Appendix 1

Common Abbreviations and Acronyms

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

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	LSE	Latex Sphere Equivalent, reference for particle size	ppma	parts-per-million-atomic

		CDV			
ppta poep	parts-per-trillion-atomic	SPV	Surface PhotoVoltage, one method to measure		
PQFP PSD	Plastic Quad Flat Pack Power Spectral Density function	SRP	minority carrier recombination lifetime Spreading Resistance Profiling, a method to		
PSI	Phase Shifting Interferometry, an interferometric	SKr	measure resistivity profiles in small scale		
131	method for measuring surface topography	SSIS	Scanning Surface Inspection System; automated		
PUA	Percent Usable Area	3313	instruments for the optical inspection of the quality		
PWA	Printed Wiring Assembly		of polished surfaces		
PWB	Printed Wiring Assembly Printed Wiring Board	SSOP	Shrink Small Outline Package		
PV	PhotoVoltaics	SSP	Single Side Polished		
P/V	Peak to Valley, for example, in roughness	STIR	Site TIR		
r/v	measurements	TIR	Total Indicator Reading, a term used to define		
QFP	Ouad Flat Pack	IIK	silicon wafer global flatness, see SEMI M1		
QSOP	Quarter Size Outline Package	TMAH	TetraMethylAmmonium Hydroxide, in water		
Ra	Rayleigh number	IMAII	mixture used as anisotropic etchant of silicon		
Ra Ra	Average value of surface roughness	TO	Transistor Outline package		
RFID	Radio Frequency IDentification	TPMS	Tire Pressure Measurement System		
RGA	Residual Gas Analysis	TQFP	Thin Quad Flat Pack		
RMF	Rotating Magnetic Field	TSOP	Thin Small Outline Package		
Rms	Root mean square	TSSOP	Thin Shrink Small Outline Package		
ROG	Radial Oxygen Gradient, radial variation of oxygen	TTV	Total Thickness Variation, thickness variation of the		
ROG	in silicon wafers	117	wafer measured from several points, in MEMS		
rpm	revolutions-per-minute		applications typically <1 μm, see SEMI M1		
RRG	Radial Resistivity Gradient, radial variation of	TXRF	Total reflection X-ray Fluorescence Spectroscopy, a		
KKG	resistivity in silicon wafers	12111	surface metal analysis technique capable of		
Rq	Root-mean-square value of surface roughness		sensitivity down to >10 ¹⁰ at/cm ² (Cu)		
RT	Room Temperature	UBM	Under-Bump Metallurgy		
RTA	Rapid Thermal Anneal	USOP	Ultra Small Outline Package		
SAW	Surface Acoustic Wave	UTQFP	Ultra-Thin Quad Flat-Pack		
SBIR	Site flatness, back side reference	VPD	Vapor Phase Decomposition, a technique where a		
SC	SuperConducting		surface oxide of silicon wafer is dissolved with HF-		
SCP	Single Chip Package		vapor. Subsequently the residue on the surface is		
SD	Small Dual in-line package		collected with a small chemical droplet traversed		
SEMI	Semiconductor Equipment and Materials		over the wafer surface. This method enhances the		
	International		detection limit of TXRF by factor 10 or more. It is		
SFQR	A term to define local flatness of a silicon wafer, front		used also together with AAS technique.		
	reference, a most commonly used site flatness	W/B	Wire Bonding		
	definition, see SEMI M1	WLP	Wafer Level Packaging		
SiC	Silicon Carbide	ZD	Zero Dislocation		
SIMOX	Separation by IMplantation of Oxygen, SOI wafer				
	produced by oxygen implantation and anneal				
SiO	Silicon monoxide	A1.1 DEFINITIONS			
SIMS	Secondary Ion Mass Spectroscopy; a method for				
	measuring impurities based on mass spectrometry of		device performing mechanical work		
	ions generated from the sample through ion	_	etch A selective etch that exhibits different		
	bombardment		on different crystallographic planes		
SIRM	Scanning Infrared Microscope; a scanning optical	Annealed wafer A silicon wafer, where a COP-			
	microscope that uses an infrared laser as light source	surface a	area has been formed through annealing under		
slpm	standard-liters-per-minute	hydrogen or neutral atmosphere			
SMC	Surface-Mounted Component	Anodic bonding A technique to bond silicon to glass			
SMD	Surface Mount Device	under electric field and elevated temperature			
SMT	Surface Mount Technology	Aspect ratio The ratio of the long dimension to one other			
SO	Small Outline package	dimension in two- or three-dimensional structure			
SOC	System On Chip	Autodoping Appears in epi wafers, a phenomenon where dop-			
SOI	Silicon On Insulator, a silicon wafer with a	ant from substrate is incorporated into growing epi layer			
202	sandwich structure				
SOS	Silicon On Sapphire		Backseal Silicon dioxide (typically LTO) film, which is		
SOT	Small Outline Transistor	_	ng dopant outgassing from the back surface,		
SPM	Scanning Probe Microscope	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 centerpoint 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 Yshape 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 (100)

- 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
- Flexular 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 laver 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

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

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