

Appendix 1

Common Abbreviations and Acronyms

(100), (111),	low index crystallographic planes, notation	COB	Chip-On-Board
(110)	according to Miller index system	COP	Crystal Originated Particle (or Pit), a vacancy agglomerate formed during crystal growth, also known as Flow Pattern (term related to a specific test method); seen on polished surface as a light scatterer in particle inspection, typical size 50–160 nm (size and density depends on crystal growth parameters). Degrades gate oxide integrity.
(100)	any (100) plane and equivalent planes, including e.g. (010) and (001)		
(100)	crystal orientation perpendicular to (100) plane		
(100)	any orientation equivalent to [100]		
AAS	Atomic Absorption Spectroscopy, a technique to analyze impurities		
AC	Alternating Current	CPGA	Ceramic Pin Grid Array
AFM	Atomic Force Microscope, used in wafer surface nanotopography characterization	C_{pk}	Process capability index
ALD	Atomic Layer Deposition	CQFP	Ceramic Quad Flat Pack
ANSI	American National Standards Institute	CS	Constitutional Supercooling
AOG	Axial Oxygen Gradient, oxygen distribution in crystal along the axis	CSP	Chip Scale Package
APCVD	Atmospheric Pressure CVD	CTE	Coefficient of Thermal Expansion
ASIC	Application-Specific Integrated Circuit	CCZ	Continuous Czochralski
ASTM	American Society for Testing and Materials, developed standards formerly to silicon technology, SEMI has taken that role now	CZ	A crystal growing technology named after its inventor Jan Czochralski; crystal is grown by pulling it from a silicon melt held in a crucible. A vast majority of silicon crystals are grown with a CZ technology
BCB	Benzocyclobutene, known also under the commercial name Cyclotene [®]	CVD	Chemical Vapor Deposition
BDD	Bulk Defect Density	D/B	Die Bonding
BESOI	Bonded and Etchback SOI	DBG	Dicing Before Grinding
BGA	Ball Grid Array	DC	Direct Current
BMD	Bulk Micro Defect, typically silicon dioxide precipitate, stacking fault or combination of both, typical density after thermal treatments can be 10 ⁷ –10 ¹⁰ /cm ³	DIL	Dual InLine
BOE	Buffered Oxide Etch	DF	Dislocation-Free
BOX	Buried Oxide in SOI wafers	DIN	German industry standard (Deutsche Industrie Normen)
BPSG	Borophosphosilicate glass	DIP	Dual Inline Package
BSD	Back Side Damage, a wafer back side gettering method	DPW	Dies Per Wafer
BTAB	Bumped Tape Automated Bonding	DRIE	Deep Reactive Ion Etching
CBGA	Ceramic Ball Grid Array	DSP	Double Side Polished
CC	Chip Carrier	DZ	Denuded Zone, oxygen lean (and defect free) area near the wafer surface in annealed wafers
CCC	Ceramic Chip Carrier	ED	Electro Deposition
CER-DIP	Ceramic Dual In-line Package	EDP	Ethylene diamide pyrocatechol, in water mixture used as anisotropic etchant of silicon, toxic
CFC	Carbon Fiber Composite (aka C/C = carbon-carbon)	EMI	Electromagnetic Interference
CFP	Ceramic Flat Pack	ESF	Epitaxial Stacking Fault
CMOS	Complementary Metal Oxide Semi-conductor	ESP	Electrostatic Potential, the potential energy of a test unit charge in a given charge distribution (Note that the test charge is assumed not to disturb the given charge distribution)
CMP	ChemoMechanical Polishing or chemical mechanical polishing		

FC	Flip Chip	LST	Light Scattering Tomography; an optical method for the characterization of defects in silicon, based on the scattering of laser light
FEM	Finite Element Method		
FDP	Focal Plane Deviation, a wafer flatness specification, distance of the plane fitted on the wafer surface to the parallel focus plane of the optical system		
FDTD	Finite-Difference Time-Domain, a popular scheme to numerically solve time-dependent Maxwell equations by discretization of continuous space and time elements combined with appropriate basis functions	LTCC	Low Temperature Co-fired Ceramic
FIB	Focused Ion Beam, commonly refers to a focused ion beam instrument	LTO	Low Temperature Oxide, used for example in back sealing of heavily doped wafers to minimize dopant outdiffusion
FPD	Flow Pattern Defect, see COP	LTV	Local Thickness Variation
FQA	Fixed Quality Area of a silicon wafer	MBE	Molecular Beam Epitaxy
FTIR	Fourier Transform Infrared Spectroscopy, for example, to measure oxygen and carbon content in wafers and epi thickness	MCM	MultiChip Module
FZ	A Float Zone crystal growing technology; a method where a crystal is grown from a small pool of silicon melt formed on a silicon feedrod	MCM-C	MCM-Ceramic
GBIR	A term to define global wafer flatness, most commonly used, see SEMI M1	MCM-D	MCM-Dielectric
GFA	Gas Fusion Analysis, to measure oxygen content in heavily doped silicon	MCM-P	MCM-Plastic
GOI	Gate Oxide Integrity	MCP	MultiChip Package
Gr	Grasshof number	MCz	A Magnetic Czochralski crystal growing technology, silicon melt is in magnetic field during crystal growth
GTIR	Global Total Indicated Reading, see SEMI M1	MEMS	Micro Electro Mechanical System
GUI	Graphical User Interface	MD	Molecular Dynamics, a popular method to analyze materials properties by numerically solving atomic or molecular motions based on the Newton equations
HARM	High Aspect Ratio Micromachining	MIT-IR	Multiple Internal Transmission Infrared spectroscopy
HZ	Hot Zone	MLB	Multi Layer Board
IC	Integrated Circuit	MLP	Micro Leadframe Package
ICP-MS	Inductively Coupled Plasma Mass Spectroscopy	MLPWB	Multi Layer Printed Wiring Board
IG	Internal Gettering	MOEMS	Micro Electro-Optical Mechanical System
IO	Input Output	MST	Micro Systems Technology (Same definition as MEMS)
IR	Infra Red light	NTD	Neutron Transmutation Doping, an intrinsic FZ crystal turned to high resistivity n-type crystal; a very uniform resistivity can be achieved
JEITA	Formerly known as JEIDA; Japan Electronic and Information Technology Industries Association, develops Japanese standards for silicon materials and technology	NTV	Nonlinear Thickness Variation (old term, rarely used today)
JIS	Japanese Industry Standard	O_i	Interstitial oxygen in silicon
k_{eff}	effective segregation coefficient of dopant or impurity	OLB	Outer Lead Bond
LCC	Leaded Chip Carrier	OPP	Optical Precipitate Profiling; an optical technique for characterizing bulk defects in silicon
LCCC	Leadless Ceramic Chip Carrier	OSF	Oxidation induced Stacking Fault, a defect formed in oxidation, especially in wet oxidation of a silicon wafer. OSF density can be minimized by engineered wafer specifications and by tuning the oxidation process.
LDV	Laser Doppler Vibrometer, an interferometer	PACE	Plasma Assisted Chemical Etching
LED	Light Emitting Diode	PBGA	Plastic Ball Grid Array
LIGA	Lithographie, Galvanoformung und Abformung (German), aka lithography, electroforming, and molding	PCAD	Packaging Computer-Aided Design
LLCC	Leadless Chip Carrier	PCB	Printed Circuit Board
LLPD	Large Light Point Defect	PCI	Peripheral Component Interconnect
LOCOS	Local Oxidation of silicon	PGA	Pin Grid Array
LPCVD	Low Pressure Chemical Vapor Deposition	PID	Proportional-Integrating-Derivative control loop
LPD	Light Point Defects, same as LLS	PLCC	Plastic Leaded Chip Carrier
LPS	Lateral Photo voltage Scanning	PMMA	Poly(methyl methacrylate) or poly(methyl 2-methylpropenoate), a transparent thermoplastic used as a resist in lithography
L/S	Loss of Structure	ppba	parts-per-billion-atomic
LSE	Latex Sphere Equivalent, reference for particle size	PPGA	Plastic Pin Grid Array
		ppma	parts-per-million-atomic

ppta	parts-per-trillion-atomic
PQFP	Plastic Quad Flat Pack
PSD	Power Spectral Density function
PSI	Phase Shifting Interferometry, an interferometric method for measuring surface topography
PUA	Percent Usable Area
PWA	Printed Wiring Assembly
PWB	Printed Wiring Board
PV	PhotoVoltaics
P/V	Peak to Valley, for example, in roughness measurements
QFP	Quad Flat Pack
QSOP	Quarter Size Outline Package
R_a	Rayleigh number
R_a	Average value of surface roughness
RFID	Radio Frequency IDentification
RGA	Residual Gas Analysis
RMF	Rotating Magnetic Field
Rms	Root mean square
ROG	Radial Oxygen Gradient, radial variation of oxygen in silicon wafers
rpm	revolutions-per-minute
RRG	Radial Resistivity Gradient, radial variation of resistivity in silicon wafers
Rq	Root-mean-square value of surface roughness
RT	Room Temperature
RTA	Rapid Thermal Anneal
SAW	Surface Acoustic Wave
SBIR	Site flatness, back side reference
SC	SuperConducting
SCP	Single Chip Package
SD	Small Dual in-line package
SEMI	Semiconductor Equipment and Materials International
SFQR	A term to define local flatness of a silicon wafer, front reference, a most commonly used site flatness definition, see SEMI M1
SiC	Silicon Carbide
SIMOX	Separation by IMplantation of Oxygen, SOI wafer produced by oxygen implantation and anneal
SiO	Silicon monoxide
SIMS	Secondary Ion Mass Spectroscopy; a method for measuring impurities based on mass spectrometry of ions generated from the sample through ion bombardment
SIRM	Scanning Infrared Microscope; a scanning optical microscope that uses an infrared laser as light source
slpm	standard-liters-per-minute
SMC	Surface-Mounted Component
SMD	Surface Mount Device
SMT	Surface Mount Technology
SO	Small Outline package
SOC	System On Chip
SOI	Silicon On Insulator, a silicon wafer with a sandwich structure
SOS	Silicon On Sapphire
SOT	Small Outline Transistor
SPM	Scanning Probe Microscope

SPV	Surface PhotoVoltage, one method to measure minority carrier recombination lifetime
SRP	Spreading Resistance Profiling, a method to measure resistivity profiles in small scale
SSIS	Scanning Surface Inspection System; automated instruments for the optical inspection of the quality of polished surfaces
SSOP	Shrink Small Outline Package
SSP	Single Side Polished
STIR	Site TIR
TIR	Total Indicator Reading, a term used to define silicon wafer global flatness, see SEMI M1
TMAH	TetraMethylAmmonium Hydroxide, in water mixture used as anisotropic etchant of silicon
TO	Transistor Outline package
TPMS	Tire Pressure Measurement System
TQFP	Thin Quad Flat Pack
TSOP	Thin Small Outline Package
TSSOP	Thin Shrink Small Outline Package
TTV	Total Thickness Variation, thickness variation of the wafer measured from several points, in MEMS applications typically <1 μm, see SEMI M1
TXRF	Total reflection X-ray Fluorescence Spectroscopy, a surface metal analysis technique capable of sensitivity down to >10 ¹⁰ at/cm ² (Cu)
UBM	Under-Bump Metallurgy
USOP	Ultra Small Outline Package
UTQFP	Ultra-Thin Quad Flat-Pack
VPD	Vapor Phase Decomposition, a technique where a surface oxide of silicon wafer is dissolved with HF-vapor. Subsequently the residue on the surface is collected with a small chemical droplet traversed over the wafer surface. This method enhances the detection limit of TXRF by factor 10 or more. It is used also together with AAS technique.
W/B	Wire Bonding
WLP	Wafer Level Packaging
ZD	Zero Dislocation

A1.1 DEFINITIONS

Actuator A device performing mechanical work

Anisotropic etch A selective etch that exhibits different etch rate on different crystallographic planes

Annealed wafer A silicon wafer, where a COP-free surface area has been formed through annealing under hydrogen or neutral atmosphere

Anodic bonding A technique to bond silicon to glass under electric field and elevated temperature

Aspect ratio The ratio of the long dimension to one other dimension in two- or three-dimensional structure

Autodoping Appears in epi wafers, a phenomenon where dopant from substrate is incorporated into growing epi layer

Backseal Silicon dioxide (typically LTO) film, which is preventing dopant outgassing from the back surface, used in heavily doped wafers, reduces autodoping

- BioMEMS** MEMS for biological, biomedical or analytical applications
- Bosch process** A DRIE technology to achieve high aspect ratio etching, developed at Bosch
- Bow** Shape error of silicon wafer; distance of the center-point of the unclamped wafer to the reference plane formed by three equally spaced support points near the periphery of the wafer. Typical values for the 150 and 200 mm wafers are below 30 μm
- Buckling** Collapse of mechanical structure due to excessive compressive stresses
- Bulge test** A method for determining material properties of thin films based on the deflection of the film caused by uniform pressure
- Compressive stress** Axial stress producing a shortening of the body
- Crow's foot** Small + shape crack on 100-wafers and Y-shape crack on 111-wafers, coming typically from hard contact between wafer and point-like object
- Crystallographic orientations, conventions of notation** In notation distinction is made between planes and directions with different types of bracket:
- Plane (100)
- Family of planes {100}
- Direction [100]
- Family of directions $\langle 100 \rangle$
- Denuded zone** A zone near the wafer surface, where oxygen is diffused out through thermal treatments and BMD concentration is close to zero
- Dimple** A shallow round depression on a wafer surface, large dimples can be seen visually under suitable illumination
- Dislocation** A linear crystal lattice defect; a moving dislocation causes translation of the lattice parts, dislocation content in a good silicon wafer should be zero
- Dislocation etch pit** An etch pit is formed on the preferentially etched wafer surface where dislocation is coming to the surface
- Dopant striation rings** Circular features seen on heavily doped wafer surfaces coming from dopant variations along the axis of a silicon crystal. Especially in heavily boron doped wafers striation rings can be visible
- Eddy current gauge** An instrument for measuring the resistivity of a bulk material
- Elastic deformation** Reversible change in the shape of a body subject to stress
- Ellipsometry** An optical technique for measuring optical and structural properties of thin films
- Eltran** SOI wafer produced using porous silicon for layer transfer, trade mark of Canon
- Epitaxial layer** A single crystalline layer of element(s) grown on a single crystalline substrate; the orientation of the substrate is copied on the growing layer
- Etch stop** A layer or interface in the structure stopping etching (for instance P + layer stopping alkaline etching)
- Eutectic bonding** A technique to join materials with a metal alloy having lower melting temperature, e.g., silicon-to-silicon using a gold alloy melting at low temperature
- Fabry–Perot interferometer** An optical interferometer consisting of two parallel, highly reflective mirrors; also called an etalon
- Flatness** A deviation of the wafer front surface from the ideal reference plane; there are several ways to express the wafer flatness, it can be local (site) or global flatness and there are several ways to specify reference plane. SEMI M1, Appendix 1 discusses various specifications
- Flexural rigidity** Force couple required to bend a rigid structure to a unit curvature
- Four point probe** An instrument for measuring the resistivity of a material
- Fracture toughness** A parameter describing the strength of bonding between wafers
- Gettering** A method to immobilize impurities and make them inactive. In silicon technology, gettering can be done with BMD's, with thin films or mechanical damage (polyback, BSD) or with heavily diffused areas (like phosphorus or boron diffusion)
- Glass frit bonding** A technique to bond wafers using glass powder having low melting temperature
- Haze** An area defect on a wafer surface causing light scattering, caused by impurity film; small, dense pits or by microroughness
- Hillock** A hill-like surface defect in wafers
- Interferometer** A displacement measuring instrument based on the interference of coherent light beams
- Lineage** A small angle grain boundary caused by array of dislocations
- Microroughness** Small scale roughness of polished surface
- Mound** A rounded protrusion on the wafer surface, seen especially on an epi wafer; can also have facets
- Nanoindentation** A method of measuring mechanical properties by pressing into the sample a very small hard tip whose mechanical properties are known
- Orange peel** Rough wafer surface seen under suitable illumination with unaided eye, typically results from too low material removal in polishing or from improper polishing conditions
- Phonon** Quantum of lattice vibration in solid matter
- Pit** A depression on a wafer surface. Sides of the pit are more steeply sloped compared to dimple, which has rounded sides
- Plastic deformation** Irreversible change in the shape of a body subject to stress
- Poisson's ratio** A coefficient giving the ratio of the transverse strain (normal to the applied load), to the axial strain (in the direction of the applied load)
- Polyimide** Flexible polymer of imide monomers, used as an adhesive and photoresist

Profilometry Electromechanical or optical techniques for measuring surface topography

Pull-in voltage Voltage that causes electrodes to move into contact in an electrostatically actuated capacitive structure

Raman spectroscopy An optical method used for measuring phonon energies in solid materials

Residual stress Stress that remains in a material or structure after processing, in the absence of external forces or thermal gradients

Resistivity A parameter describing a material's ability to conduct electricity

Sacrificial layer A layer in a multilayer structure that is intentionally removed to release the layers above

Saw mark Surface irregularity left on wafer surface after wafer slicing coming from ID-blade or from wires

Secco etch A chemical etching method for characterizing defects in silicon

Shallow etch pit Similar to pit, but seen only under microscope with higher magnifications, if density of shallow etch pits are high, they can be seen also as a haze

Sheet resistance For a thin film, resistivity divided by layer thickness

Sirtl etch A chemical etching method for characterizing defects in silicon

Slip Dislocation movement causes plastic deformation in a crystal; in silicon wafers are normally arranged on distinct shear planes, which are visible under microscope or with higher deformation with unaided eye

SmartCut Trade mark of Soitec, SOI wafer produced by bonding and layer exfoliation

Sori Originally Japanese definition of shape error, maximum distance above, plus the maximum distance below the front surface best-fit plane of a free, unclamped substrate

Stacking fault A 2-dimensional defect in the crystal, fault in the stacking sequence of the atoms in crystal, in silicon their habit plane is {111}, which means that on (100) wafer surfaces stacking fault lines are in [110] directions

Stiction Unwanted adhesion of moving part to substrate or another moving part

Stoney's formula A formula linking wafer curvature and stress in the thin film deposited onto the wafer

Strain The elongation or compression caused by stress

Strain gauge A device used to measure the strain of an object

Stress Force per unit area

Supercritical drying Drying or cleaning the product with liquefied gas (e.g., CO₂) at a pressure above the triple point

Swirl Small, shallow pits formed in concentric or helical formation of wafer surface, seen after preferential etching, seen visually under collimated light

Taper Error in the wafer shape, thickness variation from edge to edge of a wafer

Tensile stress Axial stress producing an elongation of the body

Warp Error in the wafer shape in free-standing wafer (non-chucked), distance from the lowest point on wafer surface to the highest point

μ-PCD Microwave Photoconductive Decay

Wright etch A chemical etching method for characterizing defects in silicon

Young's modulus Coefficient of elasticity given by the ratio of stress to strain

A1.2 LIST OF SOME COMMONLY USED MEMS RELATED COMPUTATIONAL PROGRAMS

IntelliSuite v8.5

Electrical, piezo-electrical, mechanical, electromagnetic, fluidic and thermal analysis tools for executing linear or nonlinear static or transient analysis

<http://www.intellisensesoftware.com/>

CoventorWare

Integrated toolset for designing MEMS and microfluidic systems, evaluating their performance and optimizing them for manufacturability

<http://www.coventor.com/MEMS.html>

MEMS Pro v6.0

CAD tool suite for the design and analysis of MEMS in mechanical, thermal, magnetic, fluidic, optical, and electrostatic domains including their associated electronics and packaging

http://www.softmems.com/mems_pro.html

Materials Explorer 4.0

Modeling and analytical capabilities for the full spectrum of molecular dynamics

http://www.computers.us.fujitsu.com/www/products_bioscience.shtml?products/bioscience/materials_explorer