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Glossary of Terms for Ion Implantation And Related Processes

Acceptor(s):

The term applied to dopant (q.v.) atoms (p-type) that "accept" electrons to leave a "hole" in the silicon, i.e., Boron, Indium. (Acce**p**tor = p-type). See Donor.

Amorphous/Amorphization:

Amorphous is a term applied to a form of silicon that is not crystalline – not structured. Amorphous applies absence of any long-range atomic order. No crystallinity – or totally random. Amorphization occurs when the "damage" caused by high dose implant changes the crystalline structure of a wafer, for example, to a more "amorphous" material on the surface down to about the mean range of the implant ions (that range depends on specie and energy). Some fabs use an "amorphising implant" using Si or Ge ions into silicon wafers as a way of minimizing channeling (q.v.). This amorphizing implant technique is often called "preamorphizing" or preamorphization implant (q.v).

Angstrom:

A unit of measure using the symbol Å. (1×10^{-10} meter). One Angstrom is equal to 0.0001 micron or 0.0000000001 meter. The Angstrom is used for measurement of thin oxide, shallow implants (ultra low energy).

Anneal:

The name of the process steps in which the implant dopant is electrically activated. The anneal process is a thermal process where one implanted wafer (serial annealers) or many implanted wafers (batch annealers/furnaces) is heated to a high temperature.

Generally the temperature is between 950C and 1150C. The anneal times for a serial annealer and a batch annealer is on the order of 10 seconds to 30 minutes or longer respectively. The anneal performs three functions:

a) Recrystallization of the damaged, amorphized (q.v.) silicon.
b) Proper distribution of the implanted ions.
c) Proper/full electrical activation.

Argon Backside Implant:

See Backside Implant.

Axial Scan:

Beam scanning method where the beam is electrostatically scanned horizontally and/or vertically in front of the wafer and allowed to move across the wafer so that the beam is 0° in the center and an increasing angle as the beam moves towards the edge of the wafer (this can be up to 2° or more for some implanters on large diameter wafers, i.e., ≥ 200mm). Note that the alternate scan technique is called parallel scan (q.v.)

BF_2 :

A molecular ion consisting of one Boron atom and two Fluorine atoms with a total of one electron removed. The total mass of the molecule is 49 [11 + (19 X 2)]. It is used by some fabs as a means of achieving lower energy Boron. When the BF_2^+ ion strikes the surface of the wafer, the Boron contains 11/49th of the total energy of the molecular ion … or about 1/5th.

Backside Implant:

An implant which has been reduced somewhat in popularity where, in Bipolar processes for example, an implant of say Argon is done on the rear of the wafer in order to create damage site. Subsequent thermal processes cause certain contaminants near the front of the wafer to move towards the damaged area. This is often called a “gettering implant”.

Beam Current:

The term that denotes how many ions (atoms) are available in the ion beam. The measurement is in amperes or more exactly, milliamps for high current implanters (generally batch) and microamperes in medium current implanters (generally serial).

- One microampere = 0.000001 ampere
- One milliampere = 0.001 ampere

Beam Filter:

An active electrode in serial implanters (an option) placed just prior to the final acceleration. This electrode is used as an electroststic mirror that repels “half energy contaminants” in multiple charged beams.

Beam Line:

That part of some implanter types where there are no accelerating assemblies present but where the beam is either focused or scanned or where it is allowed to drift for a short length. It is generally after the final acceleration and is often an area where charge exchange and the consequential energy purity degradation could occur.

Beam Purity:

The term applied to the % purity in the energy of the ions being implanted. Neutralization of multiply charged ions, i.e., P^{++} for example discharging to P^{+} due to poor vacuum can cause a lower energy for 1 – 5% or more of the total ions. This is often called “energy purity”.

Bridging Implant:

A special sheet resistance measurement process in which a controlled implant at a mid level energy is run in order to “connect” the surface of the wafer to a deeper, high energy implant layer (> 750keV B for example).

Bulk Doping:

The silicon wafers in the semiconductor fab are doped during the crystal growing cycle with either Boron (p-type dopant) or with Phosphorus (n-type dopant). More or less of one of these dopants will set the Resistivity (q.v.) value of the wafer material as measured in ohm-cm or Ω-cm.
Note: it should be remembered that for proper electrical measurement (sheet resistance), the wafer dopant type (n or p) must be opposite than the implant dopant type.

i.e., Boron ions (p-type) into n-type wafers and, conversely
Arsenic ions (n-type) into p-type wafers.

Buried Layer:

One of the first steps in the Bipolar process. Here either an implant step or a diffusion step is done to lay down a high concentration of Antimony or Arsenic. These layers are often covered with an epitaxial (q.v.) layer of silicon so the surface damage from the Buried Layer implant process must be cured, i.e., re-crystallized, well prior to growing the epi layer. The Sb (Antimony) implant recipe might be close to 70 keV, 5E15).

Capacitance-Voltage (C-V) Measurement:

A technique used for measurement of charge/breakdown of gate oxide – and, in conjunction with a metal film, can measure and map sheet resistance, although this is usually time consuming.

Cap, Capping:

See Oxide Cap.

Channeling:

The term applied to an ion trajectory following an open path through the silicon lattice structure in cases where the wafer has not been oriented (tilted/twisted) correctly. It produces a generally incalculable penetration of the ion since all the majority of the implant models use randomized silicon atoms (amorphous – q.v.). Channeling can be controlled with a screen oxide or proper tilt and twist (orientation) of the wafer. Proper tilt of the wafer from vertical (with respect to the beam) will reduce or eliminate axial channeling, i.e., a small % of ions deeper into the wafer. Proper wafer orientation or twist (with respect to the beam) will reduce or eliminate planar channeling, i.e., a small % of ions implanted laterally.

Clustering:

See Solid Solubility.

Concentration:

This is a volumetric term referring to the number of atoms per unit volume in the silicon. This is generally in terms of atoms/cm^3 or atoms/cc. Note the difference between this term and dose (q.v.). Since the depth of an implant layer is so thin (< 1 micron or < 0.0001cm), the concentration values are generally 1000 or more times higher than the dose had been. The peak concentration is the concentration at the highest part of the dopant profile (sort of a “bell shaped” curve).

Contamination:

In ion implantation, there are four or five distinctly different types of contamination. A detailed explanation would consume many pages gut in summary, these types are:

a) Cross Contamination – sometimes called "implant memory". In this case the parts of the implanter coated from the previously used species will sputter with the "next species" sometimes with the contamination sputtering to or condensing onto the wafer. This is a surface contamination that can last for up to or longer than 30 minutes after changing to the "next species". Reduction or elimination is through the use of a screen oxide, a dedicated implanter or other, approaches.
b) Elemental Contamination/Surface – this relates to elemental contamination onto the wafer (surface related) from beam impingement from the walls or from key assemblies near the wafer. Use of proper implanter design and silicon coatings can reduce or virtually eliminate this contamination.
c) Elemental Contamination/Deep – this type relates to a contaminant from the source area where a material from previous source use or from the source materials (Ta, W, Mo, etc.) might be analyzed (bent) along with the desired beam. In this case the "contaminant" is energetic and deep into the wafer material. Elimination or reduction requires careful selection of source parts. A good example of this is the use of BF_2^+ where a 1% or more part of the beam might contain Molybdenum if that material is used in the source. Alternate materials are available.
d) Particulates/Foreign Matter – this type of contaminant is large in that it can be measured with several types of optical instruments in the fab whereas other contaminants are at the "atomic level". Particles down a diameter of 0.1 μ or lower are key contributors to yield loss in the fab.
e) Organic Contamination: this type of contamination might appear on the wafer surface in the form of an oily material from either pumping (less likely over the last 12 – 15 years since implanters are shipped with "oil free" pumping) or from improperly selected materials in or near the wafer handling and implant sections of the implanter. This type of contamination can also affect annealers or probing after implant.

Cross Contamination:

See Contamination.

Decel:

The popular term for the implanter configuration where the beam is in a decelerating mode. In the past, when low energy beams were used, the beam current for lower energies – especially where the energy we much lower than the extraction voltage, the beam could be decelerated. In these cases, a normal or reasonable voltage could be supplied to the extraction to achieve reasonable beam current yields and then after analysis a second electrode set would be arranged (automatically in most cases) to change the polarity of the accelerating voltage with respect top the extraction with the resultant energy being something on the order of ½, ¼ of the extraction with useable beam currents. In recent years, this has lost some level of popularity since some % of the ions at the initial energy can stay at the same momentum as they were at the original energy and become "energy contaminants".

Dimer:

A word used to denote a molecule consisting of two (2) atoms of the same type, i.e., N_2 or P_2 . The effective mass is doubled in these cases. Note that for every "electron charge" being counted in the dose measurement system of an implanter, there are two atoms being implanted. The implanted dose is twice that dialed into the operation system of the implanter and must be properly adjusted.
Note: there are also molecules such as "trimers" and "quadrimers" i.e., P_3 or P_4 but these are generally less likely to occur.

Disk/Implant Disk/Implant Wheel:

See Platen.

Donor:

The term applied to the dopant atom type (n-type) that provides an electron (e^-) to the silicon, i.e., Arsenic, Phosphorus. Do**n**or = n-type. See Acceptor.

Dopant:

A dopant is implant specie (q.v.) that will form a junction with another dopant already residing in (or injected later) in the substrate material. In silicon based process these dopants include: B, P, As, Sb and In. For Gallium Arsenide (GaAs) technologies, the dopants include Si and Be.

Dose:

The dose is the parameter describing how many ions (atoms) will be implanted onto the wafer surface. The value is in terms of area, i.e., ions or atoms/cm^2 – an area term. Typically implanters for Silicon based technologies have a dose range between 5E11 up to 1E16+ ions/cm^2. Another way of stating this is $8 \text{ X } 10^{11} – 1 \text{ X } 10^{16}$ atoms/cm^2.

Dose Sensitivity:

The term used to denote the capability of a dose measurement tool or system (anneal and probe for sheet resistance for example) to "see" or detect a change in the actual dose. If the dose of a known, well-characterized implant is changed 10%, what % is the measurement change? If the % change in the measurement is exactly the same as the % change in the dose, the sensitivity is said to be 1.0. The dose sensitivity is calculated in the following manner: S_D = % change in measurement/ % change in dose.

Double Implant Technique:

A term referring to a low dose measurement technique using a Four Point Probe (FPP). An infrequent technique used by a few fabs where a high dose (> 5E14 generally) is done on a series of wafers and then annealed and probed. Wafers with good uniformity results are then used for subsequent low dose implants (E11 – E12 range) where the lighter dose "damages" the surface of the wafer and it's previous implant layer. The amount of damage is measured with no anneal and is a result of contact resistance change.

Doubly Charged/Double Plus:

The implantation of ions with two electrons instead of one removed from the outer shell. The production of doubly charged ions in most ion sources is about $1/10^{th}$ to $1/20^{th}$ that of singly charged ions. When a doubly charged ion traverses, say, 200 kV of accelerating voltage the resultant energy will be 400 keV. The ion will come to rest at the same depth in the target material as singly charged ion that has accelerated through 400kV of accelerating voltage.
Note: For every two "electron charges" counted in the dosimetry system, only one atom of the desired specie is implanted. The implanted dose is one half that dialed into the dose processing system. Most modern implanters will do the calculation for the user – if in doubt … check the implanter manual.

Edge Exclusion:

The term used to denote the thickness of the "ring around the outside of the wafer" that is not factored into the measurement. That part of the wafer is excluded from the measurement. Almost all measurement tools (wafer surface particle counters, Sheet Resistance maps and maps for other dose tools, including CorMap have an optional edge exclusion. This exclusion is selected as a way of eliminating known areas that are under a clamp on some equipment for example. Sheet resistance for example cannot accurately measure to the extreme edge of the wafer without a known shift in the sheet resistance due to a well-characterized edge effect. Most edge exclusions are on the order of 3 – 4 mm with sheet resistance edge exclusion at 3 – 7 or more mm. Do not confuse the edge exclusion (a radius measurement) with a test diameter.

Ellipsometry/Laser Ellipsometry:

See Oxide Cap.

Energy:

The term used to denote the "energy of the ion" – measured in keV or kilo-electron-volts. The implanter sets up a specific voltage kV or kilo-volts, through which the ion will be accelerated. If a single charged ion, i.e., B^+, gets accelerated through, say 200 kV, the energy = 200keV (one electron is missing, one charge state). If the charged ion selected is a doubly charged ion, i.e., B^{++}, and goes through the same power supply setting of 200 kV, the energy = 400 keV (two electrons are missing, two charge states). Note that the ions in both cases have the same momentum and depth into the target material.

Epitaxy (epi):

A process by which good quality, single crystal can be grown on top of existing crystal. The epi may have a different Resistivity than the original crystal but will be the same crystal orientation (q.v.), i.e., <100>, <111>, etc. The epi system needs good quality crystal surface to begin the process otherwise there will be many defects and/or amorphous (q.v.) regions in the epi.

Note that some processes use a very thick epi where the epi thickness makes the overall wafer thickness 30% or more thick than a standard wafer. Special awareness is needed since there could be handling issues with certain platens or wands.

Extraction:

A key part of an implanter that is usually a specially shaped electrode located just downstream (a few cm or so) and which has a hole or a slit in the center aligned to a corresponding hole or slit in the ion source arc chamber. The extraction electrode will be set at a negative voltage with respect to the ion source (remember that the ions in >99.9% of all commercial implanters are positive) at a level of ~ 40 – 80 kilovolts or more.

This voltage causes the ions to accelerate out of the ion source and through and beyond the extraction electrode.

Faraday:

The measurement hardware on an implanter is often called a "faraday" or sometimes, more specifically a faraday cup or faraday cage, depending on the physical nature of the assembly. The faraday assembly is often a box or cup shaped device that has an electrically isolated bottom or one that has a mask in the from so that the cup (or the bottom of the cup) can capture a "sample" of the implanted ions for measurement and dose calculations. It is often masked by a screen with a projected area of - or samples an area = 1.00 % of the implanted area. (The faraday is named for Michael Faraday; 1791 – 1867. A scientist who discovered electromagnetic induction and who did much of the early work in laying the foundation for modern electromagnetic technology)

Gettering Implant:

See Backside Implant.

Implant Characterization:

See Post Implant Characterization Methods.

Implant Memory:

See Contamination/Cross Contamination

Implant Range:

The range of the ions entering the target material – measured in microns (μ) or Angstroms (Å). (See Projected Range)

Ion:

An ion is an atom (or a molecule, i.e., BF_2) with one or more electrons removed or added. In conventional ion implanters used for semiconductor doping or materials modification positive ions (one or more electrons removed) are used. The addition or subtraction of one or two electrons does not change the mass (AMU) of the atom/species.

Ion Source:

The heart of the implanter *(depending on who you might talk with some might indicate that the dosimetry system is the heart)* where the ions are generated. A gas is bled into the implanter vacuum system directly into a small chamber within the source. The high temperature (> 1200C) and the bombardment by energetic electrons emitted from the filament causes the gas to disassociate and the atoms from many of the gas atoms will have electrons knocked away from there outer shells – making them “positively charged”. See Vaporizer.

Junction (X_j):

The term applied to the position/region in the substrate where the implanted dopant concentration equals the background doping concentration, i.e., where the conductivity type changes from n to p or vice versa. In high-energy implants where the profile is very deep, there can be two junctions one deep and one shallower.

Lattice:

The term used to describe the structure of atoms in a crystal. They can be cubic, face centered cubic, hexagonal, etc. Single crystal Silicon is a face-centered crystal. The orientation of the crystal uses an index called “Miller Index” to define the structure of a given plane (X, Y or Z) of the crystal. These terms are shown as <100>, <111> and others.

Mask:

A term used to describe one of several materials applications where the material (photoresist, Silicon Nitride/Si_3N_4 , Silicon Dioxide/SiO_2, Polysilicon, and others) are used as a barrier to stop the implanted atoms (ions) from entering at selected locations. Areas where an implant is desired have openings selected made across the wafer using a photo process.

Measurement (of Implant Dose):

Common measurement tools for measuring dose on the wafer include:

a) Sheet resistance probes or Four Point Probes (FPP). These probe tips are generally fixed at 0.040 inch (1mm) apart and measure and map 49, 121 points or more across the wafer. An anneal (q.v) of the wafer is needed to electrically activate the implant dopant in the wafer prior to probing. The dose range of this technique is about 1E13 – 1E16 ions/cm^2 or higher. Major manufacturers include KLA-Tencor/Prometrix, CDE and Four Dimension.

b) Crystal damage measurement tools use a single laser or a double laser assembly to look at the amount of crystal damage. Lower doses are measured in a different manner than higher doses. These tools generally measure 49 – 131 points/wafer. Major manufacturers include Therma-Wave, Boxer Cross, Jenoptic (Europe).

c) Polymer damage tool(s). There is one tool in this category that uses a special polymer coat on standard silicon wafers for low dose measurement with high sensitivity. The tool takes measurements at 37,700 points on a 200mm wafer. No other post implant processing is required. The major manufacturer is Core Systems (CorMap).

Micron:

A unit of measure with the symbol μ. A micron is 1 millionth of a meter (0.000001m) and is about 40 millionths of an inch (3.937E-5). It is used to describe implant depth, critical device geometry size and larger particle sizes.

Nanometer:

A unit of measure with the symbol nm. It is equal to 1/1000th of a meter and 10 times larger than an Angstrom (q.v.). It is often used to characterize device geometry – especially small feature sizes and thin gate oxides.

Orientation/Wafer Orientation:

Proper orientation or twist of the wafer during implant is critical in reducing planar channeling (q.v.). The orientation of a given wafer lattice type, i.e., <100>, <111> will require different orientations for different implanter models in order to achieve minimized channeling. It should be noted here that wafers are also oriented to accommodate a feature on the wafer such as a "well" or a mesa/raised formation to ensure that the proper side(s) are implanted.

Oxide Cap:

A term used for a thin layer of SiO_2 (Silicon Dioxide) layer which is grown after implant but prior to – or very early in the anneal cycle. It is thick enough to prevent outdiffusion where the dopant atoms close to the wafer surface leave the wafer in a non- uniform manner. It "caps" the dopant. This should be considered as a different process from "screen oxide (q.v.) although there can be cases where a screen oxide can play both roles.

Note: For some lower energy implants, the user needs to consider the thickness of the oxide with shallow (Low energy) implants. Sometimes the user grows a thin oxide during the initial phase of anneal. Alternatively the fab may want to deposit (as opposed to growing) an oxide with a CVD (lower temperature) oxide cap after implant to avoid dopant redistribution.

Oxide Strip:

A post anneal step sometimes called chemical clean or pre-probe clean and is used to remove buildup of thin oxide formed during anneal or to remove the screen oxide used during implant in order to electrically probe the wafer.

Parallel Scan:

The term used to denote the scan technique that is unlike the axial scan (q.v.) in that there is some form of angle correction (either electrostatic or electromagnetic) downstream of the scanning that, ideally, puts the beam at 0° incident at all points on the wafer. There are various techniques to measure the overall uniformity of scanning since the design and setup is somewhat complex.

Platen:

The term used to describe the assembly that holds the wafer(s) during implant. In a serial implanter this hold one wafer, in a batch impanter the "platen" is a disk or a wheel that has many platens (sometimes called pads or pedestals on a batch implanter). In most cases there will be thirteen (13) 200mm wafers on a wheel – more or less with smaller or larger wafer sizes. In modern implanters the majority of platens and/or disks are cooled for higher beam power. The platen often will have the ability for integrated actions for tilt, twist/orientation and other motions.

Polysilicon (Polycrystalline):

A term used to denote an aggregate form of silicon that is between amorphous and crystalline. It can be prepared using a CVD process. Polycrystalline material is deposited as compared with most SiO_2 that is "grown" on the base material (generally single crystal silicon). Poly silicon is often called Poly and is used for many device applications such as resistors, gate arrays, etc.

Post Implant Evaluation Methods:

a) Electron Microscopy for Chemical Analysis (ESCA): The interaction of X-rays on a sample causes photo-ionization and ejection of an inner shell electron. Because the binding energies of the electron is modified by it's surrounding, energies can be used to determine the bonding characteristics of the emitting atom … or the atoms bounded to it. Species and chemical information.

b) Inductively Coupled Plasma Mass Spectroscopy (ICPMS): Generally a large area or “whole wafer” sampling techniques where the surface oxide that can contain implant and contaminant is stripped in an HF. The resultant solution is injected into an inductively coupled argon plasma as a mist that is rapidly desolvated and vaporized. The resultant gas is then analyzed in a quadrupole mass analyzer. New Laser Ablation technique uses a small spot size (~20μ) similar in size to SIMS. Elemental contamination information.

c) Secondary Ion Mass Spectrometer (SIMS): The most popular technique to analyze the elemental purity of an implant as well as measure and map the implant species profile in the target material. A fine, controlled beam of Cesium (Cs) or Oxygen (O) is used to bombard the surface of the target material. (Our interest is a wafer). The beam has a known “erosion rate” and while it is boring a hole in the target material, ejected material can be analyzed and characterized in a small mass spectrometer. SIMS needs a special lab and dedicated personnel. The setup and measurement for one wafer and 1 – 3 points might take a couple of hours. Elemental and depth information.

d) Spreading Resistance Probe (SRP): A special Two Point Probe used to accurately measure the sheet resistance by depth. A piece of the material being tested (implanted and annealed in our case), is carefully broken then one side is ground down at a bevel with a very small angle – on the order of ≤ 0.25 to ~ 2° degrees. As the probe is moved along the bevel the X and/or Y axis motion is translated to a depth change (along the bevel) on the order of a fraction of a micron. Beginning in the mid to late 90s, some labs were able to get SRP beveling and probing so they could accurately measure junctions formed by sub 5 keV Boron implants. Dopant profile (depth) information – needs an anneal and cannot determine species only type (n or p). Also note that unactivated dopant will not be measured.

e) Total X-Ray Fluorescence (TXRF): Probably the second most popular implant contamination characyerization tool (after SIMS). Conventional X-rays are incident on the wafer surface with such a small grazing angle that total external reflectance is achieved. Only the near surface is excited (the top 60Å). Fluorescence X-rays from the surface are detected using an X-ray energy dispersive spectrophotometer. Elemental contamination on the surface only and for atomic numbers 20- 35 and 56 – 83.

Pre-amorphization Implant:

A de-channeling implant used in damaging the surface of single crystal using a mid to high dose (~5 – 8E14) implant of Silicon or Germanium. This implant is not annealed prior to the doping implant.

Projected Range:

The statistically generated penetration depth of a selected implant ion/specie (at a specified energy) into a specified target material. The "projected range", often referred to, as R_P is the mean or the average of the stopping depth of all of the ions calculated entering the silicon. A second term "delta R_P" or written as ΔR_P is the standard deviation (SD) of the range of the ions. Delta R_P is sometimes referred to as "straggle" or range straggle. Both of these terms are used to determine many implant related factors such as oxide thickness required, sheet resistance desired, etc.

The measurement units are either in Angstroms (Å) or microns (μ). The R_P of a given species at a given energy into a given target will vary 5 – 10% depending on the text or the modeling software being used. Phosphorus at 80 keV into Silicon will have an R_P of 990Å … or about 0.1μ.

Quad Mode Implant:

An option on many implanter types where the process engineer elects to implant a single wafer (or wafers in a batch implanter) in "quadrants". I this case each quadrant of the wafer receives 1/4th of the dose. This usually requires a longer implant time. The purpose of the quad mode feature allows for the user to distribute the dopant so as to minimize effects due to shadowing (q.v.) or to ensure even doping of sidewalls of wells, etc.

Recipe/Implant Recipe:

The term that describes the set of key parameters for an ion implant request. These terms include:

a) Species: The atom to be ionized and implanted, i.e., Boron, Phosphorus, etc.)
b) Energy: The energy in units of keV (kilo electron volts) that the ion will have when it strikes the target (wafer). (The higher the energy, the deeper the ion will penetrate the target material).

c) Dose: The "amount" of ions to be delivered to wafer per unit area (each square cm), for example, 3.5 X 10^{12} ions/cm^2 - or 3.5E12 ions/cm^2.
d) Beam Current: A parameter not always as critical as the three items preceding this but important in many recipes. It is the amount of ions available for implant in terms of "milliamperes" or "microamperes". (It is the dose rate … sort of like GPM)
e) There are other parameter but these are usually in terms of implanter configuration or wafer tilt and twist.

A typical implant recipe will be stated as: **B, 30 keV, and 2E12 ions/cm^2**. This means that the requester wants Boron ions implanted at an energy of 30 keV at a dose of 2 X 10^{12} ions/cm^2. (Many engineers use "engineering notation" (2E12) as opposed to "scientific notation" (2 X 10^{12}). The beam current and other features may not be necessary or are understood as fab standard or a default value.

Repeatability (of the implant or the dose measurement):

The word that denotes the S.D.% (1δ - often called "one sigma") of all of the measured dose means/averages of all wafers within a batch or batch to batch. It is a measurement of how well the implanter (or the dose measurement with the same wafer) can maintain its setup integrity. See Uniformity (of the dose). Note that in cases where the investigator is trying to determine the repeatability of the measurement for a specific implant, the dose sensitivity should be factored into the daily "means".

Resistivity:

See Bulk Doping.

Screen Oxide:

The term applied to a thin oxide (SiO_2 , Silicon Dioxide) generally "grown" prior to the implant to:

a) Prevent surface contamination from local sputtering effects
b) Reduce or eliminate channeling effects. The oxide tends to randomize the trajectory of the ions.

c) Prevent outdiffusion of the dopant (loss from the surface of the wafer)

Note A: The Silicon Dioxide “growth process” is one where high temperature and steam or oxygen is applied and the oxygen consumes the base silicon material in the SiO_2 growth. For every 10 Angstrom of SiO_2 grown, 0.45 Angstrom of silicon is consumed.

Note B: that lower energies, especially for high mass species (As, Sb) cannot use oxide caps in many cases since they shallow nature of the specie at low energy will not penetrate the oxide.

Semiconductor:

Materials with bulk electrical resistance (Resistivity) between that of an insulator and a conductor. The conductance (the opposite of resistance) can be varied over several orders of magnitude by introducing impurity atoms. In silicon, the most frequent impurity atoms are:

Boron and sometimes Indium – p-type dopants. These are often called “acceptors” (q.v.)

Arsenic, Phosphorus and sometimes Antimony – n-type dopants. These are often called “donors” (q.v.). Semiconductor materials include silicon and germanium.

Scribe:

The term used to denote the method(s) where an ID number is placed on the outer edge of the wafer. It can be done manually – a risky step. Most fabs use an automatic laser scribe set to SEMI standard for position and font size on the wafer.

Shadowing:

The eclipsing of the incident ions due to the wafer tilt or the beam angle with axial scan (q.v.) when the beam strikes an opening in the resist or other coating with a high aspect ratio – one where the depth is ~ 3 or more times greater than the width. In these cases, parallel scan implanters and/or quad mode implant (q.v.) are often used.

Sheet Resistance:

Sometimes referred to as sheet rho. Incorrectly referred to as Resistivity (although sheet resistivity if often used and is commonly acknowledged). It is the term applied to the resistance of an ultra thin layer, i.e., an implanted layer. It is measured in ohms/square, Ω/square or Ω/□. (the unit area is arbitrary – it can be square cm, square miles, square furlongs, square anything. The number will remain the same)

Solid Solubility:

There is a limit depending on temperature, to the maximum concentration (atoms/cm^3) of the implant species in a given target material. Above this level, the implant species atoms will begin to agglomerate or form clusters. In Arsenic into Silicon material, this occurs about a dose of 8E15 ions/cm^2 at 80 keV. (Note that the concentration and dose terms are different – one is an area density and one is a concentration/volumetric term). The As at 80 keV, 8E15 ions/cm^2 will have an "as –implanted" concentration of about 1.5E21 atoms/cm^3.

Specie:

The word used to denote any one of the elements including those that are used by ion implanters for doping semiconductors or the change the characteristics of a material, i.e., hardening by Nitrogen. Over 75 elements are known to be implanted for many industries. Only those that are used for forming a transistor junction in a semiconductor may also be called dopants.

Straggle:

See Projected Range.

Threshold Voltage:

Many ambiguous definitions are used for this term. One basic parameter for the JFET (for example) is the gate voltage cutoff for drain current (I_D). This voltage is called threshold voltage (V_T). The threshold voltage requirement must be uniform across an array of transistors within a circuit, across a wafer and wafer-to-wafer. Another definition states: "The voltage where the silicon/silicon dioxide interface becomes strongly inverted and the transistor "turns on". The three most important parameters which set the threshold adjust are: the purity and repeatability of the gate oxide (controlled Na and K throughout the process for example), oxide thickness and the doping concentration (implant energy, dose, elemental purity) and repeatability of these factors.

Threshold Adjust Implant:

This is a common implant used to set the threshold voltage across all devices on the wafer. The threshold adjust implant is doping under the gates of the transistors as a means of setting the "turn-on" voltage of the transistors. Generally this is a lower energy (boron at 15 – 30 keV) and a dose in the range of 8E11 – 3 E12 or so (lower for some MOSFETS). There are other means but they are limited to changing the work function of the gate. One of these methods includes changing thickness, material(s) of the gate itself.

Tilt:

a) When the implant user wishes to ensure that the crystal lattice of the target material (in most cases, Silicon or Gallium Arsenide) will not be in a position to have unmanageable channeling, the wafer is tilted with respect to the beam incidence. Usually this tilt is between 5 and 8 degrees. Depending on the implanter type, the tilt might be vertical or horizontal.

b) There are occasions when the user needs to ensure that a raised surface/mesa on the wafer or a well – whether square or round, is equally doped on all sides, the implant dose is divided by four (4) and each 1/4th dose is done at 0°, 90°, 180° and 270°. (Some processes are done in two steps; 0° and 180°. These are not quad mode but serve a similar purpose.

c) High Tilt Implant refers to any number of specific applications (LATID, Pocket, Halo implants) where the wafer is tilted 20° and as high as 60° in order to implant under a gate or other transistor feature. High Tilt implants are often done on bimode (0/180°, Quad or rotational mode

ULE (Ultra Low Energy):

The term used to describe the energy range for implanter or other doping techniques to form a shallow junction or ultra shallow junction/USJ (q.v.). For standard beamline implanters, the range falls between 100eV (0.1keV) and 5 keV.

Ultra Shallow Junction/USJ:

The term used to describe the formation of a junction that is on the order or 1000Å (0.1μ) or less. An ultra shallow junction is the outcome of a repeatable, energy-pure implant below 2 –3 keV Boron and with appropriate rapid annealing so as not to change the distribution of the implant dopant while electrically activating it to the correct level. Ultra shallow junctions are needed to form appropriate source-drain extensions so as to ensure that there are no adverse effects in sub 0.15μ technologies. Note: a junction is formed at the location where the implant dopant level (in at/cc) equals the background dopant.

Uniformity (of the dose):

The term that denotes the S.D.% (1δ - often called “one sigma”) of all measured points taken on a wafer. Traditionally, this has been 49 – 131 points but some systems have more or even as high as 37,000+ on a 200mm wafer. Most implanter specifications call for a dose uniformity of ≤ 0.5% (1δ) of the mean. What this means is that all measured points are to be equal to or less than ½ of 1% of the mean value of the whole wafer.

Vaporizer:

A small, optional assembly located in the ion source where solid material can be placed for “vaporization”. It is a small crucible capable of ithstanding high temperature and is surrounded by a heating element. Some desired implant species (q.v.) cannot be readily obtained in a gaseous form so a compound of solid material is obtained and vaporized within the source. The source is “makes” its own gas with a vaporizer.

Wafer Size/Dimensions:

Wafer dimensions and specs are strictly governed by SEMI – a standards committee for the industry. The standards are applied to silicon as well as GaAs and other wafer types (check GaAS or other compound semiconductor specs).

Wafer Size Nomenclature	**Diameter**	**Thickness**	**Primary Flat Length**	**Secondary Flat Length**	**Primary Flat Location**
2"	2.000" +/- 0.015" (50.8 +/- 0.38mm)	0.011" +/- 0.001" (279 +/- 25 microns)	0.625" +/- 0.065" (15.88 +/- 1.65mm)	0.315" +/- 0.065" (8 +/- 1.65mm)	{100} +/- 1 deg
3"	3.000" +/- 0.025" (76.2 +/- 0.63mm)	0.015" +/- 0.001" (381 +/- 25 microns)	0.875" +/- 0.125" (22.22 +/- 3.17mm)	0.44" +/- 0.06" (11.18 +/- 1.52mm)	{100} +/- 1 deg
100mm	100 +/- 0.5mm	525 +/- 20 microns or 625	32.5 +/- 2.5mm	18.0 +/- 2.0mm	{100} +/- 1 deg
125mm	125 +/- 0.5mm	625 +/- 20 microns	42.5 +/- 2.5mm	27.5 +/- 2.5mm	{100} +/- 1 deg
150mm	150 +/- 0.2mm	675 +/- microns or 625 +/- 15 microns	57.7 +/- 2.5mm	37.5 +/- 2.5mm	{100} +/- 1 deg
200mm	200 +/- 0.2mm	725 +/- 20 microns	NA (Notch on some)	NA	NA or {100} +/- 1 deg if there is a notch
300mm	300 +/- 0.2mm	775 +/- 20 microns	NA (Notch on some)	NA	NA or {100} +/- 1 deg if there is a notch

Wheel/Implant Wheel:

See Disk.