

(Crystal Defect)



(point defect)

intrinsic

vacancy (a)

self interstitial atom (b)

extrinsic

substitutional impurity atom (c)

interstitial impurity atom (d)

dangling bond (e)



(line defect)

dislocation

edge- (f), screw-



(plane defect)

stacking fault

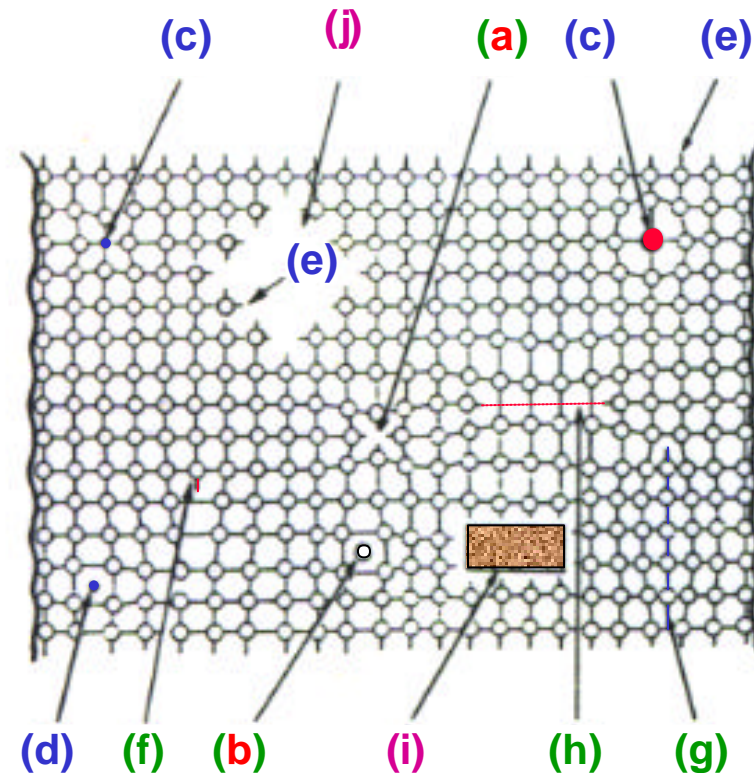
interstitial- (g), vacancy-type (h)

twin, grain boundary

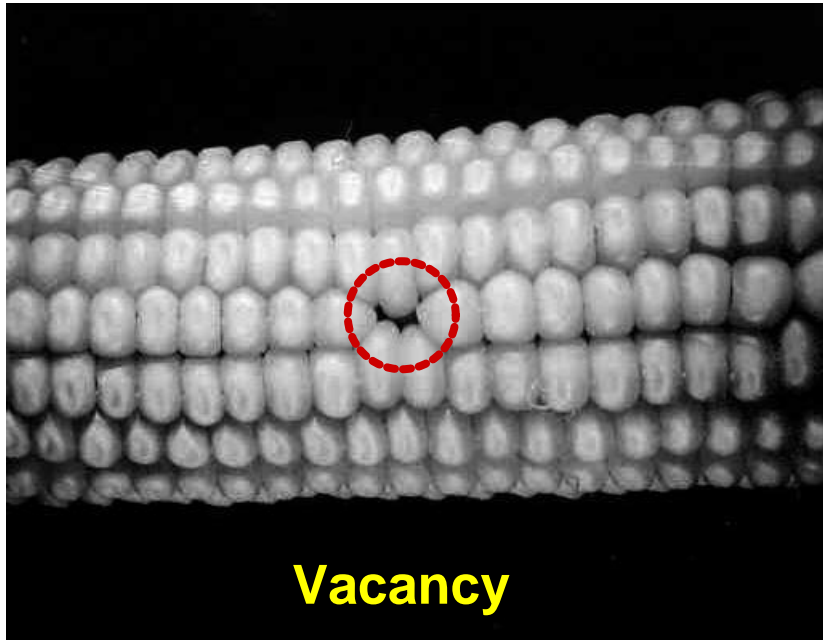


(volume defect)

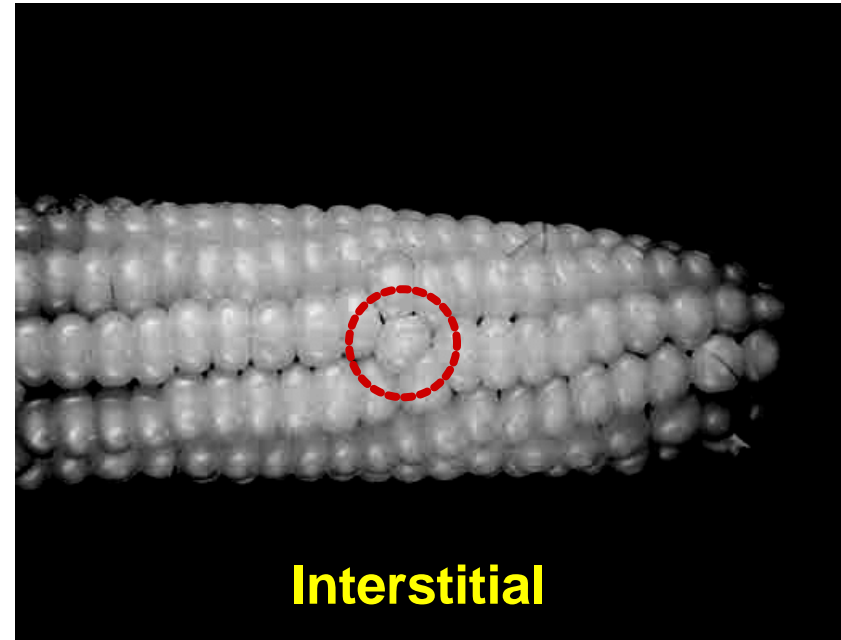
precipitate (i), void (j)



(Point Defect)

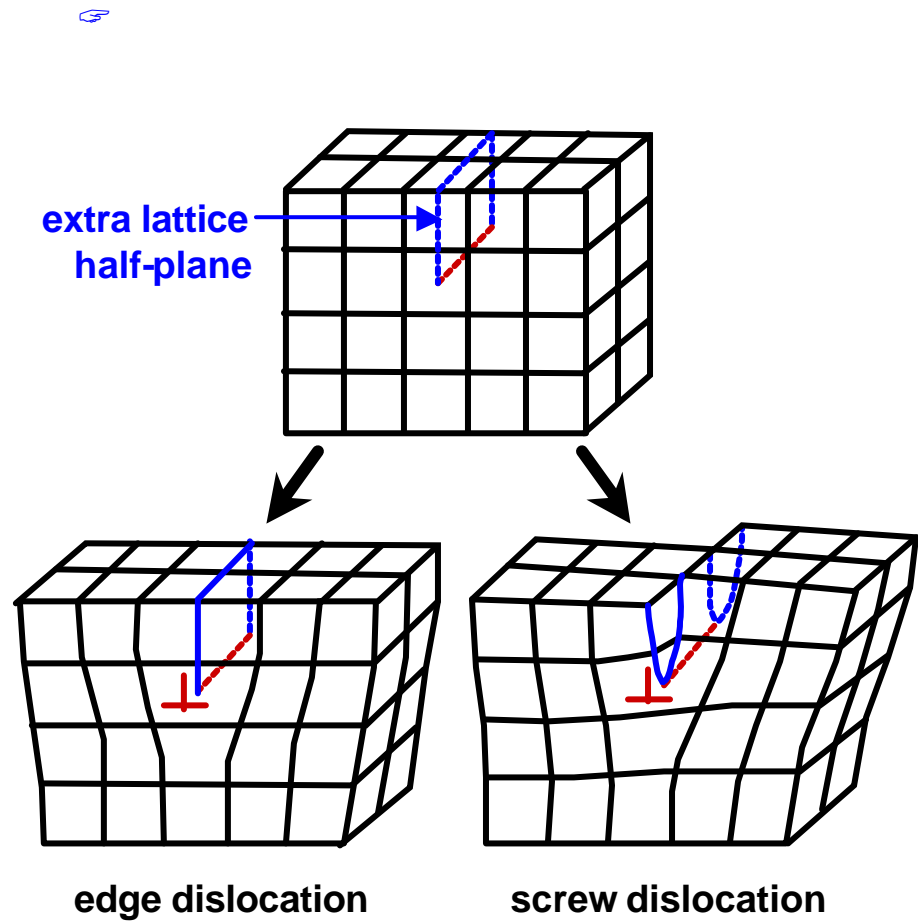
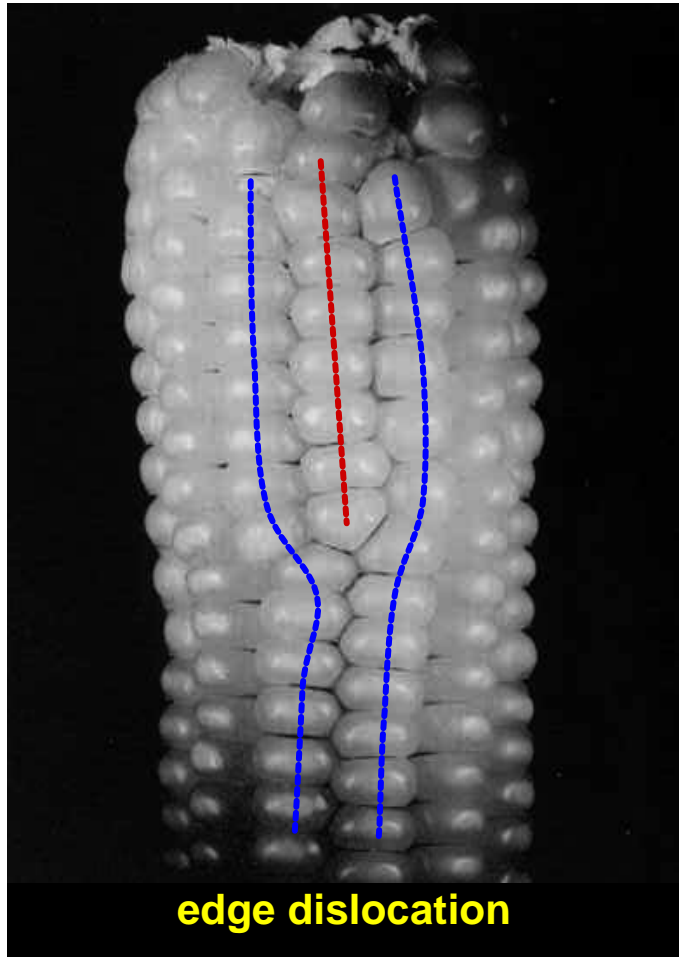


가



가

(Dislocation)



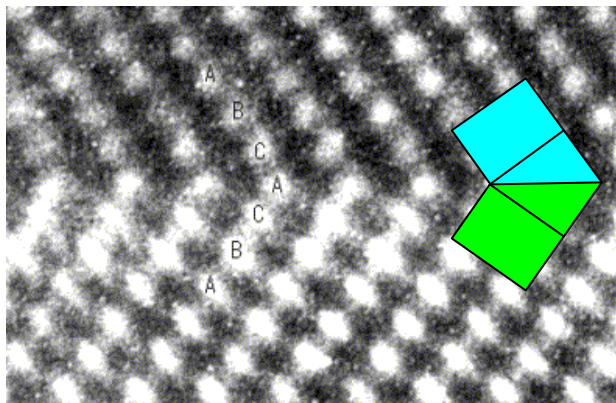


(plane defect)

()

(stacking fault)

(twin)



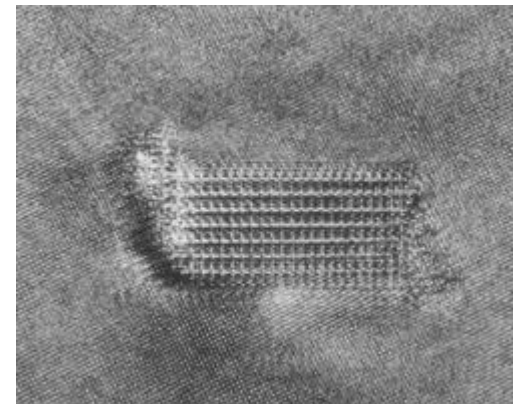
(volume defect)

()

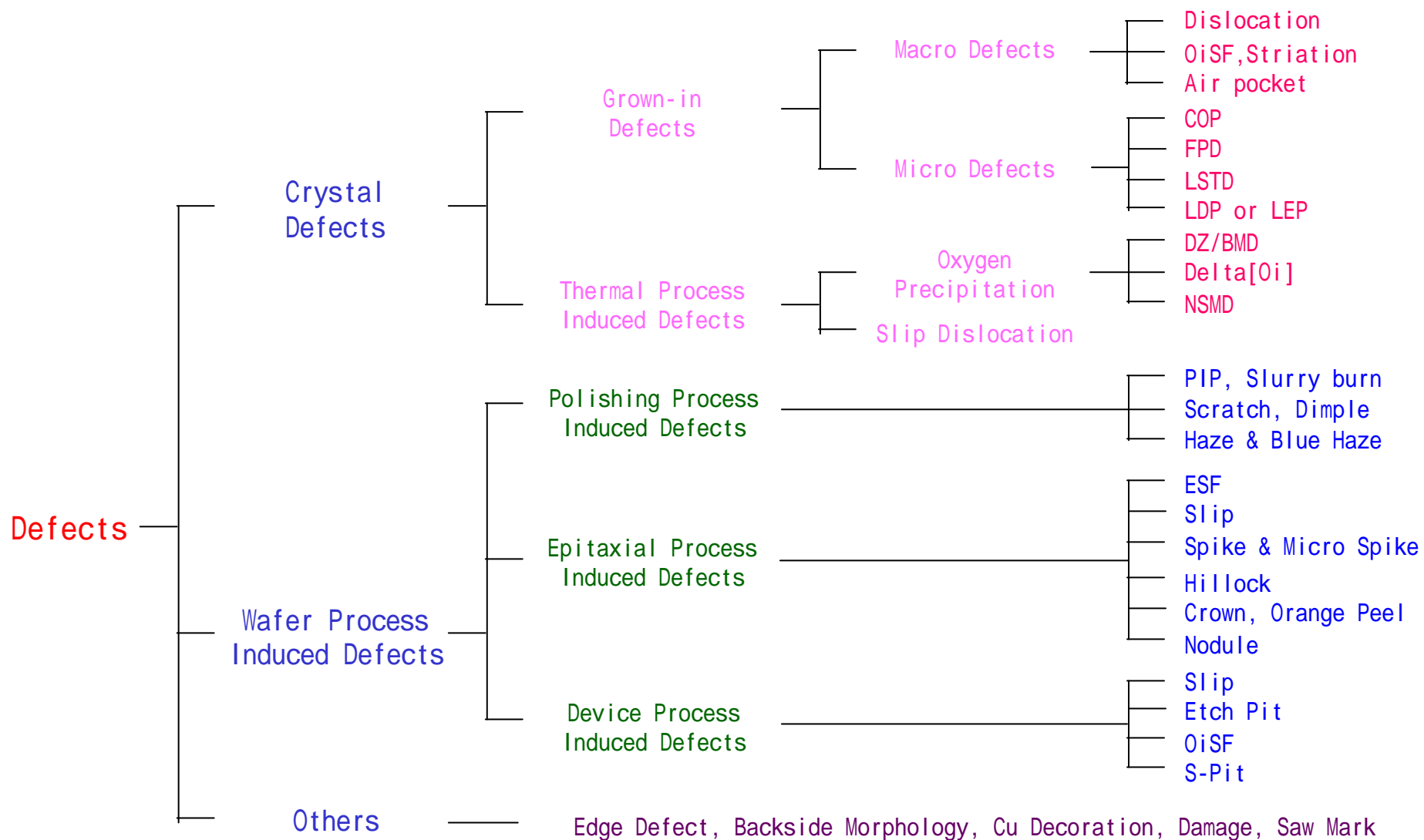
(precipitate)

(void)

(inclusion)



Classification of Defects of Si wafer



1. Crystal Defects

Various Defect Distribution

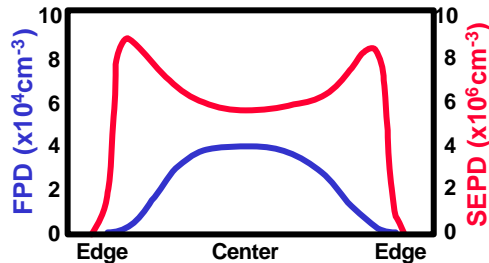
Interstitial-rich region

- LDP
- SEPD
- lower O_i
- lower O_{ppt}
- smaller O_i

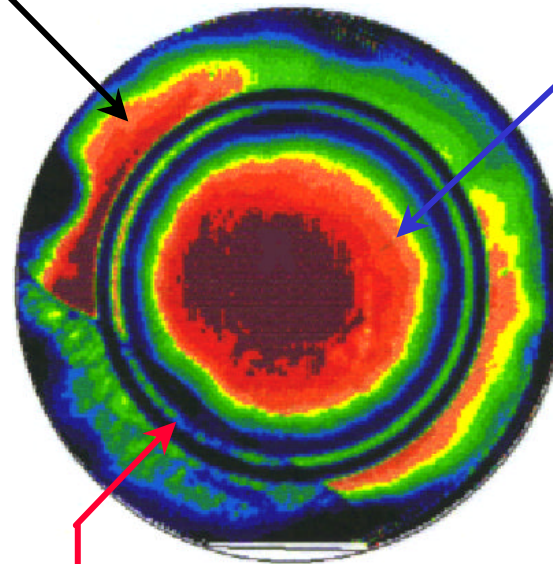
Si-wafer

Vacancy-rich region

- COP
- FPD
- LSTD
- SEPD
- higher O_i
- higher O_{ppt}
- larger O_i



Distribution of FPD & SEPD



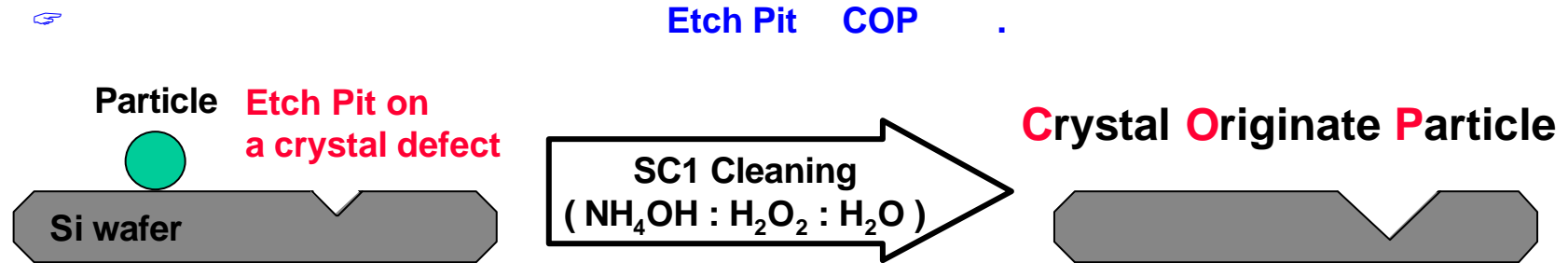
Lifetime mapping (after 2-step heat treatment)

OSF-ring

- low oxygen precipitation after heat treatment

1. Crystal Defects

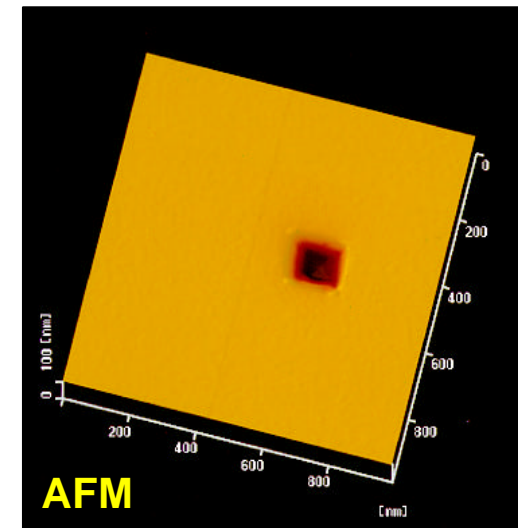
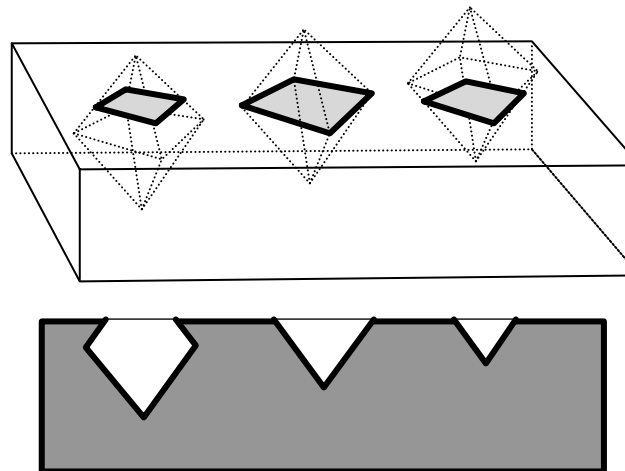
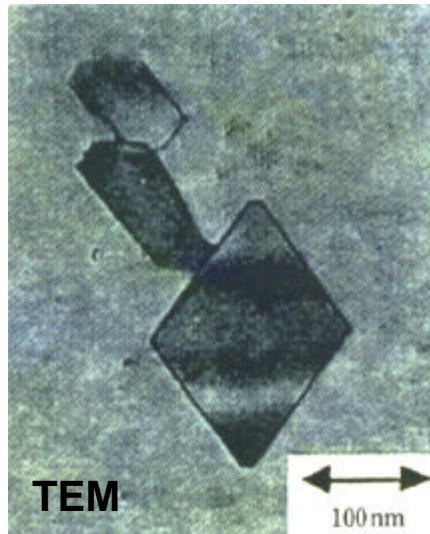
Particle and COP



COP

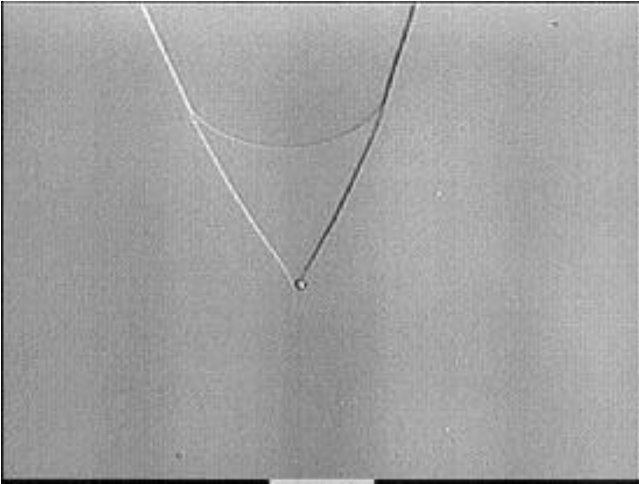
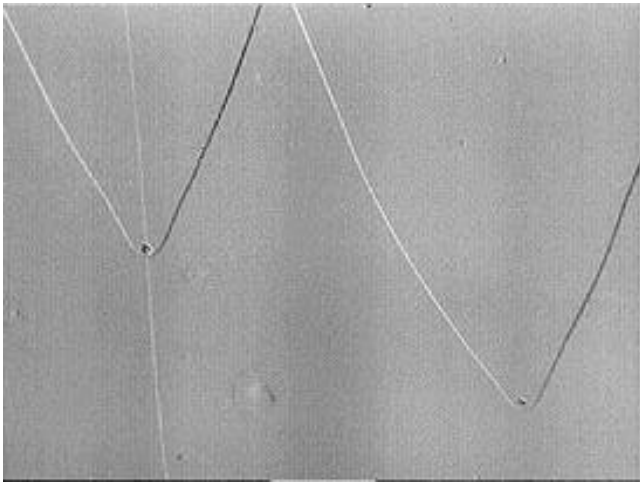
Vacancy가

(Void)



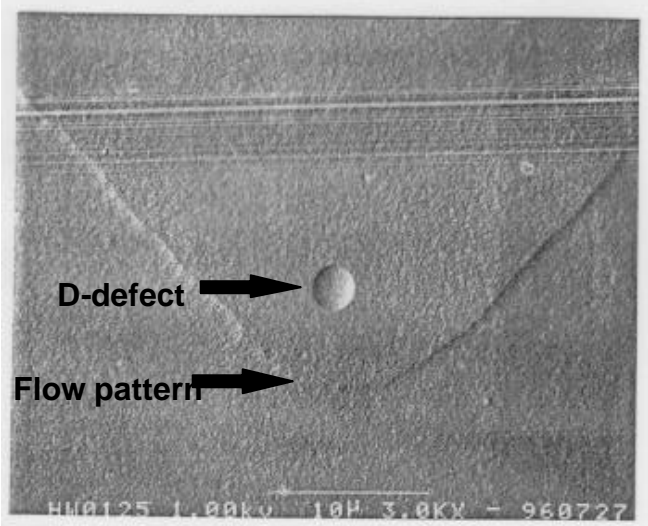
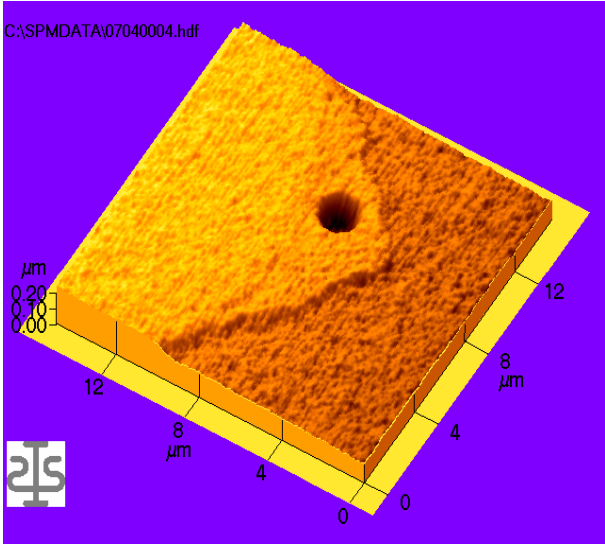
1. Crystal Defects

Grown-in Defects

FPD	
	
Silicon wafer Flow pattern defect(FPD):P08 (Secco 30min, 200X,by Microscope)	Silicon wafer Flow pattern defect(FPD):P08 (Secco 30min, 200X,by Microscope)
Grown-in Defects Secco etching etching Flow pattern defect	etching H2 gas etching

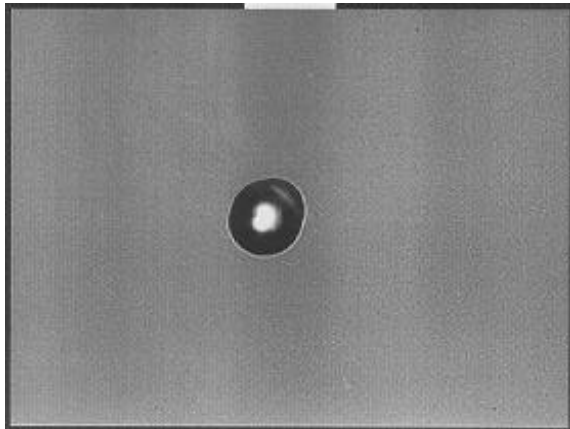
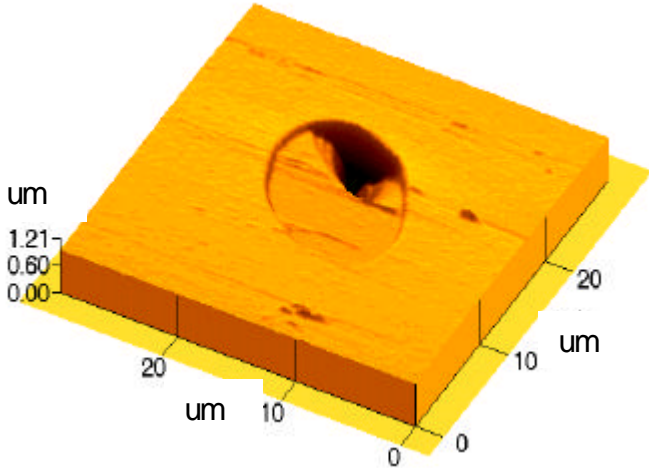
1. Crystal Defects

Grown-in Defects

FPD	
	
Silicon wafer (Secco 30min, 3,000X, by SEM)	Silicon wafer (Secco 30min, by AFM)
FPD etching	Flow pattern
H2가	가
H2 bubble (wafer가	source
D-Defect). Hole	

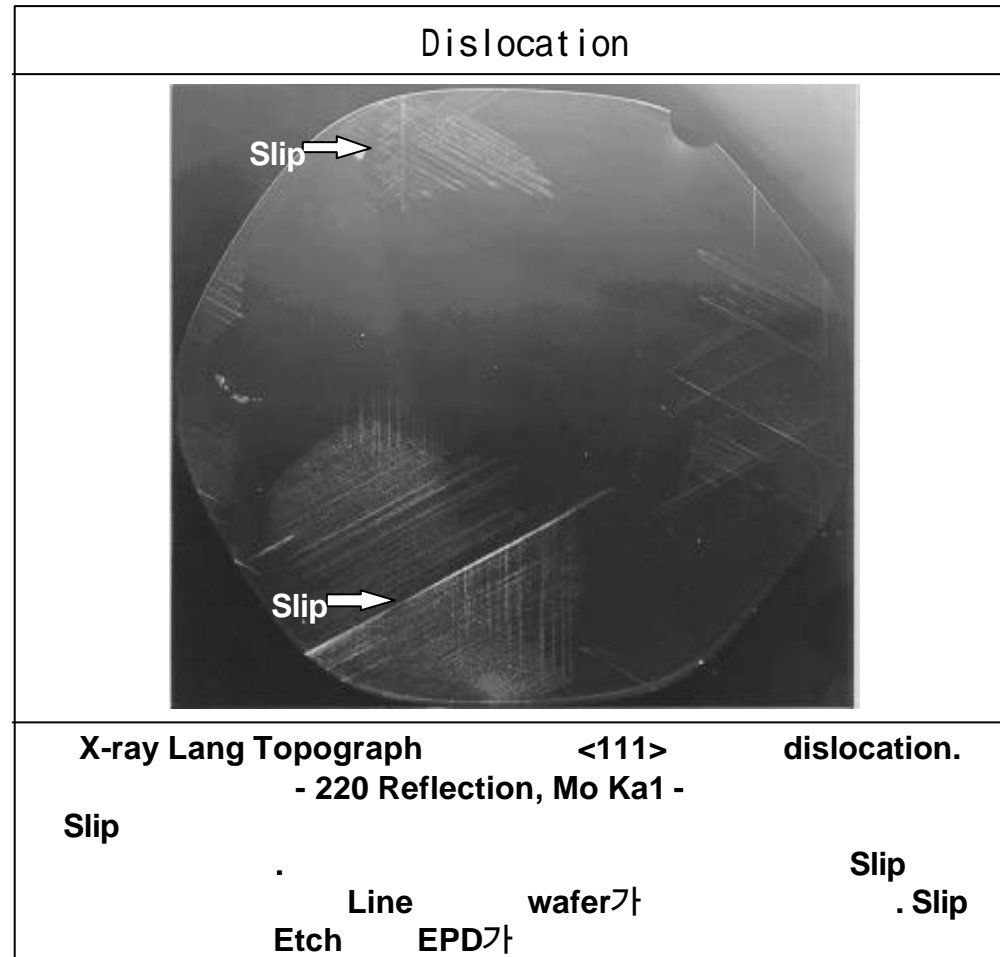
1. Crystal Defects

Grown-in Defects

LDP	
	
Silicon wafer Large dislocation pit(LDP) :P08 (Secco 30min, 500X, by Microscope)	Silicon wafer Large dislocation pit(LDP) :P08 (Secco 30min, by AFM)
Interstitial-Rich dislocation loop	defect dislocation loop defect . Large Secco etching Secco Etch Pit(SEP)

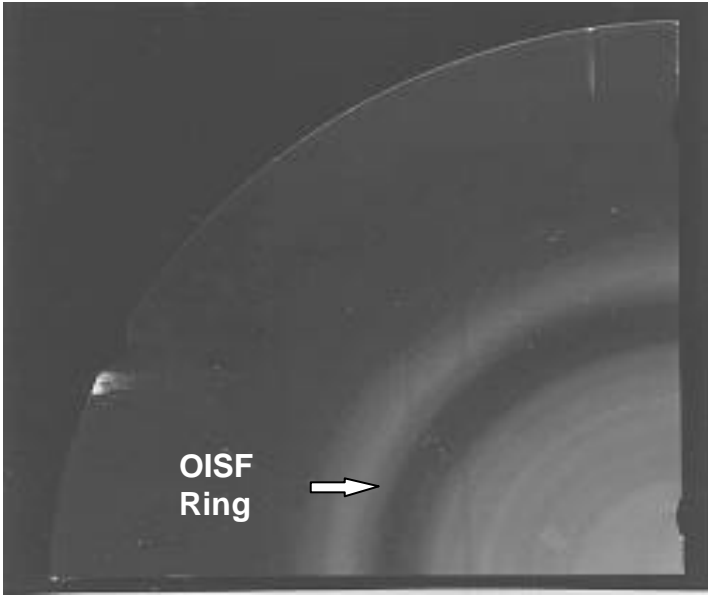
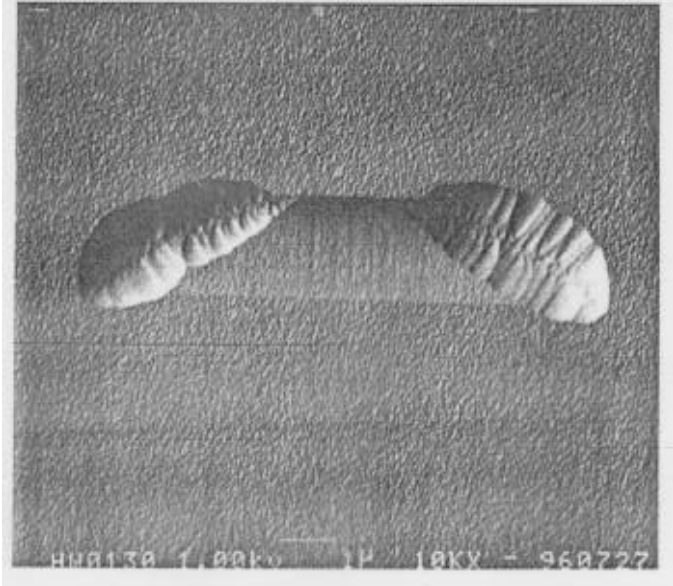
1. Crystal Defects

Grown-in Defects



1. Crystal Defects

Grown-in Defects

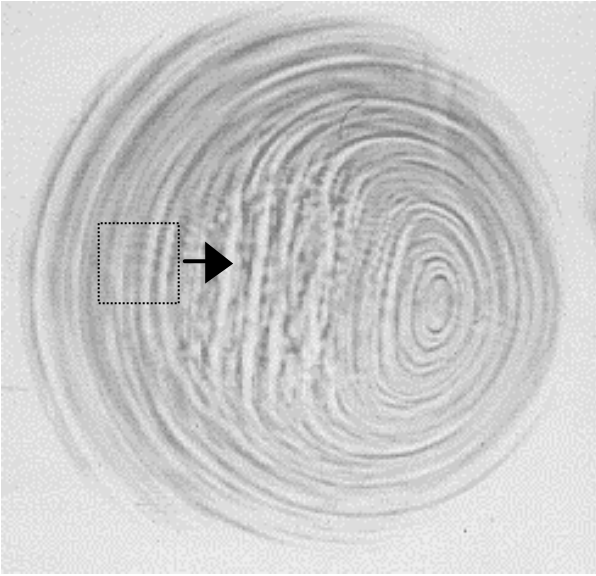
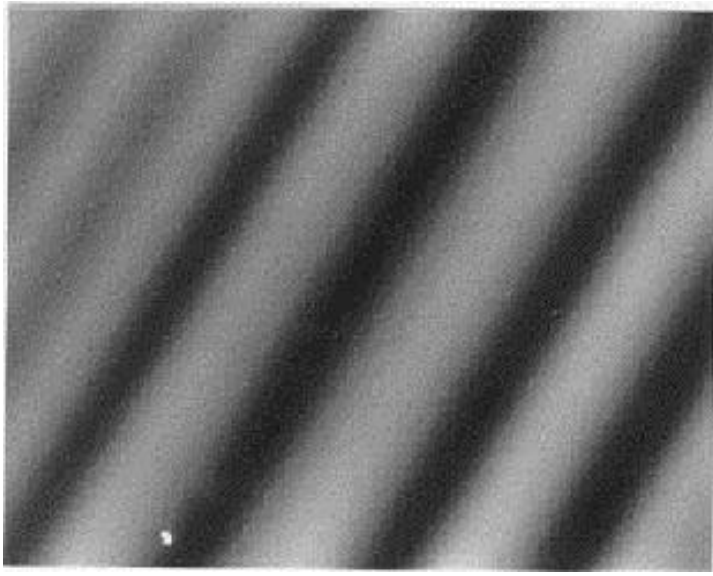
OISF	
	
1100 60 wet oxidation OISF-Ring(P08). (Lang Topo. 220 Reflection, Mo Ka1)	1100 60 wet oxidation etching OISF(P08). (Wright 5min, 10,000X, by SEM)
Damage OISF OISF	가 , OISF Process

1. Crystal Defects

Grown-in Defects

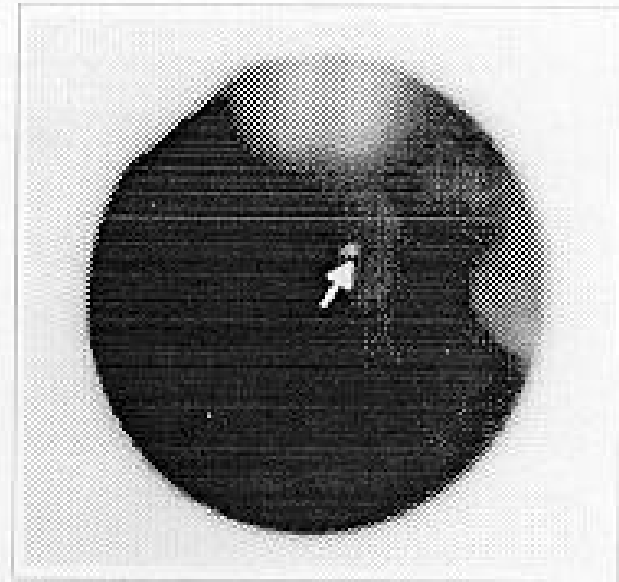
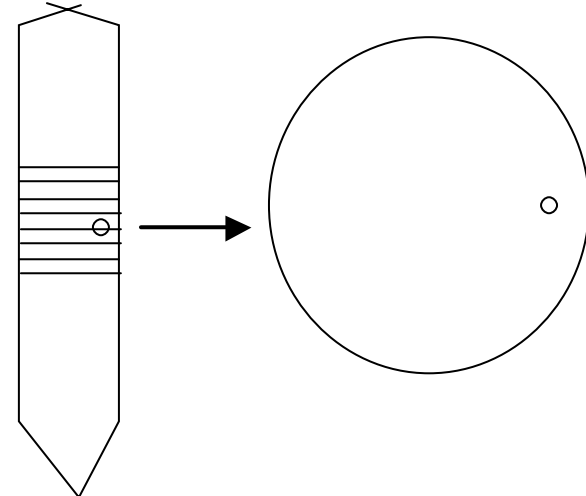
1. Crystal Defects

Grown-in Defects

Dopant Striation	
	
<p>Wright etching Magic mirror Heavily doped wafer Striation pattern</p>	<p>Wright etching Micro scope Heavily doped wafer Striation pattern</p>
<p>Striation pattern ingot Etching Etch rate</p>	<p>dopant .</p>

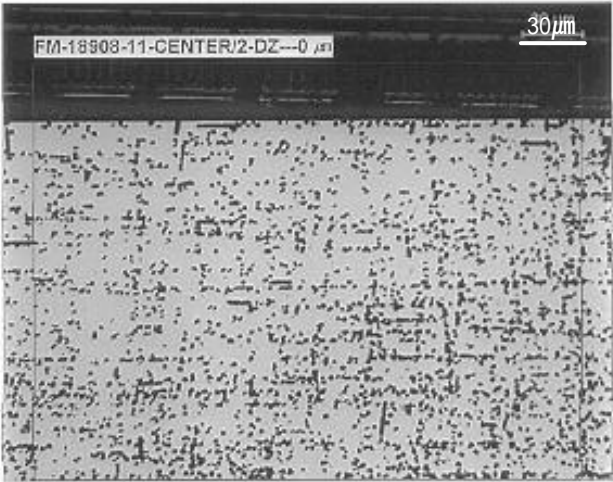
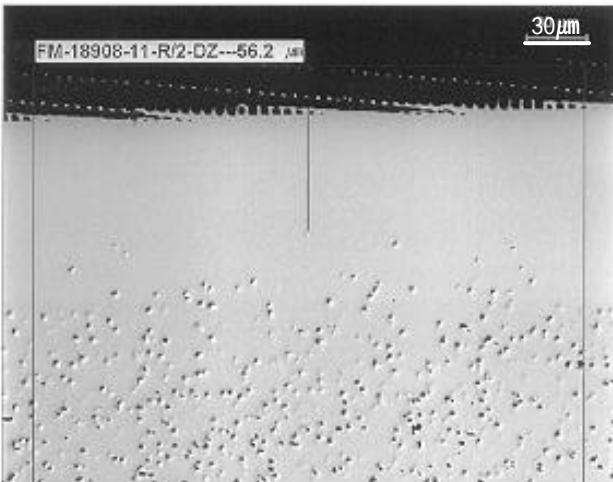
1. Crystal Defects

Grown-in Defects

Air Pocket					
					
mm	Growing . Dimple	Ingot	Air가 Sparkle	Wafer가 Polishing 가 .(Front-side)	Hole

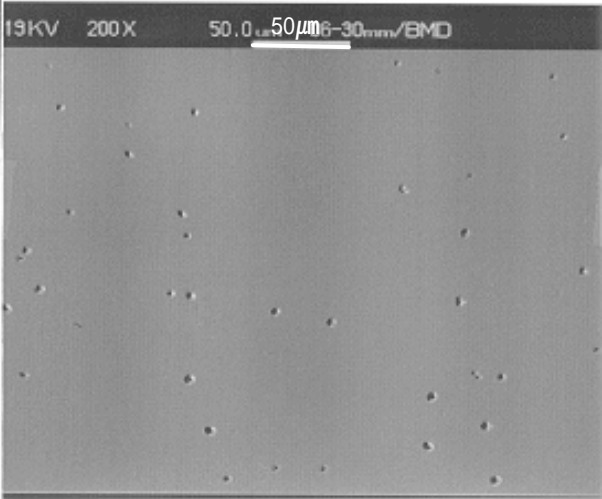
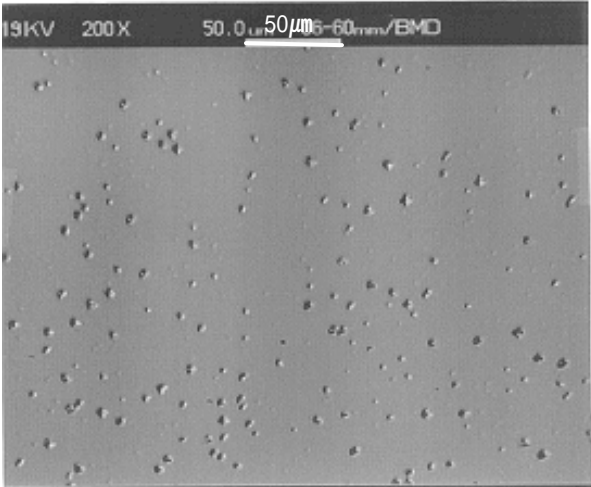
1. Crystal Defects

Thermal process induced defect

	DZ가	DZ가
Morphology		
DZ	0 μm	56.2 μm
<div>etching</div> <div>DZ가 BMD가 , BMD가 Bulk defect Initial[O_i] Delta[O_i] chemical . DZ/BMD가</div> <div>DZ가 .</div>		

1. Crystal Defects

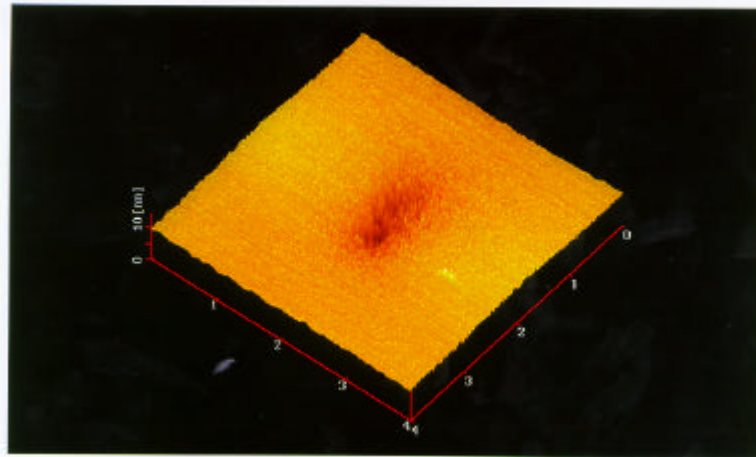
Thermal process induced defect

	BMD가	BMD가
Morphology		
BMD	5.43E4 ea/cm ²	2.64E5 ea/cm ²
<div>wafer bulk defect</div> <div>Gettering parameter .</div> <div>BMD(Bulk Micro Defect) Stacking Fault . BMD Gettering site , Intrinsic</div>		

2. Wafer Defects

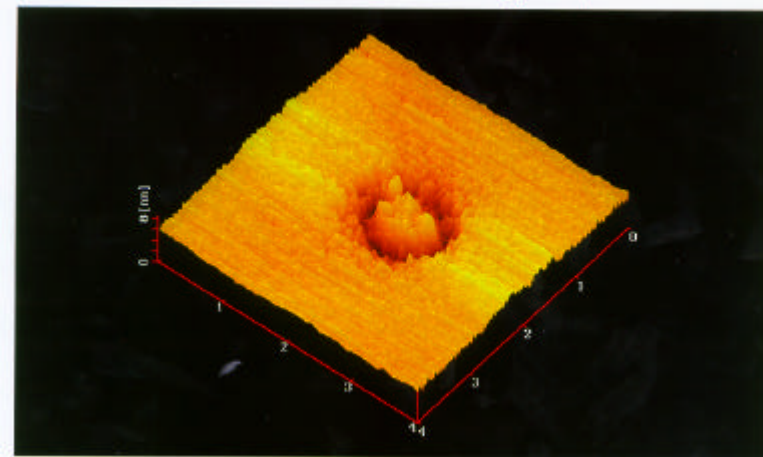
Polishing process induced defect

PIP(Polishing Induced Pit)



Polishing
defect
AFM


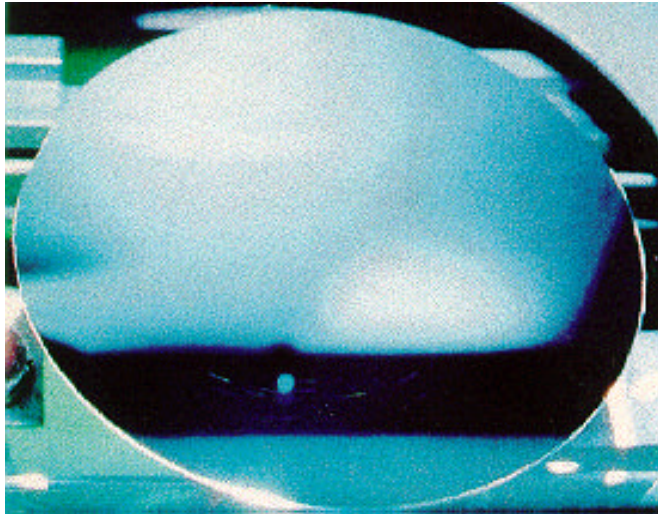
0.12~0.15 μm Damage가
. COP



etching
가

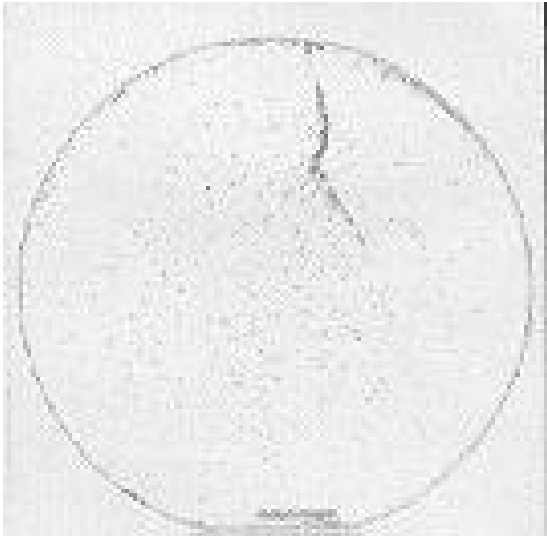
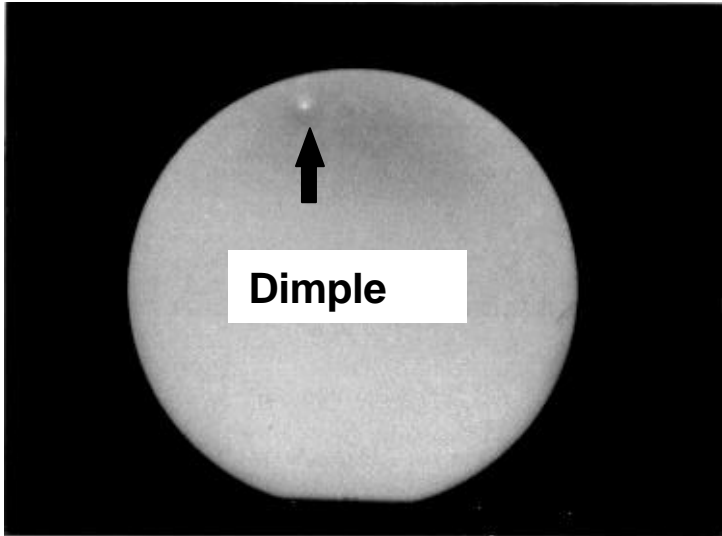
2. Wafer Defects

Polishing process induced defect

Polishing Scratch	Scrubber Scratch
	
<p>Scratch Polishing 가</p> <p>.(Front side)</p>	<p>Wafer PVA Brush 가 , Brush Damage . , NH4OH Fume Blue Haze Defect . (Front & Backside)</p>

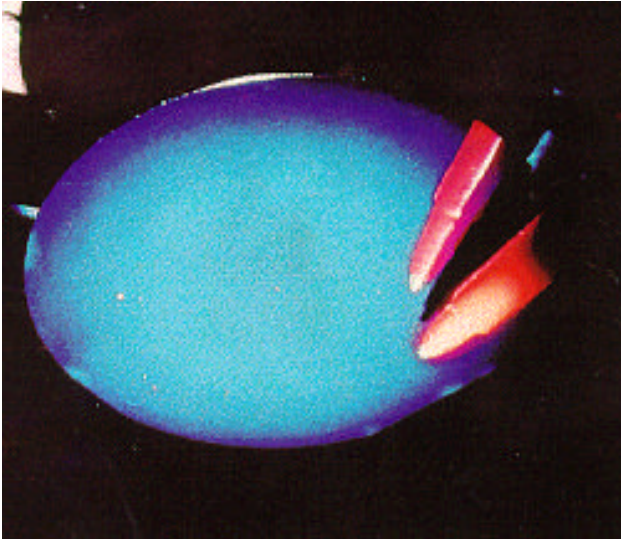
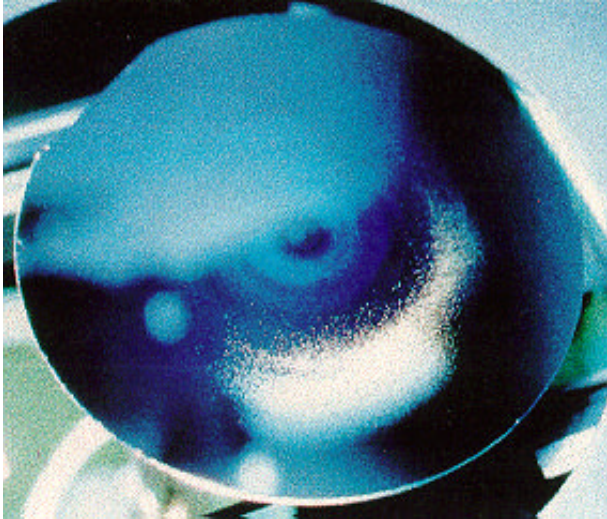
2. Wafer Defects

Polishing process induced defect

Scratch	Dimple
	
<p>Grinding,Lapping,Polishing Pressure Damage가 Polishing Scratch , Front side(Edge Center) .</p>	<p>Polishing depo. Air가 counter Magic mirror 가 Wax . Particle 가 .</p>

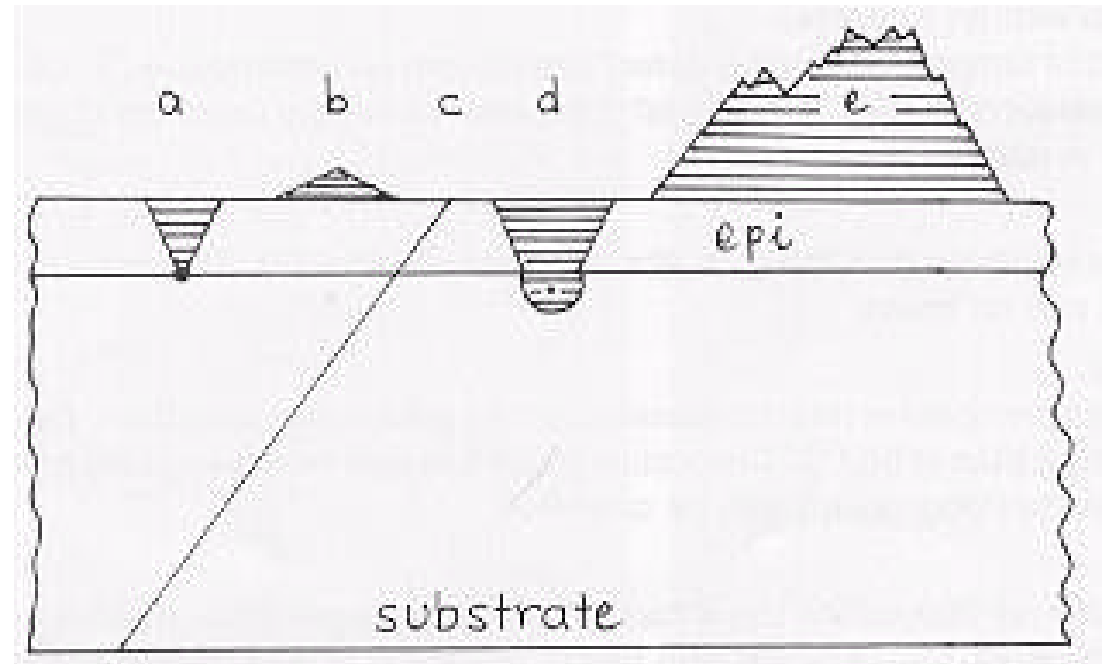
2. Wafer Defects

Polishing process induced defect

Haze	Blue Haze
	
<p>Polishing</p> <p>Magic Mirror</p> <p>Brown</p>	<p>Shipping Box Cleaning ,</p> <p>Clean Room</p> <p>Dot Film</p> <p>Front side</p>

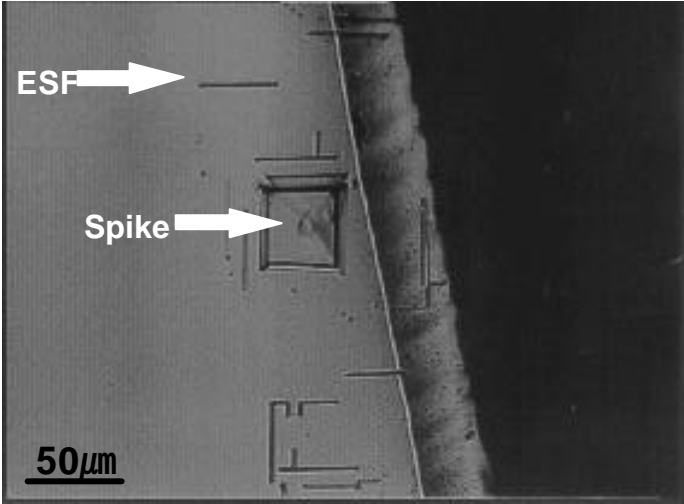
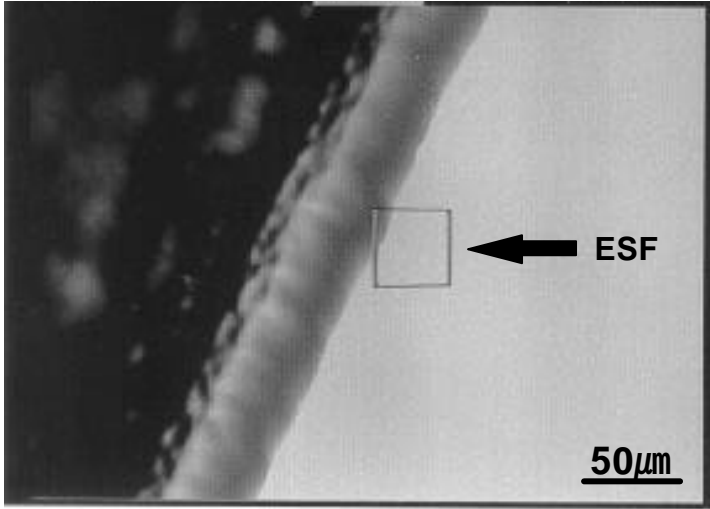
? TYPICAL DEFECTS IN EPI LAYER

- a: Epi stacking fault
- b: Growth hillock
- c: Dislocation
(from the bulk)
- d: Stacking fault
(from the bulk)
- e: Epi spike



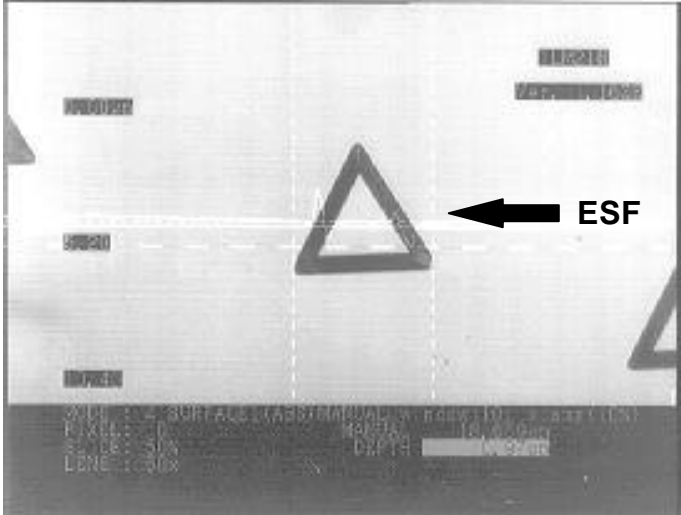
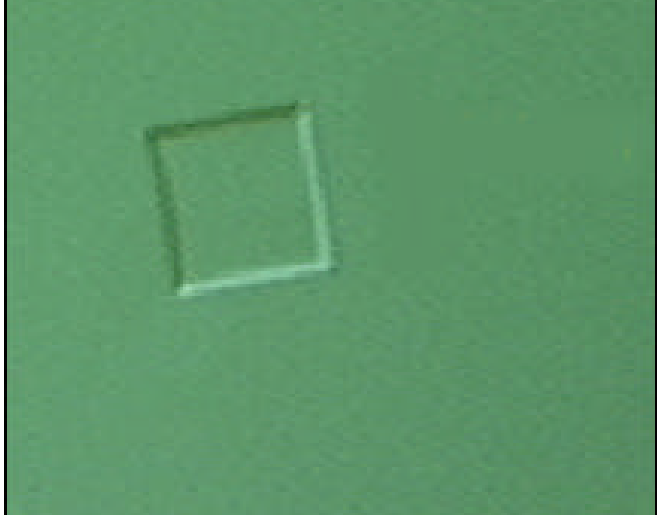
2. Wafer Defects

Epitaxial process induced defect

ESF	
 <p>Micrograph showing the edge of a P-/P+(P06) Epi Wafer. A white arrow labeled 'ESF' points to a horizontal line, and another white arrow labeled 'Spike' points to a rectangular feature. A scale bar in the bottom left corner indicates 50μm.</p>	 <p>Micrograph showing the (100) surface of a P-/P+(P06) Epi Wafer. A black arrow labeled 'ESF' points to a rectangular feature. A scale bar in the bottom right corner indicates 50μm.</p>
<p>P-/P+(P06) Epi Wafer ESF wafer edge (without etching, 200X, by Microscope)</p> <p>ESF Epi spike.</p>	<p>P-/P+(P06) Epi Wafer (100) Epi wafer</p> <p>ESF.</p>

2. Wafer Defects

Epitaxial process induced defect

ESF	ESF
	
<p>(111) Epi wafer ESF. (Without etching, 3,750X, by Laser-microscope)</p>	<p>(100) Epi wafer ESF. ESF , Epi , Damage . Line ESF가 .</p>

2. Wafer Defects

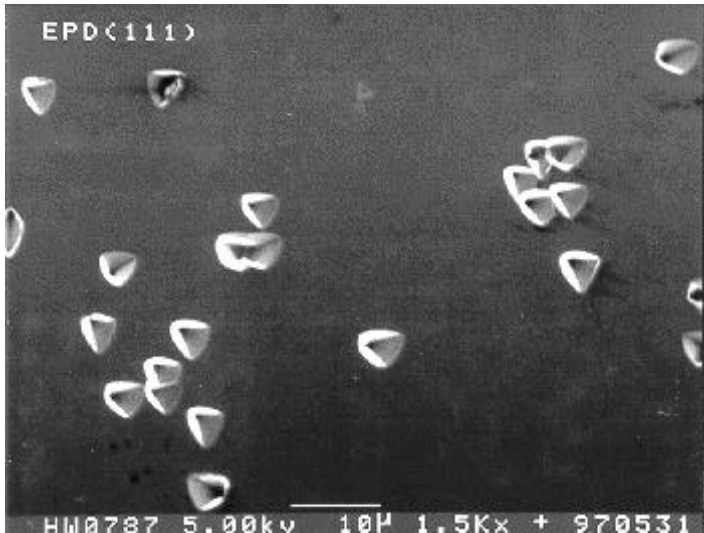
2. Wafer Defects

Slip Dislocation					
<p>Secco Etching</p> <p>EPD →</p> <p>HM0556 5.00kV 10μ 1.2Kx + 980404</p>		<p><u>20μm</u></p>			
P-/P+(P05) Epi wafer (Secco 5min, 1,200X, by SEM)		P-/P+(P05) Epi wafer (Wright 5min, 500X, by Microscope)			
EPD(Etch Pit Dislocation)	Slip	Slip wafer	chemical etching	Pit defect	
.		etching	EPD	.	

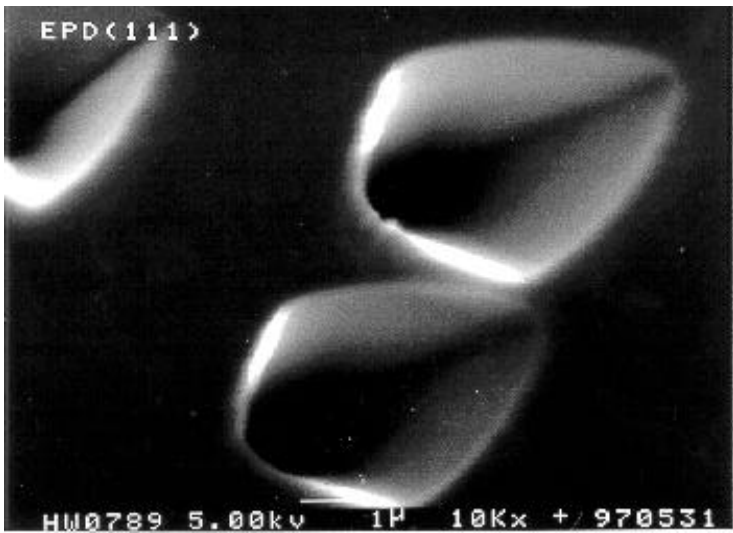
2. Wafer Defects

Epitaxial process induced defect

Slip Dislocation



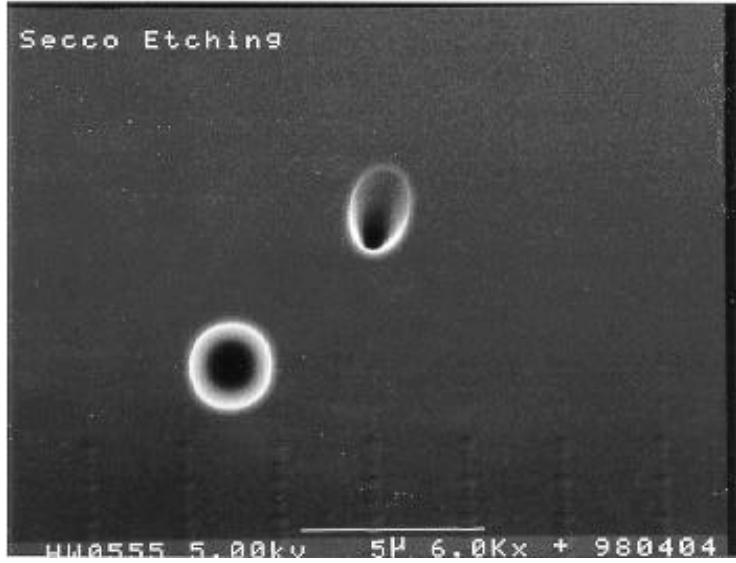
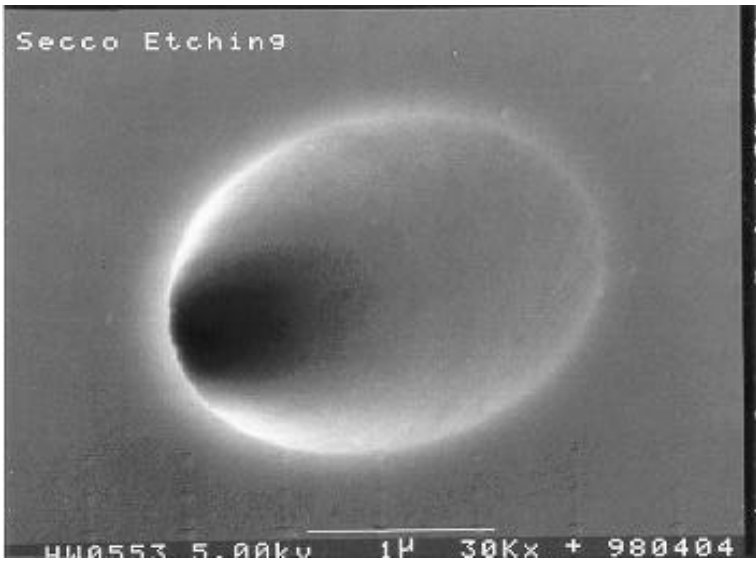
P-/P+(111) Epi wafer EPD.
(Wright 4min, 1,500X, by SEM)



P-/P+(111) Epi wafer EPD.
(Wright 4min, 10,000X, by SEM)

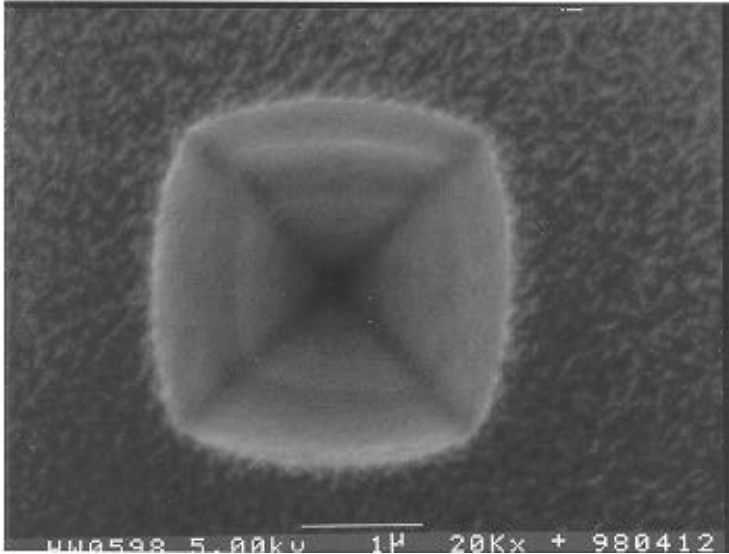
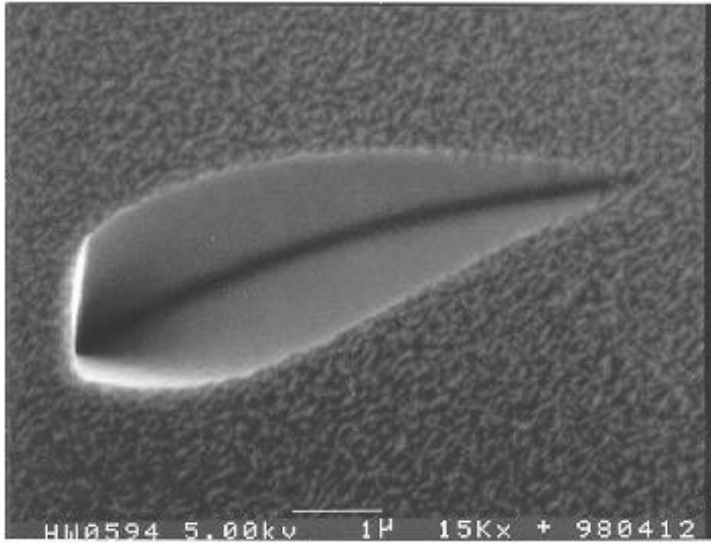
2. Wafer Defects

Epitaxial process induced defect

Slip Dislocation	
	
P-/P+(100) Epi wafer EPD. (Secco 5min, 6,000X, by SEM)	P-/P+(100) Epi wafer EPD. (Secco 5min, 30,000X,by SEM)
EPD Etchant Secco etchant	EPD .


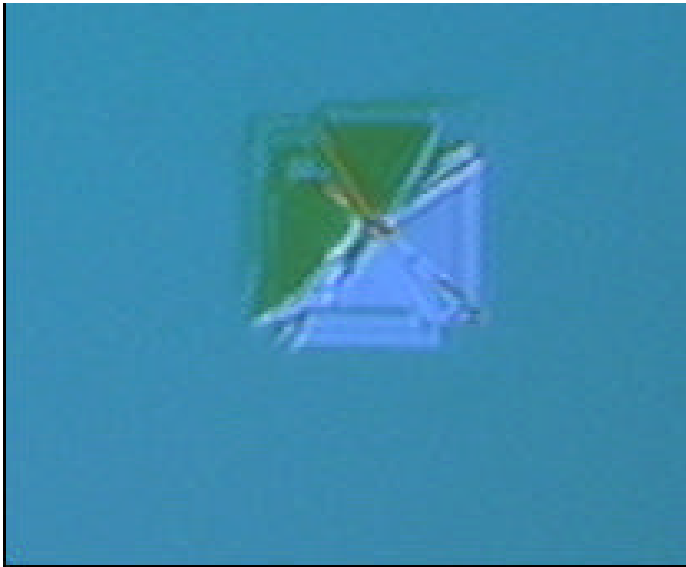
2. Wafer Defects

Epitaxial process induced defect

Slip Dislocation	
	
<p>P-/P+(100) Epi wafer EPD. (Wright 5min, 20,000X, by SEM)</p>	<p>P-/P+(100) Epi wafer EPD. (Wright 5min, 15,000X, by SEM)</p>

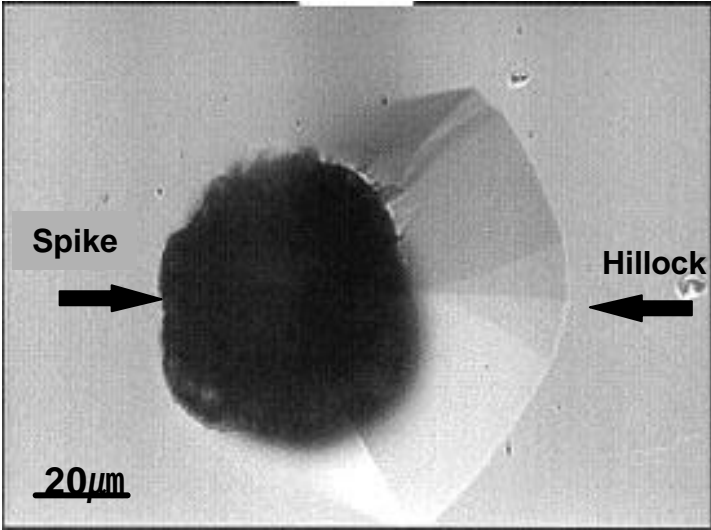

2. Wafer Defects

Epitaxial process induced defect

Spike	Micro spike
	
<div>(111) Spike</div> <div>Epi spike. Substrate Particle Particle .</div> <div>Particle</div> <div>Epi</div>	<div>(100)</div> <div>Epi micro spike(without etching)</div>

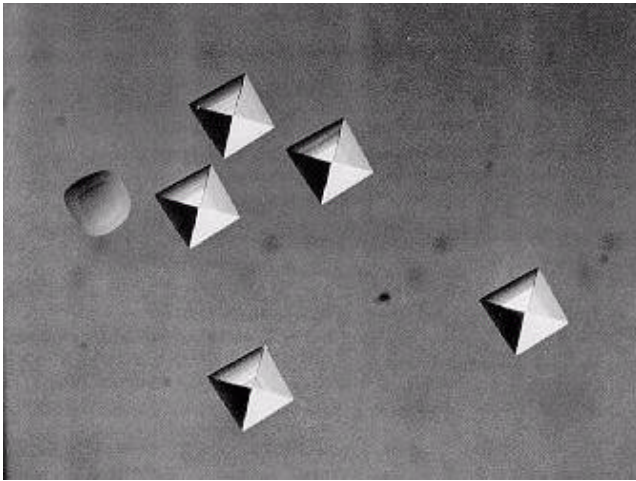
2. Wafer Defects

Epitaxial process induced defect

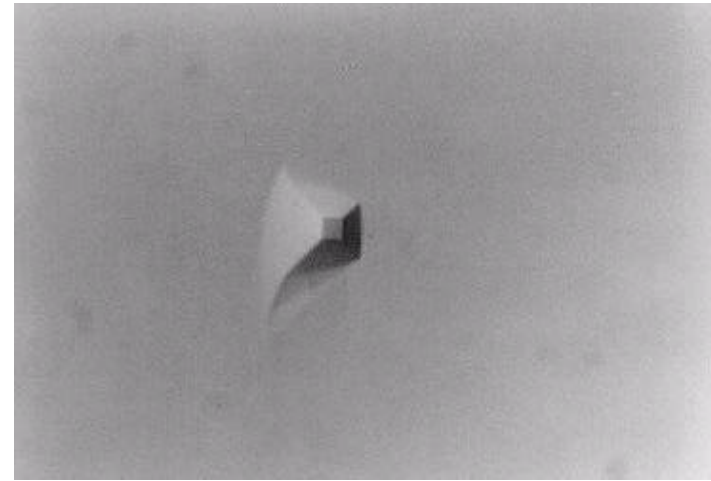
Spike and Hillock	Hillock
	
(111) Hillock Epi spike. (Wright 5min, 500X, by Microscope)	p/p+(100) Epi wafer Hillock.

2. Wafer Defects

Epitaxial process induced defect



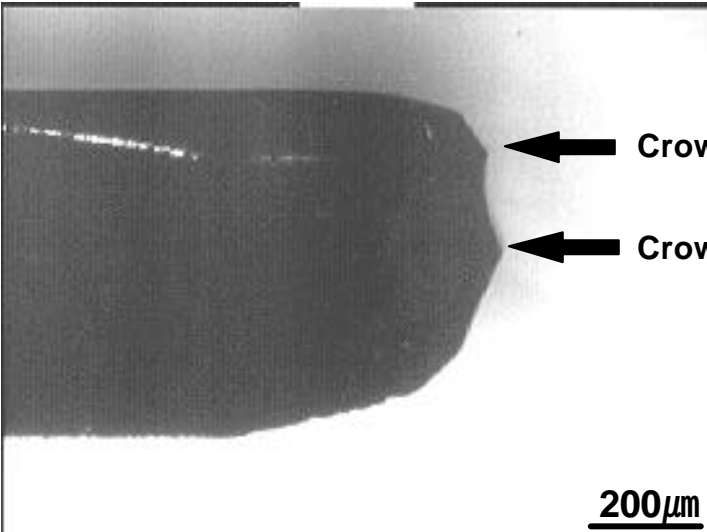

Growth hillock



Growth hillock(without etching)

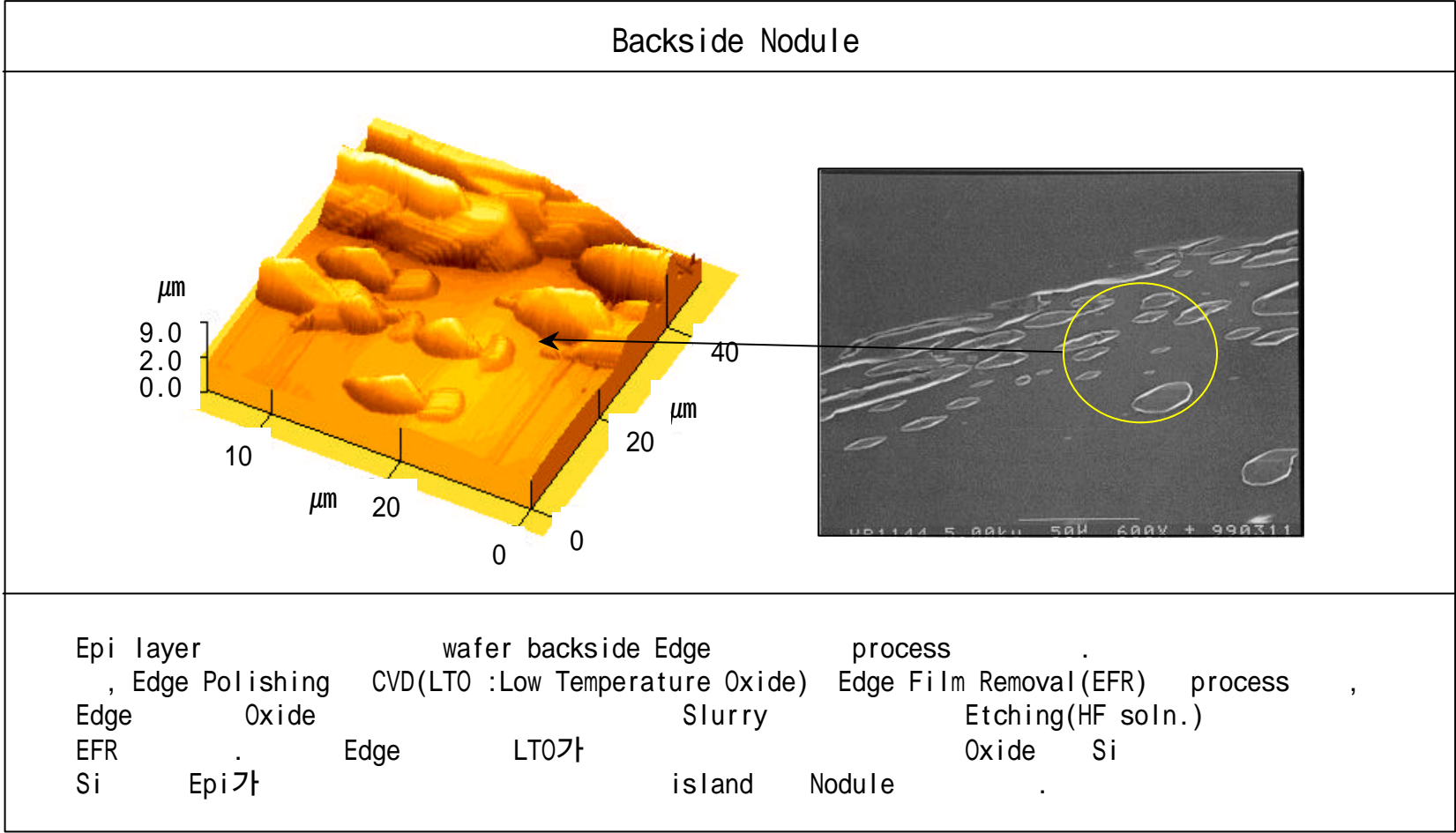
2. Wafer Defects

Epitaxial process induced defect

Crown	Orange Peel
	
<div>Wafer edge</div> <div>Epi crown</div> <div>Epi crown.</div> <div>Epi</div> <div>Edge</div> <div>(without etching, 50X, by Microscope)</div>	<div>Orange Peel</div> <div>Haze</div> <div>Substrate Leak</div> <div>Epi</div>


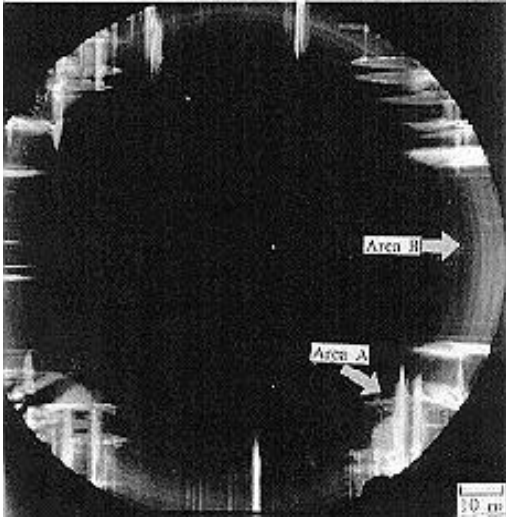
2. Wafer Defects

Epitaxial process induced defect



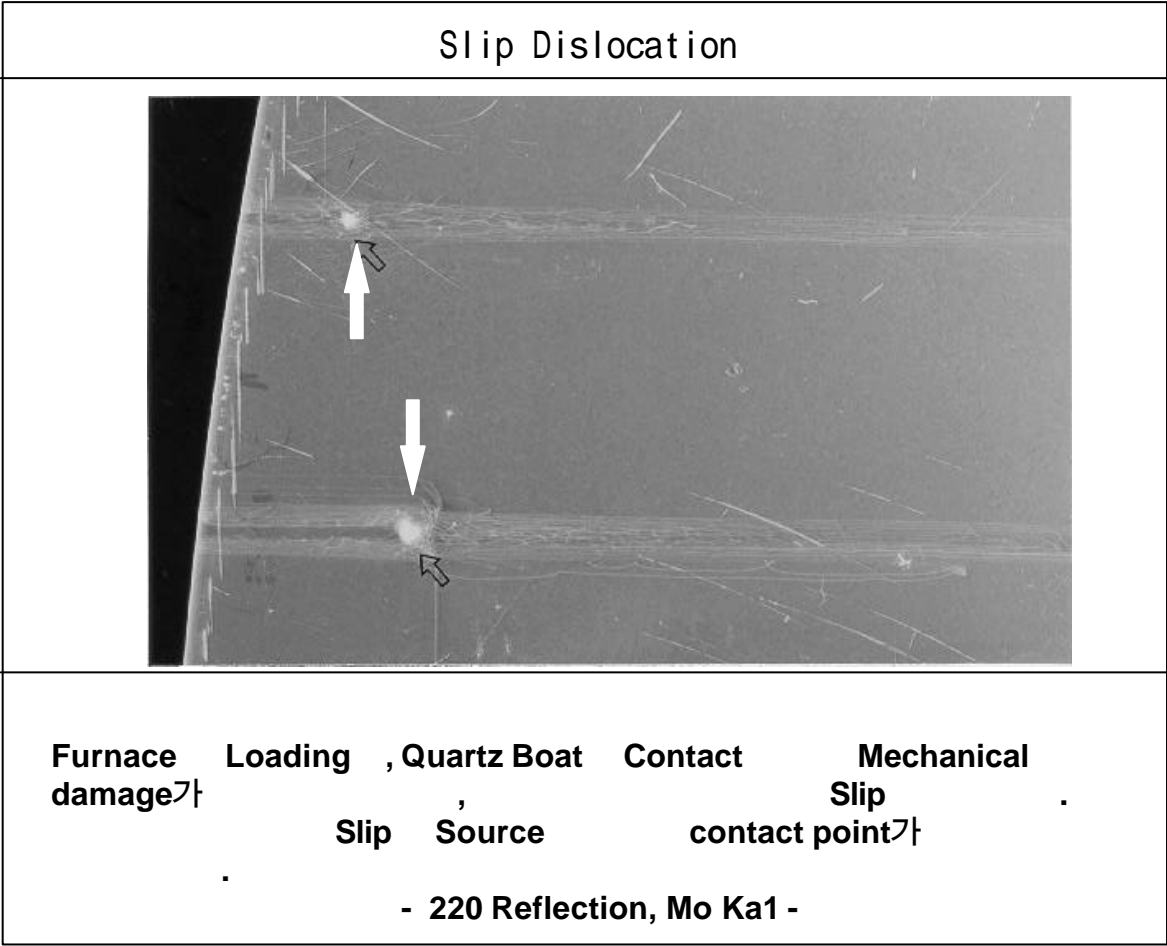
2. Wafer Defects

Device process induced defect

Slip Dislocation	Slip Dislocation
	
<div>Laser Marking Damage 220 Reflection, Mo K 1</div> <div>Slip Dislocation</div>	<div>Mechanical Damage 220 Reflection, Mo K 1</div> <div>Slip Dislocation</div>

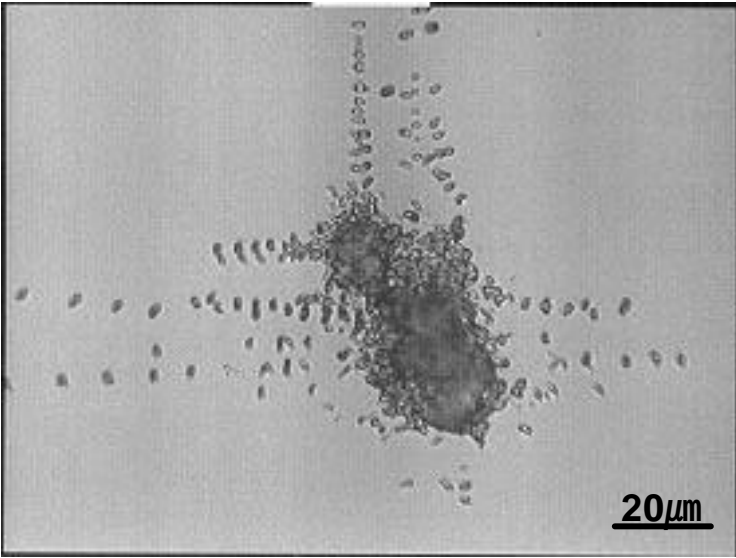
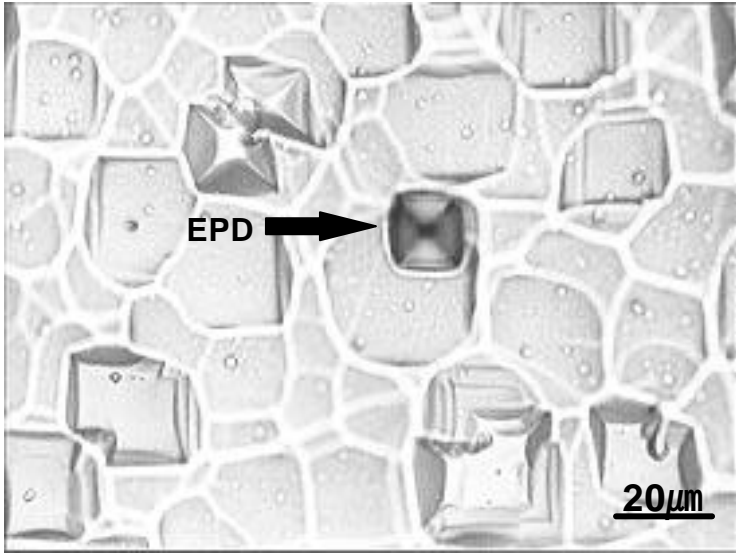
2. Wafer Defects

Device process induced defect



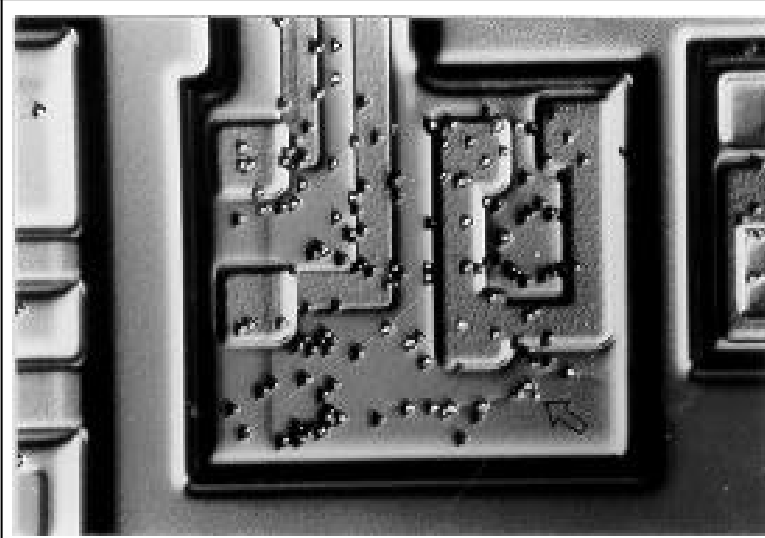
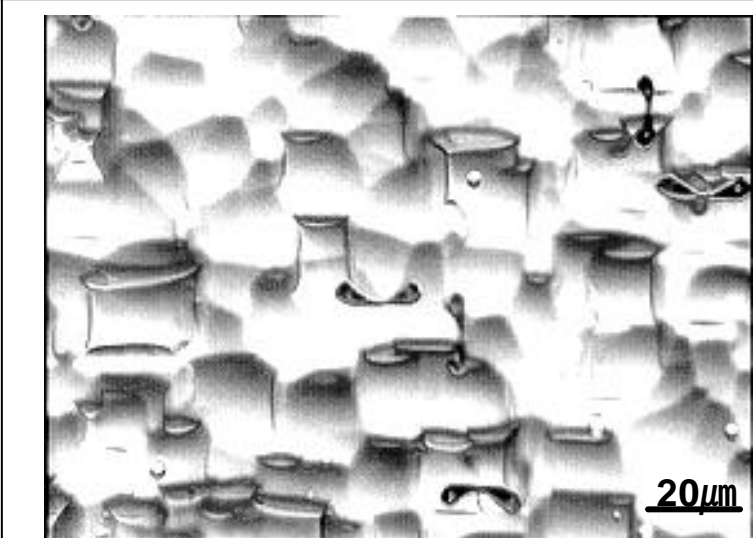
2. Wafer Defects

Device process induced defect

Slip Dislocation	
	
1100 60 wet oxidation (100) dislocation. dislocations mechanical damage (Wright 5min, 500X, by Microscope)	Dislocation (100) wafer backside EPD.(Wright 7min, 500X, by Microscope)

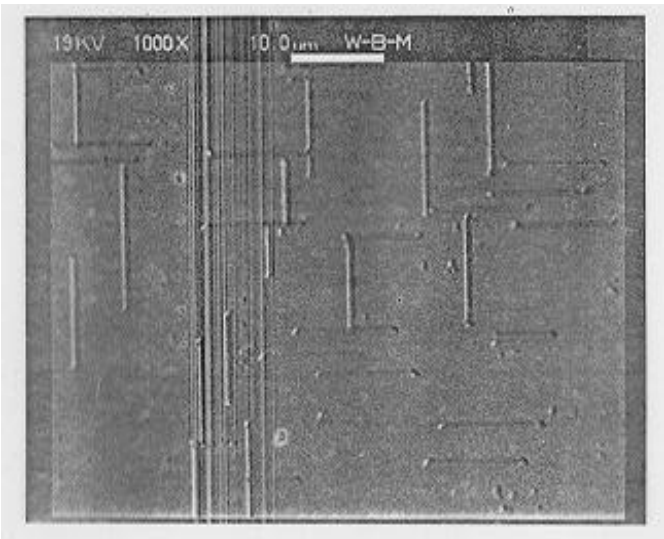
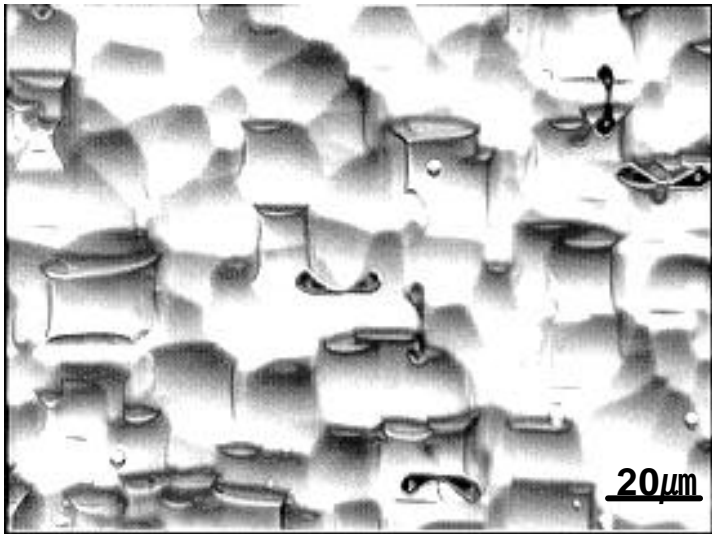
2. Wafer Defects

Device process induced defect

Etch Pits	OiSF (Backside)
	
<p>Ion Implanted Area Etch Pits (Wright 5min, 500X, by Microscope)</p>	<p>1100 60 wet oxidation (100) wafer Backside damage OiSF. (Wright 5min, 500X, by Microscope)</p>

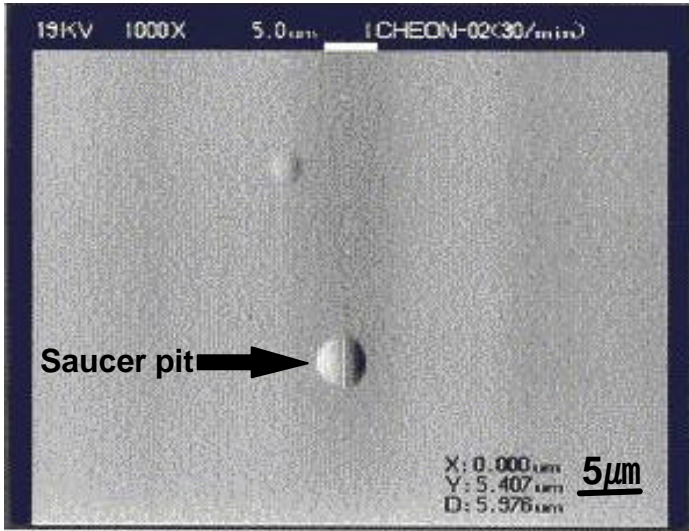
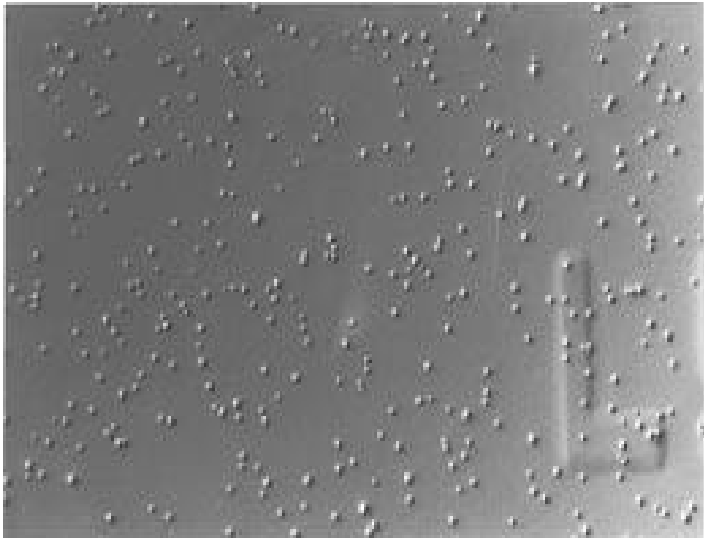
2. Wafer Defects

Device process induced defect

OISF	
	
<p>1100 60 wet oxidation (100) wafer Frontside damage OISF. OISF (Wright 5min, 1,000X, by Microscope)</p>	<p>1100 60 wet oxidation (100) wafer Backside damage OISF. (Wright 5min, 500X, by Microscope)</p>

2. Wafer Defects

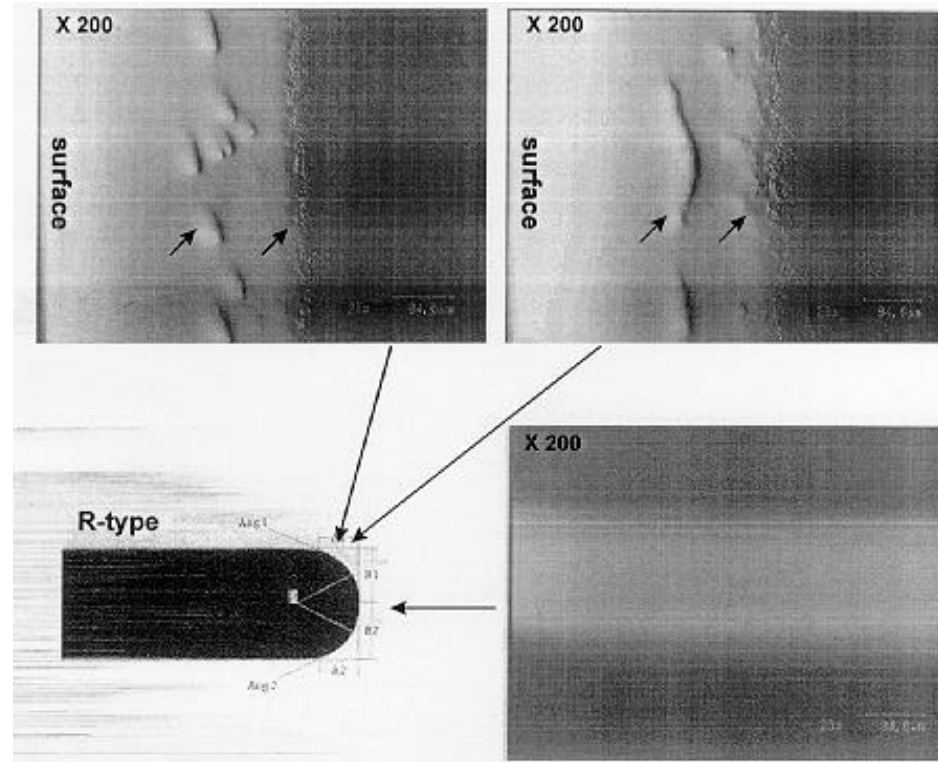
Device process induced defect

Saucer Pits by Contamination			
			
Gettering wafer (Wright 30min, 1,000X, by Microscope)	Saucer pits (111)	contamination	Saucer pits

3. Others

Edge Defect

Edge Defect

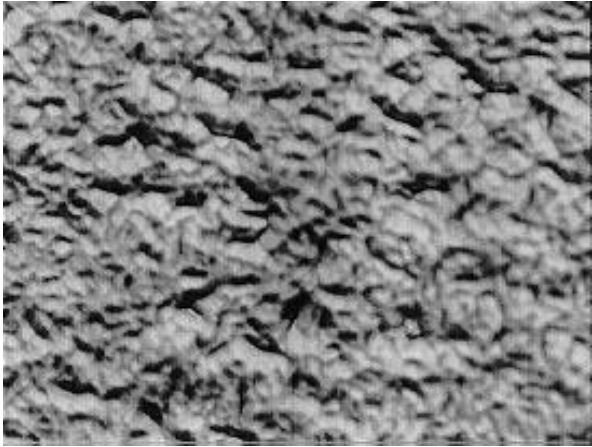
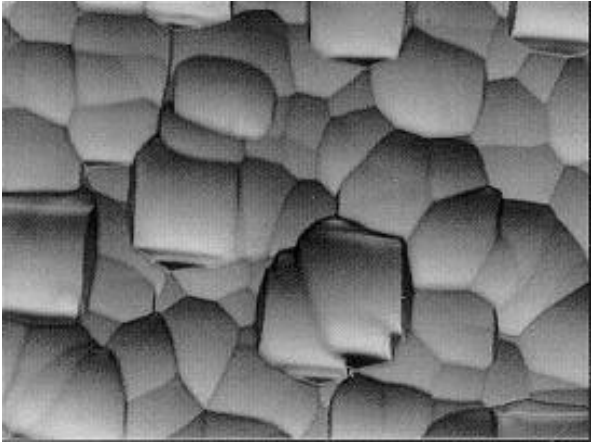
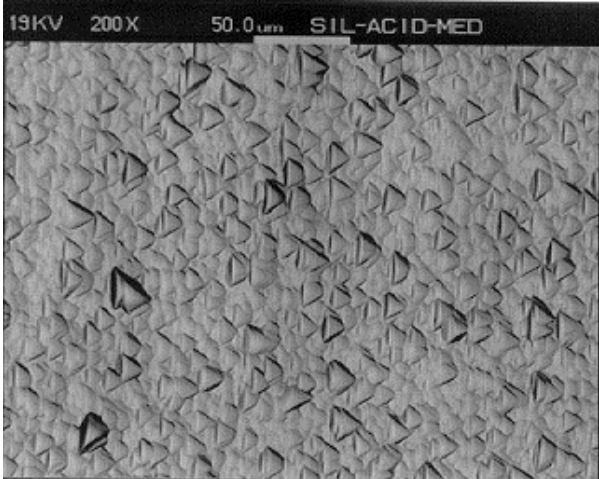
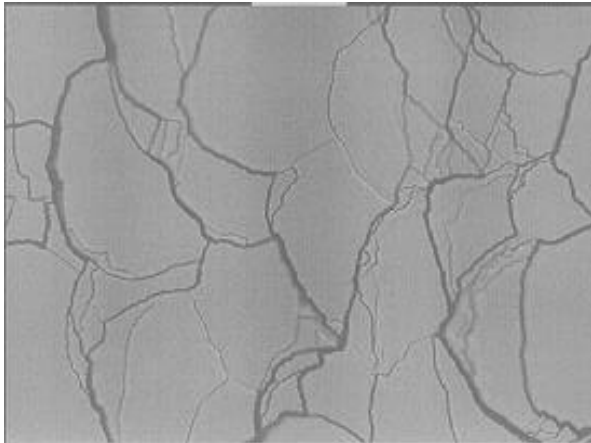


Images by Laser Microscope

3. Others

Backside Etched Morphology

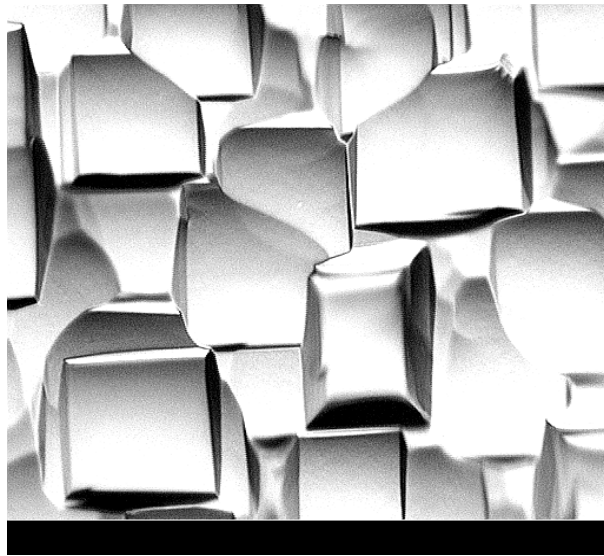
(500x, by Microscope)

	Acid Etch	Caustic Etch
(100)		
(111)		

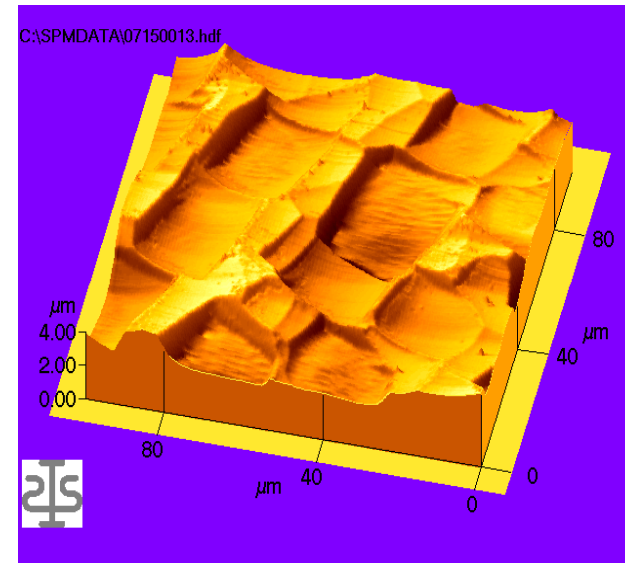
3. Others

Backside Etched Morphology

Caustic Etched Surface(100)



(100) wafer Caustic Etched Surface
(1,000X, by Microscope)

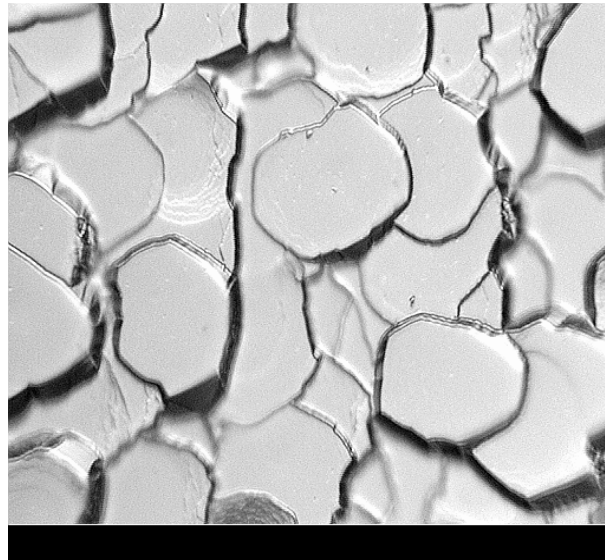


(100) wafer Caustic Etched Surface
(by AFM)

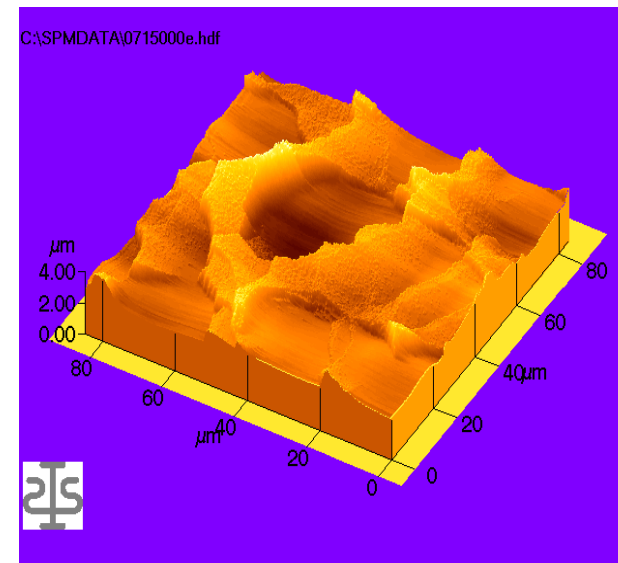
3. Others

Backside Etched Morphology

Caustic Etched Surface(111)



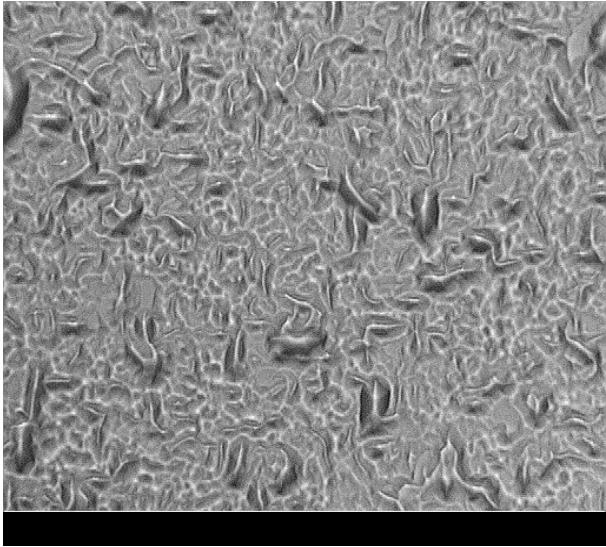
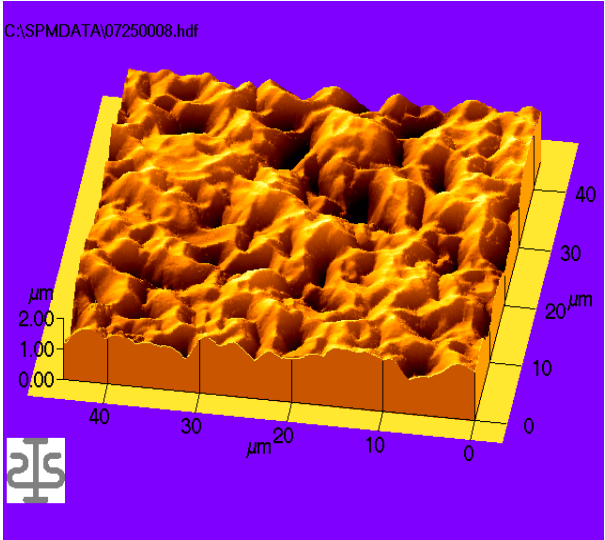
(111) wafer Caustic Etched Surface
(1,000X, by Microscope)



(111) wafer Caustic Etched Surface
(by AFM)

3. Others

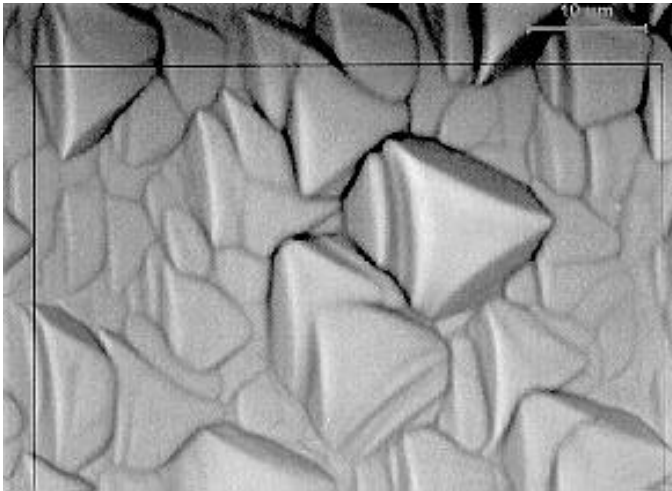
Backside Etched Morphology

Acid Etched Surface(100)	
	
(100) wafer Acid Etched Surface (1,000X, by Microscope)	(100) wafer Acid Etched Surface (by AFM)

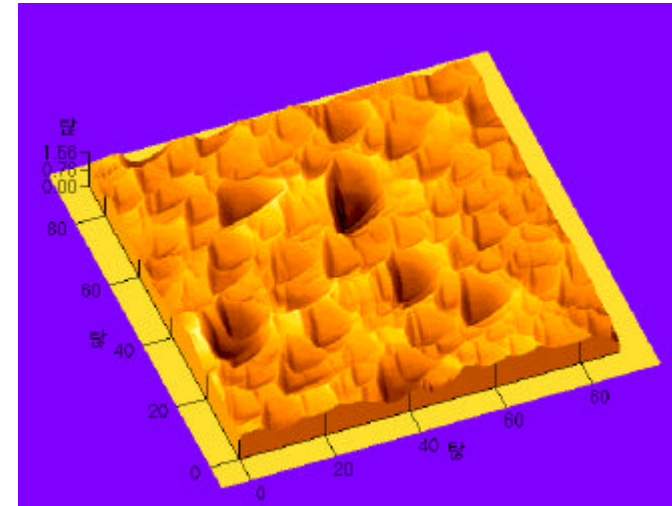
3. Others

Backside Etched Morphology

Acid Etched Surface(111)



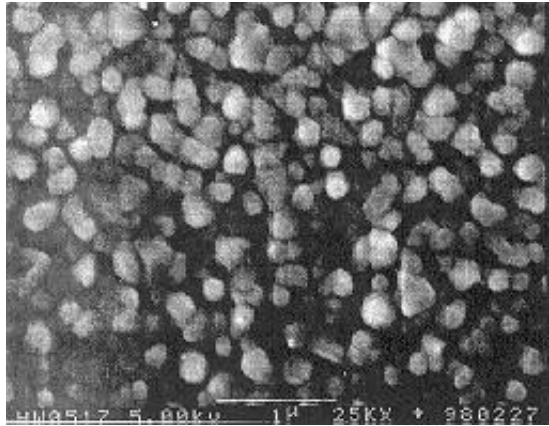
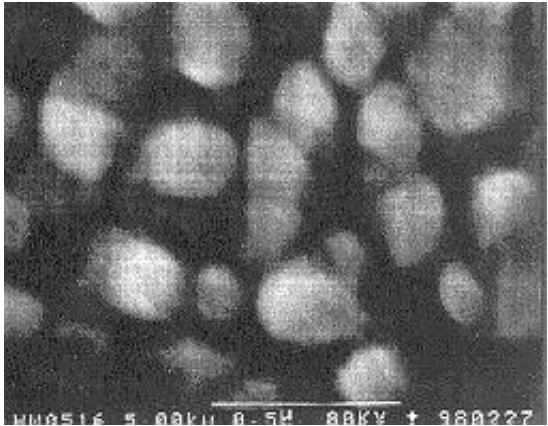
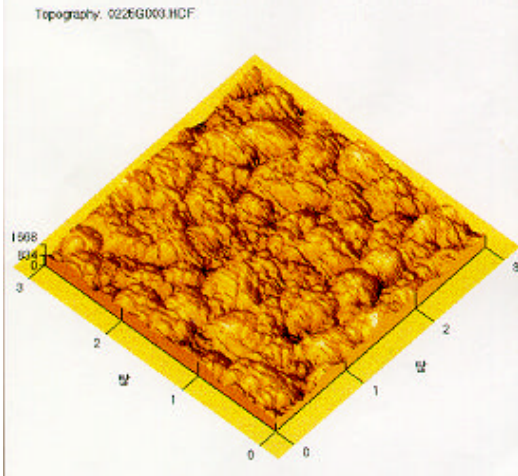
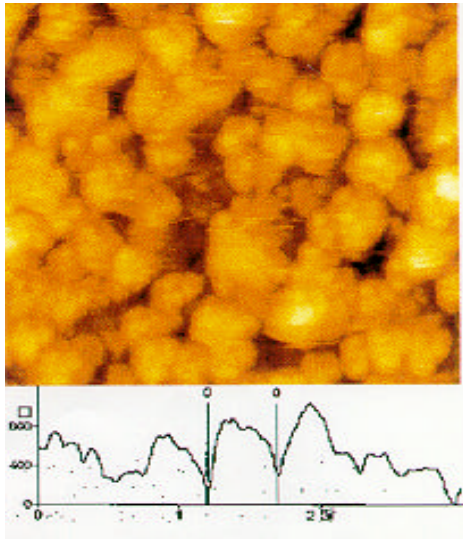
(111) wafer Acid Etched Surface
(1,000X, by Microscope)



(111) wafer Acid Etched Surface
(by AFM)

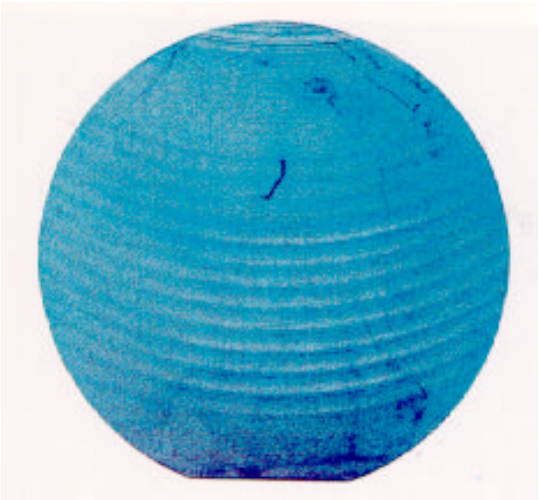

3. Others

Poly-Backseal Morphology

SEM	 <p>SEM image showing a dense array of small, rounded grains. The image is labeled with technical data: HM0517 5.00kV 1μ 25KV + 980227.</p>	 <p>SEM image showing a dense array of small, rounded grains. The image is labeled with technical data: HM0516 5.00kV 0.5μ 88KV + 980227.</p>
AFM	 <p>AFM image showing a 3D topography of the surface. The image is labeled with technical data: Topography: 0226G003.HCF. The image shows a dense array of small, rounded grains.</p>	 <p>AFM image showing a 3D topography of the surface. The image is labeled with technical data: 0000 400 0 2. The image shows a dense array of small, rounded grains.</p>
Backside Poly-backseal Morphology (Grain Size : 0.2~0.4 μm)		

3. Others

Saw Mark

Saw Mark	Saw Mark(at I.D Sawing)
	
<div>Slice</div> <div>Blade mark가 가</div>	<div>Polishing</div>

III. Appendix

Si wafer

Etchant

	Wright	Secco	Sirtl
Formula	<ul style="list-style-type: none"> • $\text{HF} + \text{HNO}_3 + \text{CrO}_3 + \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{CH}_3\text{COOH}$ step1) 45g CrO_3 (in 90ml H_2O) step2) 6g $\text{Cu}(\text{NO}_3)_2$ (in H_2O) step3) step2 (in 180ml H_2O) step4) 90ml HNO_3 + 180ml CH_3COOH + 180ml HF	<ul style="list-style-type: none"> • $\text{HF} + \text{K}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{O}$ step1) 44g $\text{K}_2\text{Cr}_2\text{O}_7$ (in 100ml H_2O) step2) 50% HF 50ml Total HF:H ₂ O=1:2	<ul style="list-style-type: none"> • $\text{HF} + \text{CrO}_3 + \text{H}_2\text{O}$ step1) 50g CrO_3 (in 100ml H_2O) step2) 50% HF 100ml Total HF:H ₂ O=1:1
Etching rate	approx. 1.0 $\mu\text{m}/\text{min}$	approx. 1.5 $\mu\text{m}/\text{min}$	approx. 3.5 $\mu\text{m}/\text{min}$
Comments	-Widely applicable for all surface orientation -Surface & Bulk Defects (Defect : BMD, OiSF, COP..)	-Best applicable to (100) -Highly boron doped wafer - Surface Defects .(Defect : FPD..)	-Best applicable to (111) -Etching heats up the etchant
Reference	M.Wright Jenkins J.Electrochem.Soc. May.1997. pp757~762	Secco d'Aragona Jelectrochem.Soc. Jully.1972. pp948~951	E.Sirtl & A.Alder, Z.f.Metallkunde 52 1961. p529