviolet Light - electromagnetic waves with a wavelength of 10 to 700 nanometers. See also near ultraviolet light, mid ultraviolet light and deep ultraviolet light.
- Undercut - etching underneath the edge of a layer. Occurs during isotropic etching.
- Unexposed - an area of photoresist that has not interacted with radiation.
- Unipolar - a semiconductor that uses only one type of carrier for conduction - either holes or electrons.
- UPW - see Ultrapure Water.
- Utilization - the actual hours a tool is producing product divided by the scheduled production hours for the tool.
- UV - see Ultraviolet Light.

## V

- Vacuum Tube - a tube containing a low pressure gas and two or more metal plates that control the flow of electrons.

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- Vapor Priming - a process where wafers are exposed to a vapor of HMDS to prime the wafer surface prior to photoresist coating. Vapor priming improves photoresist adhesion with only minimal HMDS consumption.
- Valence Band - a band of allowed energy states that exists in solids and is completely filled with electrons at zero degrees kelvin. The valence band is separated from the conduction band by an energy gap in insulators and most semiconductors and overlaps the conduction band in metals.
- Very Large Scale Integration (VLSI) - integrated circuits with greater than 100,000 transistors.
- Via - a contact between two conductive layers.
- Visible Light - Electromagnetic Waves with a Wavelength of 450 to 700 nanometers.
- VLSI – see Very Large Scale Integration.
- Volatile Memory - memory devices that lose the stored data when power is removed.
- Voltage - the electric potential driving current flow given in volts. The higher the voltage the higher the current flow will be through a given resistance.

## W

- Wafer - a round disc of semiconductor material most commonly Silicon, although Gallium Arsenide and other semiconductor materials are also used. Wafers are a few millimeters thick and are available in a variety of diameters with 100 millimeter, 125 millimeter, 150 millimeter and 200 millimeter and 300 millimeter. Previous sizes smaller than 100mm have largely disappeared. The next wafer size is 450mm and is in development as of 2012. Many Integrated Circuits are simultaneously fabricated on wafers during the wafer fabrication process.
- Wafer Fab - abbreviation for Wafer Fabrication Facility.
- Wafer Fabrication - the process of creating integrated circuits on the surface of wafers.
- Wafer Fabrication Facility (Wafer Fab or Fab) - a facility where the wafer fabrication process is performed. Fabs include a high quality cleanroom as well as support systems such as ultrapure water, gas and chemical generation and delivery systems, waste water treatment, extension HVAC equipment, as well as other support functions.
- Wafer Probe - the test step where each individual die on a wafer surface is tested and bad die are marked as bad. Also called wafer test or wafer sort.
- Wafer Size - the diameter of a wafer. Wafer sizes for 2 inch and 3 inch wafers were in inches, wafer sizes for all larger wafer diameters are in millimeters. Many people refer to a 4, 5, 6, 8 or 12 inch wafers, but in fact a "4 inch wafer" is 100 millimeters , 3.937 inches. There are also 125mm, 150mm, 200mm, 300mm and currently in development 450mm wafers.
- Wafer Sort - see Wafer Probe.
- Wafer Test - see Wafer Probe.

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- Wafer Yield - the number of wafers completed through the wafer fabrication process, divided by the numbers of wafers started into the wafer fabrication process, multiplied by 100. Sometimes referred to as line yield.
- Wavelength - the length of one complete cycle of a wave. In semiconductors, wavelength is typically applied to light.
- Wedge Bond - a type of wirebond where the wire end attachment looks like a wedge.
- Well - a relatively deep, doped area in which devices are fabricated. CMOS requires at least one well because NMOS requires a P background doping and PMOS requires an N background doping.
- Wetting - the degree to which a liquid maintains contact with a surface. Poor wetting is indicated by liquids beading up on a surface and good wetting is indicated by a continuous sheet of liquid forming on the surface.
- WIP - see Work In Process.
- Wirebond - the process where tiny wires are connected from chip bond pads to the leadframe.
- Work In Process (WIP) - the work undergoing a manufacturing process, for example, wafers in a Fab or die during packaging.
- Working Plate - when contact printing was in use, masks wore out or became contaminated from direct wafer contact. Working plates are copies of an original or master plate. Many working plate copies of a master plate can be made before a new master plate needs to be generated. Working plates are less expensive than a master plate.

## X

- X Ideal - the actual cycle time divided by the ideal cycle time.
- X86 - a type of microprocessor which can execute the X86 instruction set developed by Intel in the early seventies.
- X-Ray - electromagnetic radiation with a wavelength greater than 10 nanometers and less than 10 picometers.

## Y

- Yellow Room - because photoresist is sensitive to ultraviolet light, ultraviolet light must not be present in photoresist processing rooms. The filters used to remove ultraviolet light from the output of fluorescent lights give the room a yellow appearance.
- Yield - the number of units good after some test or measurement divided by the number of units measured.



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- Yield Learning - the identification of yield limiting defects, analysis of the cause of the defect and corrective action to fix the defect and improve yield.
- Yield Model - a mathematical probability model used to convert defect density to a projected yield.