APPENDIX A
SILICON TECHNOLOGY TERMS AND DEFINITION

Conductivity type – defines the nature of the majority of the carriers in silicon: n-type material, in which electrons are the majority carrier, is formed when a donor dopant impurity is added to the silicon: p-type material, in which holes are the majority carrier, is formed when an acceptor dopant impurity is added to the silicon.

Crystal orientation – the crystallographic axis, described in terms of its Miller indices, on which the silicon crystal is grown. Commercial silicon is generally supplied in [100] or [111] orientations.

Pattern shift – when the image of the step in an epitaxial layer deposited over a buried layer is examined, it is sometimes found that its position is shifted relative to its position in the buried layer (become distorted).

Flat orientation (primary) – the crystallographic plane, described in terms of its Miller indices, which ideally coincides with the surface of the primary flat. In silicon, the primary flat is usually a [110] plane.

Resistivity (ohm.cm) – the ratio of the potential gradient (electric field) parallel with the current to the current density. In silicon, the resistivity is controlled by adding dopant impurities; lower resistivity is achieved by adding more dopant.

Subsurface damage – residual crystallographic imperfections apparent only after preferential etching of the polished silicon surface. Such damage is usually considered to be caused by mechanical processing of the wafer.

Wafer orientation – the crystallographic plane, described in terms of its Miller indices, with which the surface of the wafer is ideally coincident. Generally, the surface of the wafer correspondance within a few degrees with the low index plane perpendicular to the growth axis. In such cases, the orientation may also be described in terms of the angular deviation α of the low-index crystallographic plane from the polished wafer surface.

Bow – a measure of concave or convex deformation of the median surface of the wafer, independent of any thickness variation which may be present. Bow is determined at the center point of the wafer with respect to a reference plane determined by three points equally spaced on a circle whose diameter is 6.35mm less than the nominal wafer diameter. Bow is a bulk property of the wafer, not a property of an exposed surface. Generally, bow is determined with the wafer in a free, unclamped position. (Not to be confused with warp.)

Diameter – the linear distance across a circular silicon wafer which includes the wafer center and excludes any flats or other peripheral fiducial areas.

Edge contour – the cross sectional profile of a wafer edge shaped by grinding or etching. Edges may be either rounded or beveled.

Flatness - for wafer surfaces, the deviation of the front surface, expressed as TIR or maximum FPD, relative to a specified reference plane when the back surface of the wafer is ideally flat, as when pulled down by vacuum onto an ideally clean flat chuck. The flatness of a wafer may be described as:

1. the global flatness, or
2. the maximum value of site flatness as measured on all sites, or
3. the percentage of sites which have a site flatness equal to or less than a specified value.

Flatness quality area – that portion of the surface of a wafer over which the specified flatness value apply. The flatness quality area is most frequently defined with an edge exclusive area, a peripheral annulus usually 3mm wide.

Focal plane – the plane perpendicular to the optical axis of an imaging system which contains the focal point of the imaging system.

Focal plane deviation (FPD) – the distance parallel to the optical axis from a point on the wafer surface to the focal plane.

Global flatness – the TIR or maximum FPD within the flatness quality area relative to a specified reference plane.

Maximum FPD – the largest of the absolute values of the focal plane deviations.

Primary flat – the flat of longest length which is oriented with respect to a specific crystallographic plane. Also known as major flat.

Reference plane – a plane specified by one of the following:

1. three points at specified locations on the front surface of the wafer, or
2. the least squares fit to the front surface of the wafer using all points within the flatness quality area, or
3. the least squares fir to the front surface of the wafer using all points within a site, or
4. an ideal back surface (equivalent to the ideally flat chuck surface that contacts the wafer).

Secondary flat(s) – the flat or flats of a length shorter than that of the primary flat whose angular position with respect to the primary flat identifies the conductivity type and orientation of the wafer. Also known as minor flat.

Site – a rectangular area, on the front surface of the wafer, whose sides are parallel with and perpendicular to the primary flat and whose center falls within the flatness quality area. For this experiment, the site chosen is 20 x 20 mm height and length.

Site flatness – the TIR or maximum FPD of the portion of a site which falls within the flatness quality area.

Thickness – the distance through the wafer between corresponding points on the front and back surfaces.

Total indicator readout (TIR) – the smallest perpendicular distance between two planes, both parallel with the reference plane, which enclose all points within a specified flatness quality area or site on the front surface of a wafer.

Total thickness variation (TTV) - the difference between the maximum and minimum thickness values encountered during a scan pattern or a series of point measurements on a wafer.

Warp – the difference between the maximum and minimum distances of the median surface of the wafer from a reference plane encountered during a scan pattern. Warp is a bulk property of the wafer, not a property of an exposed surface. The median surface may contain regions with upward or downward curvature of both. Generally, warp is determined with the wafer in a free, unclamped position. (Not to be confused with bow.)

Contamination – a broad category of foreign matter visible to the unaided eye on the wafer surface. In most cases, it is removable by gas blow off, detergent wash, or chemical action. See also particulate contamination, stain.

Haze – a cloudy or hazy appearance attributable to light scattering by concentrations of microscope surface irregularities such as pits, mound, small ridges or scratches, particles, etc.

Particulate contamination – a form of contamination comprising particles, such as dust, lint, or other material resting on the surface of the wafer and standing out from the surface. May usually be blown off the surface with clean, dry nitrogen.

Pit- a depression in the surface where the sloped sides of the depression meet the wafer surface in a distinguishable manner (in contrast to the rounded sides of a dimple).

Saw blade defect – a roughened area visible after polishing with a pattern characteristic of the saw blade travel. It may not be discernible before chemical polishing. Also known as saw mark.

Scratch – a shallow groove or cut below the established plane of the surface, with a length-to-width ratio greater than 5:1. A macroscratch is $\leq$0.12 μm in depth and is visible to the unaided eye under both incandescent (narrow-beam) and fluorescent illumination. A microscratch is $<$0.12μm in depth and is not visible to the unaided eye under fluorescent illumination.

LPD / Sparkles – individual fine points of reflected light seen when the wafer is illuminated by a narrow-beam light source held perpendicular to the wafer surface.

APPENDIX B

List of symbols

C	concentration, mol/m^3
DF	driving force, mol/m^3
Ea	activation energy, J/mol
f	a function
G	dimensionless gloss
h	depth defined by local peak and valley on silicon surface, m
K	universal gas constant, J/mol K
k	mass-transfer coefficient or reaction rate constant, m/s
L	total length for roughness measurement, m
MT	mass transfer
R	resistance, s/m
RN	reaction
r	rate of a mechanism or process, mol/m^2s
rl	rate of linear removal, m/s
SC	surface character
T	temperature, K
THK	thickness (phosphoric acid)
t	time, s
x	abscissa, m
Y	dimensionless removal

y	ordinate, m

Greek

Δ	total difference operator
δ	local film thickness, m
Φ	dimensionless roughness
ϕ	roughness, m
η	efficiency
λ	local roughness, m
μ	viscosity, kg/cm s
τ	characteristic time, s
ς	conversion factor, m^3/mol of HF

Subscripts and superscripts

avg	average
b	liquid bulk conditions
bm	critical bubble masking value
eff	effective
f	interfacial (film)
g	gas phase, bubbles
HF	HF

HNO_3	HNO_3
i	a given species
inst	instantaneous
j	a given species
m	mass-transfer
max	maximum
min	minimum
o	overall
p	peaks
pol	polishing
r	reaction
s-l	surface to linear
T	temperature
thk	thickener
v	valleys
δ	local film thickness
μ	viscosity
1	initial condition
2	final condition

NB: multiple subscripts are separated by comma.

APPENDIX C

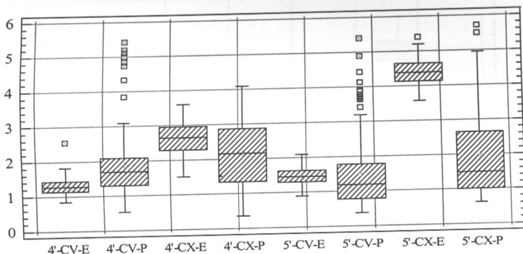

Figure A1 Box plot for TTV

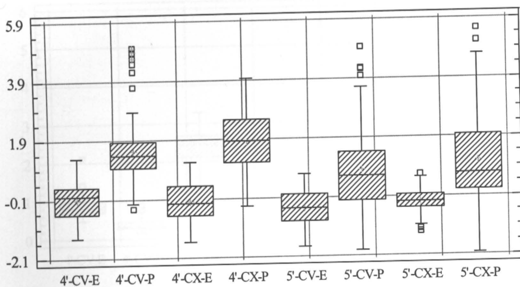

Figure A2 – Box plot for Taper

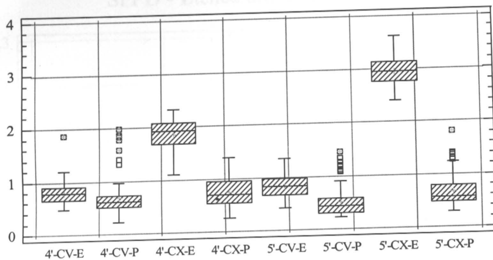

Figure A3 Box plot for STIR

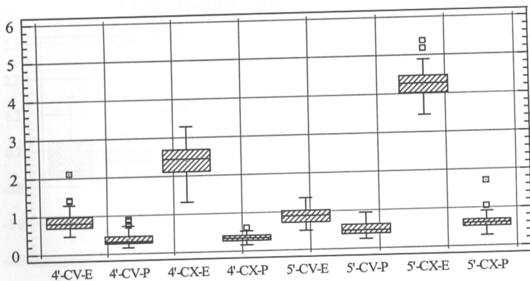

Figure A4 Box plot for TIR

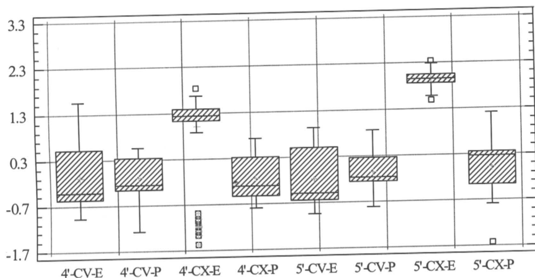

Figure A5 Box plot for SFPD

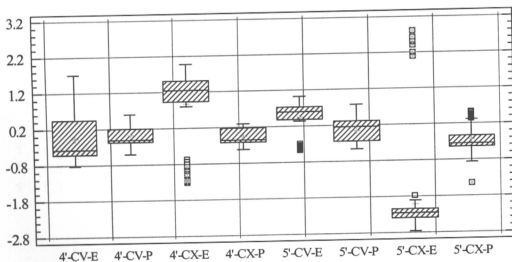

Figure A6 Box plot for FPD

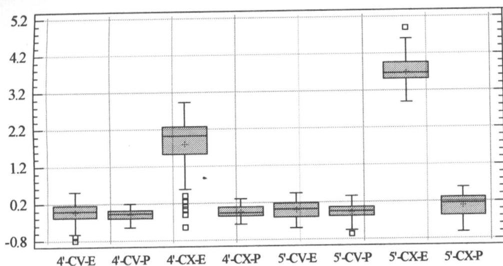

Figure A7 Box plot for Rolloff

Legend

4' – CV – E = 100mm concave etched wafer
4' – CV – P = 100mm polished concave etched wafer
4' – CX – E = 100mm convex etched wafer
4' – CX – P = 100mm polished convex etched wafer

5' – CV – E = 125mm concave etched wafer
5' – CV – P = 125mm polished concave etched wafer
5' – CX – E = 125mm convex etched wafer
5' – CX – P = 125mm polished convex etched wafer