

# Image Placement Error Due To Pattern Transfer For EUV Masks

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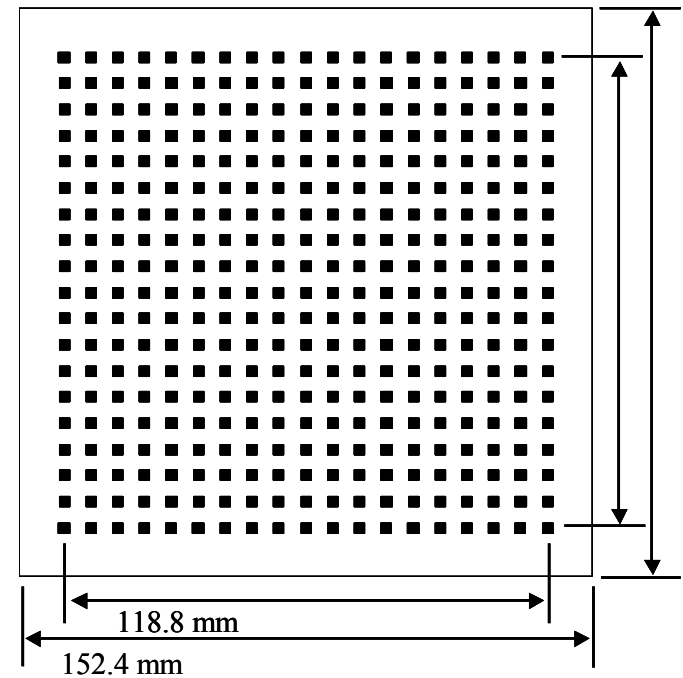


# Outline

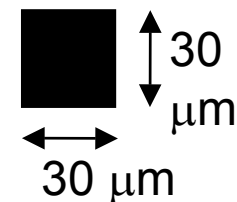
- Motivation
  - Understand the role of pattern transfer on EUV absorber stack resulting in film related stress release and subsequent in-plane distortion (IPD) and out-of-plane distortion (OPD).
    - Pattern transfer  $\Rightarrow$  IPD and out-of-plane distortion (OPD).
  - ITRS EUVL mask IP Distortion (IPD) specification
    - 2010 (45 nm node) 11 nm
    - 2013 (32 nm node) 8 nm
- Methodology
- Results and Analysis
- Summary

# Methodology

- Deposit Absorber layer stack on multilayer with known thickness and stress
- E-beam patterning using the grid array pattern
  - Exposed region consisted of ~1% of the total mask surface.
  - +ve or -ve tone resist gives 1% or 99% Clear area
- Pattern Transfer
  - 1% Clear: Dark field mask
- IPD obtained from Subtracting final pattern from resist
  - Negates the chuck contribution but does not address e-beam writing specific IP
  - LMS2020 performed image placement measurements.
    - Effective long-term repeatability ~7nm.



(a) The global mask array



(b) The measurement feature



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# Clear field vs Dark Field IPD

1 3 5 7 9 11 13 15 17 19  
2 4 6 8 10 12 14 16 18

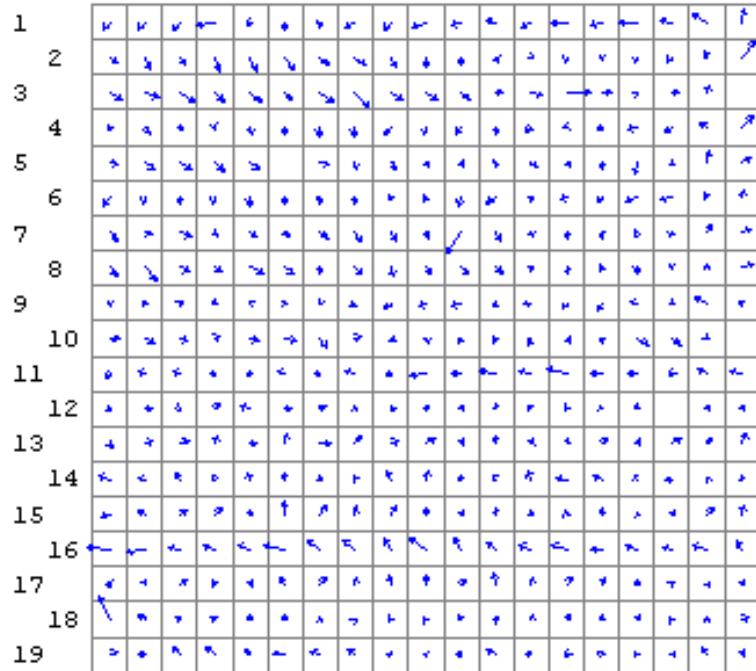
## Processing

Sites : SELECTED

Alignment : ALL

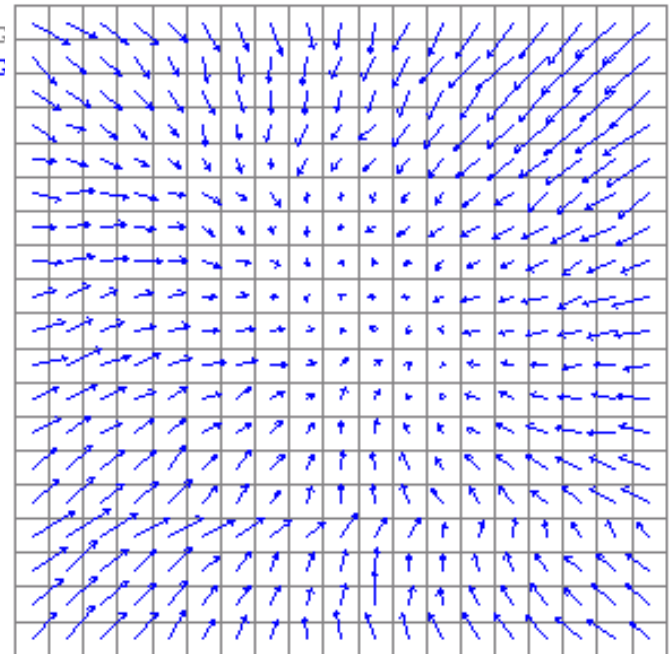
Ref. : VB6REGRS AVG

1 : 913APETC AVG



Dark field: Resist-to-Final IPD

Summary	X [nm]	Y [nm]	$\sqrt{10}$ [nm]
Mean	-0.15	-0.05	
Max 3 S.D.	7.70	6.43	
Min	-7.63	-7.25	
Max	8.48	8.59	



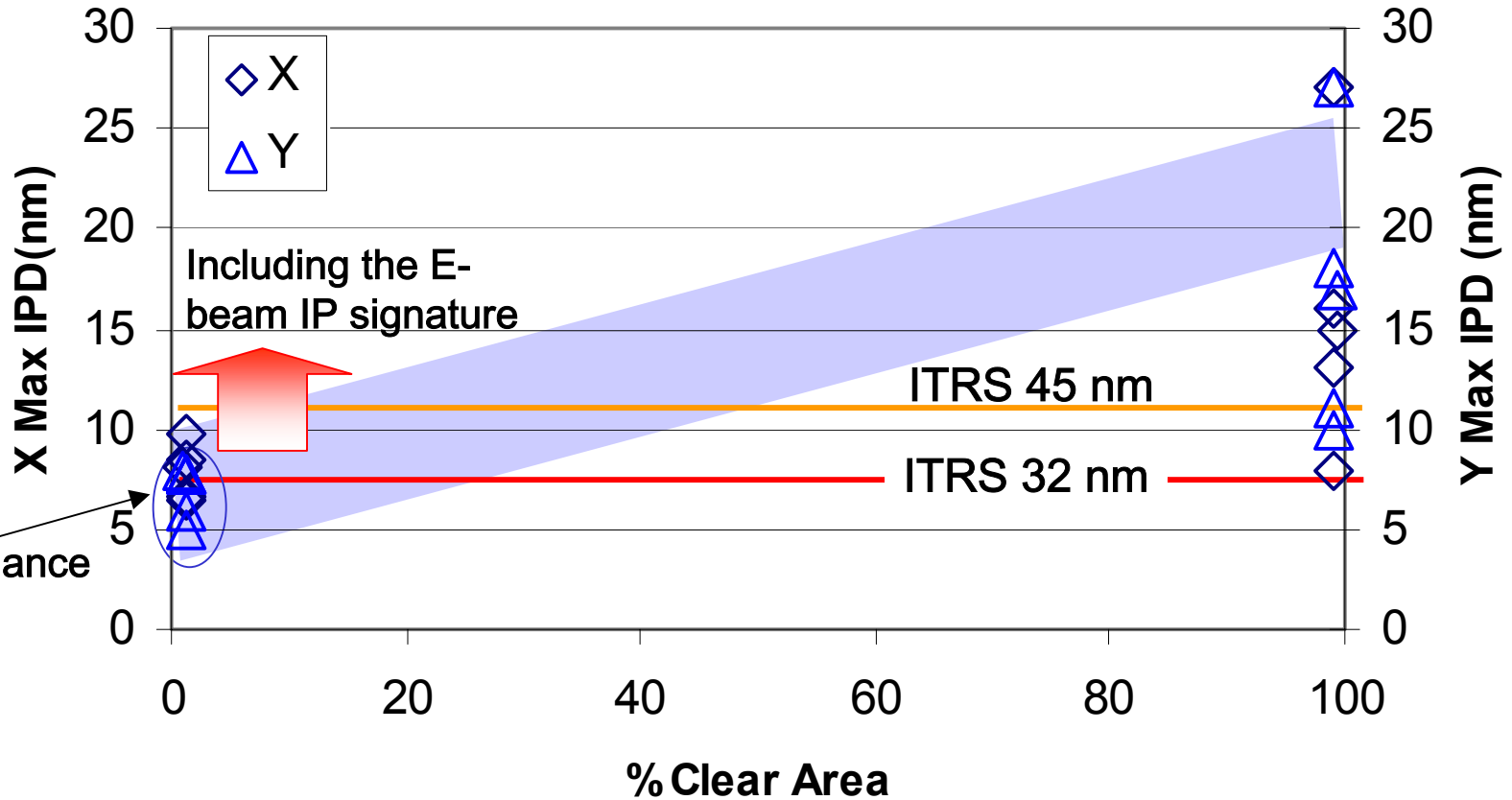
Clear field: Resist-to-Final IPD

Min	-15.02	-16.79
Max	12.57	15.90

Resist-to-final IPD is summation of individual film IPD contributions.

# IPD as Function of %Clear Area

Data from 5 dark field and 5 bright field mask



# Results

- Dark field mask stress induced IPD was negligible
  - As expected for <1% removal of the film.
- Clear field mask (worst case scenario) stress induced resist-to-final max IPD was 27 nm in each axis on one mask
  - Absorber stack composite stress will be an important factor to meet IP requirements
- Inclusion of E-beam writer contributions will adversely impact the IP
- Stress Challenge: Thin film stress on thick 6025 mask plates
  - Establish stress controls on Absorber films/6025plates
    - UW-Madison novel set up to perform stress measurement tests
- Potential Solution: e-chuck
  - Use of e-chuck for three key steps of mask manufacturing/usage will
    - Allow to relax the stress constraints of Absorber films required otherwise
    - Negate the IP impact due to e-beam writer
    - Allow to meet the ITRS 45/32nm node specification

# Film Stress Calculations

- If direct measurement of 6025 film stress is unavailable then stress related in-plane distortion measurements can be used to calculate film stress.
- Film stress calculated by using an adaptation of Stoney's equation for a square field, Eq. (1)<sup>4</sup>.

$$\delta = 6 \sigma_f t_f (a / 2)^2 (1 - \nu_s) / E_s t_s^2$$

where  $\delta$  is the OPD (bow of the mask),  $\sigma_f$  is the stress in the film,  $E_s$  is the elastic modulus of the substrate,  $t_s$  is the thickness of the substrate,  $\nu_s$  is Poisson's ration of the substrate,  $a$  is the length of the field, and  $t_f$  is the film thickness. Further, the maximum IPD can be used to estimate the OPD from Lovell's approximation<sup>5</sup>.