EUV Mask Chucking Study

- Defect Mitigation and Dynamic Flatness -

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- Object
- Methodology of Experiment
- Results
- Summary
- Future Works

Object

Quantify the impact of mask chucking operation onto the defect density of EUV mask backside.

- Does EUV mask backside meet SEMI-P37 even after mask chucking operation with electrostatic chuck (ESC) ?
- If it does not meet the SEMI standard, how do we improve it ?
- Correlate particle size on the backside to pattern flatness change on the front side.

SEMI-P37

- Backside Defects in Flatness Quality Area

Table 1.

Localized light scatter size ... PSL equivalent (See Note 2.)	Total	Total number of backside scratches (see Note 1.)
> 1.0µm	0	0
≤1.0µm	no limit	

Note 1: The maximum size for scratches and sleeks will be agreed upon between user and supplier.
Note 2: Localized light scatterers are any isolated features, such as particles or pits, on or in the substrate surface, resulting in increased light scattering intensity relative to that of the surrounding substrate surface. PSL equivalent size means the detected defect appears to be the same size as a polystyrene latex sphere examined under the same inspection conditions.

Methodology of Experiment

- Material Preparation
- ESC Pre-clean
- Chucking Operation
- Defect Inspection

1. Material Preparation

- Mask backside coating
  - 70nm thickness deposited on 6-inch quartz substrate
  - Material: Cr, TaN
    - Absorber materials for EUV mask
    - Electrically conductive
- Electrostatic chuck material (ESC)
  - Supplied from ceramic manufacturers
  - Material: Al_2O_3(poly-cristalline), Sapphire, AIN
  - Size: 30mm x 30mm
  - Surface flatness: 1μm~9μm

Table 2. Measured hardness (GPa) for ESC coupon and EUV mask backside.

ESC material			Mask backside	
AIN	**Al2O3**	**Sapphire**	**Cr**	**TaN**
7.2	**12.6**	**15.6**	**11.4**	**32.4**

2. ESC Pre-Clean

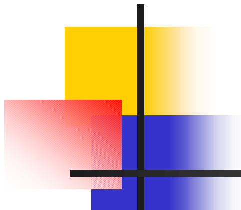
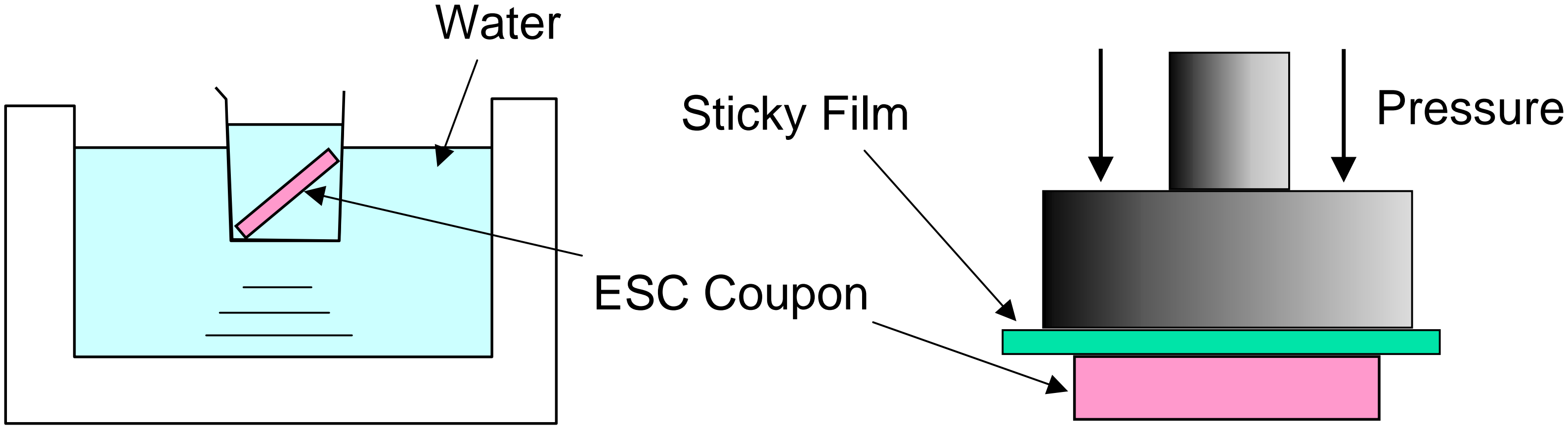


Figure 1



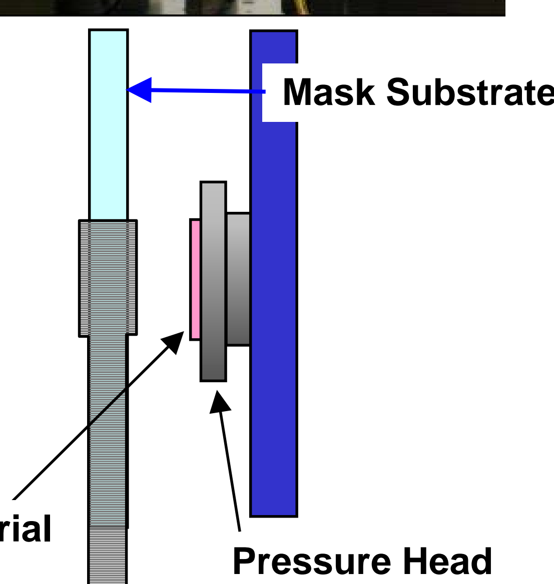
- Ultrasonic cleaning in water

- Attach sticky film on the surface of ESC coupon.
- Apply pressure

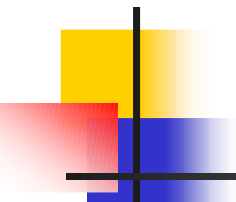
3. Chucking Test

Figure 2

- Simulate chucking conditions using pressure testing apparatus.
- Chucking pressure range is between 60kPa and 300kPa.
  - Due to the sample size and minimum force which can be achieved in this apparatus, minimum pressure was larger than SEMI standard.



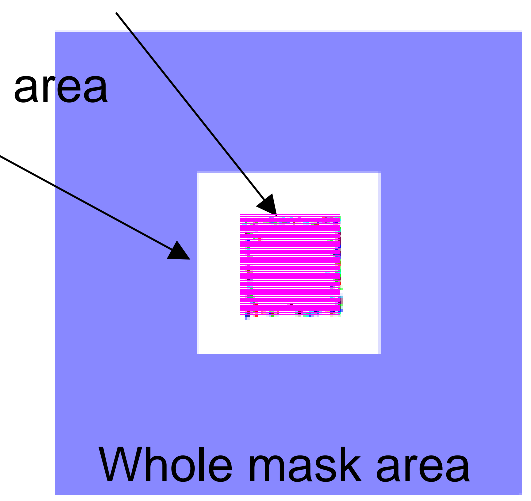
4. Defect Inspection



Contact region with ESC material

Defect inspection area

- Tool: Confocal laser inspection system
- Sensitivity was tuned to detect defects which sizes are larger than 1μm.



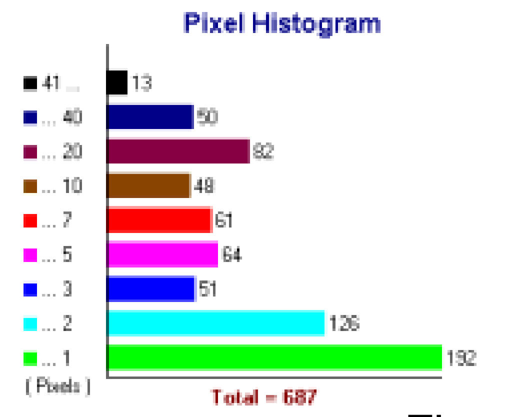


Figure 3

Results

- Defect Characterization
- In-Plane Defect Distribution
- Impact of experimental condition onto defect generation
- Impact of ESC Pre-clean

1. Defect Characterization

<table>
<tr><th></th><th></th><th>Estimated Cause</th></tr>
<tr><td>Point Defect</td><td></td><td rowspan="2">▪ Adhesive defect mitigated from ESC
▪ Pit where mask backside material was migrated to ESC.</td></tr>
<tr><td>Aggregated Defect</td><td></td></tr>
<tr><td>Scratch</td><td></td><td>▪ Rubbing motion during chucking operation.</td></tr>
</table>

Figure 4

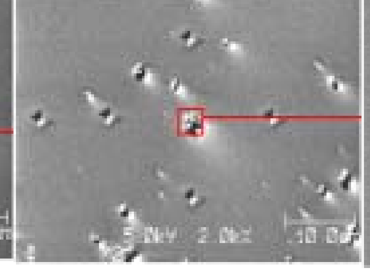
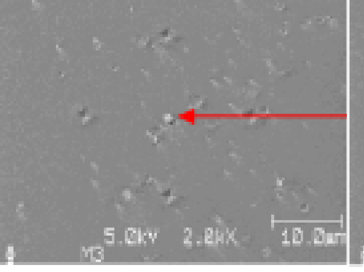
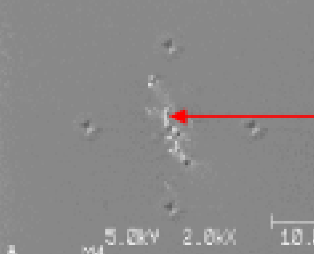
1. Defect Characterization

- Auger analysis on mask backsides -

- ESC material was migrated to mask backside after chucking.

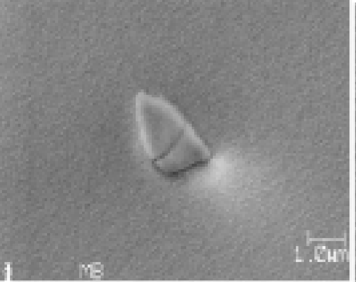
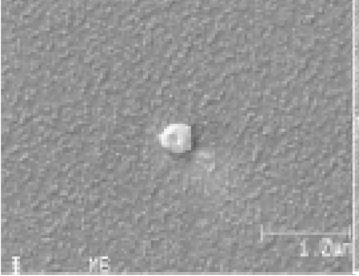
Figure 5

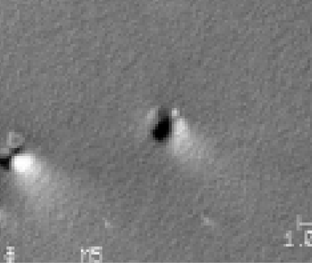
ESC: Al2O3
Mask backside: Cr
ESC Clean: standard

Detected chemicals → **Al,O** | **Si, Na, K, Ca, Cl** | **Al, O, C** | **Na, Cl, C, K, S**

ESC: Al2O3
Mask backside: TaN
ESC Clean: standard



Detected chemicals → **Al, O, C, N** | **Al, O, C, N** | **Al, O, C** | **Al, O, C, N**

* Contamination on the surface of ESC is ongoing.

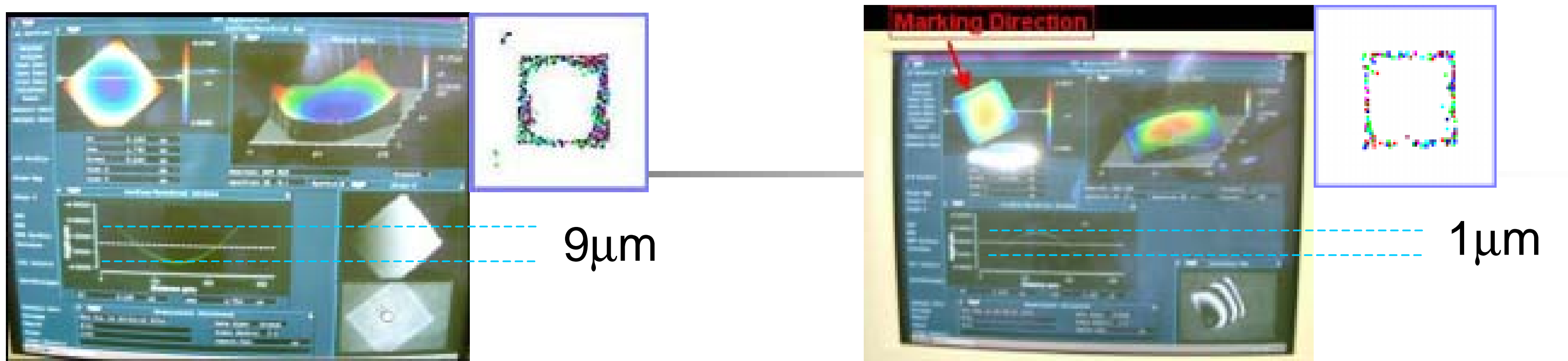
2. In-Plane Defect Distribution

- Maximum number of defects generated around the periphery of contact area with all cases.

ESC: Al_2O_3	ESC: Al_2O_3	ESC: AlN	ESC: AlN	ESC: Sapphire
Mask Backside: Cr	Mask Backside:TaN	Mask Backside: Cr	Mask Backside:TaN	Mask Backside: Cr
Pressure: 300kPa	Pressure: 300kPa	Pressure: 300kPa	Pressure: 300kPa	Pressure: 300kPa
ESC Clean: Standard	ESC Clean: Standard	ESC Clean: Standard	ESC Clean: Standard	ESC Clean: New method

Figure 6

2. In-Plane Defect Distribution



ESC material: Al_2O_3
Mask backside: Cr
ESC Pre-clean: Standard

ESC material: Sapphire
Mask backside: Cr
ESC Pre-clean: New method

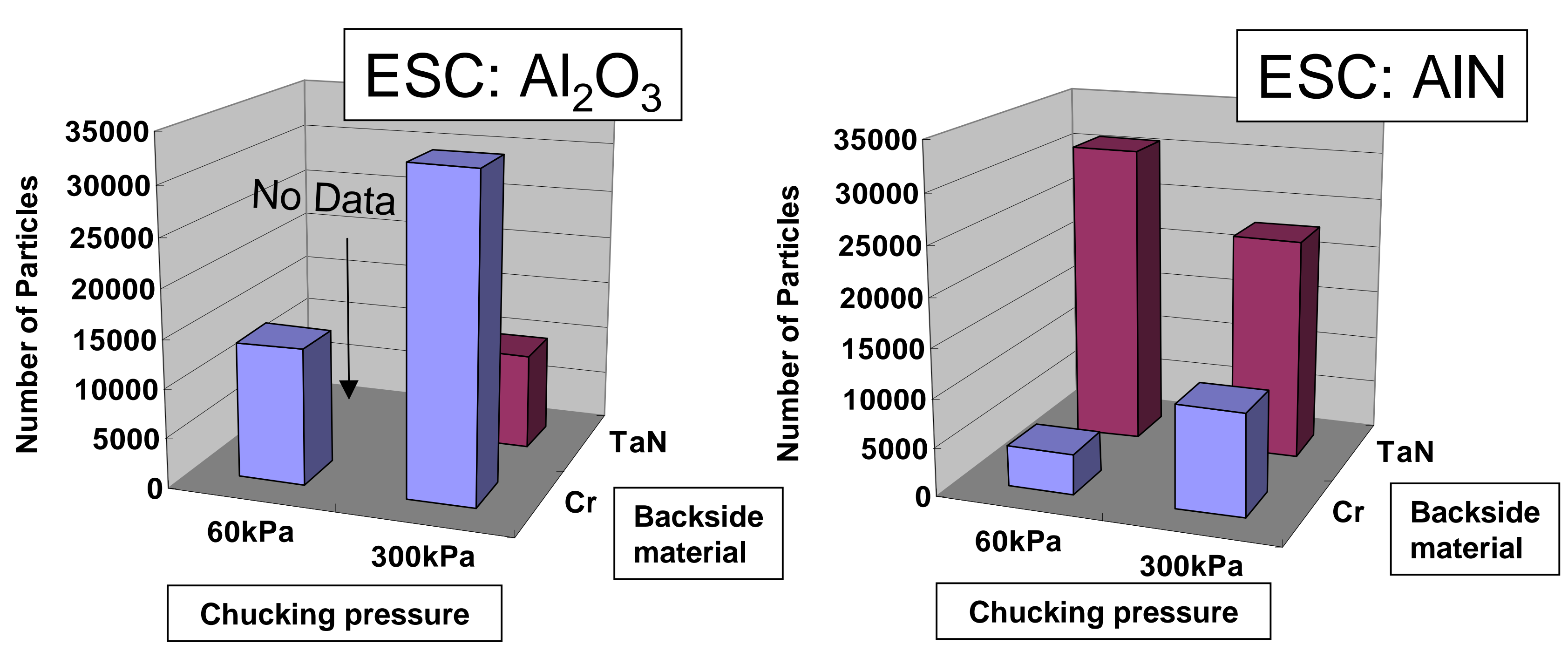
Defect non-uniformity cannot be explained only by material flatness. Other factors must be considered.

- Bending of mask substrate during chucking
- Flatness of pedestal support

Figure 7

3. Impact of experimental condition onto defect generation

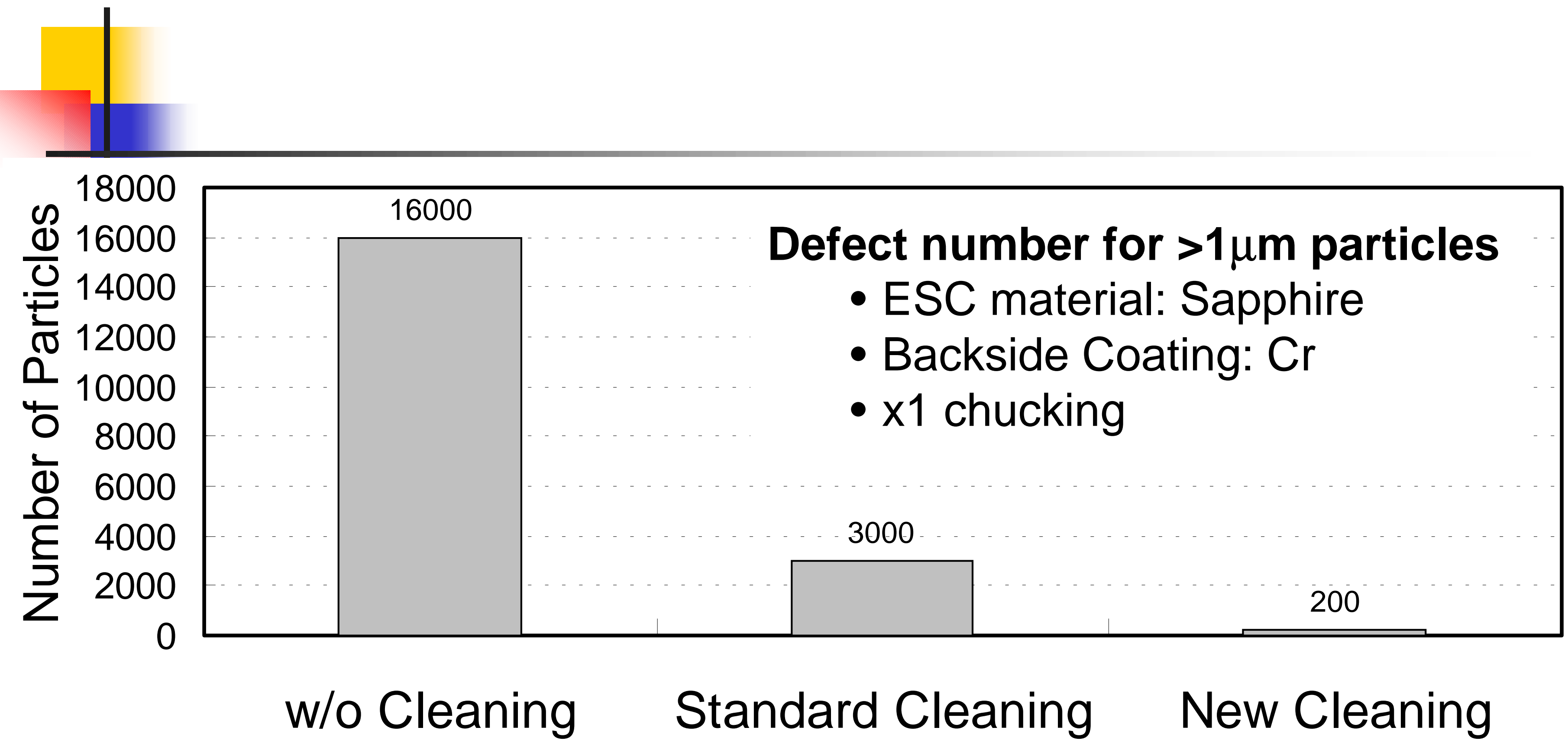
ESC material, Mask backside material and Chucking Pressure



Further evaluation will be needed to correlate experimental conditions to defect generation.

Figure 8

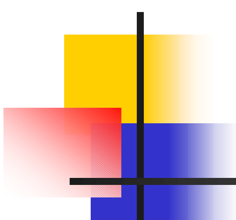
4. Impact of ESC Pre-clean



Sticky film cleaning after ultrasonic cleaning successfully mitigated defect generation with >1μm size.

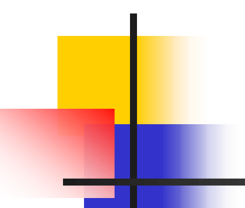
Figure 9

Summary



- We found 10^2~10^4/cm^2 defects with >1μm size on the EUV mask backside coating after chucking on mask chucking substrate (ESC).
- In-plane defect distribution was non-uniform. This may have been due to non-uniform pressure distribution over the contact area.
- ESC material was migrated into mask backside materials after chucking operation.
- ESC pre-clean with sticky polymer film is effective to mitigate defect generation with >1μm size. Further polymer improvement is needed for better cleaning efficiency.

Future Works



- Characterization of mask blank flatness under electrostatic chucking.
- Improvement of defect quantification.
- Chemical analysis on detected contaminants.
- Choice of optimal materials for backside coating and ESC materials.
- Correlate surface roughness to defect generation.
- Refinement of experimental condition for pressure testing.

1. Characterization of Mask Blank Flatness under Electrostatic Chucking

- Goal
  - Quantify the flatness change of pattern surface impacted by particles at the interface between mask backside and ESC surface.
- Status
  - Intel has started the characterization of mask flatness on Coulombic bipolar chucks to detect induced peaks on mask surface during chucking

1. Characterization of Mask Blank Flatness under Electrostatic Chucking

- Experimental Setup -

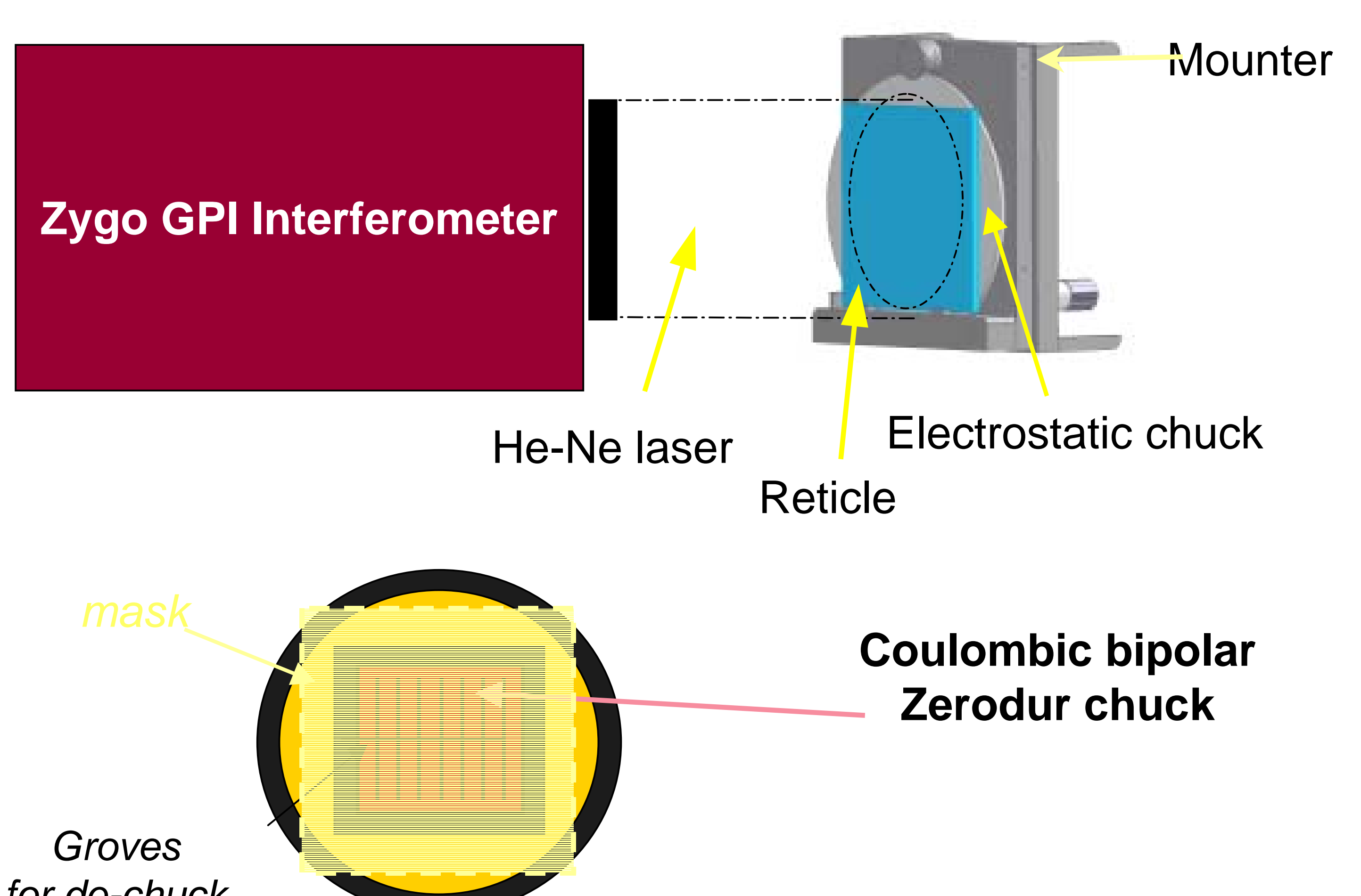
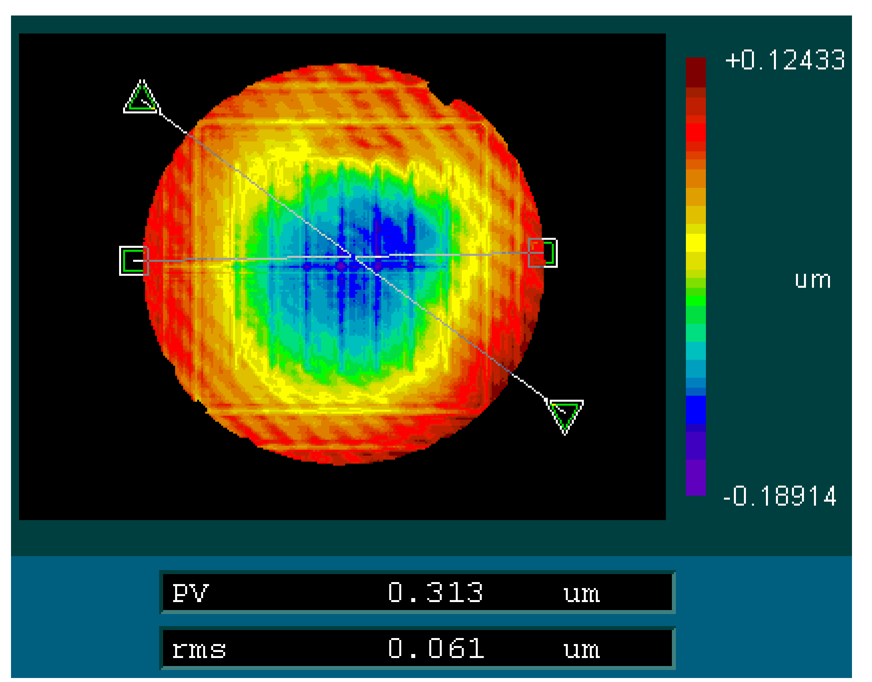


Figure 11

1. Characterization of Mask Blank Flatness under Electrostatic Chucking

- Electrostatic chuck surface flatness -



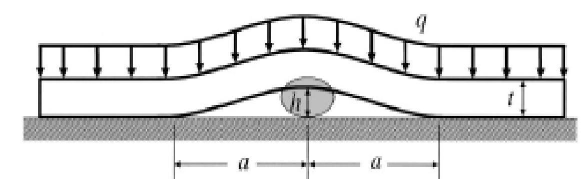
1” thick chuck surface has reached 313nm flatness within 6” diameter.

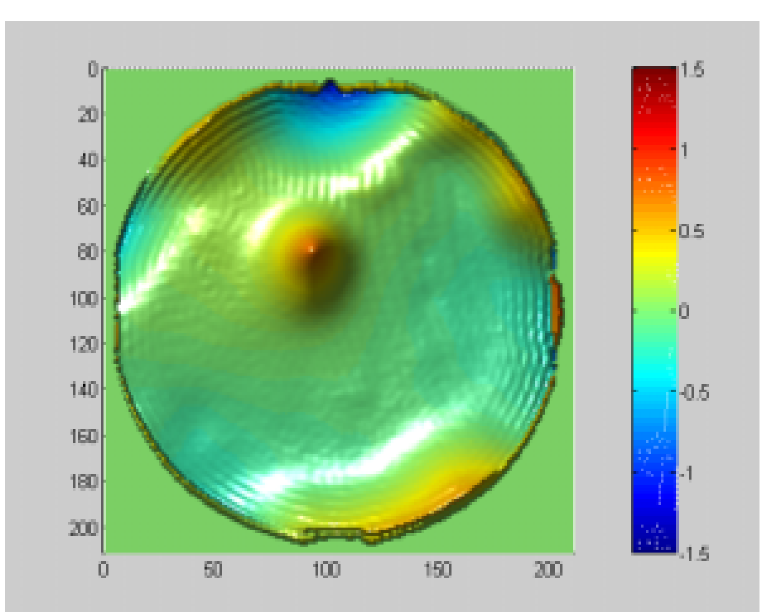
Figure 12

1. Characterization of Mask Blank Flatness under Electrostatic Chucking

First time observation of a defect-induced-peak on quartz reticle

- A small Cu particle (19.8µm) was artificially placed on the back side of the mask.
- A peak (~0.7µm) on the mask front surface showed during chucking.





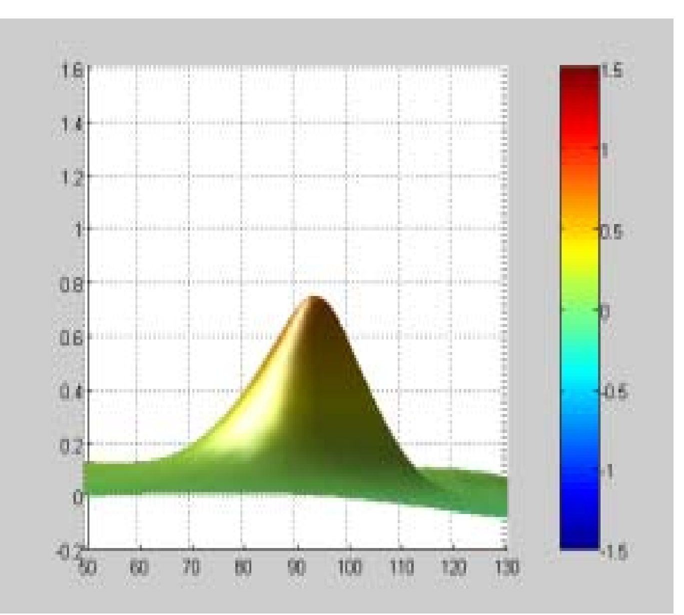


Image and profile from interferometer *(post chucking – pre-chucking)*

Figure 13

2. Improvement of Defect Quantification

Original Image

Figure 15

Brightness distribution of top-left picture

Brightness distribution of the background

100000
1000
100
10
1

0 100 200 300

Number of Pixels

Brightness

After image processing

Figure 14

- Some defects have complicated shapes on which we cannot count the number of particles. New methodology is needed to evaluate the damage on the surface of the backside.
- We will quantify the contamination level using the brightness distribution of pixels for defect images.

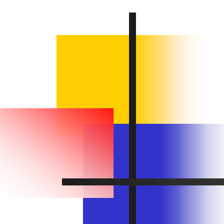
- Determine the nature and chemical composition of contaminants using chemical analysis (XRF, ICP-MS, EDX)

- Choice of optimal materials for backside coating and ESC surface.
  - Define optimal condition by physical/chemical parameters.

- Surface roughness and flatness at various length scales of chuck material to be characterized using Atomic Force Microscopy (AFM)
  - Roughness may cause local pressures to greatly exceed nominal value calculated using entire chuck/mask interaction area.

- Refinement of experimental condition
  - Flatness of ESC and Mask backside
  - Chucking condition

Acknowledgement



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