EUV Substrate and Blank Inspection

SEMATECH EUV Workshop

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EUV Substrate and Blank Inspection is one element of the NIST-ATP project 98-06.

- The NIST-ATP is partially funding a joint venture to develop a NGL mask inspector.
- Five participants: KLA-Tencor, Dupont Photomask, Photronics, Lucent, EUV-LLC
- Three year program: May 1999-2002
- Main Goal: to retire all technical risks of a SCALPEL or EUV mask inspection system
- At the end of program we have the NGL inspection tool design and inspectable NGL masks

Developing an NGL inspection tool is extremely challenging.

- NGL inspection tool needs to be ready for SCALPEL at 100 nm, EUV at 70 nm
- Must deal with new mask *materials and structure*, along with *sensitivity* improvements
- Can optical inspection do the job or do we need a next-generation platform?
- New approaches necessary
  - Must reduce defect-to-pixel ratio in optical systems, and
  - Extend optical technology to shorter wavelengths

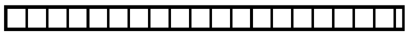
The project includes three phases.

- Phase I (year 1)
  - Build a research tool for NGL reticle inspection
  - Develop software model for NGL-steppers (aerial image)
  - Investigate EUV blank and substrate inspection
- Phase II (year 2)
  - Carry out inspectability/printability studies on the research tool
  - Correlate defects found on the wafer with those on the reticle
  - Establish the feasibility of Optical Inspection of NGL reticles
- Phase III (year 3)
  - Select 1 NGL technology and design a production prototype

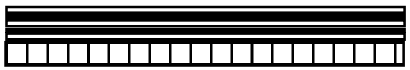
Our NIST-ATP program has to answer these questions.

- What constitutes a significant defect on EUV substrates, blanks, and masks?
- What fraction of significant defects can an optical inspection tool see?
- What would be the characteristics of an EUV mask or mask blank and substrate inspection tool?

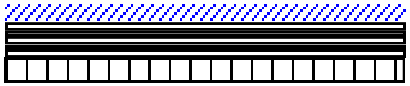
How is the mask fabricated and when do we **inspect** it?



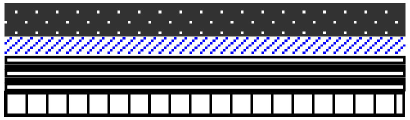
1. **Substrate qualification**



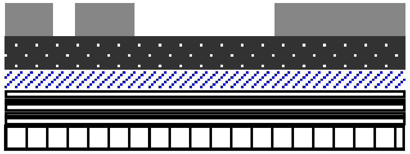
2. Multilayer deposition and **defect inspection**



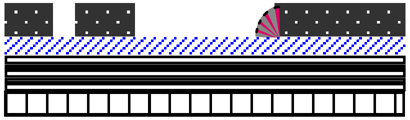
3. Buffer layer deposition



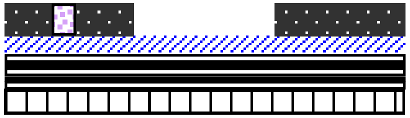
4. Absorber deposition



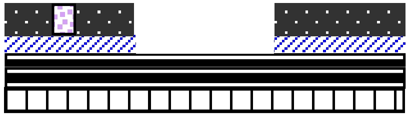
5. Pattern generation lithography



6. Pattern transfer into absorber



7. **Defect inspection** and repair



8. Buffer layer etch and **final inspection**

The current state-of-the-art in unpatterned wafer inspection is the SP1-TBI.

- Surfscan SP1-TBI:
  - 61 nm PSL sensitivity on well-polished silicon
  - Four dark-field channels, one bright-field Nomarski/DIC
  - 45 200 mm wafers per hour

The current state-of-the-art in reticle contamination inspection is the SL3UV.

- RAPID SL3UV URSA:
  - 120 nm to 150 nm contaminate sensitivity on blanks and patterned reticles
  - Back glass and pellicle inspection
  - 50 Megapixels/sec (195 minutes/100 cm² scan time)

Substrate defect roadmap

- Particle sensitivity
  - CY 2000: 60 nm PSL-sphere-equivalent on silicon
  - 2001: 50 nm
  - 2003: 45 nm on low expansion glass
- Roughness
  - HSFR (1/µm - 50/µm) 0.2 nm rms --> 0.08 nm rms

Source: 1998 EUV White Paper

Mask blank defect roadmap

- Substrate particle sensitivities plus…
- EUV "Phase" defects
  - Cylindrical pit or hillock: 3.4 nm high x 80 nm diameter
  - Scratch: 3.4 nm high x 15 nm wide
  - Step: 1 nm high

Source: 1998 EUV White Paper

We must determine if it is necessary to inspect mask blanks at 13 nm.

- Correlate optical and 13-nm blank inspections
- Determine evolution or mechanism of formation of reflectivity defects
- Model EUV defect properties in the visible/UV range
- Determine what defects we missed optically
- Determine if they are critical defects

How will we meet the substrate and blank sensitivity requirements optically?

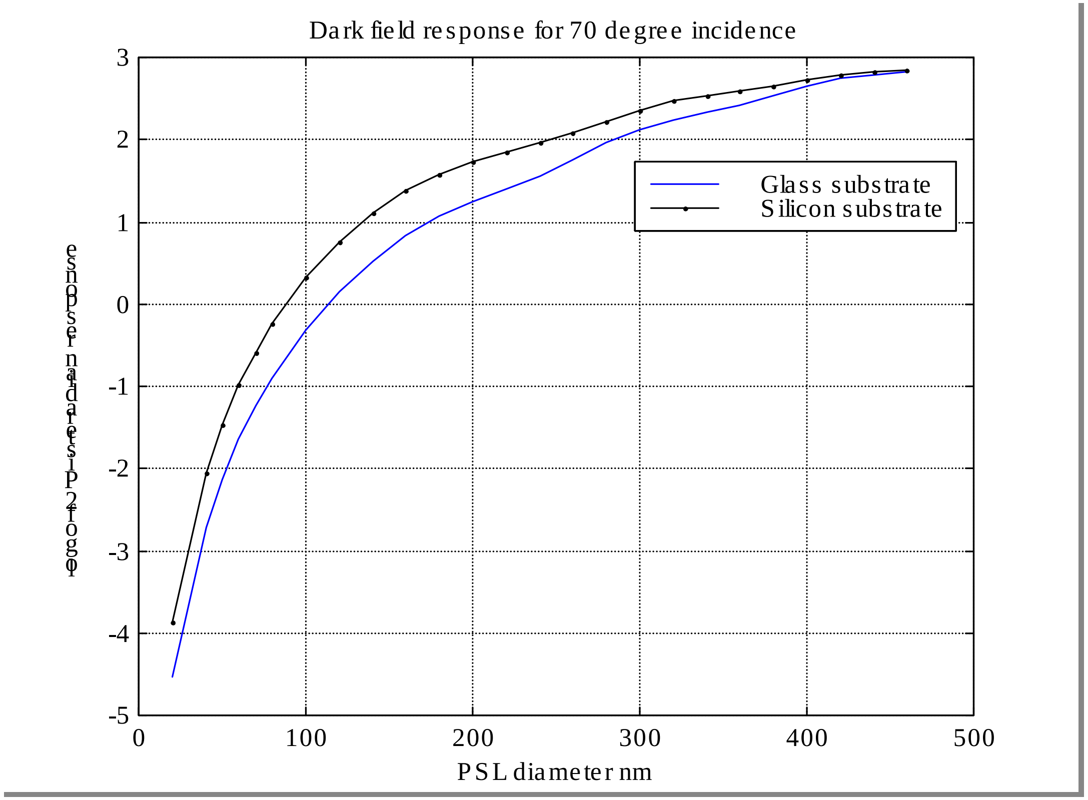
- There is no single "best" technique to find all the critical substrate and blank defects.
  - Bright-field technology is more adept at finding "planar" or phase defects
    - → Small pixel size, low throughput
  - Dark-field technology generally provides superior sensitivity for particulate defects
    - → Larger pixel size, higher throughput
- The architecture of an EUV substrate/blank inspection tool may be different than an EUV mask pattern inspection tool.

We need to achieve 45 nm particle sensitivity on glass.

- Transparent substrates impact dark-field system design.
  - Stray light and back-surfaces can lower sensitivity.
- Particles on glass scatter less light than particles on silicon.
  - Signal-to-noise ratio must be improved.
    - → The signal in the Rayleigh scattering regime can be increased by smaller spot, higher laser power, shorter wavelength.
    - → Noise can be decreased by a slower scan (if shot noise-limited);
    - → Noise increases with surface roughness and speckle (enhanced by small, coherent spot).

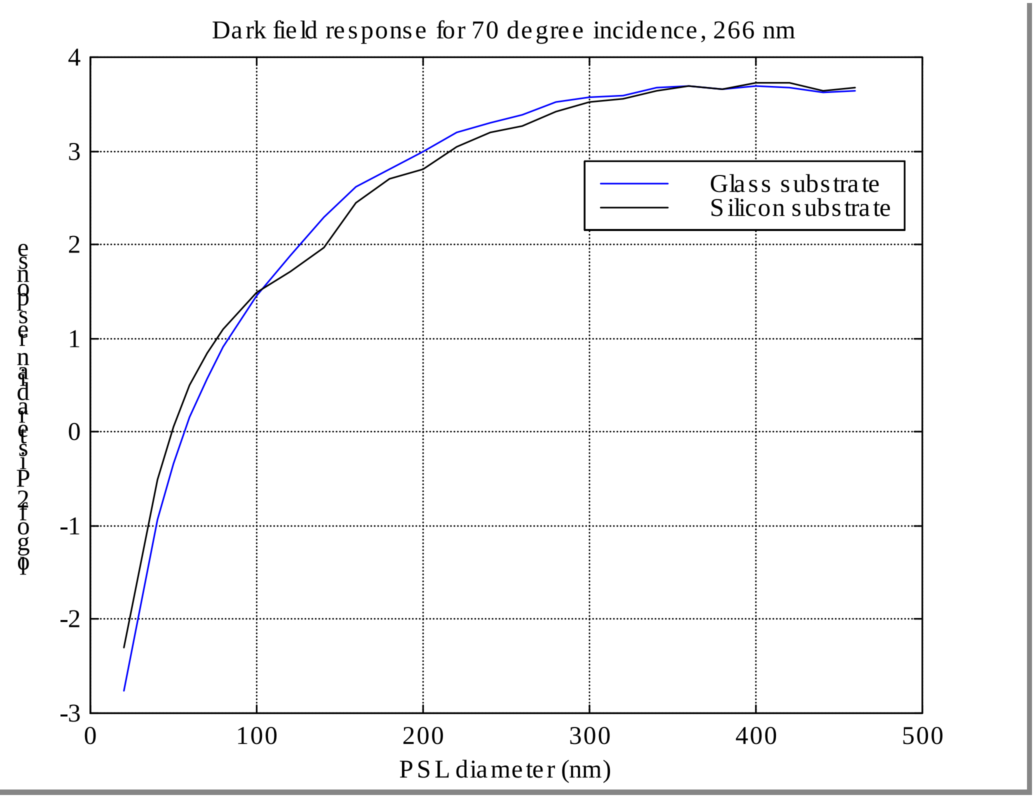
Dark-field sensitivity: PSL on glass versus silicon, oblique incidence visible

- 488 nm wavelength, 70 degree incidence, 2 Pi steradian collection.



Dark-field sensitivity: PSL on glass versus silicon, oblique incidence UV

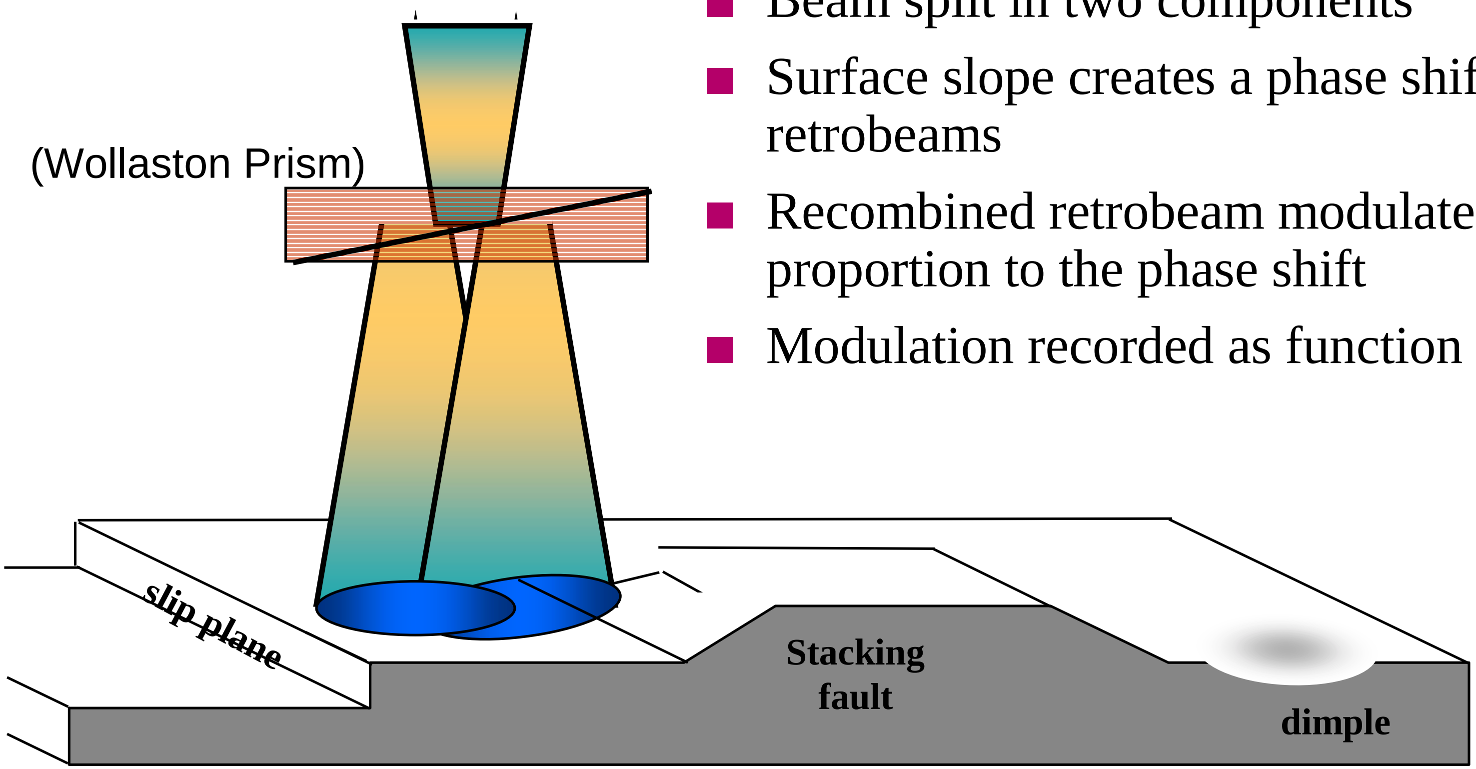
- 266 nm wavelength, 70 degree incidence, 2 Pi steradian collection.



Optical blank inspection requires phase-sensitive detection.

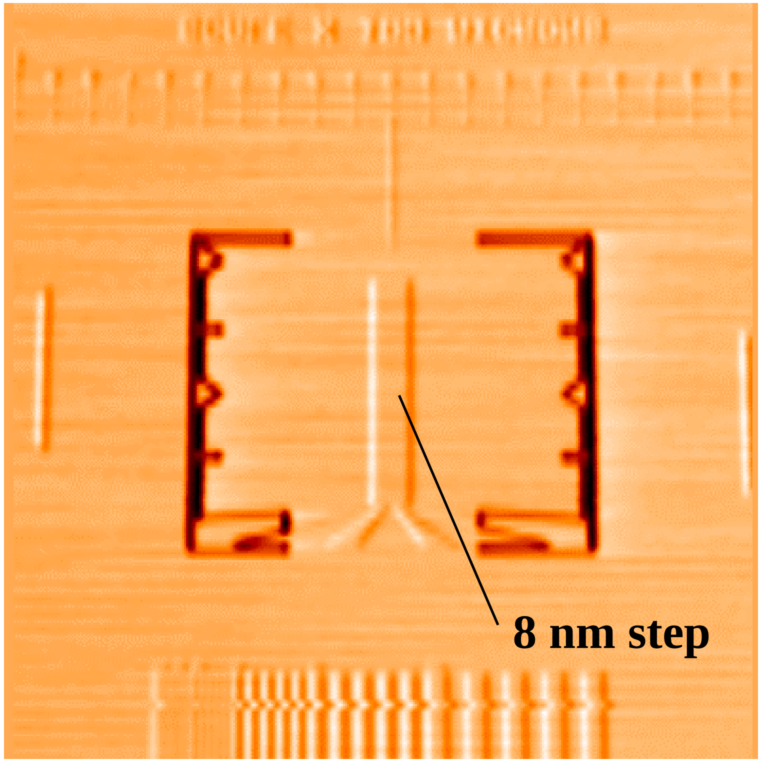
- $\lambda/2$ EUV phase defects equate to $\lambda/40$ or smaller in the UV or visible.
- It is necessary to use phase contrast systems to detect surface height variations of this order.

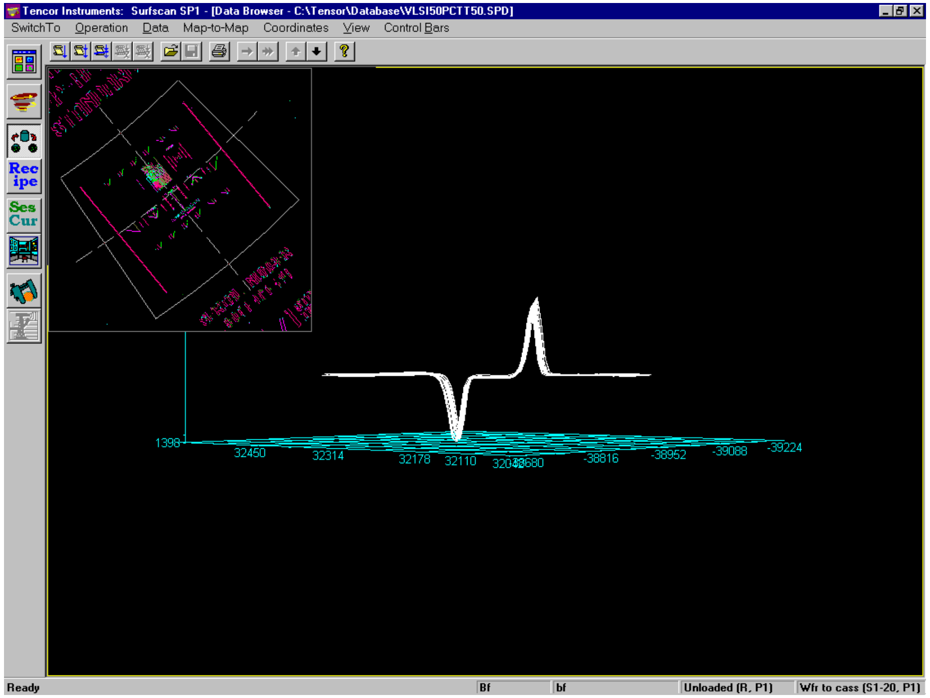
Nomarski Differential Interference Contrast (DIC): Principle of operation



- Beam split in two components
- Surface slope creates a phase shift between retrobeams
- Recombined retrobeam modulated in proportion to the phase shift
- Modulation recorded as function of (x,y)

A 8 nm step height standard can be measured with the SP1 Nomarski DIC channel.





Can DIC be extended to EUV Blank Inspection?

- DIC system sensitivity is proportional to effective volume of phase shifting object.
- Volume of 80 nm by 3.4 nm cylindrical defect is 1.75 x 10^{-5} um^3
- Dimples and hillocks of today have volumes 1000 times larger than this.

NIST-ATP will help KLA-Tencor to meet EUV substrate and blank inspection requirements.

- The present systems have contributed to EUV defect reduction efforts.
- By 2003, tool sensitivities must be improved significantly for both substrates and blanks.
- In the coming year we will be inspecting available EUV substrates and blanks with a variety of bright-field and dark-field techniques.
- We are exploring both evolutionary and innovative inspection solutions under this program.