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Removal of Nano Particles on EUV Mask Buffer and Absorber Layers by Laser Shockwave Cleaning

Young-Sam Yu[1], Tae-Gon Kim[1], Sang-Ho Lee[1], Jin-Goo Park[1], Tae-Hoon Kim[2], A. Busnaina[2] and Jong-Myung Lee[3]

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[1] Div. of Materials and Chemical Engineering, Hanyang University, Ansan, KOREA

[2] Center for High-rate Nanomanufacturing, Northeastern University, Boston, USA

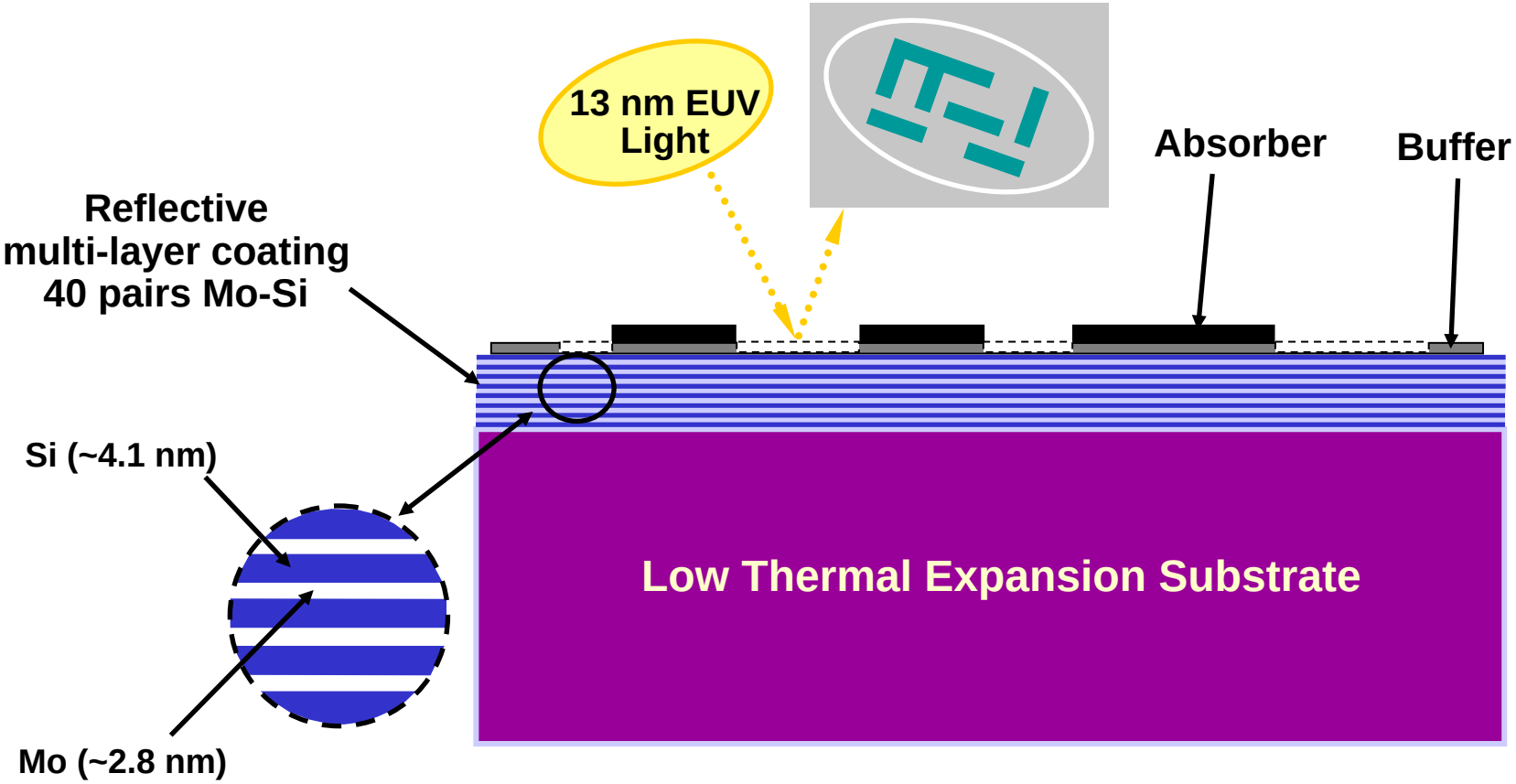
[3] IMT Co., Inc., Uiwang, KOREA

Outline

- **Introduction**
  - Buffer and Absorber Layers among the EUV Masks
- **Motivation**
- **Experimental Materials and Procedure**
- **Results and Discussion**
  - Adhesion Force of PSL Particle in Air
  - 50 nm PSL Particle Removal Efficiency
- **Summary**

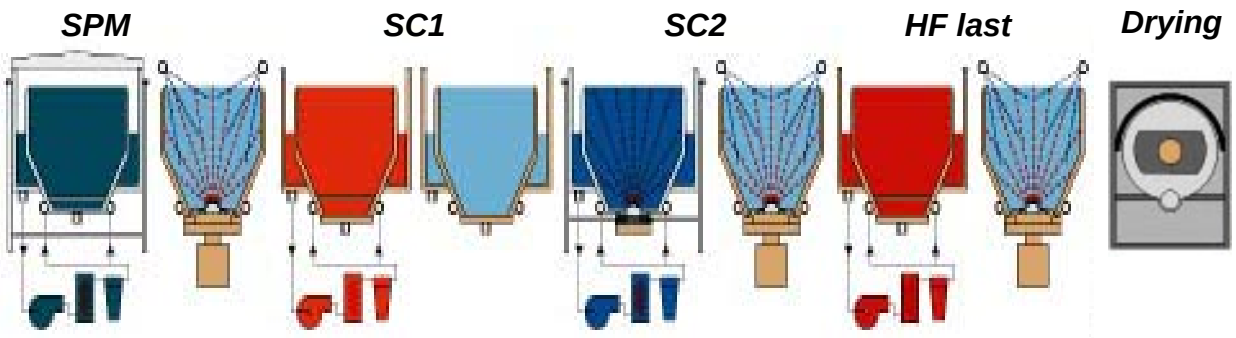
Schematic Diagram of the EUV Mask Structure

- A material of absorber layer which shows very high EUV light absorption should be deposited
- In general, Cr and TaN are thought to be good candidates for absorber layer
- A buffer layer must be inserted to avoid damage to the multi layer during absorber patterning



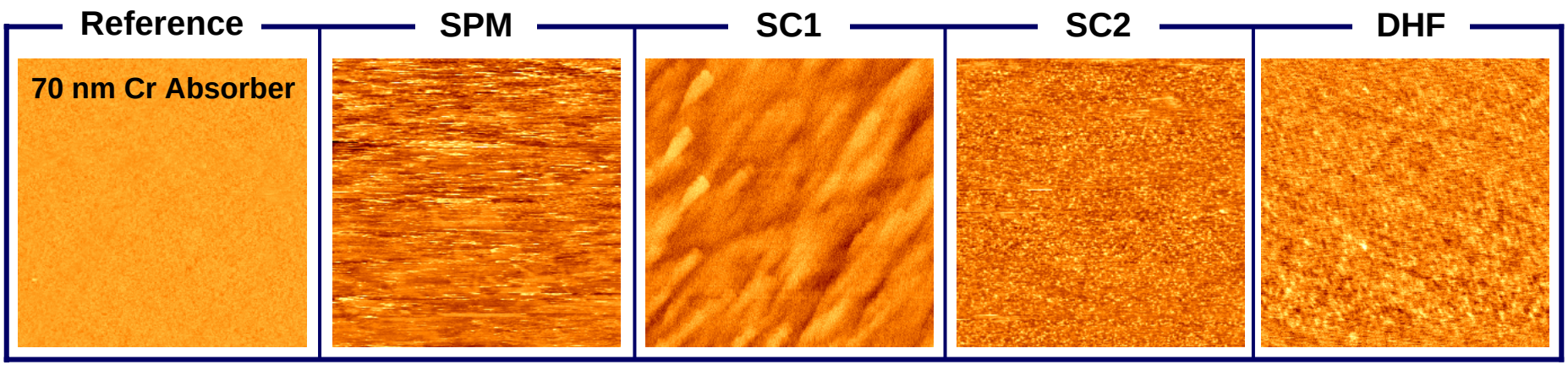
Surface Damages Induced from Wet Chemicals

❖ *Conventional Wet Cleaning Process*



- Large Tool Footprint
- Huge Consumption of Chemicals and DI water
- Higher Temp. Process
- Longer Process Time

EUV mask could be damaged



as shown

Motivation

1. Particles *below 50 nm* are not allowed on EUV mask remain.

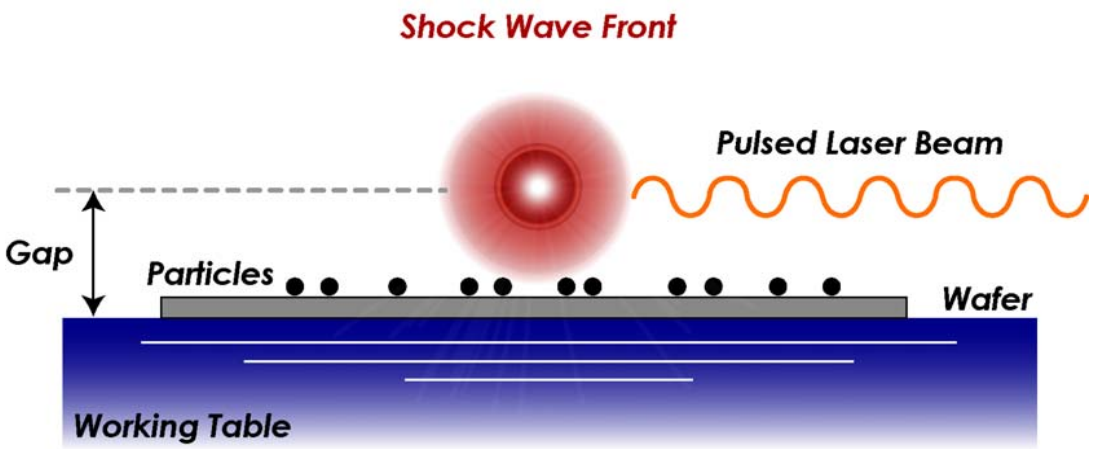
2. In certain process steps, *wet chemical cleaning* is not also allowed.

3. It necessary to process a total dry cleaning for particle removal.

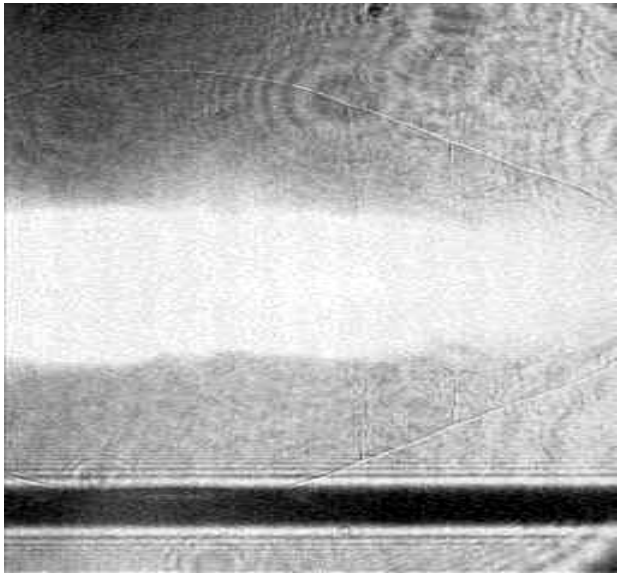
4. Removal of 50 nm PSL particles on EUV buffer and absorber layers by *novel Laser Shock Cleaning*.

Laser Shock Cleaning

- A technique to remove the contaminants on the surfaces using laser-induced plasma shock waves (multi-photon ionization).
- Laser : Nd:YAG Laser (1064 nm, 1300 mJ), UV Laser (266 nm, 80 mJ) single pulse



- The gaseous components begin to breakdown and generate an intense plasma



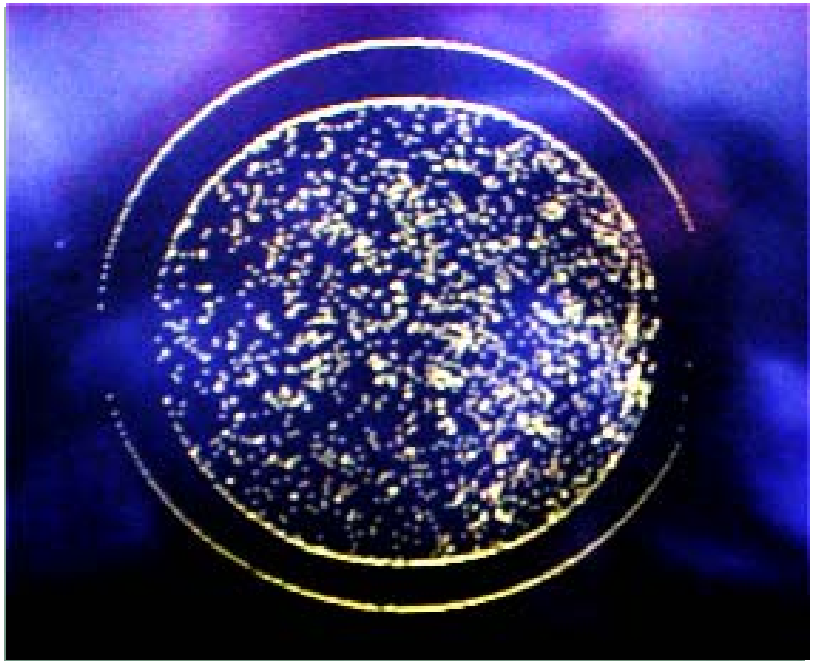
Spread out spherically toward the surface

Cleaning Condition : *Shock Wave Force > Adhesion Force*

Particle Removal using LSW Cleaning

Scanned surfaces : KLA-Tencor Surfscan 5500

- **A successful removal of the particles was carried out by Laser Shock Cleaning.**

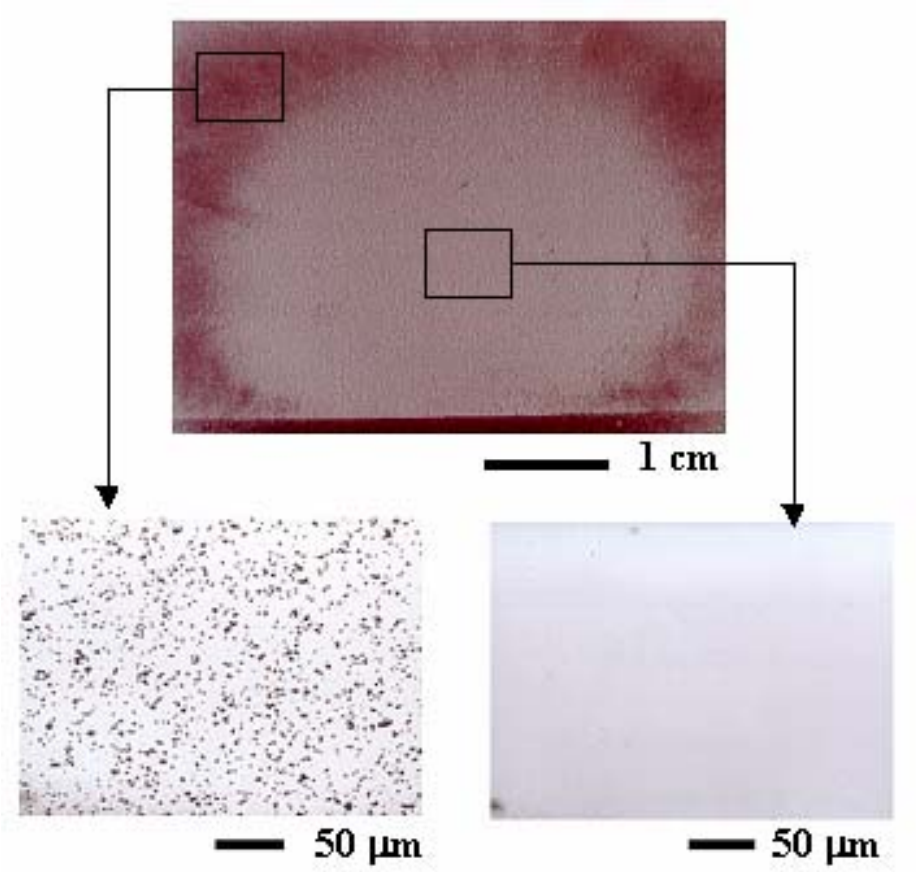


Before Cleaning

After Cleaning

Particle Removal using LSW Cleaning

LSC initial removal test of tungsten particles on Si wafer



- **Compared two surfaces:**
  Surfaces with and without LSC
- **Large area was perfectly cleaned**
- **Large cleaned area: ~ 4 cm in dia.**
  Short cleaning time
  High throughput
  : 150 sec / 8 in. wafer

Experimental Materials and Procedure

- **Contaminant Particles**

  50 nm Fluorescent PSL Particles

- **EUV Mask Layers**

  100 nm SiO_2 (buffer) and 70 nm Cr (absorber) Coupon Wafers

- **Particle Deposition Method**

  Aerosol Spray Method

- **Particle Measurement**

  Fluorescent Optical Microscopy (Optiphot 200D, Nikon Co.)

- **Adhesion Force Measurement**

  Atomic Force Microscopy (XE-100, PSIA Co.)

- **Experimental Environment**

  Class 10 / 100 Cleanroom (RH : 50%, Temp. : 25ºC)

All experiments were performed in

Experimental Materials and Procedure

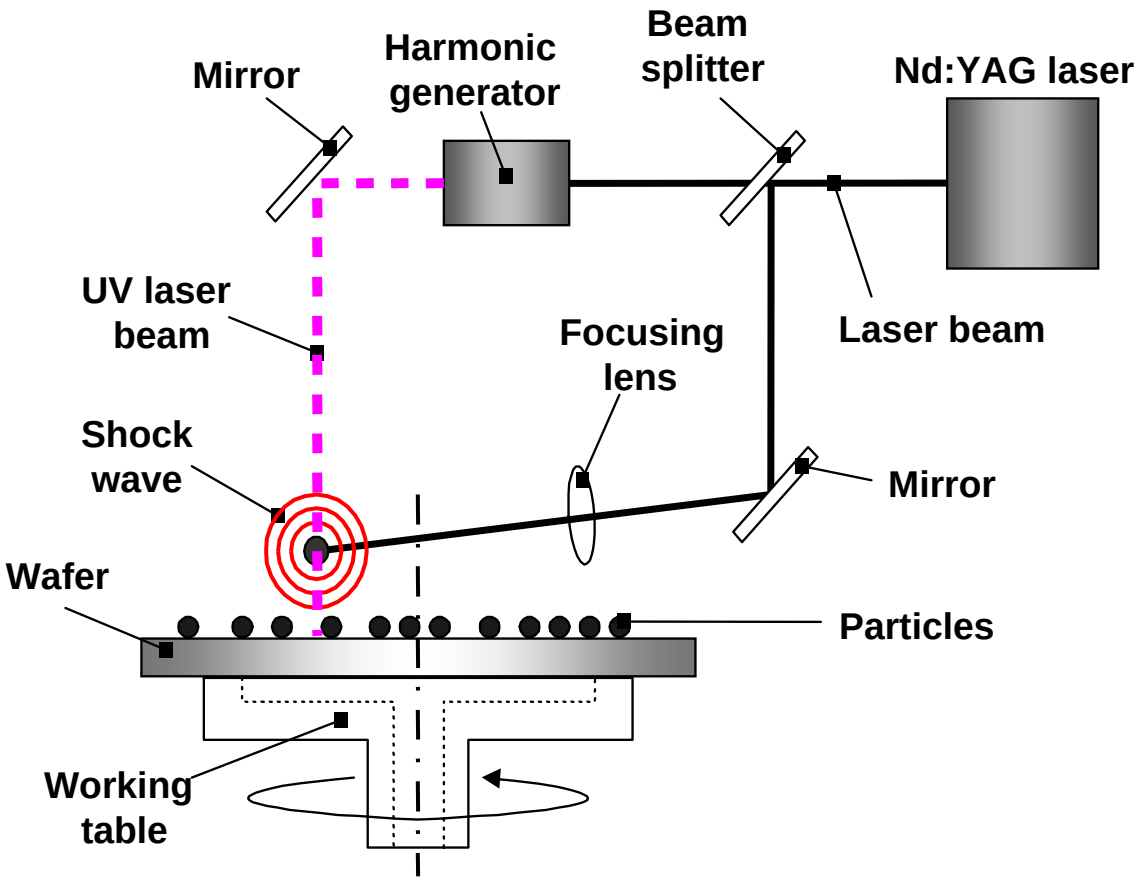
❖ **Experimental Conditions** : *LSW (1064 nm / 1600 mJ / 5.5 mm gap)*
UV Laser (266 nm / 5 mJ / 7.5 mm gap)

❖ **Experiments of Particle Removal Efficiency**

SiO_2 buffer layer	Cr absorber layer
1 LSW (***one*** laser shock cleaning)	**1 LSW**
2 LSW (***two*** laser shock cleaning)	**2 LSW**
1 UV	**1 UV**
2 UV	**2 UV**
3 UV	**3 UV**
1 UV + LSW (***UV irradiated before 1LSW***)	**1 UV + LSW**
2 UV + LSW	**2 UV + LSW**
3 UV + LSW	**3 UV + LSW**

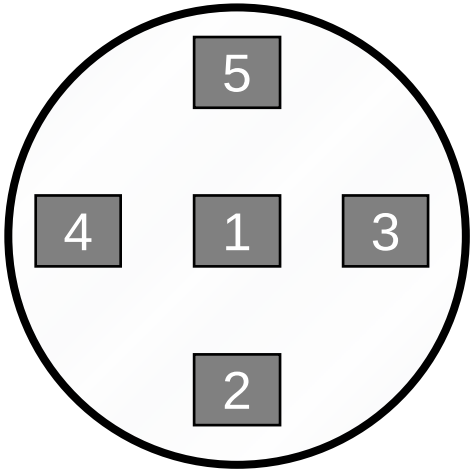
Schematic Diagram of LSC System

- Laser Shock Wave ← Nd:YAG laser passing through the focusing lens
- UV laser ← a same source using a harmonic generator
- UV laser and LSW were independently used to cleaning process



were not generated

New Inspection Method for Nano Particles

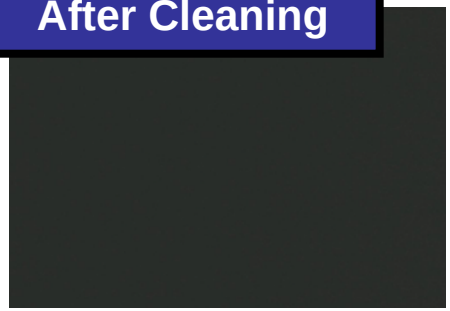


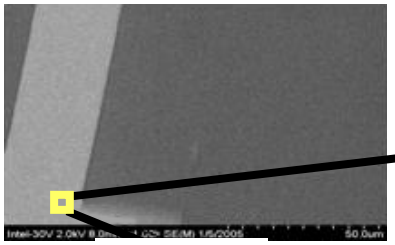
Particle Inspection Map on Wafer

- **An optical microscope used to measure the fluorescent particles before and after cleaning at five different areas**
- **To improve reliability of inspection we used auto stage and particle counting software**
- **We confirmed position by SEM compare to optical microscopy**

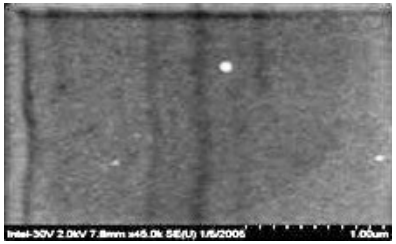
Before Cleaning

After Cleaning





FE-SEM
1K zoom



63 nm Particles
FE-SEM

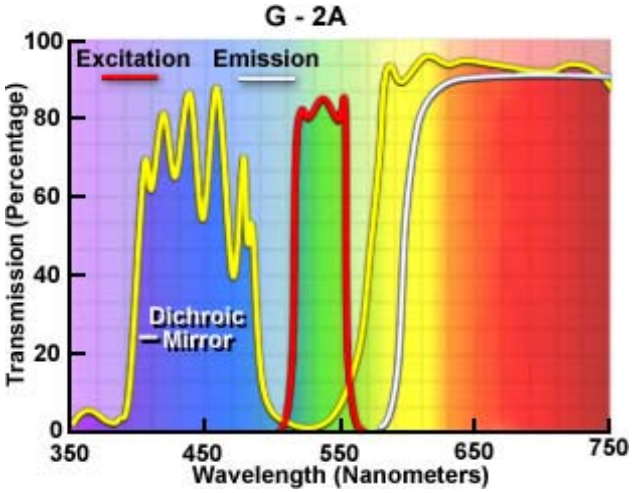
Optical Microscope
Bright Field
1K zoom

63 nm Fluorescent Particles
Optical Microscope
Dark Field 1K zoom

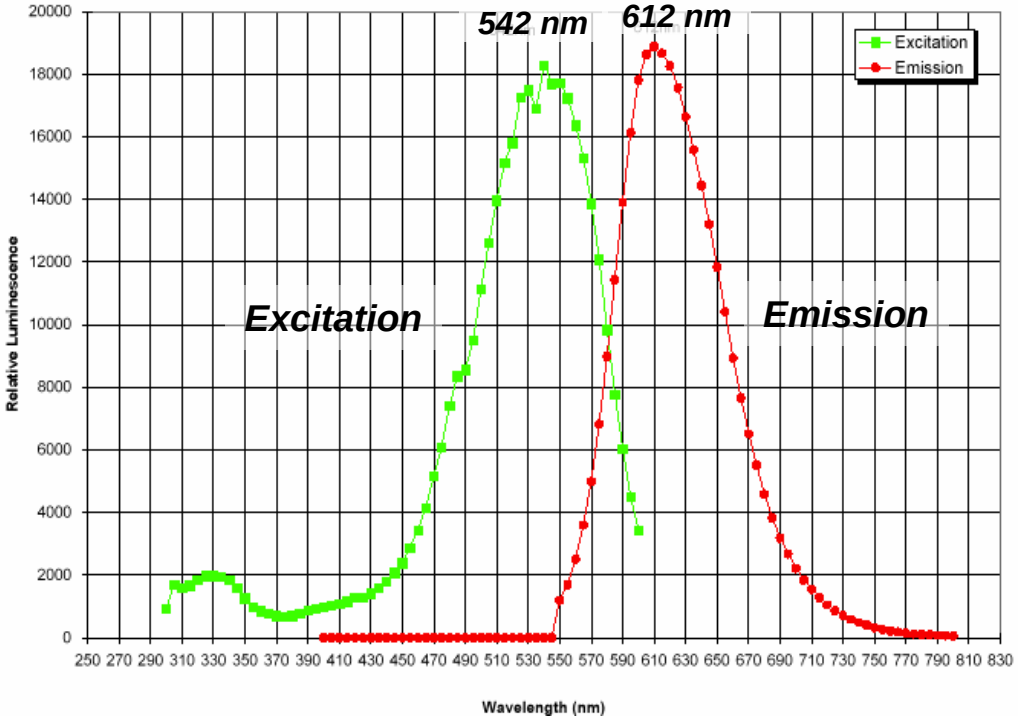
Inspection Mechanism and System

Optiphot 200D, Nikon Co.

- Since a fluorescent particle has the specific wavelengths, the particle could be visualized by emission after irradiation of light source
- Red fluorescent nano particle



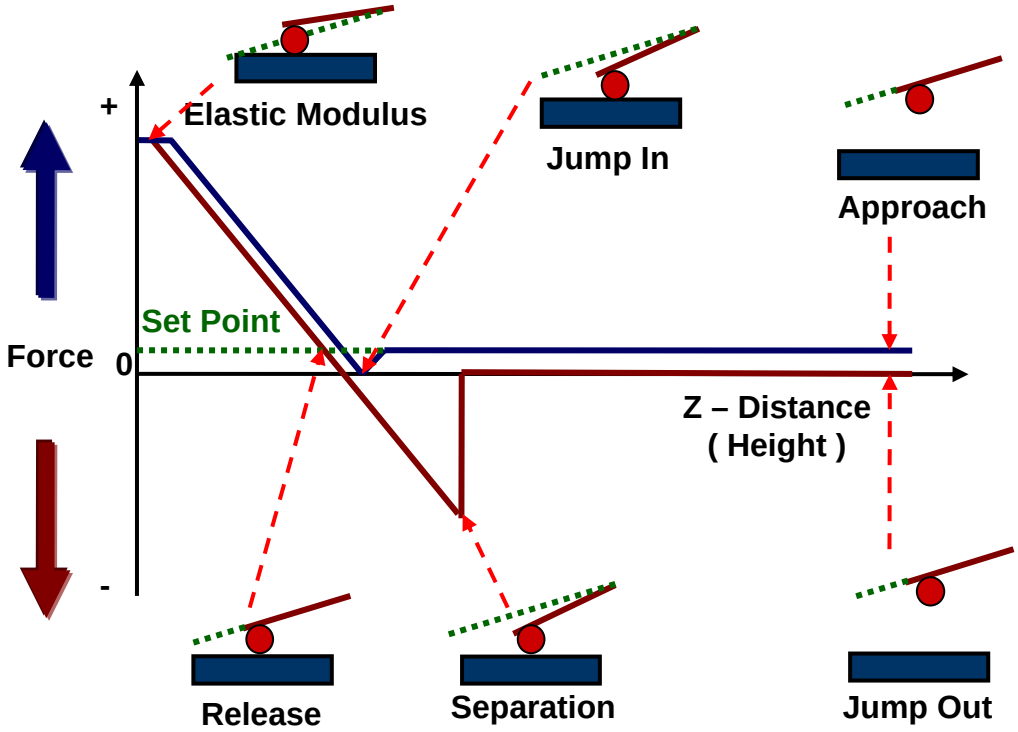
G block fluorescent filter specs.

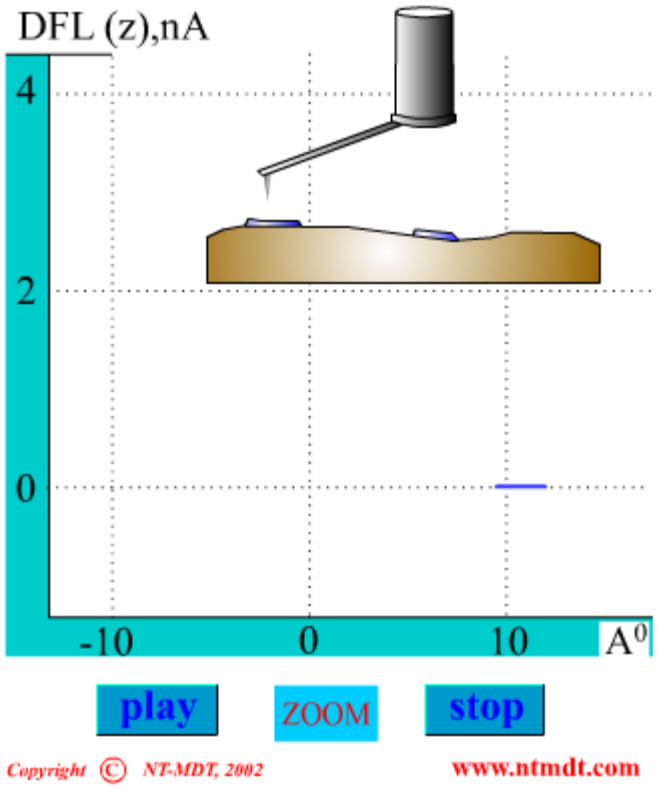


Red Fluorescing particle specs.

Adhesion Force Measurements by AFM

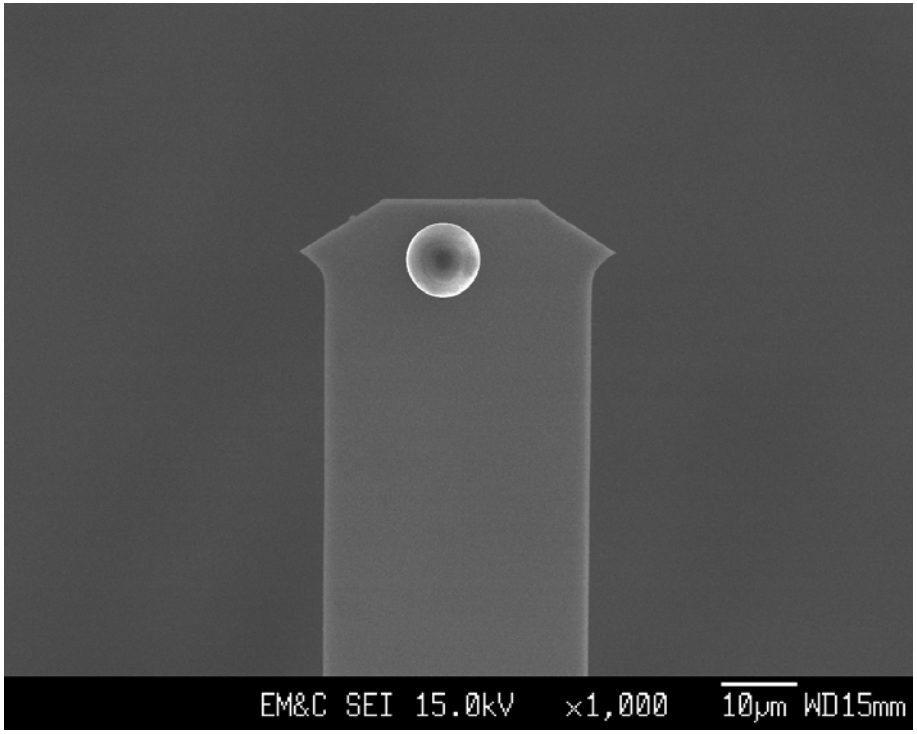
- The force distance mode can be explained as figure
- To measure adhesion force between particle and surface, modified cantilevers such as colloidal probe were used.
- Force between the tip and the same surface cause the cantilever to bend or deflect.



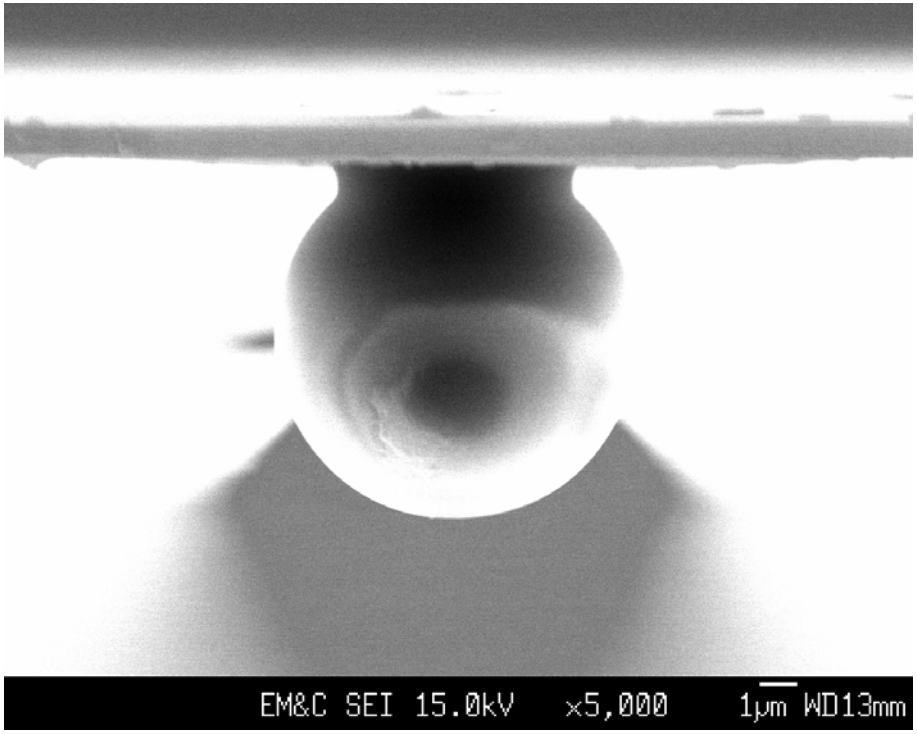


PSL Particles on the AFM Tipless Cantilever

Front view



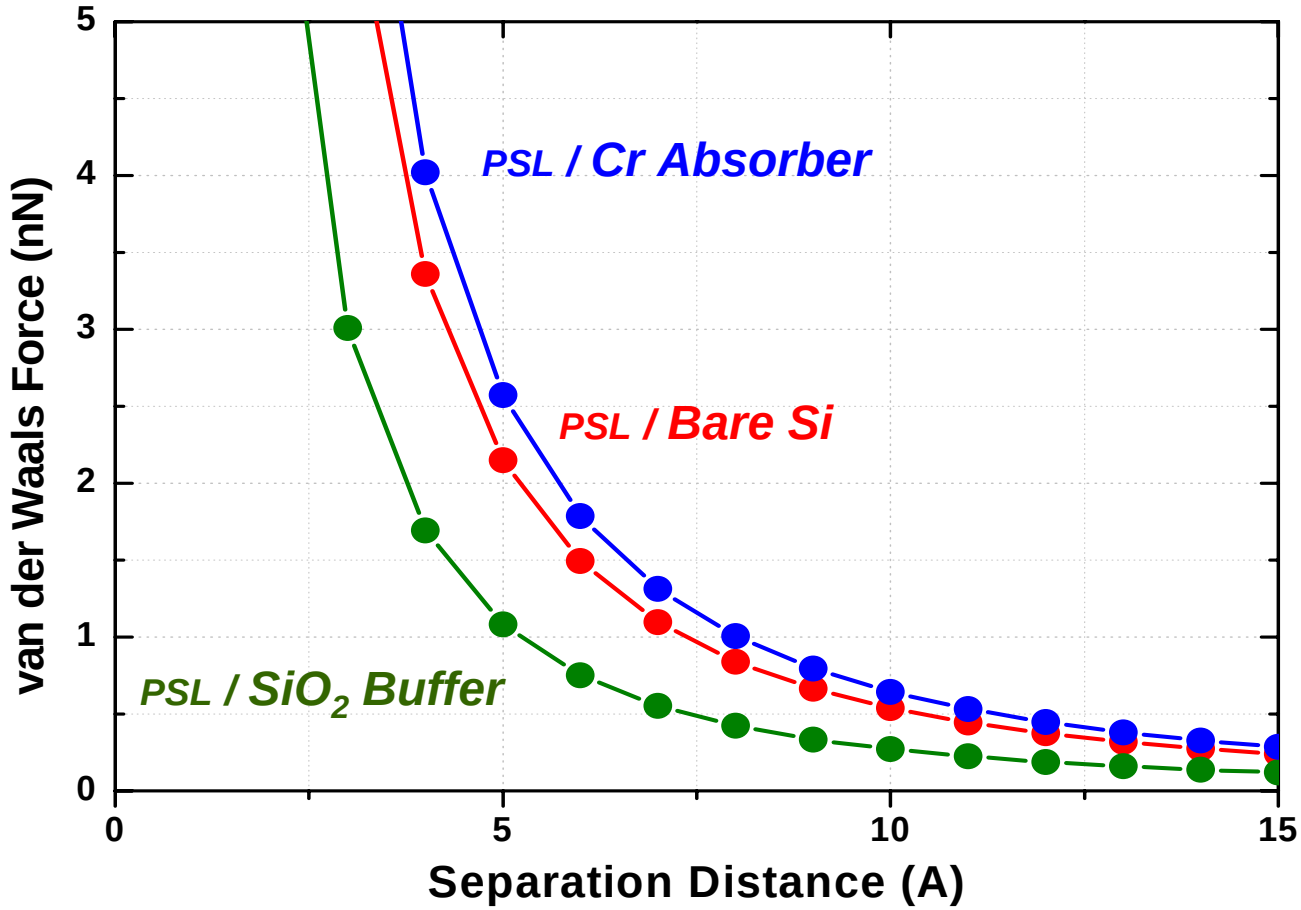
Side view



10 μm PSL particle on Silicon Cantilever

Attractive Forces between PSL Particles and EUV Mask Layers

- Since a Cr has the highest Hamaker constant, the Cr absorber layer has the highest VDW force



Calculation of Adhesion Force

- $F_{VDW} = -AR / 6H^2$ where, A is Hamaker constant.

Materials	$h\nu_o$ (eV)	Hamaker Constant (10^{-20} J)
Si	-	25.6*
SiO_2	-	6.5*
PSL	-	6.5*
Cr	30.96 **	36.67#

- Calculated Hamaker constants (10^{-20} J) between a PSL particle and EUV mask layers in air.

Si : 12.9	SiO_2 : 6.5	Cr : 15.44

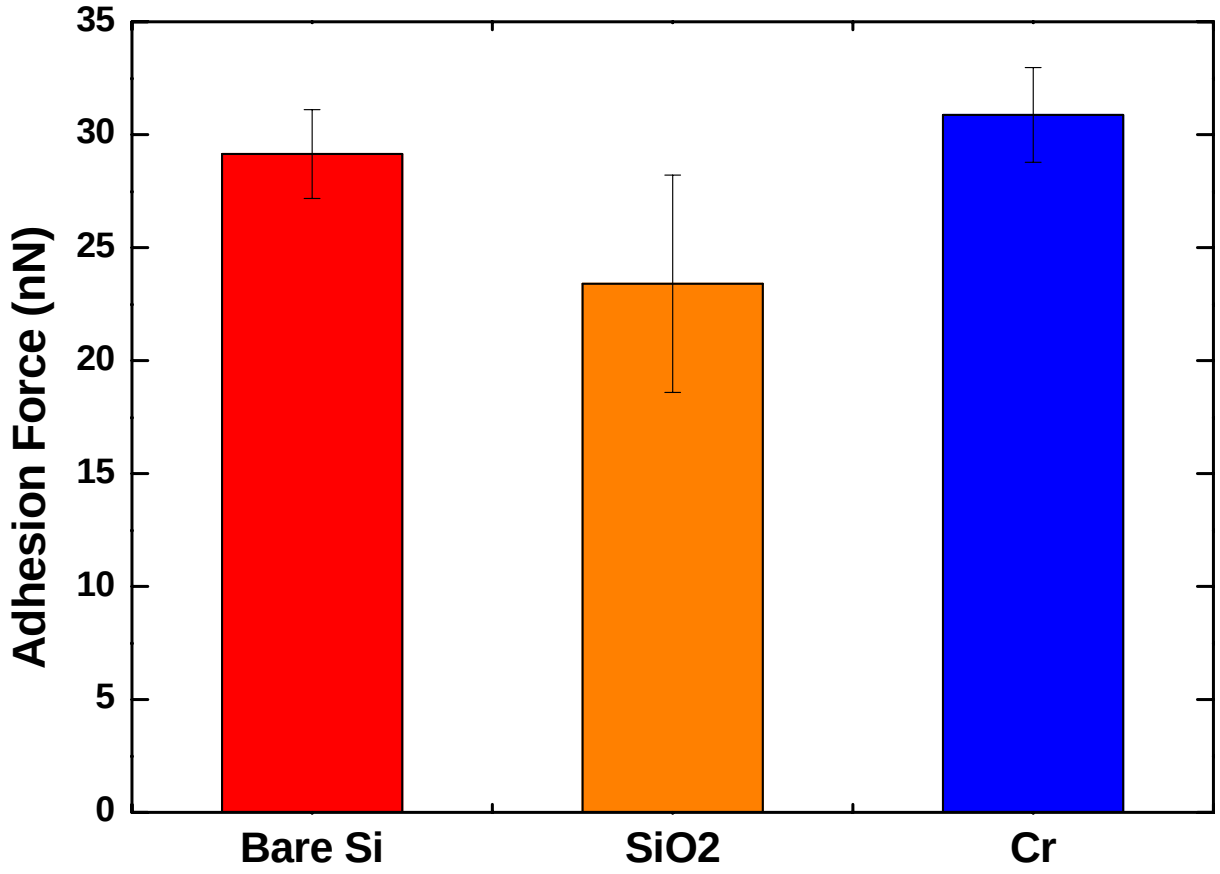
* J. Visser, "On Hamaker Constants: A Comparison between Hamaker Constants and Lifshiz-van der waals Constants", *Adv. Colloia Interface Sci*., **3**, 331 (1972)

calculated based on eq. $A=(3/4)\pi h\nu_o(0.1)^2$, where $h\nu_o$ = ionization potential(or energy)
P. C. Hiemenz, *Principles of Colloid and Surface Chemistry*, p. 645, Marcel Dekker, New York (1986)

** CRC Handbook(assumed Cr = Cr^{3+})

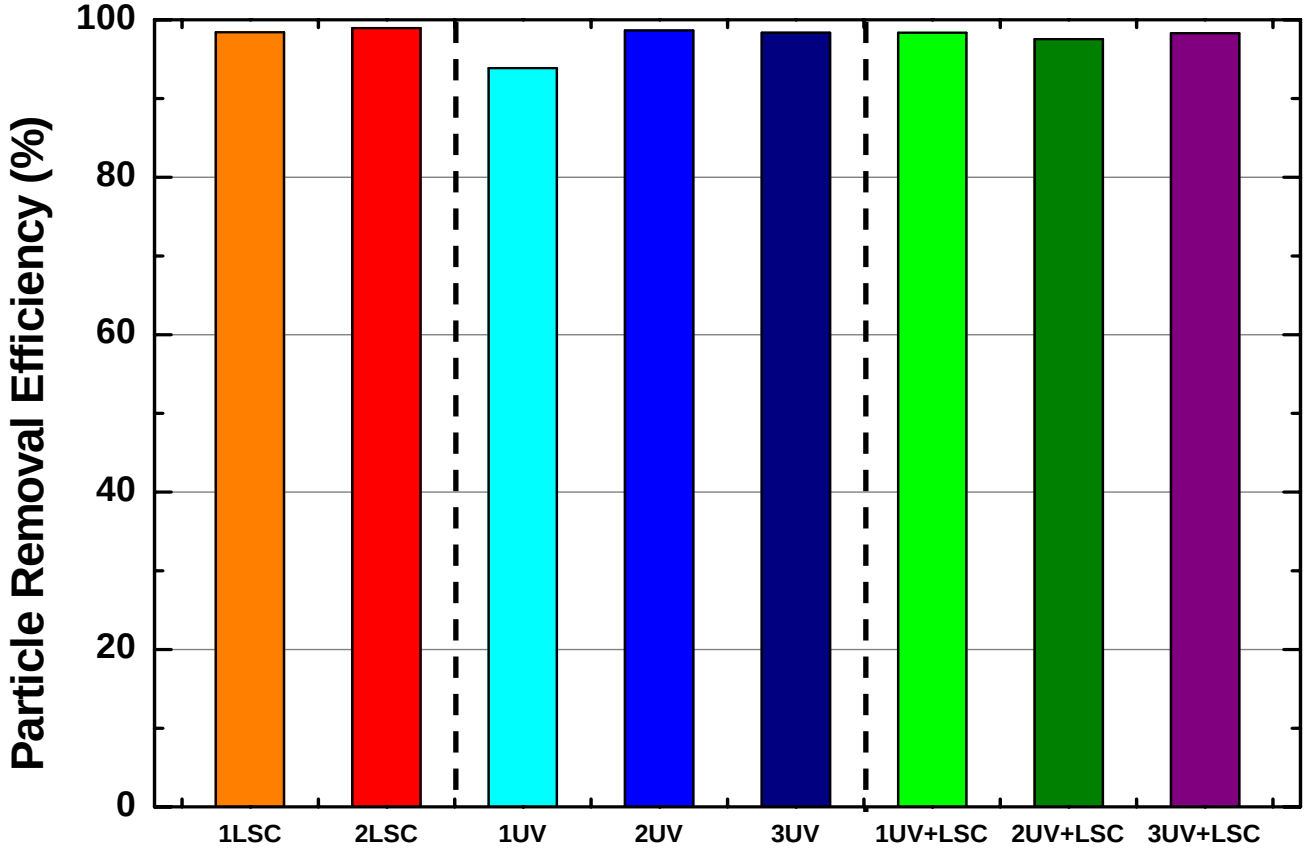
Measured Adhesion Force by AFM

- Measured adhesion force and calculated van der waals force were similar result.
- We were able to expect that the removal efficiency of PSL particles on SiO_2 buffer layer was higher than on Cr absorber layer



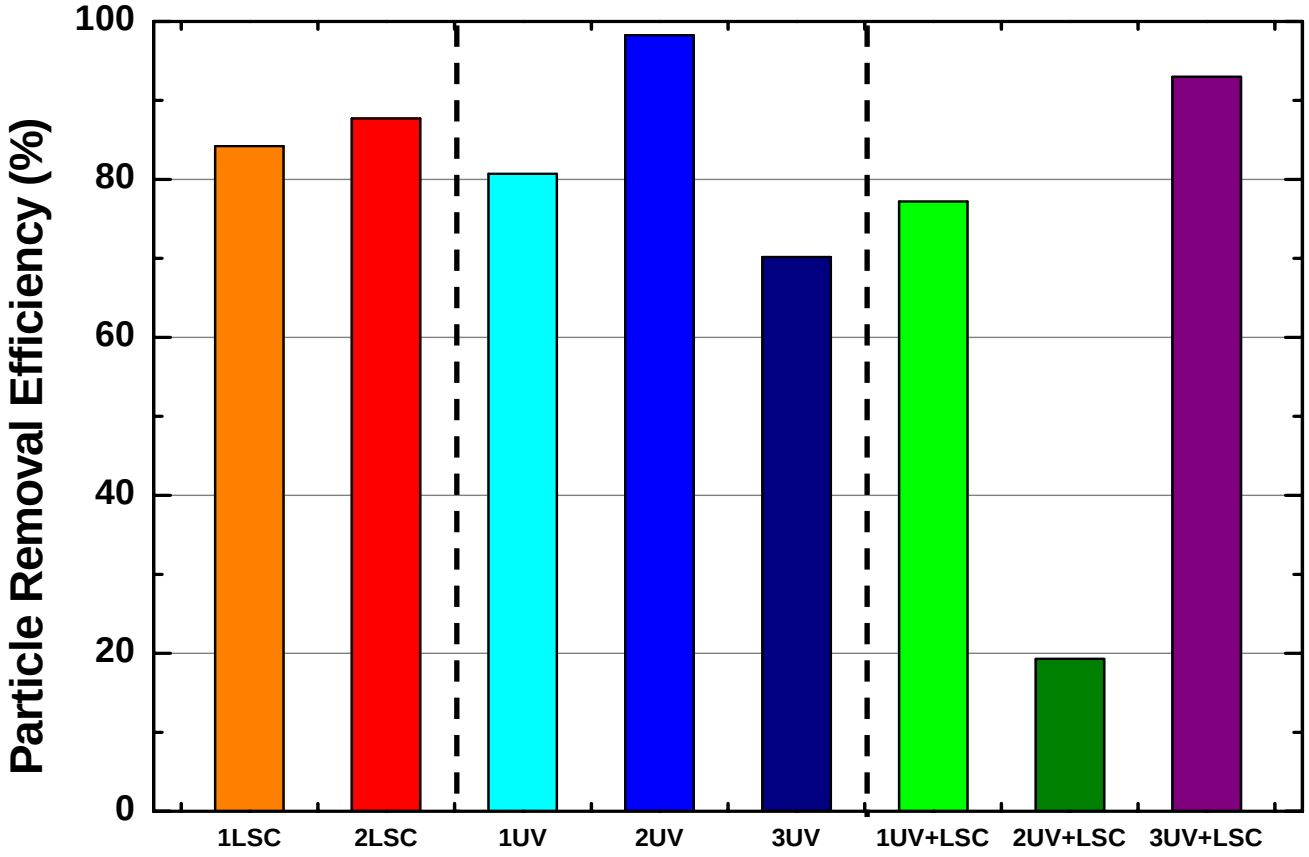
Particle Removal Efficiency (PRE) on SiO_2 Buffer Layer

- Higher PRE was measured in SiO_2 buffer layer at all cleaning conditions
- It can be attributed to the lowest particle adhesion



Particle Removal Efficiency (PRE) on Cr Absorber Layer

- Adhesion force between PSL particle and Cr absorber was more highly measured
- Although irregular PRE was examined on Cr absorber layer, it can be noted that the PSL particles are removed more effectively on SiO_2 buffer layer



was not shown on

Summary

- The laser shock cleaning method was used to remove nano particles on EUV absorber and buffer layers.
- UV laser combined laser shockwave was irradiated to obtain the highest cleaning efficiency at a damage free condition.
- The highest adhesion force was observed at Cr absorber layer.
- The PSL particle removal efficiency on Cr absorber layer was not higher than on SiO_2 buffer layer.

Acknowledgement

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