Challenges of Smaller Particle Detection on Both Bulk-Silicon and SOI Wafers

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Influence of Silicon Surface Conditions on Smaller Particle Detection on Unpatterned Wafers

CANCELLED

March 2003

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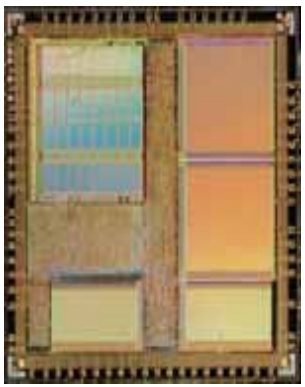
OUTLINE

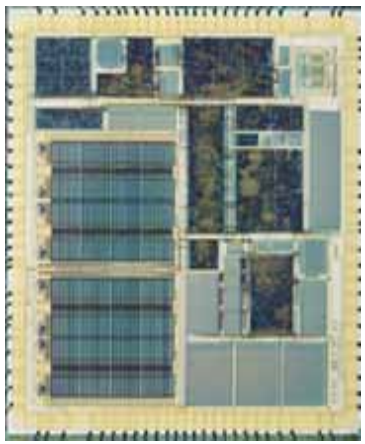
- Introduction
- Approaches to Increasing Sensitivity
- Influence of Silicon-surface Morphology
- Results Using a Deep-UV Laser
- Summary and Future Challenges

Sony's DRAM-Embedded SoC History

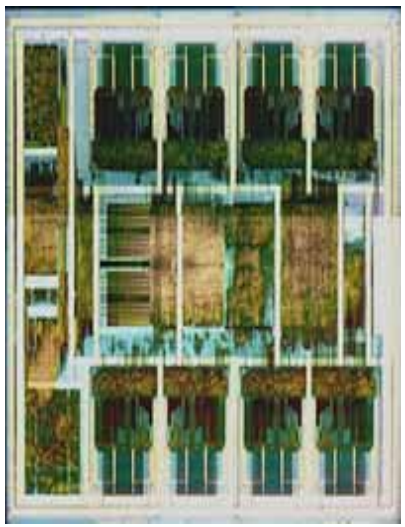
- 500nm Production started in 1995
- 350nm in 1996
- 250nm in 1998
- 180nm in 2000



8mm Camcoder LSI
512kbit DRAM



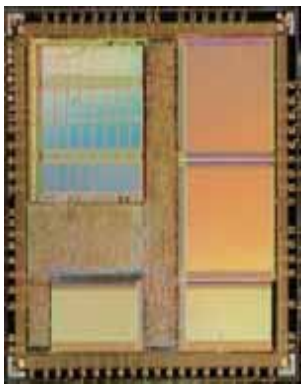
MD LSI
2Mbit DRAM



Graphics Synthesizer
for PlayStation2
32Mbit DRAM

Sony's DRAM-Embedded SoC History

- 500nm Production started in 1995
- 350nm in 1996
- 250nm in 1998
- 180nm in 2000
- 90nm in 2003



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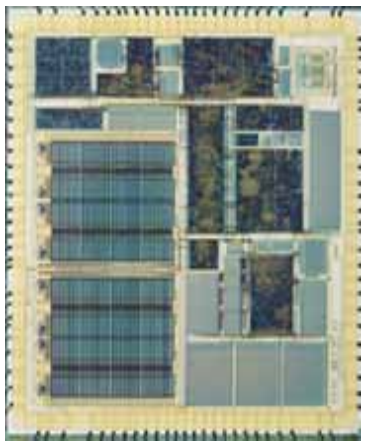

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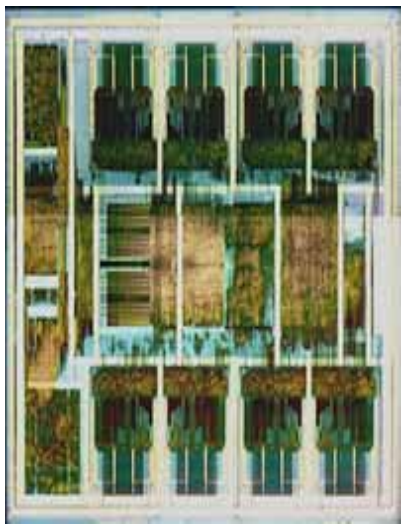

Graphics Synthesizer
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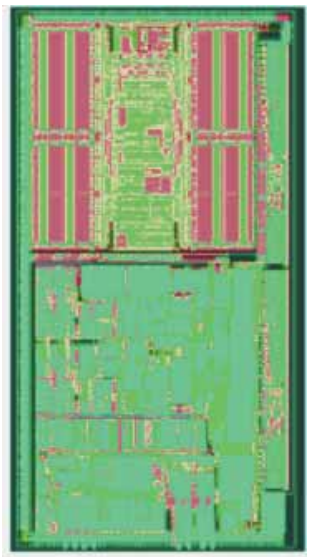
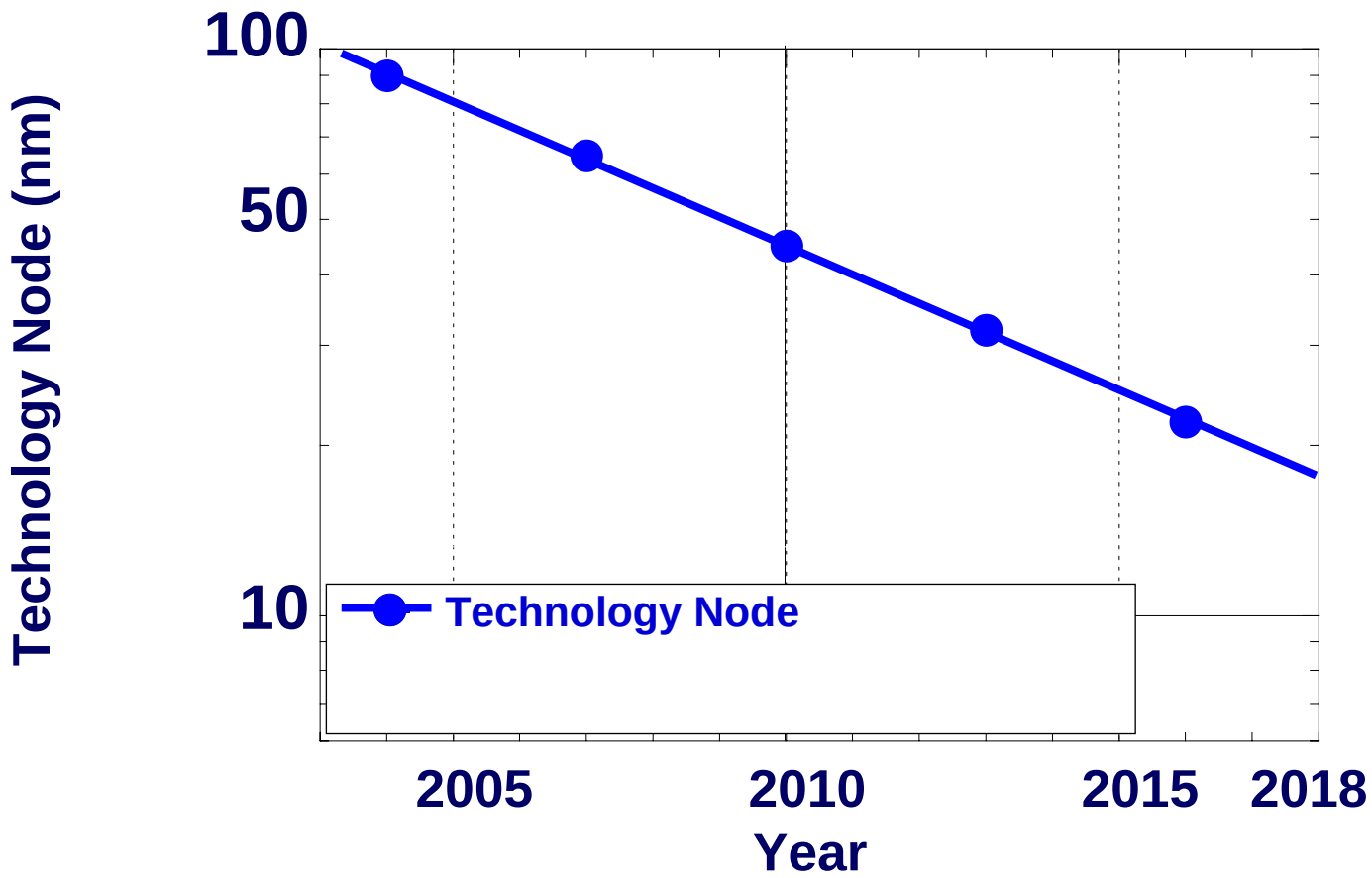


GS+ 128 bit MPU

Not to scale)

SONY

ITRS Roadmap Acceleration Continues….

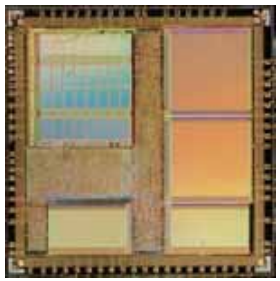


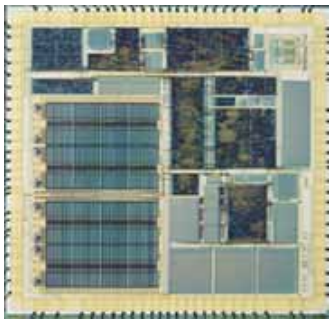
(Source: ITRS 2004Update)

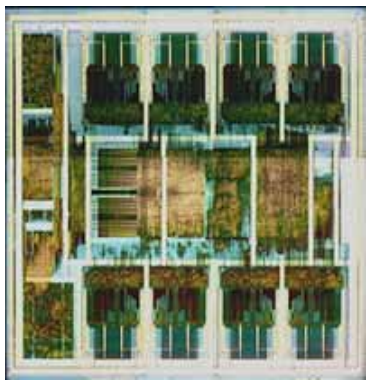
Sony's DRAM-Embedded SoC Trend

- 500nm in 1995
- 350nm in 1996
- 250nm in 1999
- 180nm in 2000
- 90nm in 2003
- 65nm in 2005
- 45nm in 2007

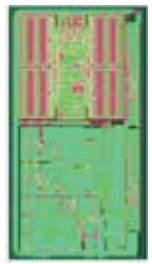
Higher-Performance SoC Products







SONY

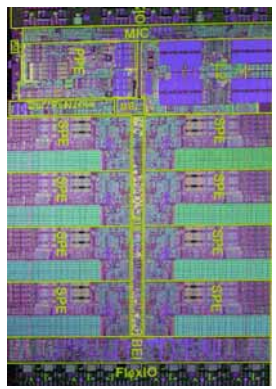


SONY + Toshiba

Production in progress

Under development

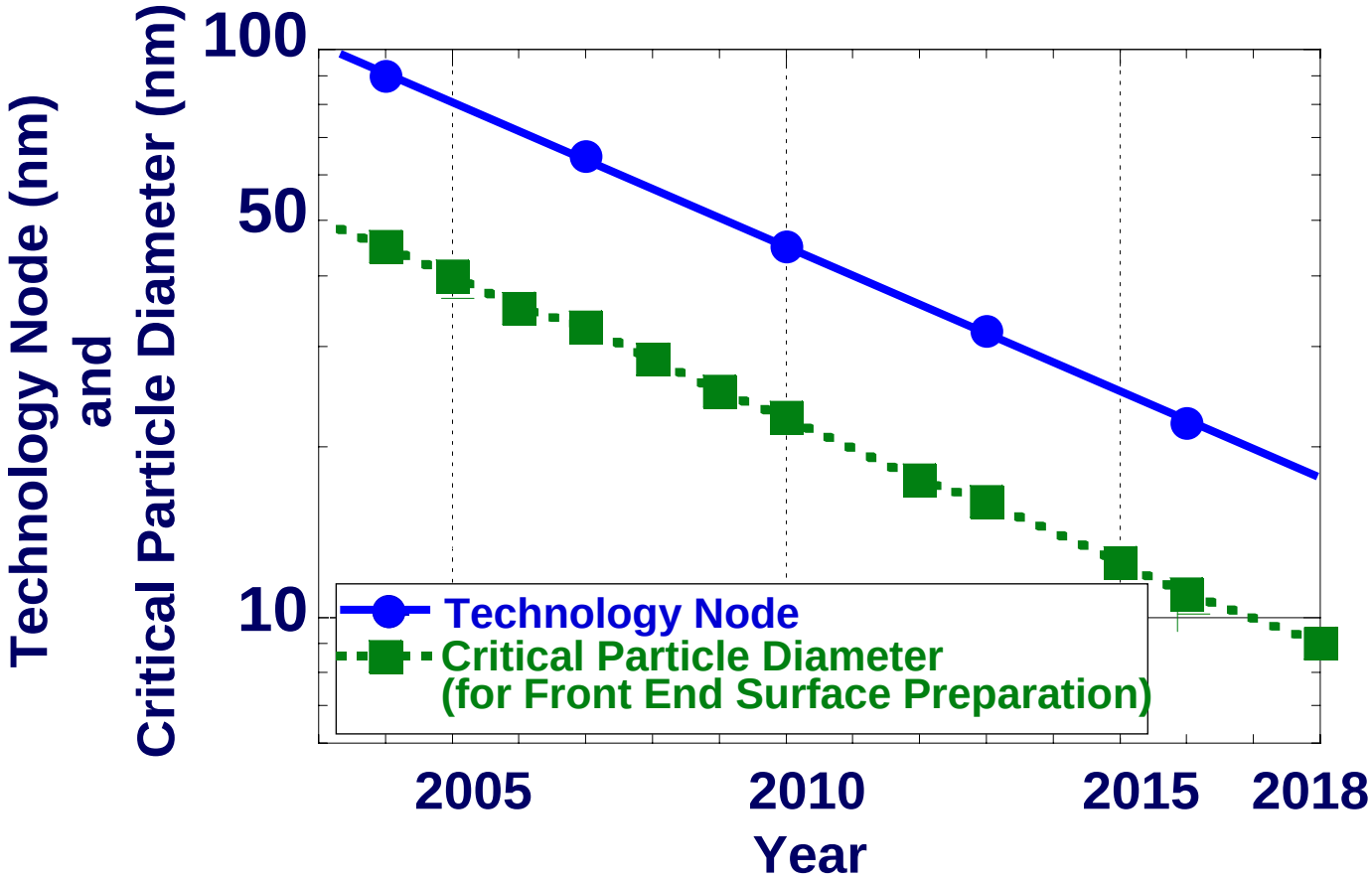
CELL



SONY + Toshiba + IBM

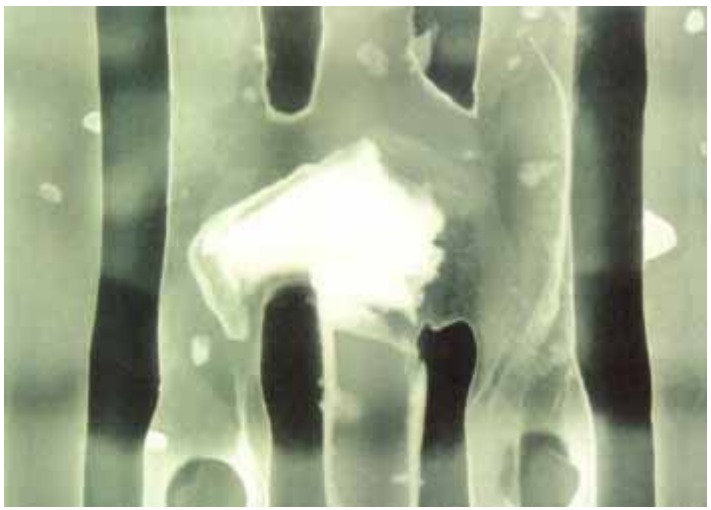
(Source :SONY)

Particle Requirement Acceleration Also Continues

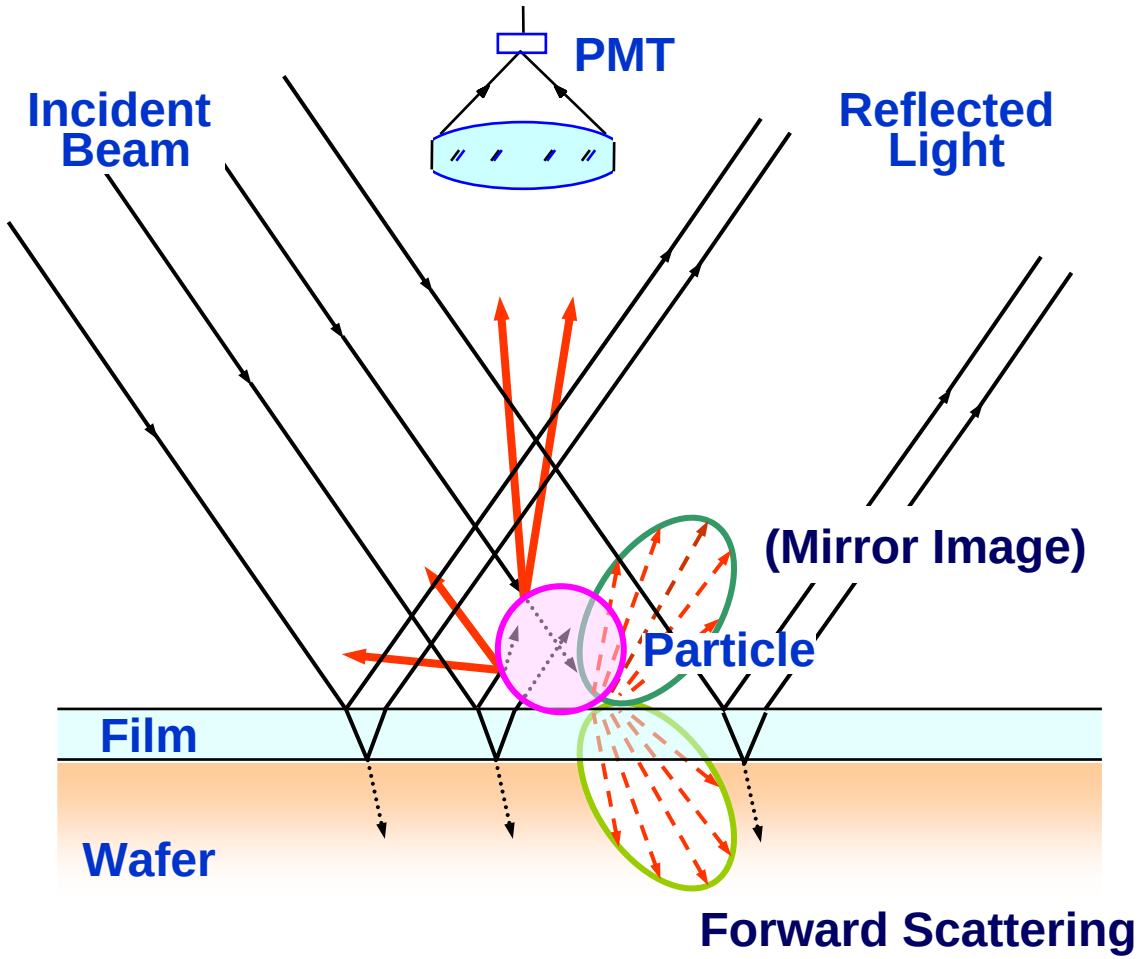


(Source: ITRS2004Update)

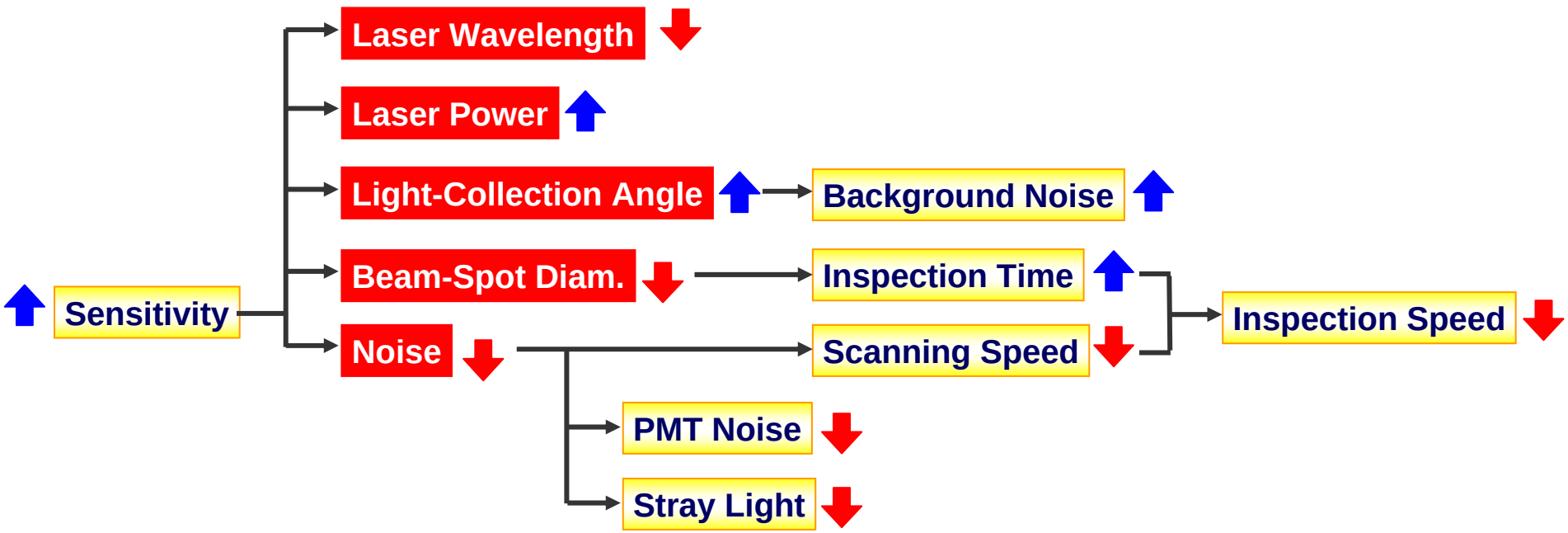
Defect Caused by a Particle beneath Lines



Light Scattering from a Particle on a Wafer



How to Increase Particle-Detection Sensitivity



Rayleigh's Equation

$$\mathbf{Is} = \frac{\pi^4 \mathbf{r}^6}{8\, d^2 \lambda^4} \left| \frac{n^2-1}{n^2+2} \right|^2 (1 + \cos^2\theta)\, \mathbf{Ii}$$

Is : Scattered light intensity
Ii : Incident light intensity
r : Particle diameter
λ : Wave length
θ : Angle of the incident list
d : Distance from the particle

Light Sources for Wafer Inspection Systems

Laser Source	Wavelength	Remarks
Nd:YAG (SHG)	**532 nm**	**CW, Presently in use**
Ar^+	**488 nm**	**CW, Presently in use**
Semiconductor (GaN)	**405 nm**	**CW, Presently in use**
Nd:YAG (THG)	**355 nm**	**Pulse**
Nd:YAG (FHG)	**266 nm**	**CW, Our choice**
? + ? (SFG)	**1xx nm**	**CW, Under development**

SHG = Second-Harmonic Generation
THG = Third-Harmonic Generation
FHG = Fourth-Harmonic Generation
SFG = Sum-Frequency Generation

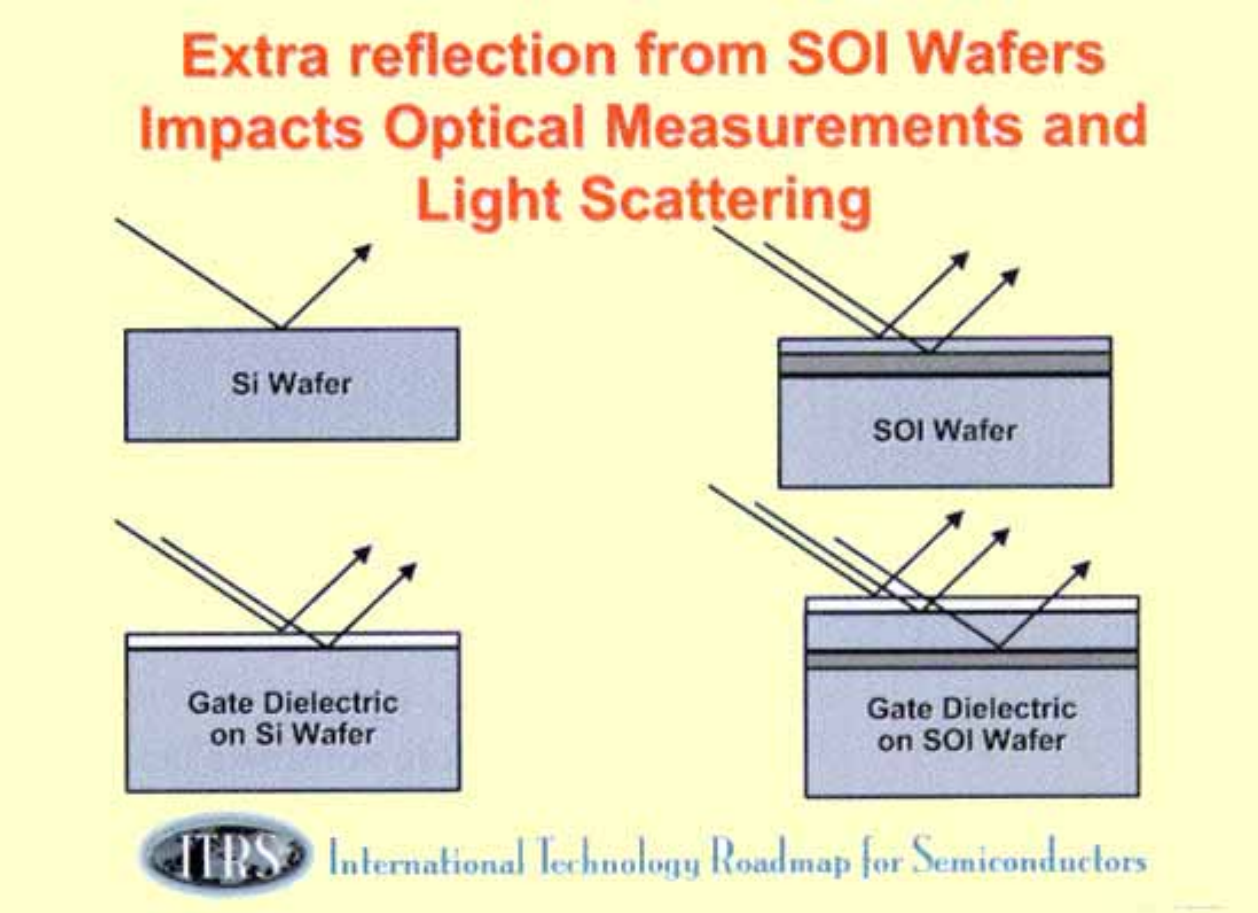
CW = Continuous Wave

Deep Ultraviolet Solid-State Laser

Employing FHG of Nd:YAG Laser and
a β-BaB_2O_4 nonlinear crystal as the wavelength converter

Specifications	**Wavelength**	**: 266 nm (Nd:YAG <FHG>)**
	Output (continuous)	**: 100 mW**
	Noise	**: 0.3 % rms or better**
	Warranty period	**: 3,000-h (virtually 7,000-h and up)**
	Dimensions	**: 270 mm×500 mm×170 mm**

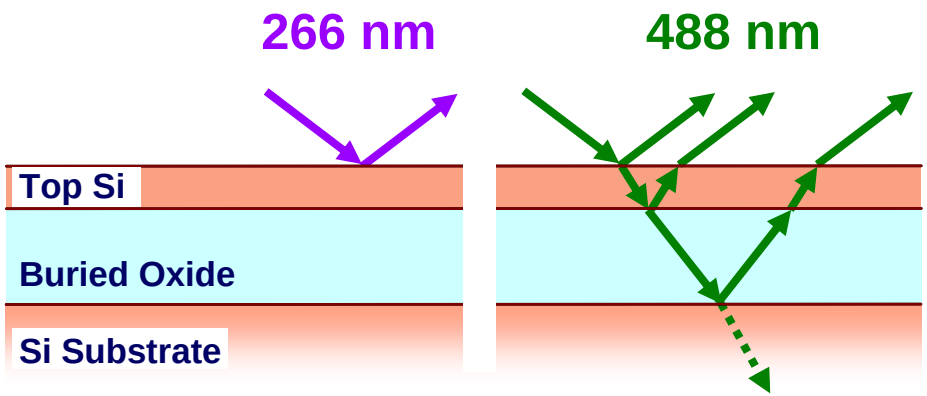
Metrological Challenge



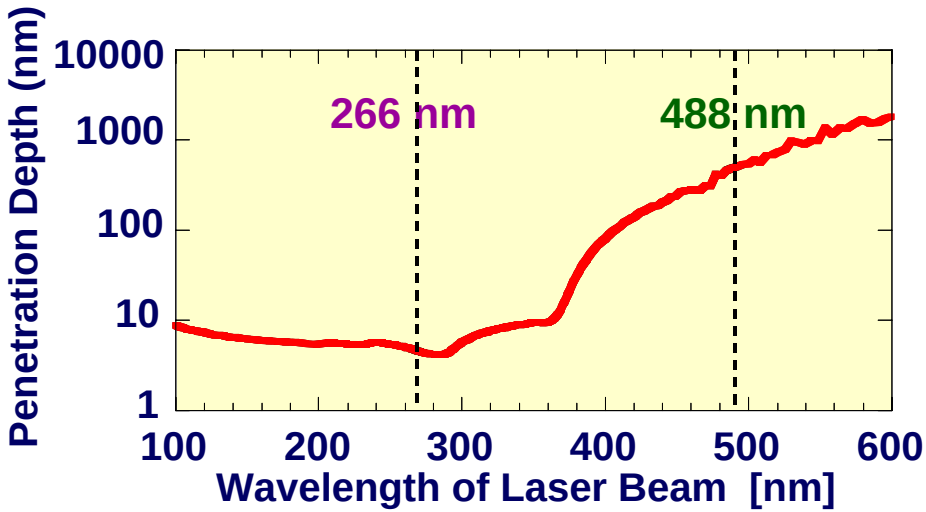
(Source : ITRS 2002 Update Conference Handout booklet, December 4 2002.)

Prevention of Additional Reflections with a Shorter Wavelength Laser

(a)



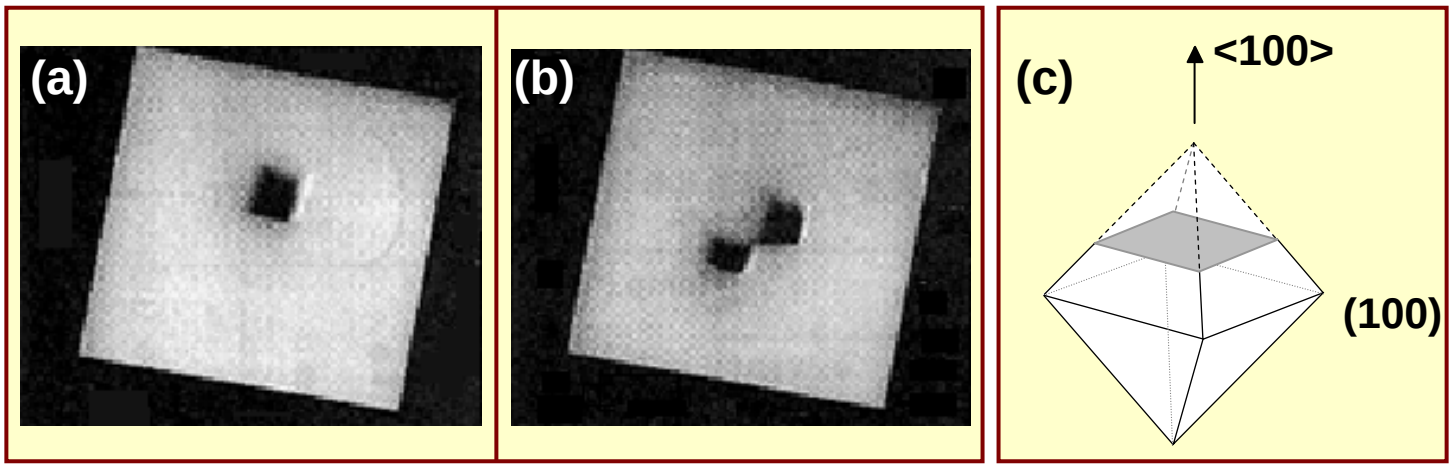
(b)



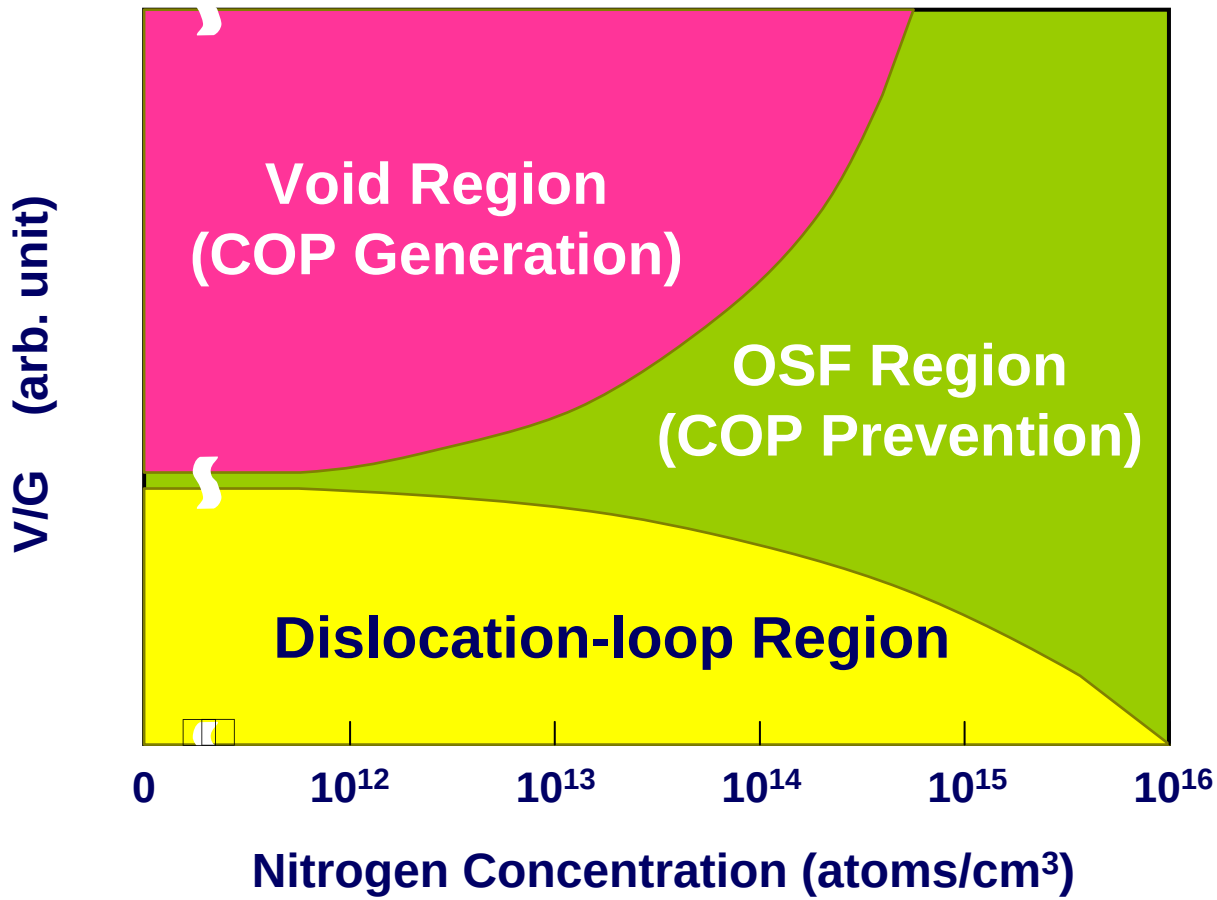
Deleterious Influence of Surface Conditions/Morphology on Sensitivity Increase

- COPs
- Micro- scratches
- Micro-roughness
- Organic contamination (“Haze”)

Crystal-Originated Pits (COPs)

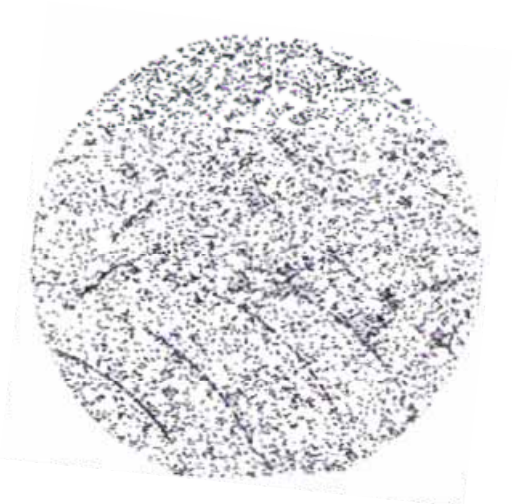


Grown-in Defect Map of Nitrogen-Doped Crystals

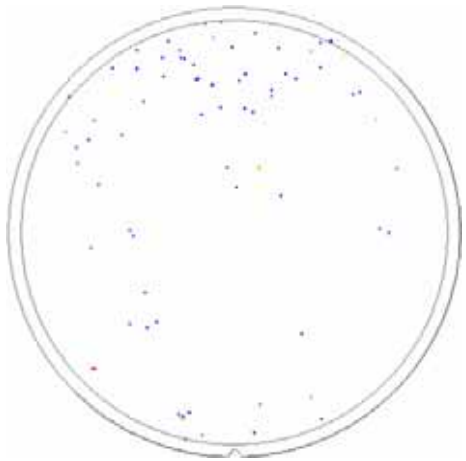


(Source :Nakai, Proc. 3rd Int'l Symp. Silicon Materials, Hawaii, 2000)

Micro-Scratches on a Wafer Surface

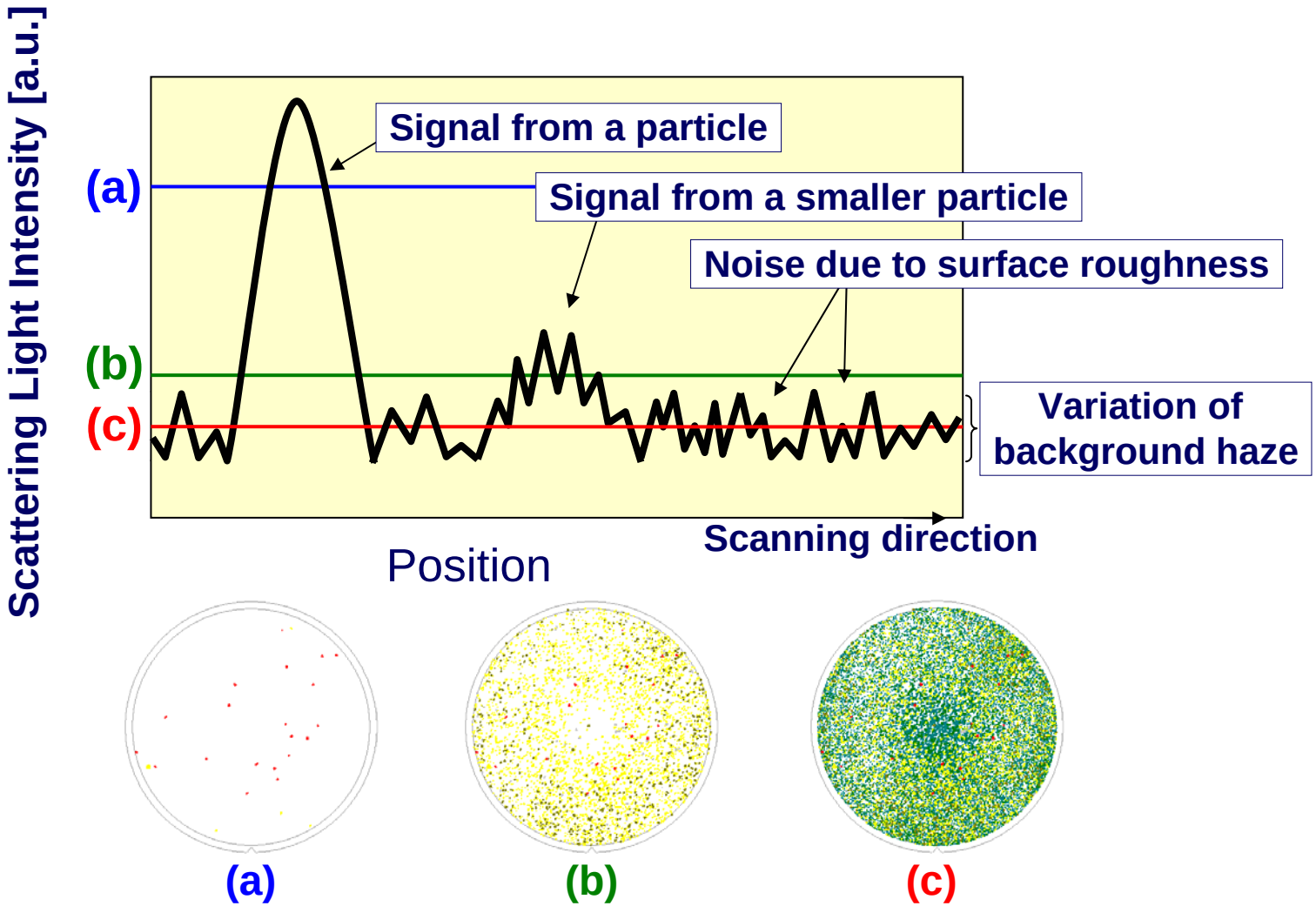


Uncontrolled



Controlled

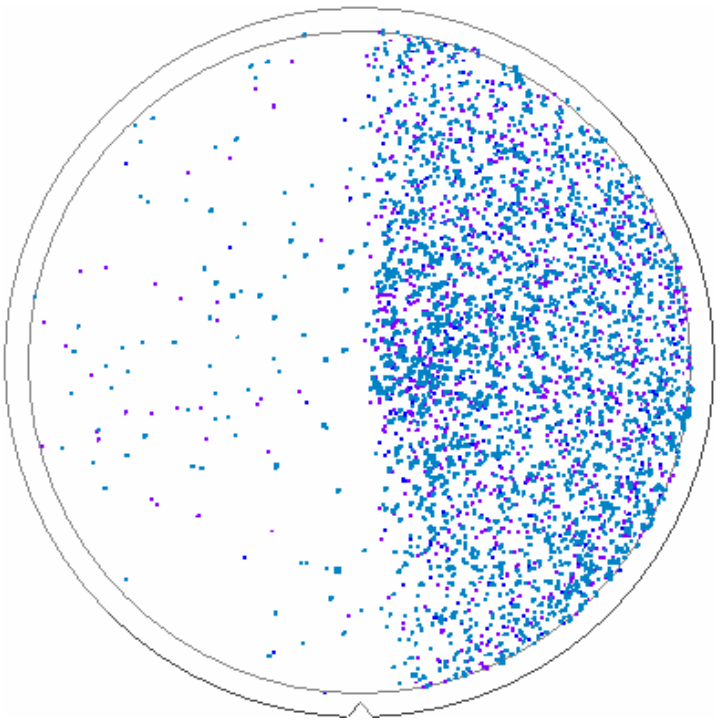
Influence of Microroughness on Wafer-Surface Particle Detection

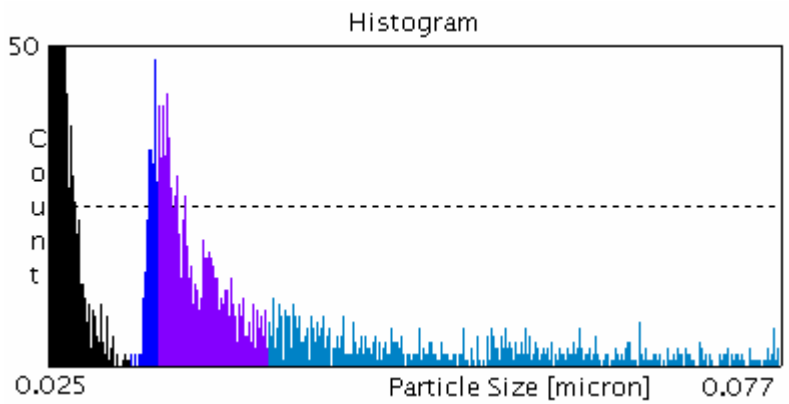


Results Using a Deep-UV Laser

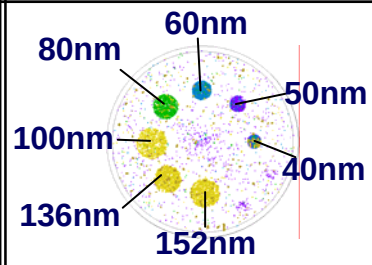
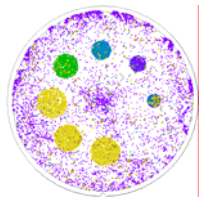
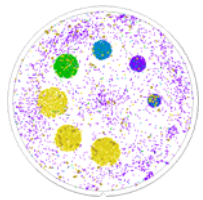
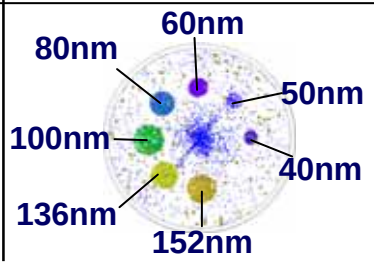
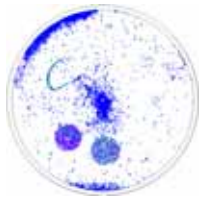
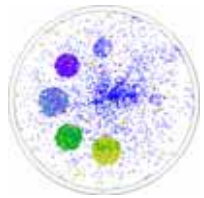
- Bulk-Silicon Wafer
- Bonded SOI Wafers
- SIMOX SOI Wafers

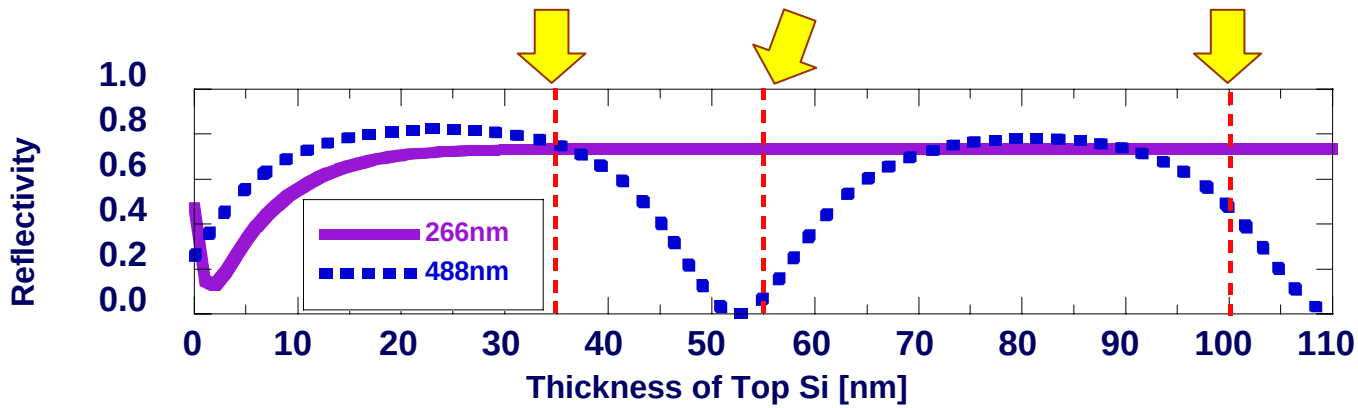
30nm PSL Detection Using 266nm Laser





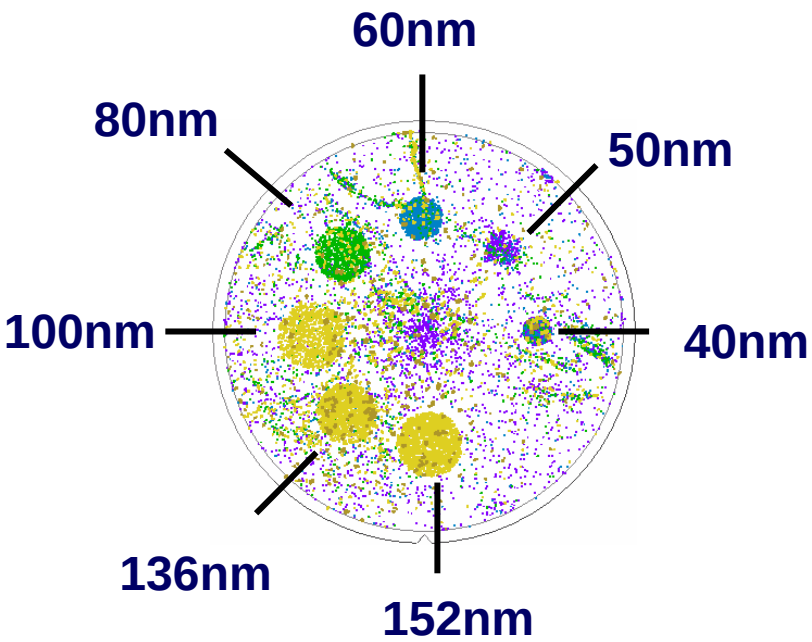
PSL Detection on Bonded SOI

Top Si thickness	35nm	55nm	100nm
266nm solid-state laser			
488nm Ar^+ gas laser			

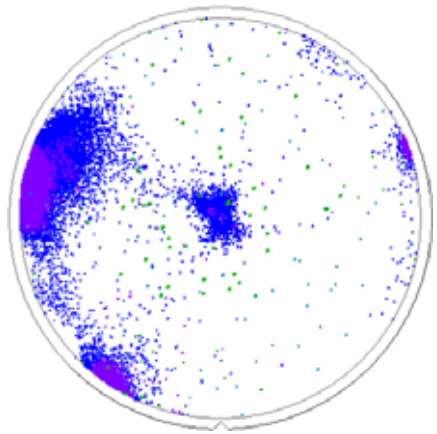


PSL Detection on SIMOX SOI

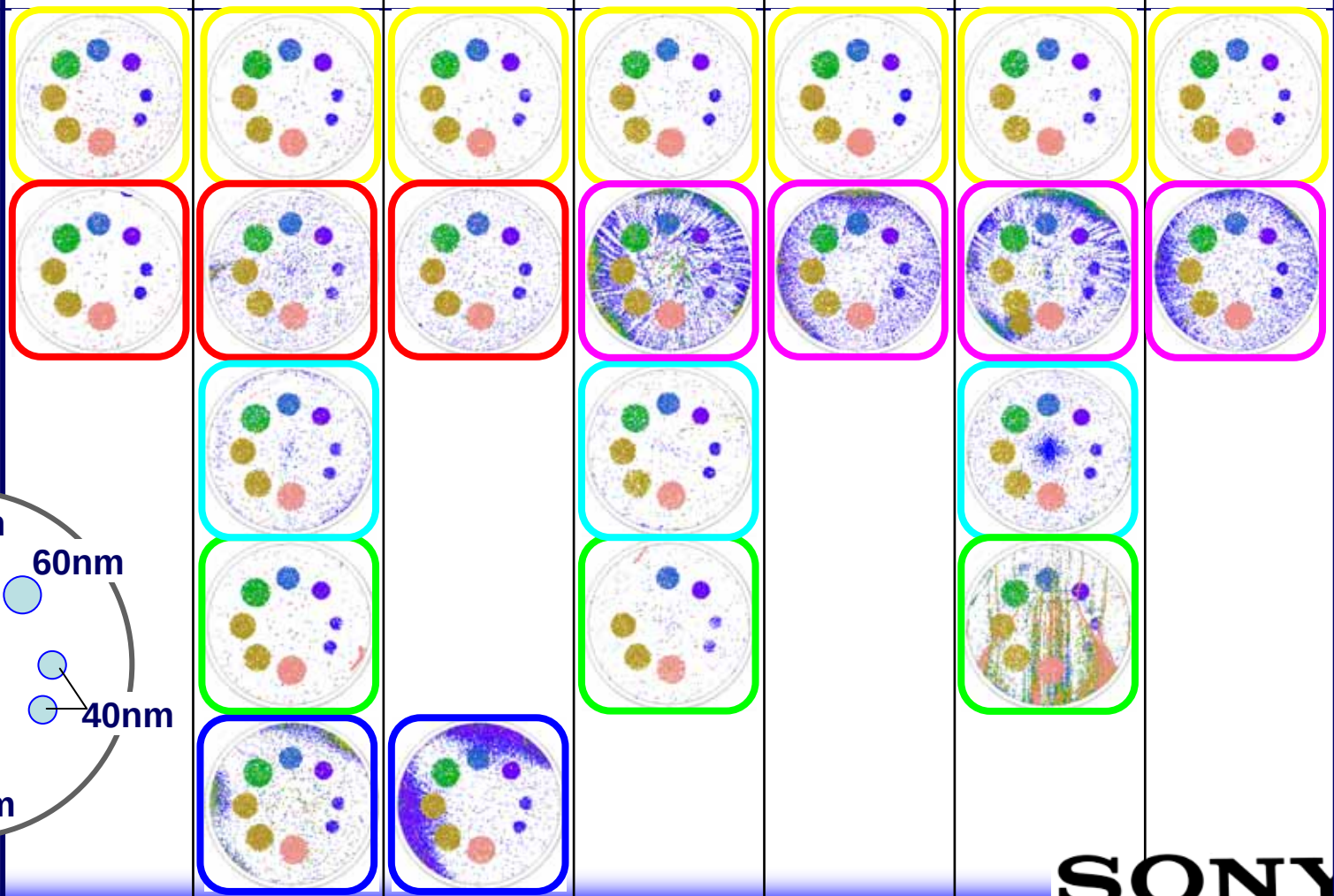
266nm laser

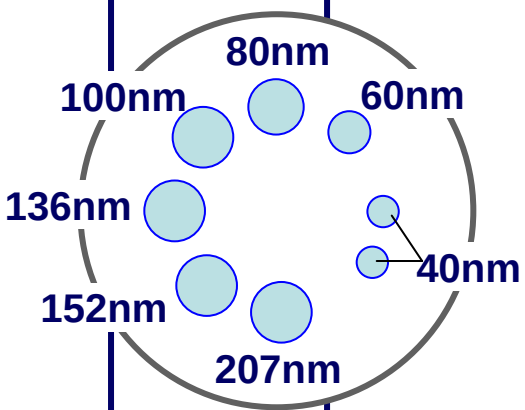


488nm laser



JEITA's SOI WAFER ROUND ROBIN

Top Si	50nm			30nm		20nm	
BOX	200nm	150nm	100nm	150nm	100nm	150nm	100nm
Company A,B,C,D,E And F							



Summary

- Lowering the wavelength of the incident light is the most effective way to increase the sensitivity of particle detection.
- Surface morphology/conditions influence on the particle-detection sensitivity, So, obtaining a very smooth silicon surfaces is a key prerequisite for smaller particle detection.
- We have developed a new wafer-inspection system employing a 266 nm DUV laser with the capability of detecting particles as small as 30 and 40 nm on bulk-Si and SOI wafers, respectively.

Future Challenges

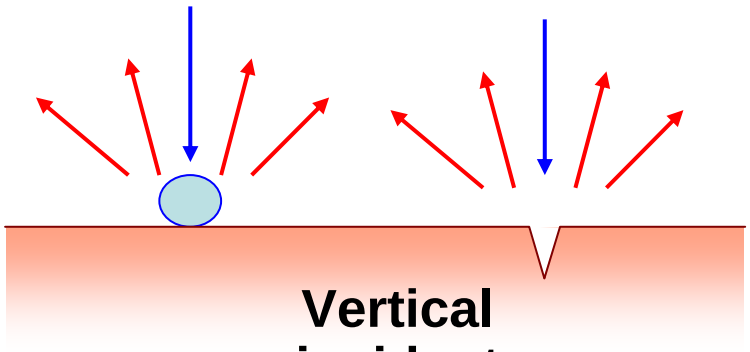
- **Future system will employ either a much shorter wavelength (< 200 nm) lasers as the light source or scanning electron beams, whose operational speed must be raised from that used in present SEM.**

ACKNOWLEDGEMENTS

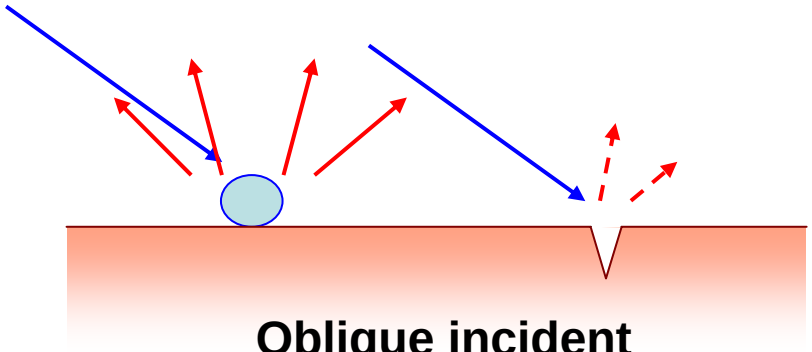
Special thanks to TOPCON Corporation for fabricating this equipment for us, employing Sony's 266nm solid-state laser.

APPENDIX

Schematic of Particle-COP Classification



Vertical incident



Oblique incident

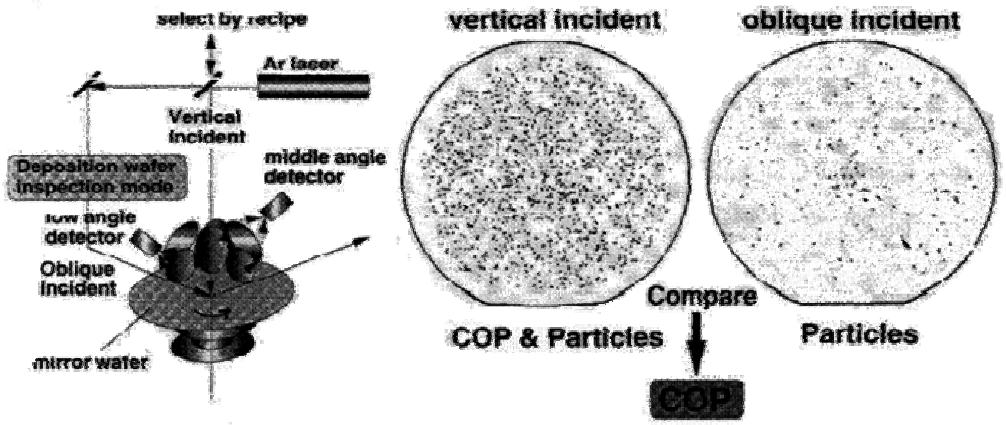


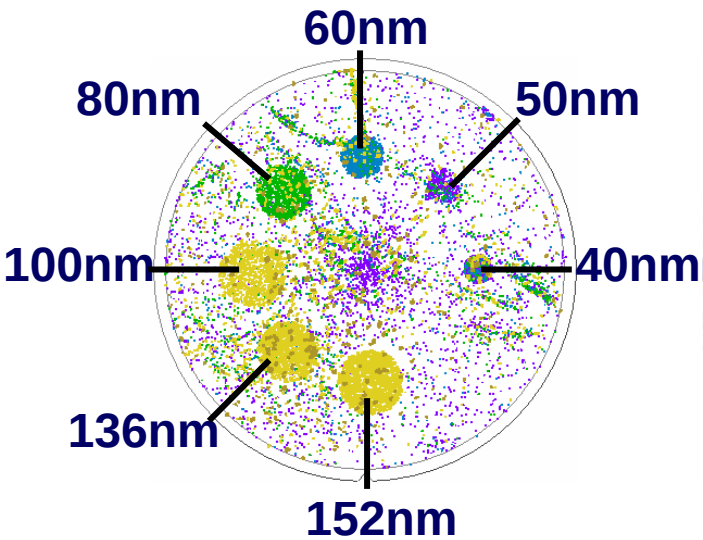
FIGURE 2. Arrangement of the optical system of a scanning surface inspection system (A) and the resulting wafer maps (B) showing the separation of particles and COPs on a polished Czochralski wafer.

Particle-COP Classification Accuracy

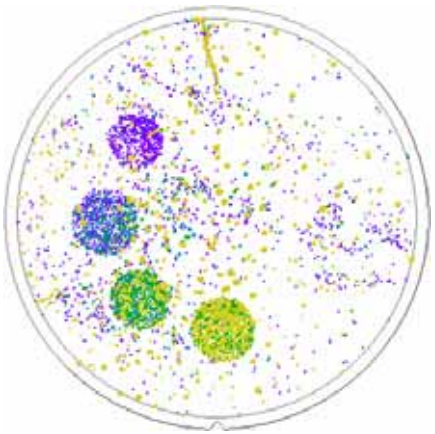
Company	Sensitivity	Particle	COP
X	100 nm	84%	85%
Y	80 nm	84%	84%
Z	80 nm	53%	93%

PSL Detection on SIMOX SOI

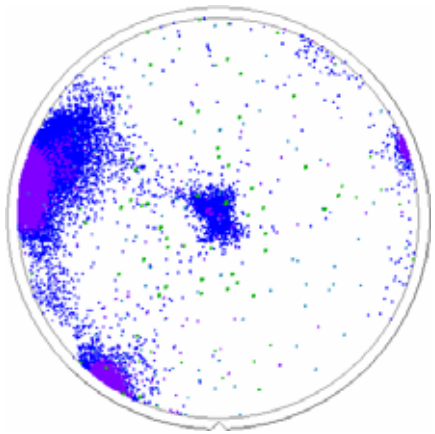
266nm laser



405nm laser

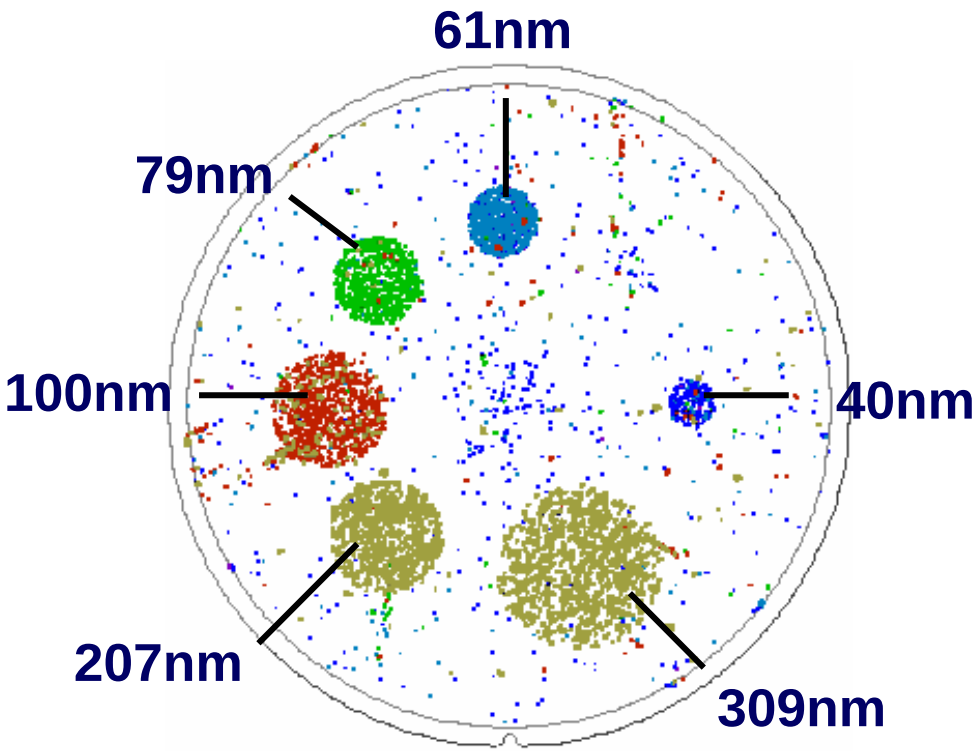


488nm laser

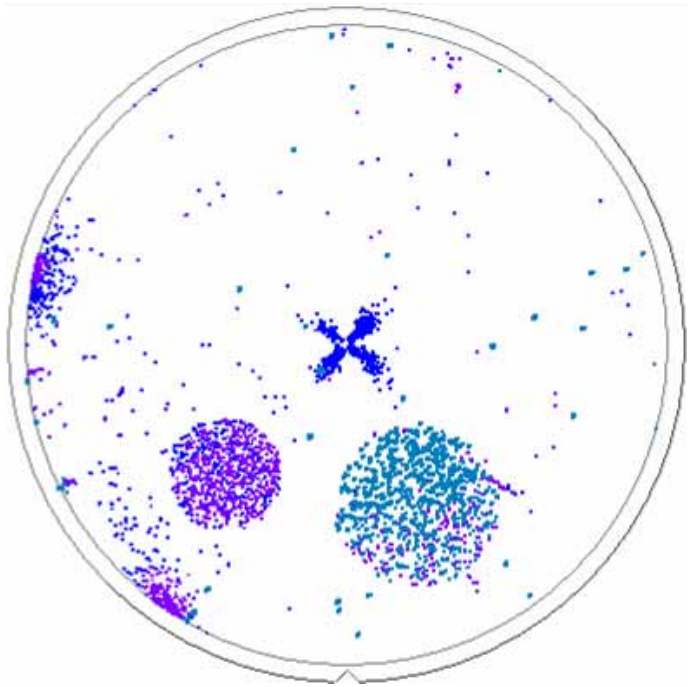


PSL Detection on SIMOX SOI

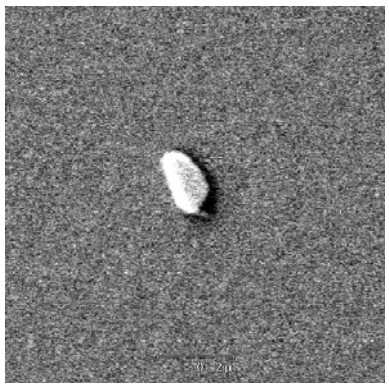
266nm laser



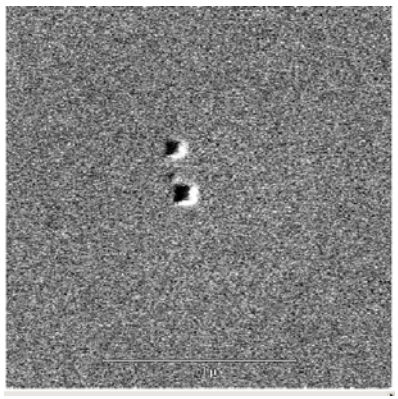
488nm laser



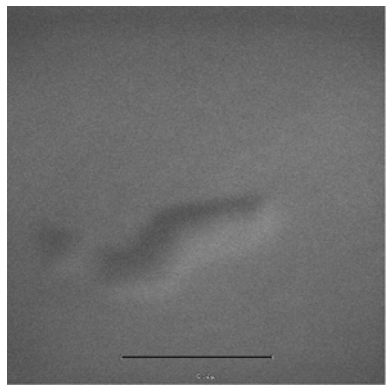
Defect Classification



Particle

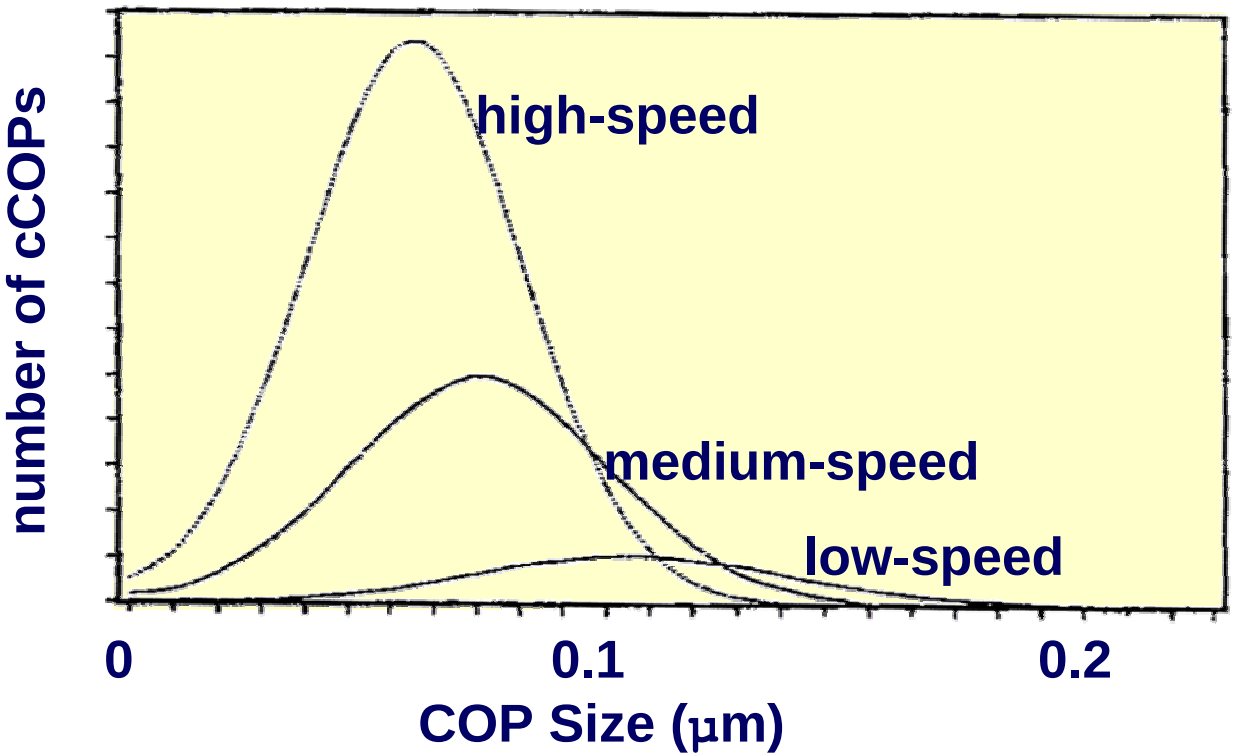


COP



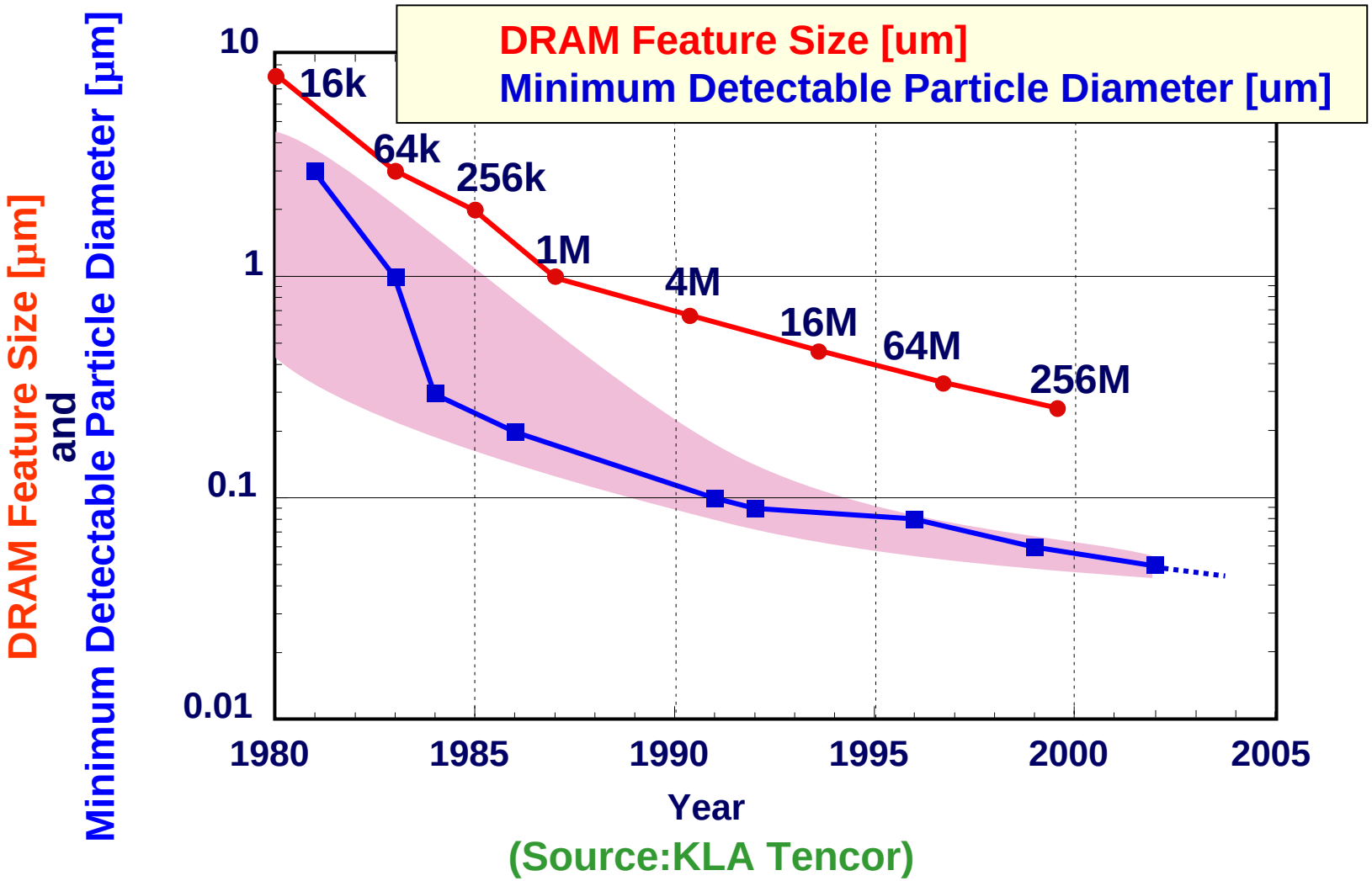
Shallow Pit

Influence of Crystal Growing Speed on COPs



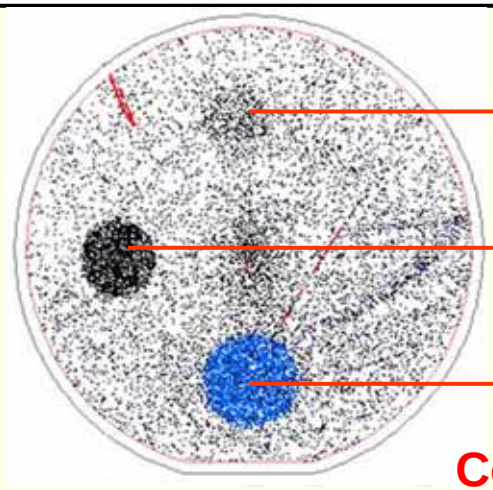
(Source : J. Ryuta, JJAP, vol. 31, L293 (1992))

Sensitivity Trend of Particle-Detection Equipment



(Source:KLA Tencor)

Sensitivity of Current Wafer Inspection Systems

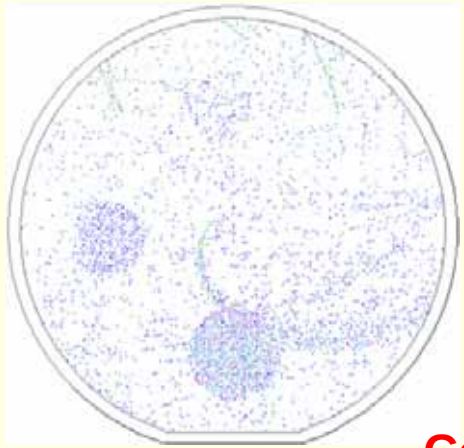


48nm PSL

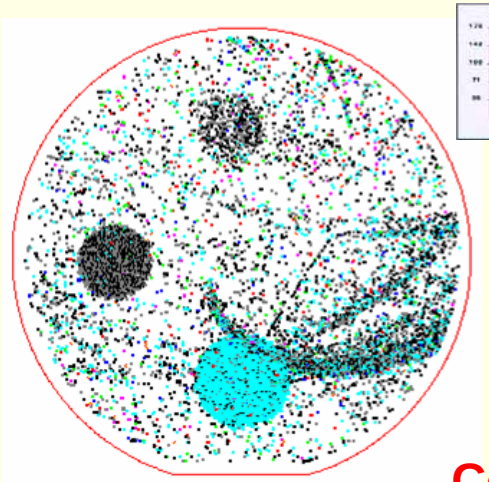
50nm PSL

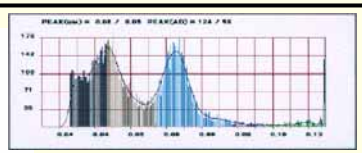
60nm PSL

Company A

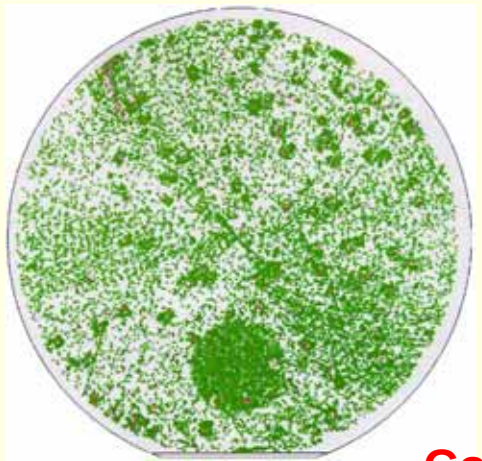


Company B





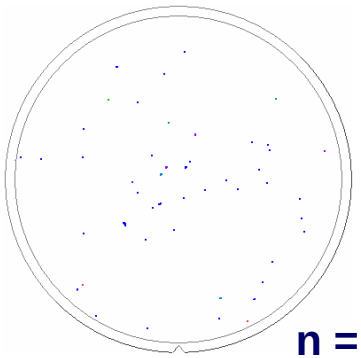
Company C



Company D

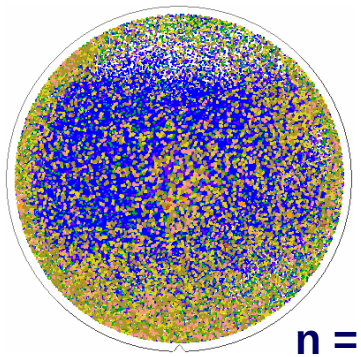
LPD Changes by Cleaning

Before cleaning



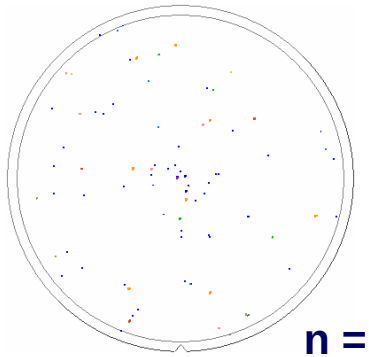
n = 85

After SC1 cleaning

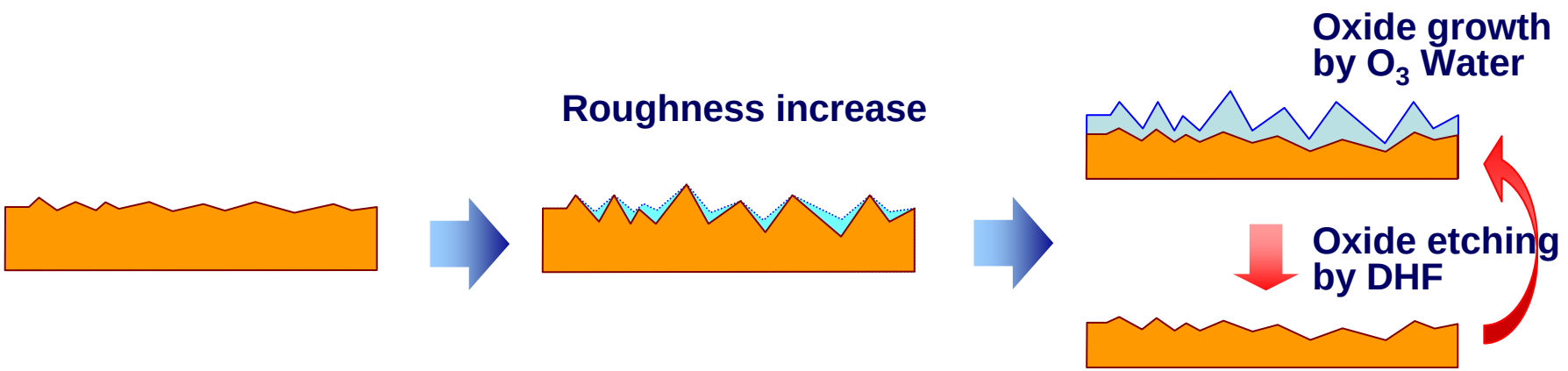


n = 125,624

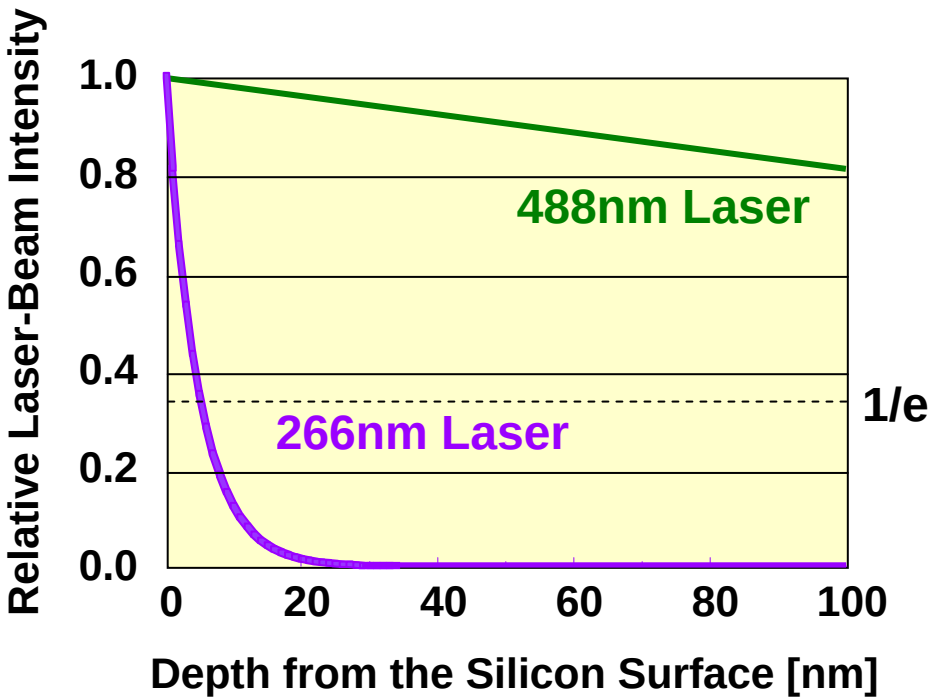
Then After SCROD cleaning

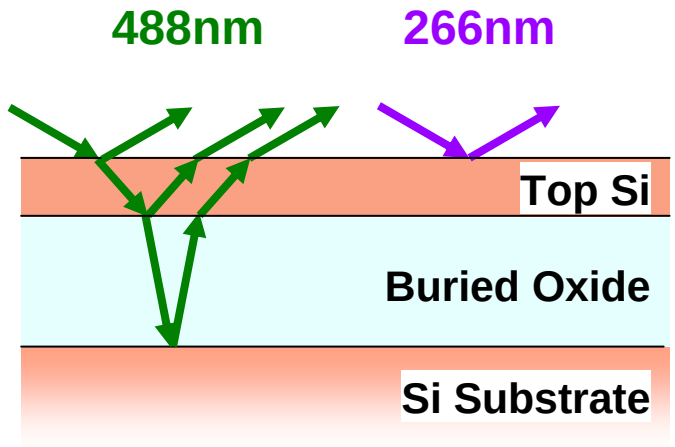


n = 86

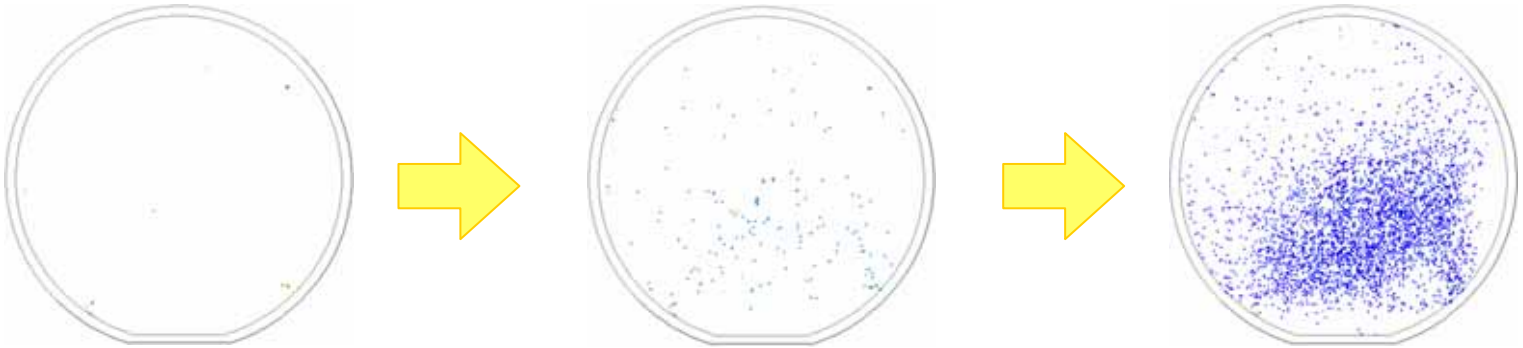


Prevention of Additional Reflections with a Shorter Wavelength Laser

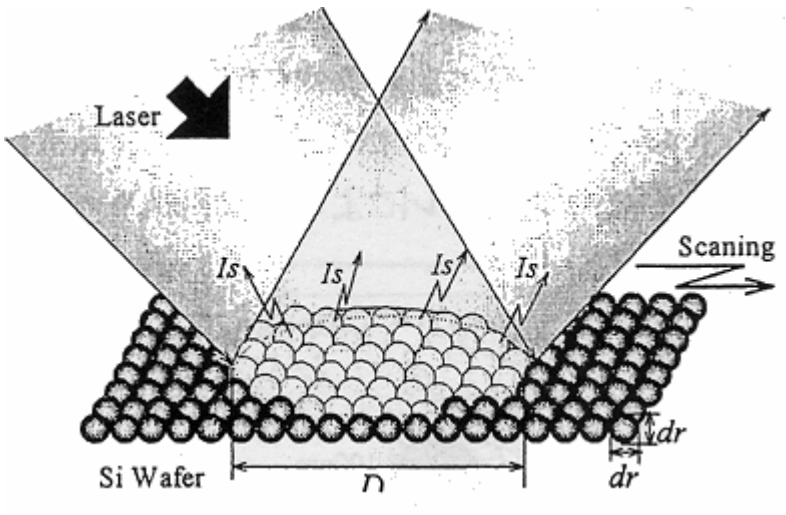


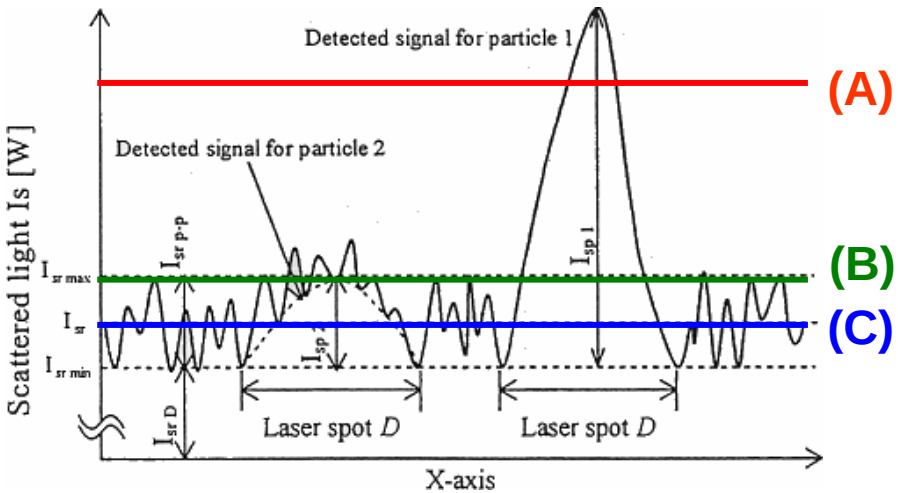


Micro-Roughness on a Wafer Surface



Sensitivity : 80nm (A) **Sensitivity : 60nm (B)** **Sensitivity : 48nm (C)**





Microroughness Increase by Lowering Threshold of Scattering Light Intensity