Designation: F 154 – 00

Standard Guide for Identification of Structures and Contaminants Seen on Specular Silicon Surfaces[1]

This standard is issued under the fixed designation F 154; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The purpose of this guide is to list, illustrate, and provide reference for various characteristic features and contaminants that are seen on highly specular silicon wafers. Recommended practices for delineation and observation of these artifacts are referenced. The artifacts described in this guide are intended to parallel and support the content of the SEMI M18. These artifacts and common synonyms are arranged alphabetically in Tables 1 and 2 and illustrated in Figs. 1-68.

2. Referenced Documents

2.1 *ASTM Standards:*

F 523 Practice for Unaided Visual Inspection of Polished Silicon Wafer Surfaces[2]

F 1241 Terminology of Silicon Technology[2]

F 1725 Guide for Analysis of Crystallographic Perfection of Silicon Ingots[2]

F 1726 Guide for Analysis of Crystallographic Perfection of Silicon Wafers[2]

F 1727 Practice for Detection of Oxidation Induced Defects in Polished Silicon Wafers[2]

F 1809 Guide for Selection and Use of Etching Solutions to Delineate Structural Defects in Silicon[2]

F 1810 Test Method for Counting Preferentially Etched or Decorated Surface Defects in Silicon Wafers[2]

2.2 *SEMI Standard:*

M18 Format for Silicon Wafer Specification Form for Order Entry[3]

3. Terminology

3.1 Related terminology may be found in Terminology F 1241.

TABLE 1 Wafer Structural Defects[A,B]

Defect	Common Synonyms and Acronyms	Illustrating Figures	Relevant ASTM Standard
Dislocation etch pit	Etch Pit, Pit	1-5	F 1725
Epitaxial stacking fault	epi stacking fault, (ESF)	6-10	F 1726
Lineage	Grain Boundary	11	F 1725
Oxidation induced stacking fault	oxidation stacking fault, (OSF), oxidation induced stacking fault (OISF)	12-18	F 1727 F 1809
Oxide precipitates	bulk micro-defect, (BMD), bulk precipitate	19	F 1727 F 1809
Shallow pits	S-pit, saucer pit	20-21	F 1727 F 1809
Slip		22-25	F 1725 F 1727 F 1809
Swirl		26-27	F 1725 F 1727 F 1809
Twin		28-30	F 1725

[A] Magnifications given in the attached illustrations are for an original frame size of 50×50-mm except as noted.

[B] Unless otherwise noted, all attached figures illustrate polished silicon wafer surfaces.

4. Significance and Use

4.1 This guide contains a compilation of the most commonly observed singularly discernible structures on specular silicon surfaces. Ambiguities and uncertainties regarding surface defects may be resolved by reference to this guide. There is close alignment between this guide and common specifications used for the purchase of silicon wafers.

5. Interferences

5.1 Defects, structures, features, or artifacts revealed or enhanced by the referenced methods and exhibited in this guide must be carefully interpreted. Unless utmost care is exercised, the identification of the structure may be ambiguous.

6. Procedure

6.1 Refer to Practices F 523 and F 1727, Guides F 1725, F 1726, and F 1809, and Test Method F 1810.

7. Keywords

7.1 contaminant; defects; dislocation; epitaxial; fracture; preferential etch; scratch; shallow pit; silicon; slip; stacking fault

[1] This guide is under the jurisdiction of Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.06 on Silicon Materials and Process Control.

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[2] *Annual Book of ASTM Standards*, Vol 10.05.

[3] Available from Semiconductor Equipment and Materials International, 805 E. Middlefield Rd., Mountain View, CA 94043.

TABLE 2 Polished Surface Visual Characteristics

Defect	Common Synonyms and Acronyms	Illustrating Figure	Relevant ASTM Standards
Area contamination	Contamination, foreign matter, residue	31-32	F 523
Crack	Cleavage, fracture	33-38	F 523
Crater	Slurry ring	39	F 523
Crow's feet	Contact damage	40	F 523
Dimple	Depression	41-42	F 523
Dopant striation ring	Striation	43	F 523
Edge chip	Chip	44-47	F 523
Edge crack	Crack	48	F 523
Edge crown		49	F 523
Epitaxial large point defect	large light point defect, (LLPD), spike	50	F 523
Foreign matter	Contamination, residue	51-52	F 523
Groove	Polished over scratch, microscratch	53-54	F 523
Haze		55-56	F 523
Localized lazer scatterers (particle contamination)	large light scatterers, (LLS)	57-58	F 523
Mound		59	F 523
Orange peel	Roughness	60	F 523
Pits	Air pocket, hole, crystal originated pit, (COP) insufficient polish	61-63	F 523
Saw mark		64	F 523
Scratches	Handling damage	65-67	F 523
Stain		68	F 523

FIG. 1 Dislocation Etch Pits on (111) Silicon, Following 3-Min Sirtl Etch, Magnification 110×.

FIG. 2 Dislocation Etch Pits on (110) Silicon, Following 5-Min Wright Etch, Magnification 110×.

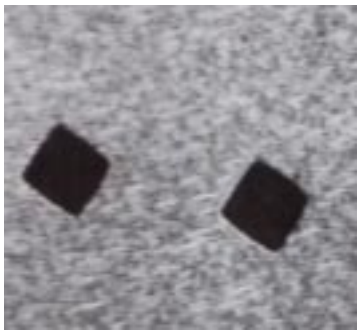

FIG. 3 Dislocation Etch Pits on (100) Silicon Following Schimmel (B) Preferential Etch, Magnification 320×.

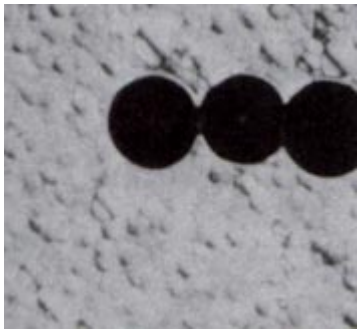

FIG. 4 Dislocation Etch Pits on (100) Silicon Following Sirtl Etch, Magnification 400×.

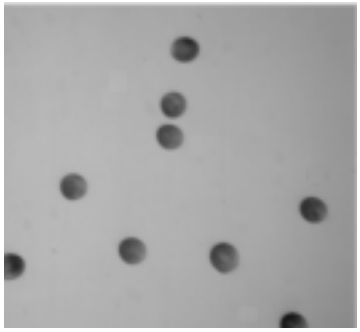

FIG. 5 Dislocation Etch Pits on (100) Silicon Following 5-Min Wright Etch, Magnification 200×.

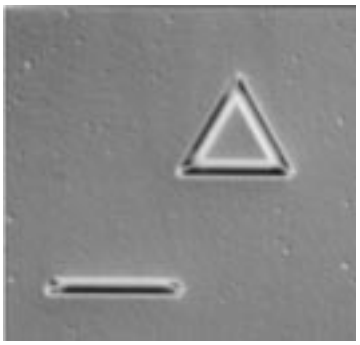

FIG. 6 Epitaxial Stacking Faults on (111), No Preparation Required, Size Dependent Upon EPI Thickness.

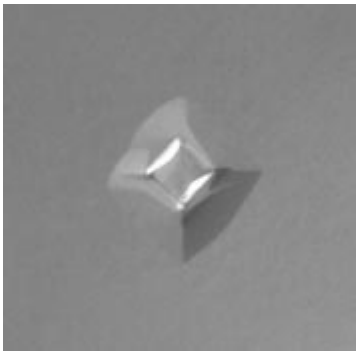

FIG. 7 Epitaxial Stacking Faults on (100), No Preparation Required, Size Dependent Upon EPI Thickness.

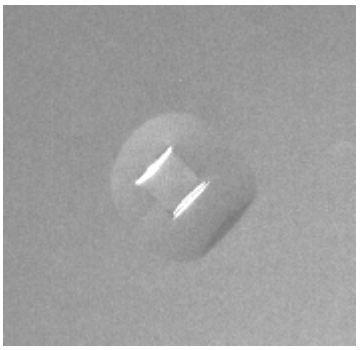

FIG. 8 Epitaxial Stacking Faults on (100), No Preparation Required, Size Dependent Upon EPI Thickness.

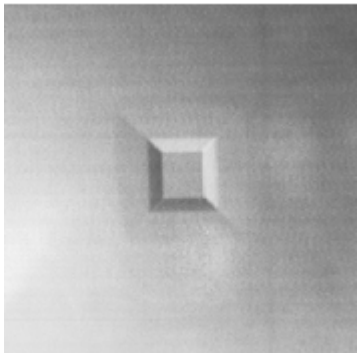

FIG. 9 Epitaxial Growth Hillock on (100), No Preparation Required, Size Dependent Upon EPI Thickness.

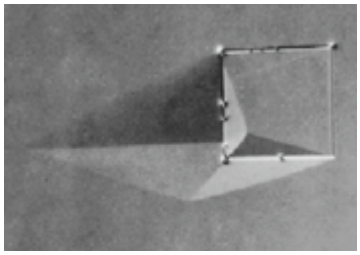

FIG. 10 Epitaxial Stacking Faults on (100), No Preparation Required, Size Dependent Upon EPI Thickness.

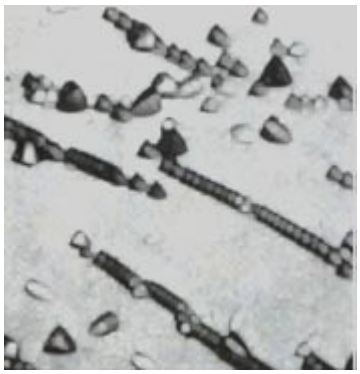

FIG. 11 Lineage on (111) Silicon Following Preferential Etch, Magnification 140×.

FIG. 12 Oxidation Induced Stacking Faults on (100) Silicon Following Oxidation and 4-min Wright Etch, Magnification 200×.

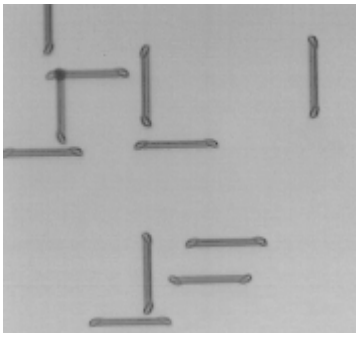

FIG. 13 Oxidation Induced Stacking Faults from Liquid Hone Damage on a (100) Silicon Polished Frontside Surface Following 1100° Oxidation and 1-min Schimmel Etch, Magnification 1500×.

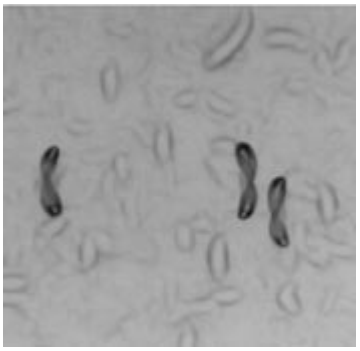

FIG. 14 Oxidation Induced Stacking Faults from Liquid Hone Damage on a (100) Etched Backside Surface Following 1100° Oxidation and 1-Min Schimmel Etch, Magnification 1500×.

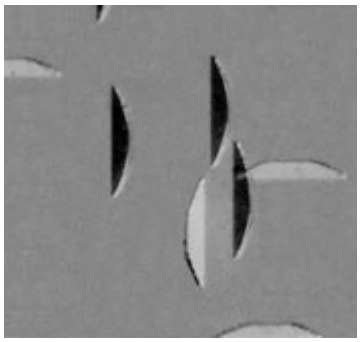

FIG. 15 Oxidation Induced Stacking Faults on (100) Silicon Following Oxidation and 3-Min Secco Etch, Magnification 500×.

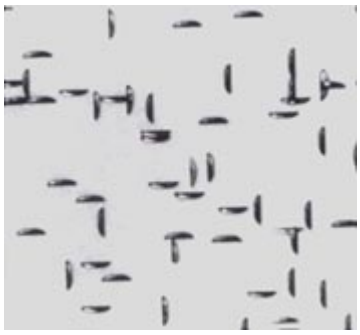

FIG. 16 Oxidation Induced Stacking Faults on (100) Silicon Following Oxidation and 3-min Secco Etch, Magnification 200×.

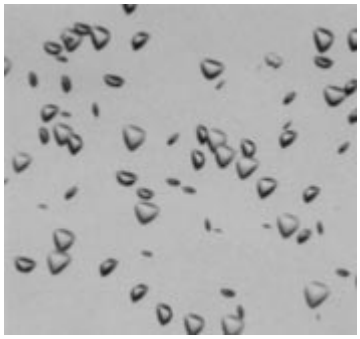

FIG. 17 Oxidation Induced Stacking Faults on (111) Silicon Following Oxidation and 4 Min Wright Etch, Magnification 200×.

FIG. 18 Oxidation Induced Stacking Faults Caused by a Scratch on (100) Silicon Following Oxidation and 2-min Wright Etch, Magnification 400×.

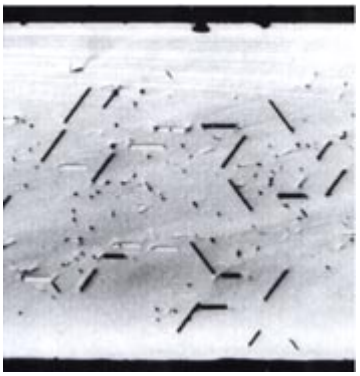

FIG. 19 Oxidation Induced Stacking Faults and Precipitates Found on the Cleavage Face of a Silicon Wafer After Thermal Treatment and 3-Min Secco Etch, Magnification 100×.

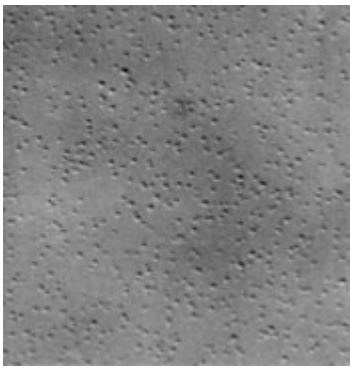

FIG. 20 Relatively Small Shallow Pits on (111) Following Oxidation and 4-Min Wright Etch, Magnification 200×.

FIG. 21 Relatively Large Shallow Pits on (111) Following Oxidation and 4-Min Wright Etch, Magnification 200×.

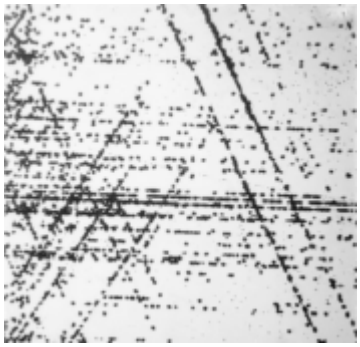

FIG. 22 Slip on a (111) Preferentially Etched Wafer, magnification 5×.

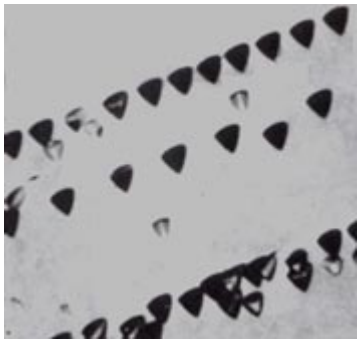

FIG. 23 Slip on a (111) Preferentially Etched Wafer, Magnification 140×.

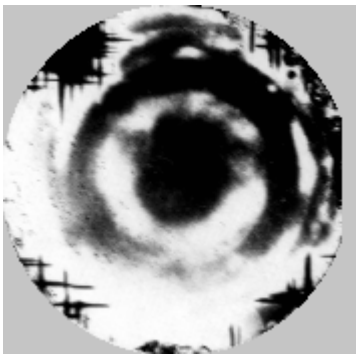

FIG. 24 Slip Lines on a (100) Wafer Visible as a Cross Hatched Pattern Near the Edge Because Shallow Pits are Gettered Following Oxidation and 4-min Wright Etch.

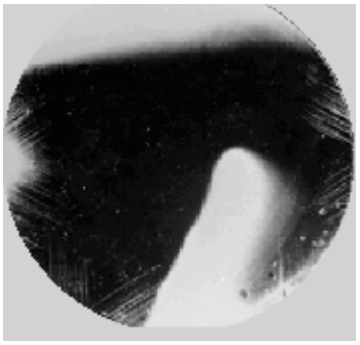

FIG. 25 Slip on a (111) Wafer Following 10-min Wright Etch, Full Wafer View.

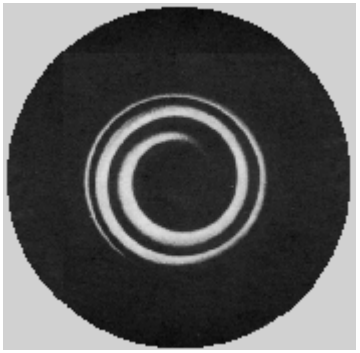

FIG. 26 Swirl Pattern Developed by Preferentially Etching a Czochralski Grown 10 to 20 ohm-cm Lapped Silicon Wafer.

FIG. 27 A-swirl on as Grown Float-Zone Silicon Following Preferential Etch, Full Wafer View.

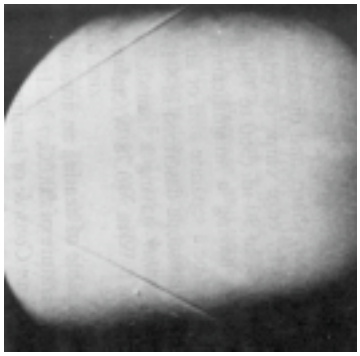

FIG. 28 Twin Lines in a (11) Wafer after Preferential Etching, Full Wafer View.

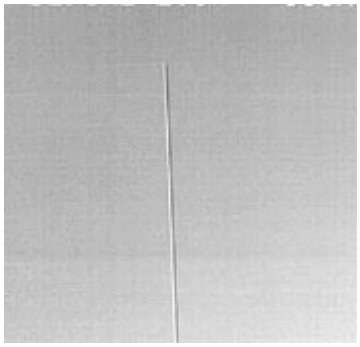

FIG. 29 Twin Line Following 6.5 micron Epitaxial Deposition, No Other Sample Preparation Required, Magnification 300×.

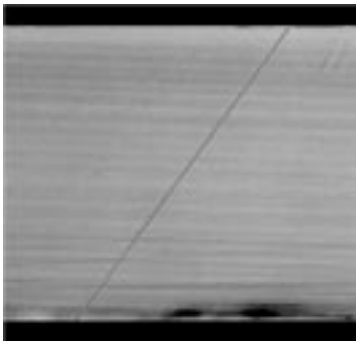

FIG. 30 Twin Lamella in a <110> Cleaved Vertical Cross Section Following 2.6 micron Removal in Leo (Modified Sirtl) Etch.

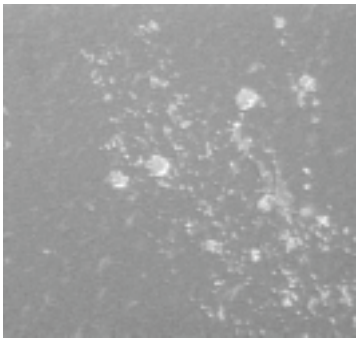

FIG. 31 Area Contamination, Magnification 100×.

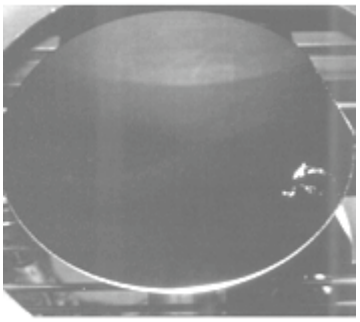

FIG. 32 Area Contamination Seen With a High Intensity Light Source, Full Wafer View.

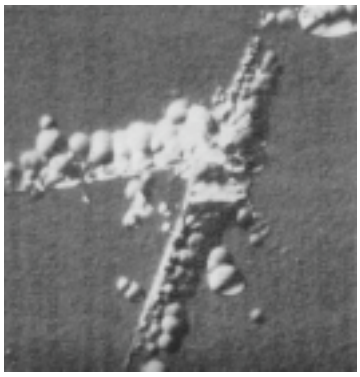

FIG. 33 Crack, Resulting from the Impact on the Wafer Surface, Following Preferential Etch, Magnification 450×.

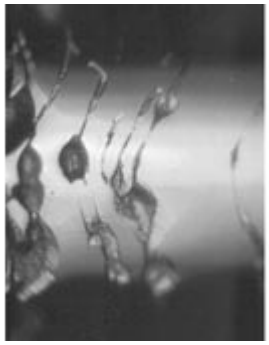

FIG. 34 Crack on the Wafer Edge Due to Mechanical Contact, No Preparation Required, Magnification 100×.

FIG. 35 Crack on a Wafer Surface Due to Mechanical Contact, No Preparation Required, Magnification 750×.

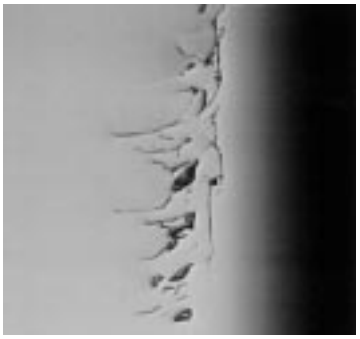

FIG. 36 Crack Near the Edge of a Wafer Surface Due to Mechanical Contact, No Preparation Required, Magnification 750×.

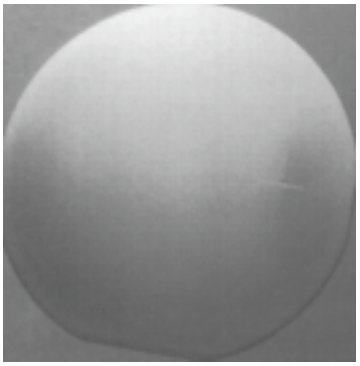

FIG. 37 Cracks in a Wafer Surface Viewed with High Intensity Light Exhibiting a Scratch-Like Appearance.

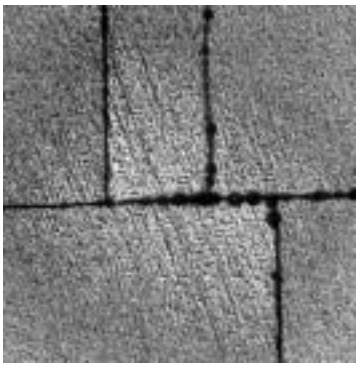

FIG. 38 Cracks in an Etched Wafer Surface, Magnification 38×.

FIG. 39 Crater, Usually Caused by Inadequate Rinse of Polishing Chemicals, Magnification 50×.

FIG. 40 "Crows-Foot" Crack Resulting from the Impact of a Hard Object with the Wafer Highlighted by Preferential Etch, Magnification 300×.

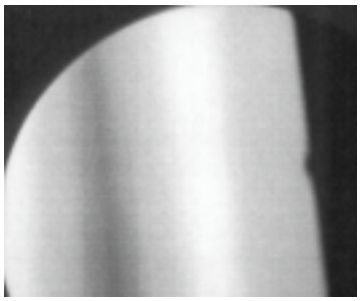

FIG. 41 Dimples Under Fluorescent Lighting Conditions Distort the Reflected Image.

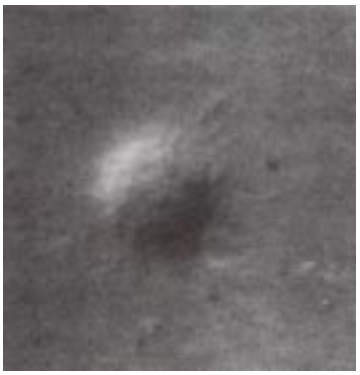

FIG. 42 Dimple, No Preparation Required, Magnification 512×.

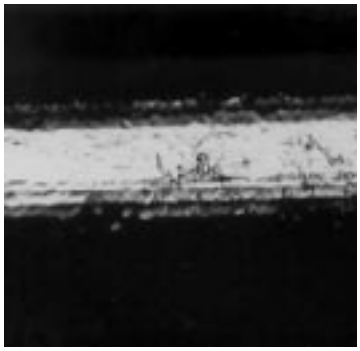

FIG. 45 Relatively Small Chips Found on an Edge Face, no Preparation Required, Magnification 100×.

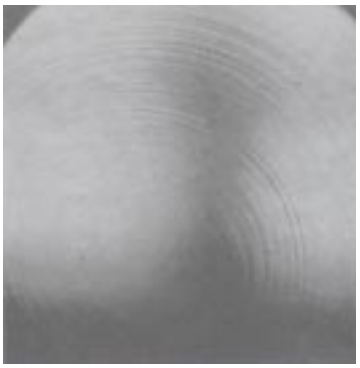

FIG. 43 Dopant Striation Rings after Preferentially Etching, Full Wafer View.

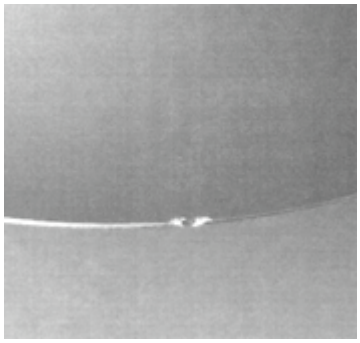

FIG. 46 Edge Chips, Full Wafer View.

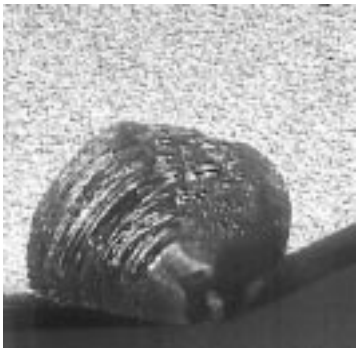

FIG. 44 Relatively Large Chip Found at the End of a Major Flat, No Preparation Required, Magnification 37×.

FIG. 47 Relatively Small Edge Chips on a Polished Edge Face, Magnification 200×.

FIG. 48 Edge Cracks on an Edge Face, No Preparation Required, Magnification 200×.

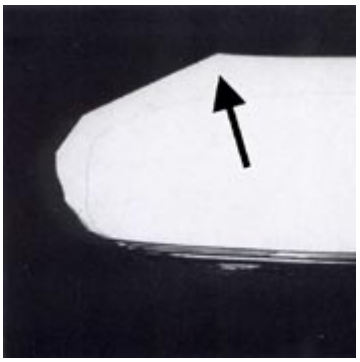

FIG. 49 Vertical Cross Section of Edge Crown on a Cleaved Epitaxial Wafer, Viewed With Low Magnification, Bright Field Microscope.

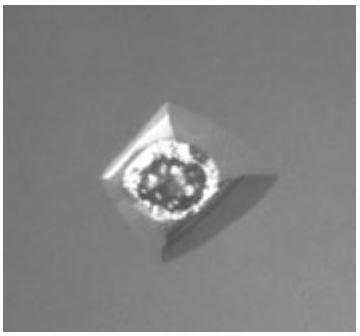

FIG. 50 Epitaxial Large Point Defect, No Preparation Required, Magnification 200×.

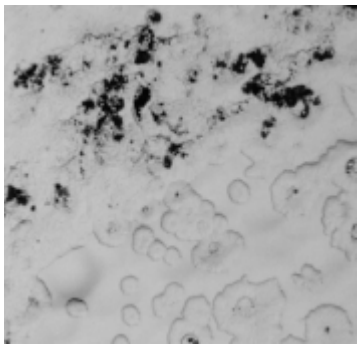

FIG. 51 Foreign Matter, Magnification 200×.

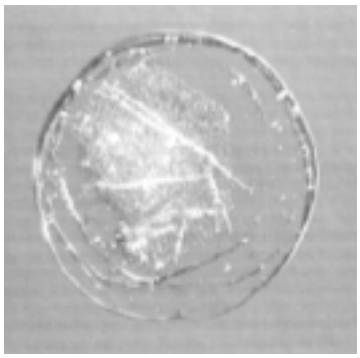

FIG. 52 Foreign Matter from a Dried Liquid Spot, Magnification 200×.

FIG. 53 Groove or Micro-Scratch, Magnification 220×.

FIG. 54 Groove or Micro-Scratch, Magnification 220×.

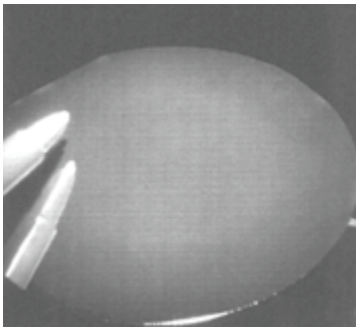

FIG. 55 Haze Seen as Distortion or Blurring of a Reflected Image, Full Wafer View.

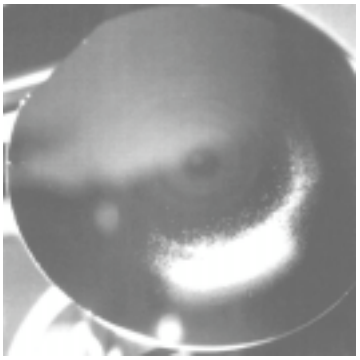

FIG. 56 Haze (Extreme Case) Seen as a White Cloudiness Under High Intensity Light, Full Wafer View.

FIG. 57 Localized Lazer Scatterers, (Particle Contamination) in the Form of Small Fiber, Magnification 200×.

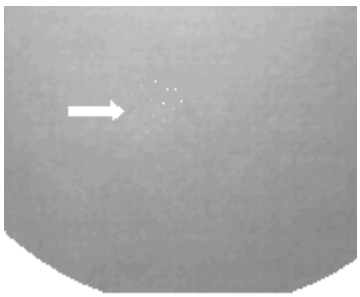

FIG. 58 Localized Lazer Scatterers Seen in High Intensity Light, Full Wafer View.

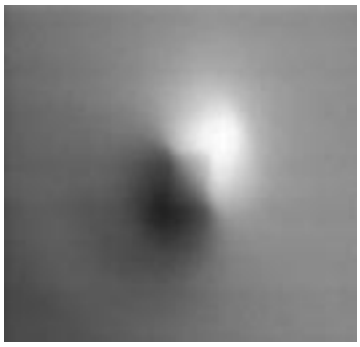

FIG. 59 Mound, No Preparation Required, Magnification 200×.

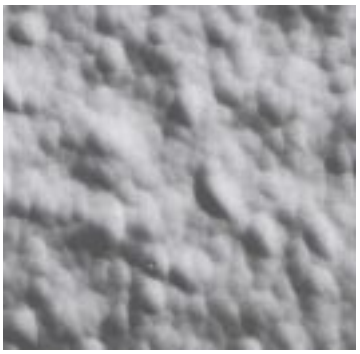

FIG. 60 Orange Peel Surface Roughness, Magnification 200×.

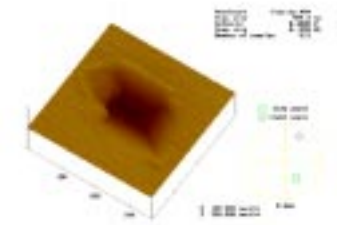

FIG. 61 Atomic Force Microscope (AFM) Image of a Faceted, Crystal Originated Particle (COP).

FIG. 62 Pit (Usually Associated With Insufficient Polishing of Caustic Etched Wafer), Magnification 1000×.

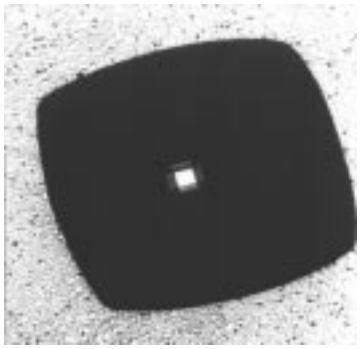

FIG. 63 Pit Associated With a Crystal air pocket on Lapped Wafer. Air pocket size Ranges from a Few microns to a Few Hundred Microns.

FIG. 64 Saw Blade Defect Seen on Lapped and Etched Wafer, Magnification 6×.

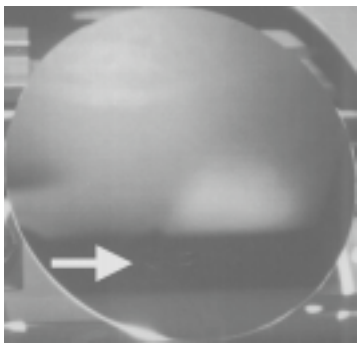

FIG. 65 Multiple scratches (located by the arrow) seen under high intensity light, full wafer view.

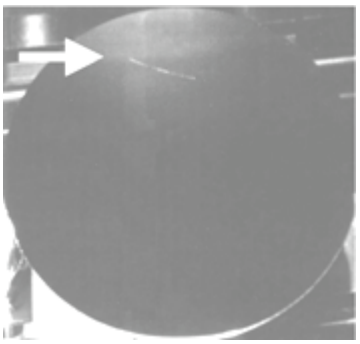

FIG. 66 A single long arc scratch (located by the arrow) seen under high intensity light, full wafer view.

FIG. 67 Scratch Resulting in a Series of Pits Following Chemical Etching, Magnification 70×.

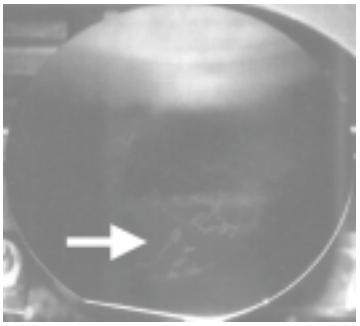

FIG. 68 Stains from Improper Cleaning or Drying (Located by the Arrow) Seen Under High Intensity Light, Full Wafer View.