Effect of Electrostatic Chucking on EUVL Mask Flatness

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Acknowledgments
This research has been supported by International SEMATECH and DARPA / ARL. The authors would also like to thank Lawrence Livermore National Labs for providing production level substrate data.

Presentation Outline

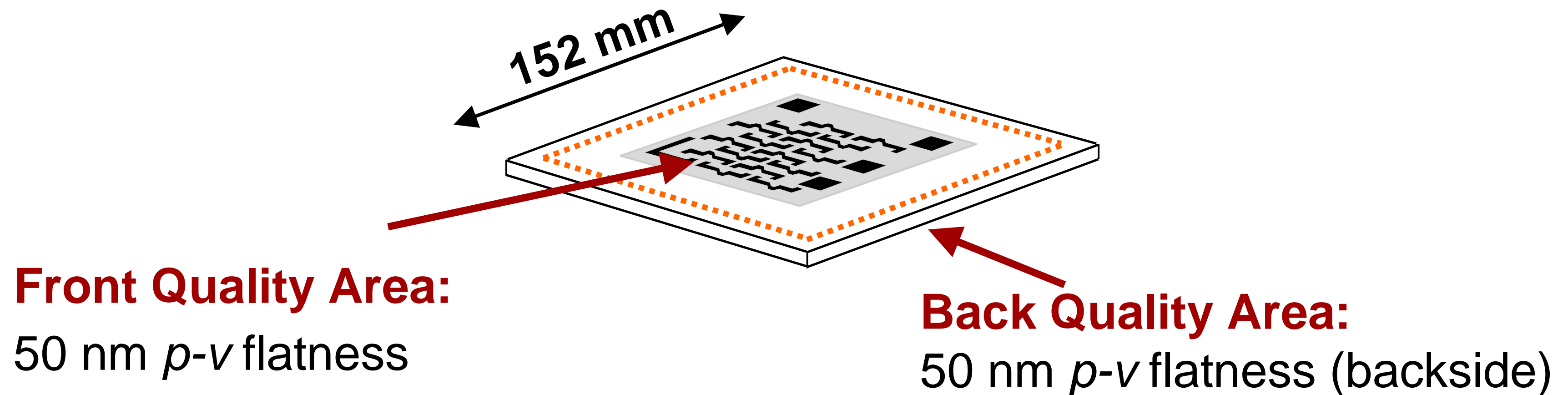
- Problem Description
- Chucking of EUVL masks with:
  - Production flatness
  - Champion flatness
  - Theoretical flatness
- Summary and Conclusions

Objectives of the Research

- Develop finite element (FE) models to simulate EUVL mask chucking.
- Examine the effect of different mechanical characteristics on the chucking response of the mask. In this case, the analysis investigates the effect of the freestanding substrate flatness and substrate thickness on the final, chucked flatness.
- Provide numerical data to assist in the development and implementation of the SEMI EUVL Chucking Standard.

Stringent EUVL Mask Requirements
SEMI Standard P37

Freestanding Substrate Flatness



A key research and development effort at the vendors is to develop polishing processes for simultaneously meeting specifications.

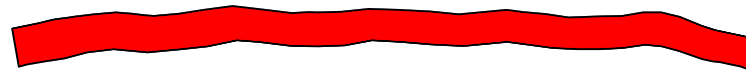
Electrostatic Chucking Response

Assumptions for the Simulation

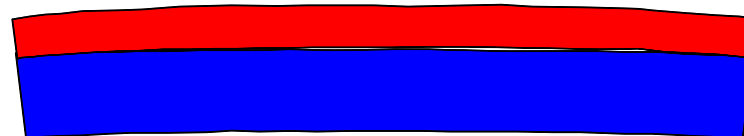
- Substrate / chuck material: ULE® glass
- Chuck stiffness: 30 kN-m
- Coefficient of friction: 0.2
- Clamping pressure: up to 15 kPa
- Mask *p-v* "bow": 1.3 μm - 2.44 μm
- Completely flat chuck (no pins)
- Solid chuck (no cooling channels)
- No mask backside layer

- **Bottom surface measured experimentally**

Freestanding Mask

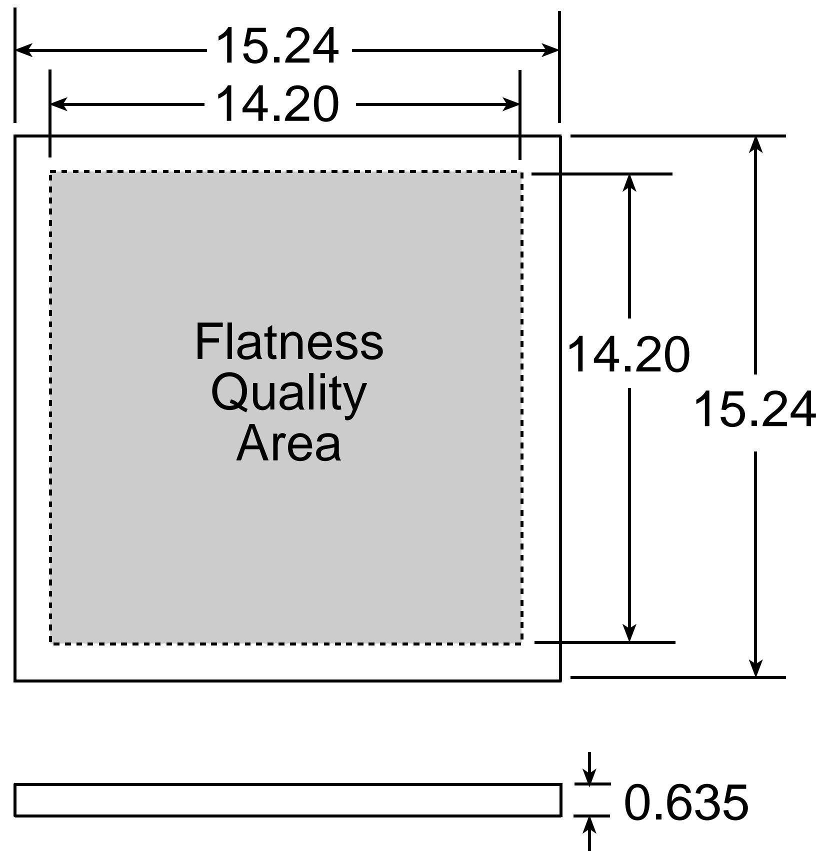


Chucked Mask



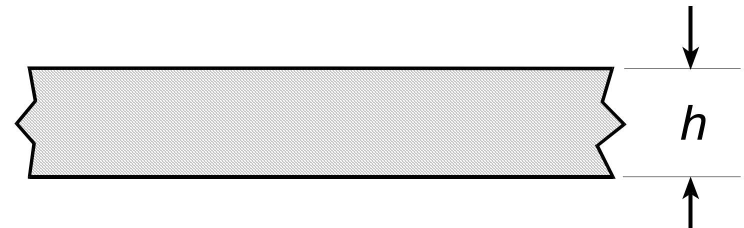
Schematics of the System Parameters

Mask Layout



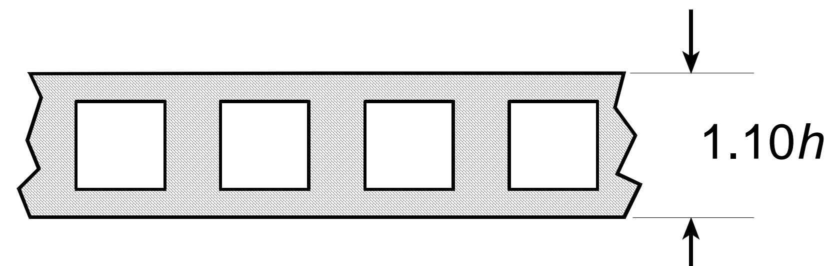
- Standard 6-in. ULE substrate.
- All dimensions in cm.

Chuck Bending Stiffness, D



$$D = \frac{Eh^3}{12(1-\nu^2)}$$

E = elastic modulus
h = the thickness
ν = Poisson's ratio



Design with square cooling channels occupying 50% of cross section. Bending stiffness is equivalent to solid chuck.

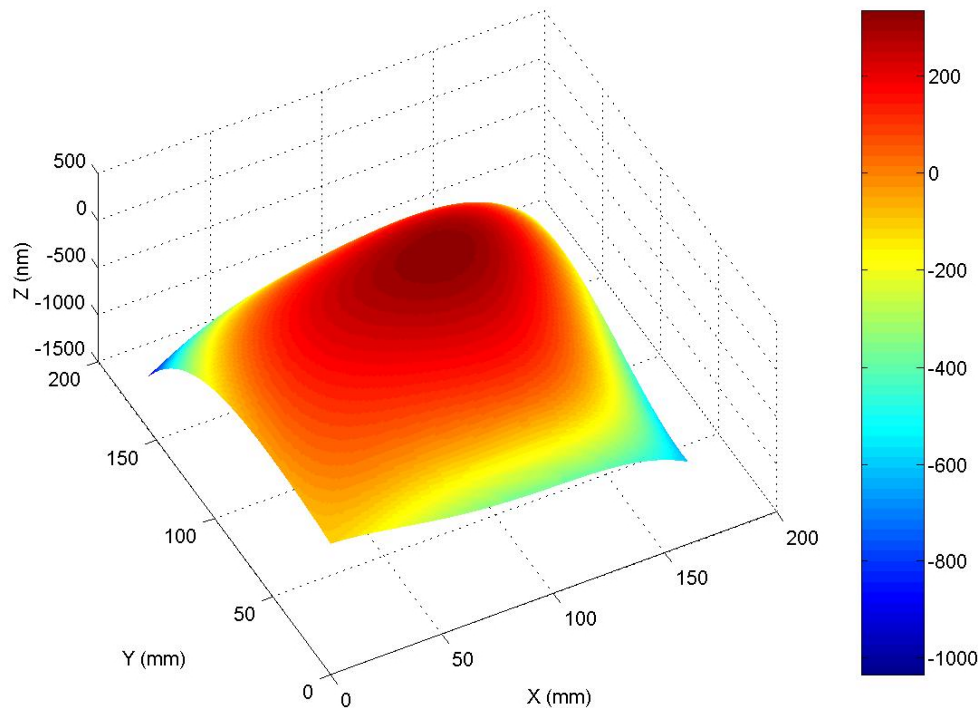
ULE Substrate Simulation Studies

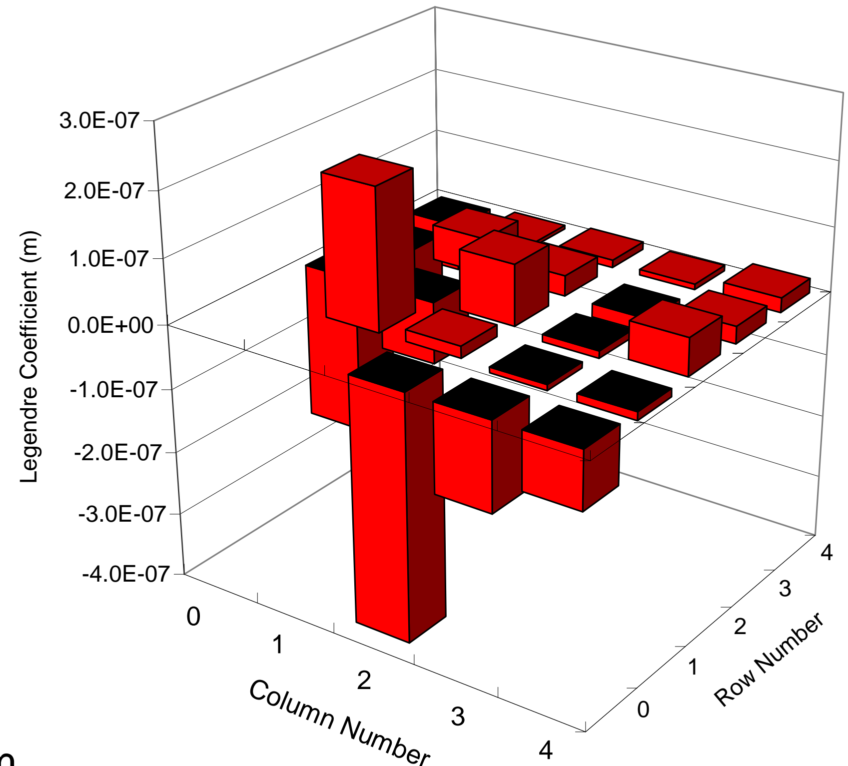
- **Production Flatness**
  - Represents what is achievable with standard production polishing techniques
  - 4.0 mm: P-V bow of 770 nm **(4.26 μm after multilayer deposition)**
  - 6.35 mm: P-V bow of 770 nm **(2.4 μm after multilayer deposition)**

- **Champion Flatness**
  - Represents the most recent polishing practices and techniques (in this case, ion beam figuring)
  - 4.0 mm: P-V bow of 60 nm **(3.19 μm after multilayer deposition)**
  - 6.35 mm: P-V bow of 60 nm **(1.31 μm after multilayer deposition)**

- **Theoretical Flatness**
  - Represents the ideal case (completely flat substrate)
  - 4.0 mm: P-V bow of 0 nm **(3.14 μm after multilayer deposition)**
  - 6.35 mm: P-V bow of 0 nm **(1.25 μm after multilayer deposition)**

EUVL Production Flatness



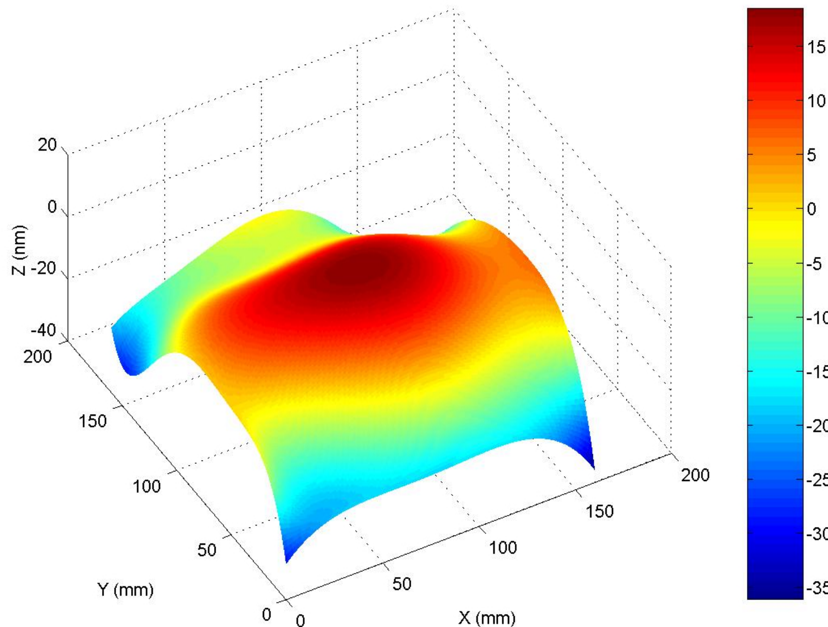


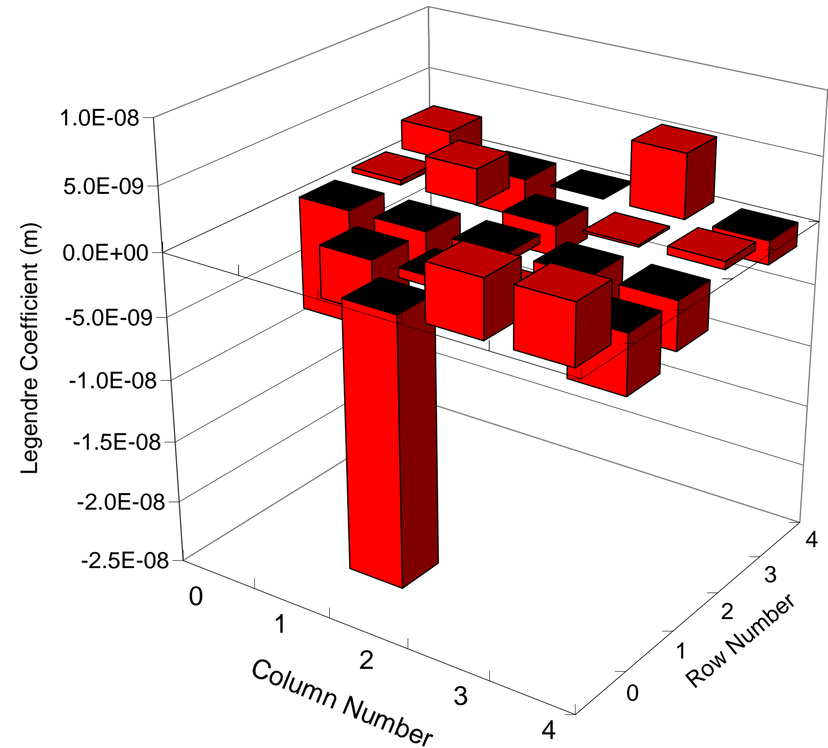
Scale is in nm.

P-V bow is 770 nm

Mathematical representation of the surface topography of the substrate resulting from standard production polishing techniques (measured by LLNL).

EUVL Champion Flatness



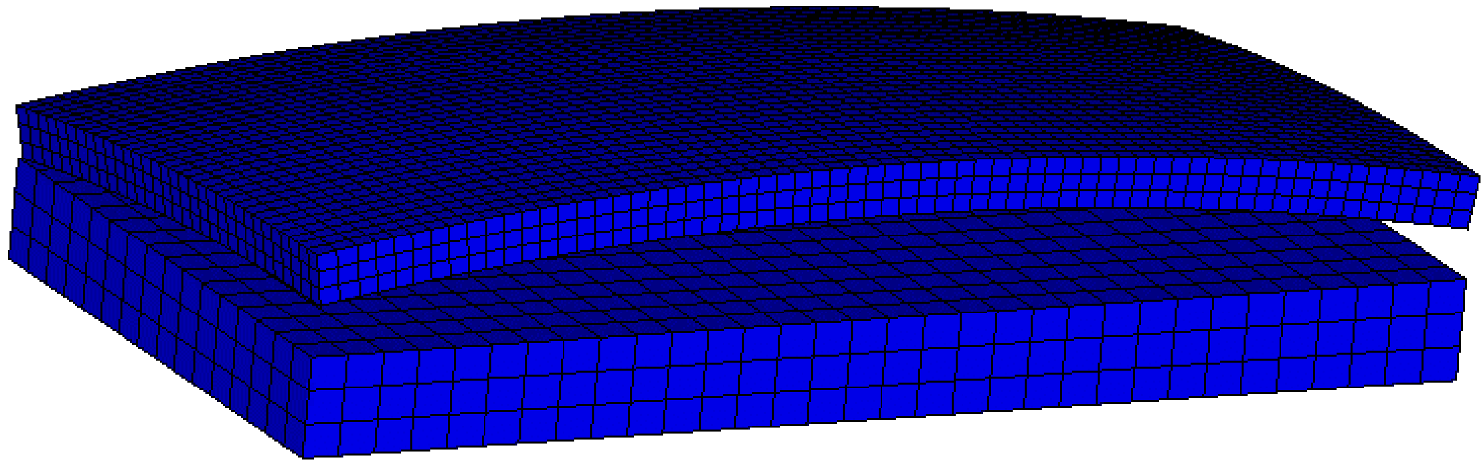


Scale is in nm.

P-V bow is 60 nm

Mathematical representation of the surface topography of the substrate resulting from advanced polishing techniques (measured by Schott Lithotec).

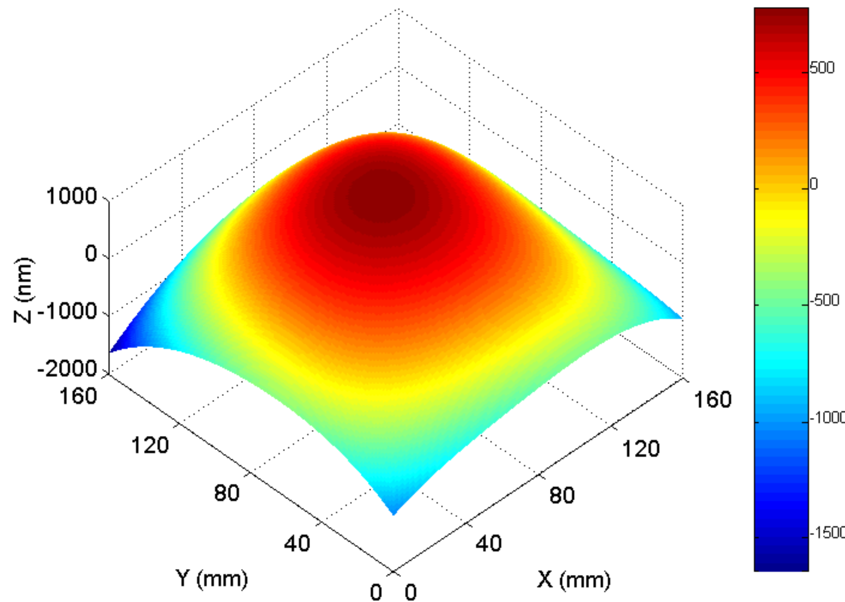
EUVL Mask and Chuck
FE Model of Theoretical Substrate

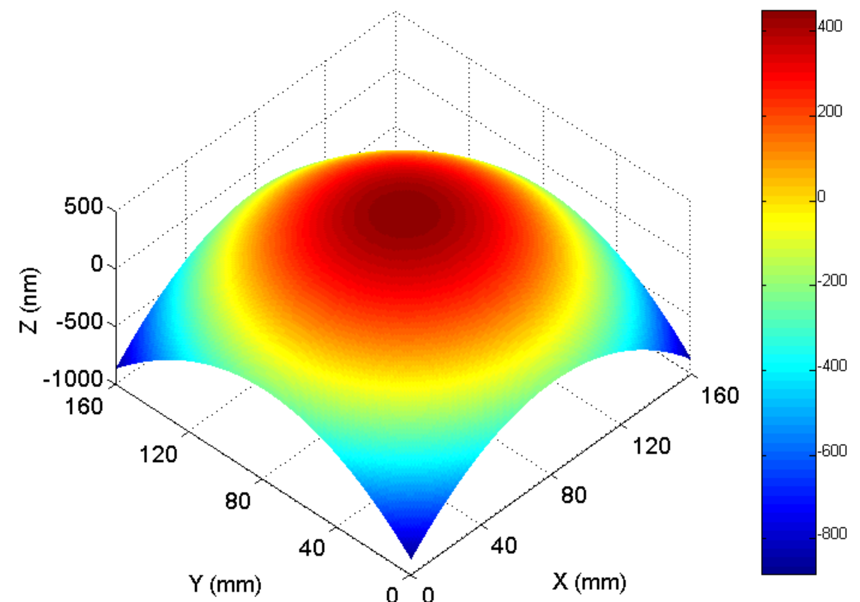


- As a base case, a theoretically flat mask was also simulated to determine the results for the best case scenario.
- Multilayer deposition causes approximately 1.25 μm of bow in a standard 6.35 mm thick ULE EUVL substrate.

Flatness After Multilayer Deposition
6.35 mm Substrate

Production Flatness | **Champion Flatness**



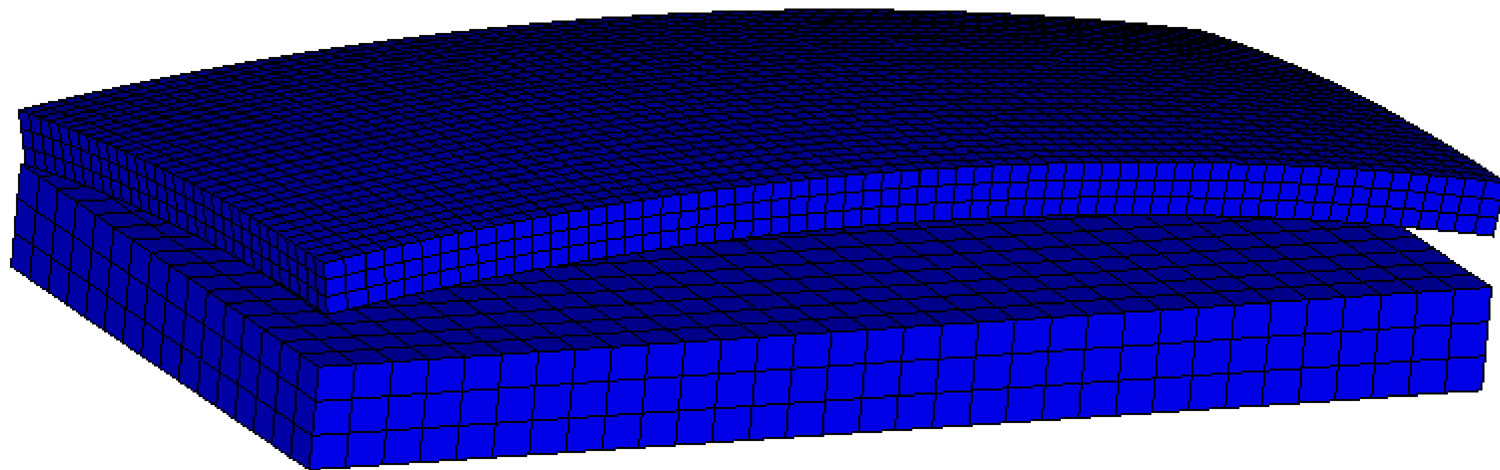


P-V bow is 2.4 μm | **P-V bow is 1.31 μm**

Substrate surface topography after multilayer deposition polished using standard production and advanced polishing and finishing techniques. Scale is in nm.

EUVL Mask and Chuck

FE Animation

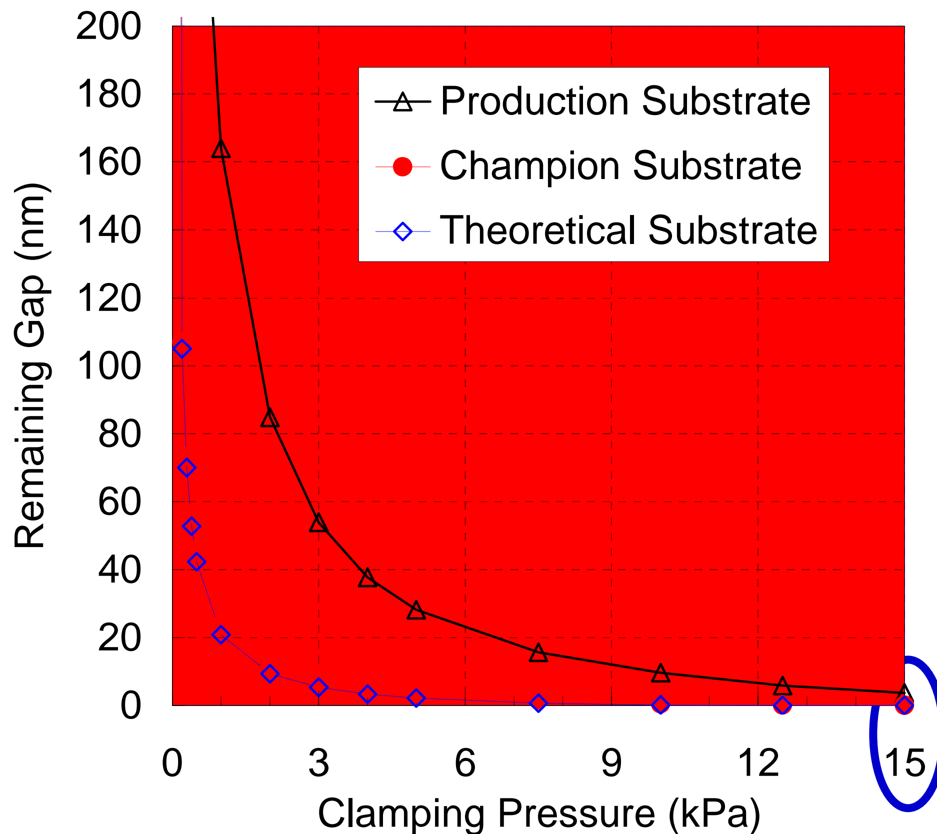


EUVL Mask and Chuck

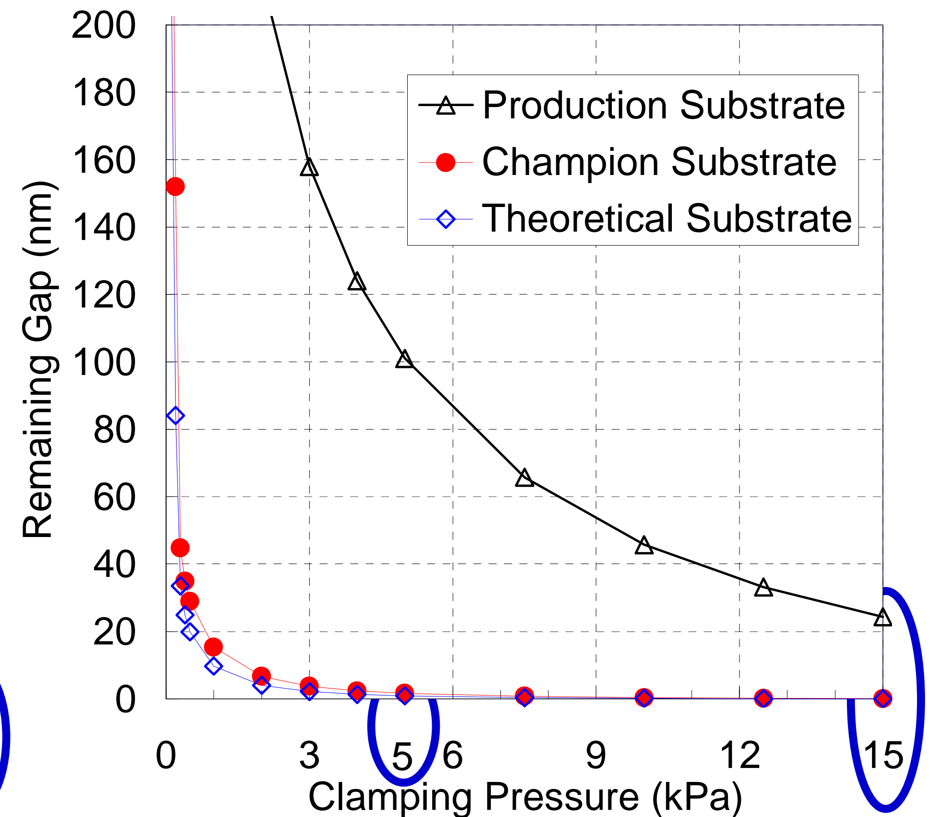
FE Animation – Close Up

Remaining Gap
Between Mask and Chuck

4.0 mm Thick Substrate



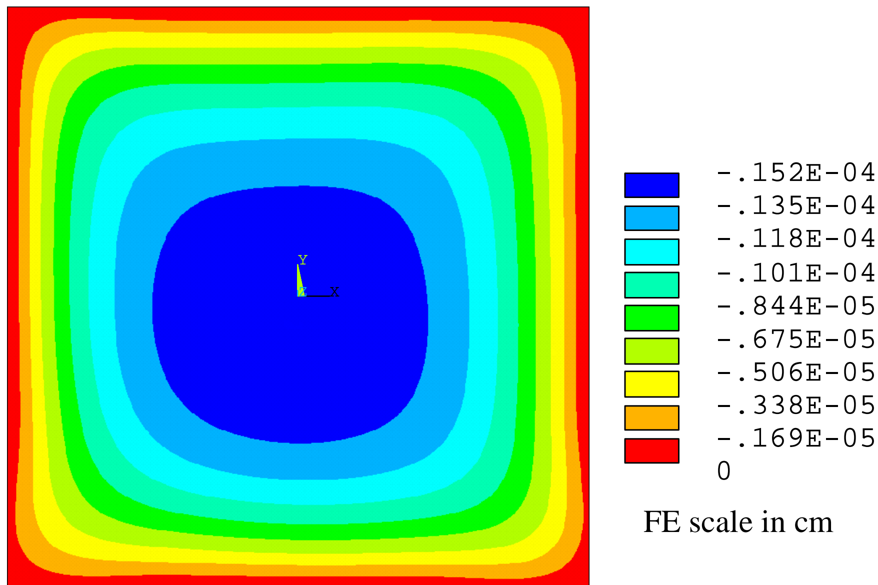
6.35 mm Thick Substrate



Since the maximum remaining gap occurs in the Flatness Quality Area, the maximum gap over the entire mask is the same as the gap over the Flatness Quality Area.

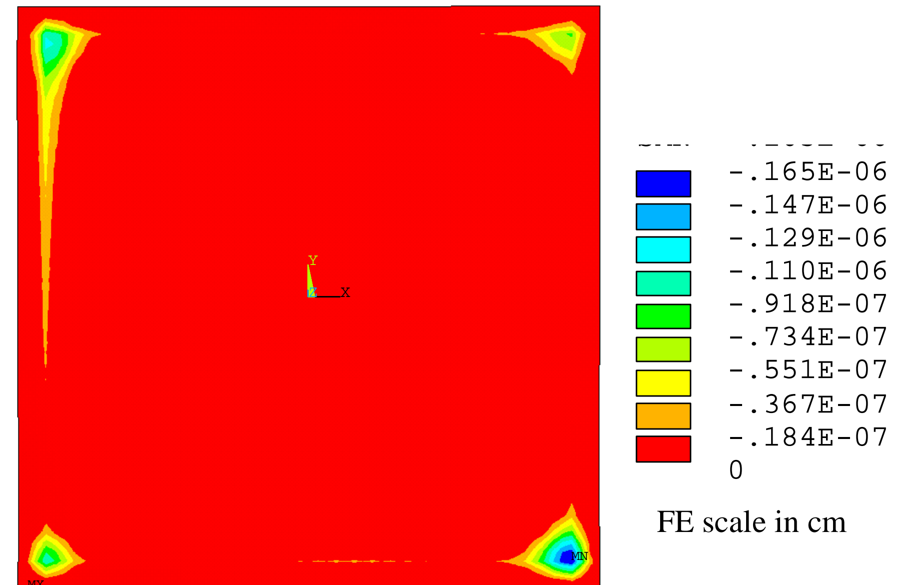
Remaining Gap
Champion Flatness on 6.35 mm Substrate

Clamping Pressure of 0.2 kPa



Maximum gap is 152 nm.

Clamping Pressure of 5.0 kPa



Maximum gap is 1.7 nm.

Remaining Gap

Champion Flatness on 6.35 mm Substrate

1

ANSYS 5.7.1
NODAL SOLUTION
STEP=1
SUB =3
TIME=.035
CONTGAP (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.368E-05
SMN =-.192E-07

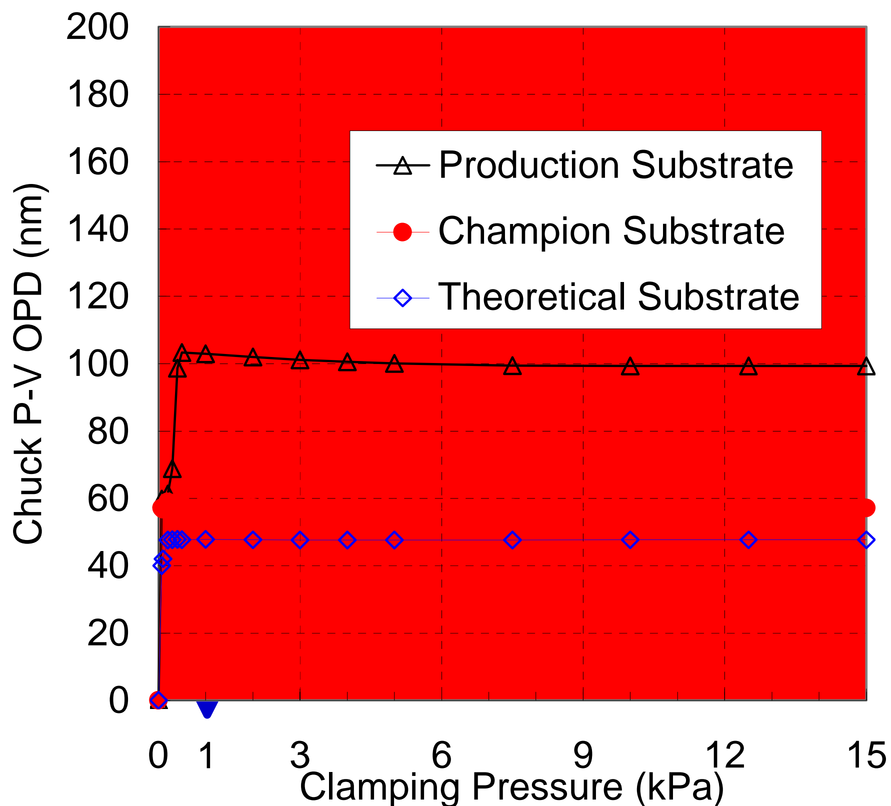
ZV =1
DIST=8.382
Z-BUFFER

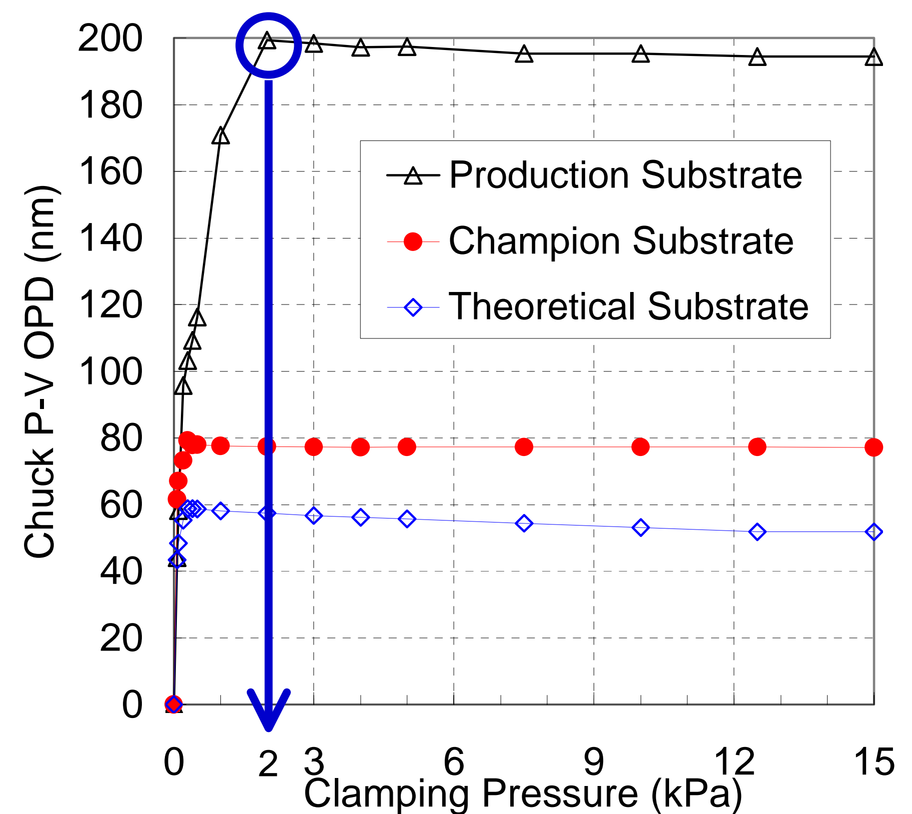
-.192E-07
-.171E-07
-.149E-07
-.128E-07
-.107E-07
-.853E-08
-.639E-08
-.426E-08
-.213E-08
0

Y
Z
X

Chuck Out-of-Plane Displacement

OPD levels off, since corners and edges have made contact



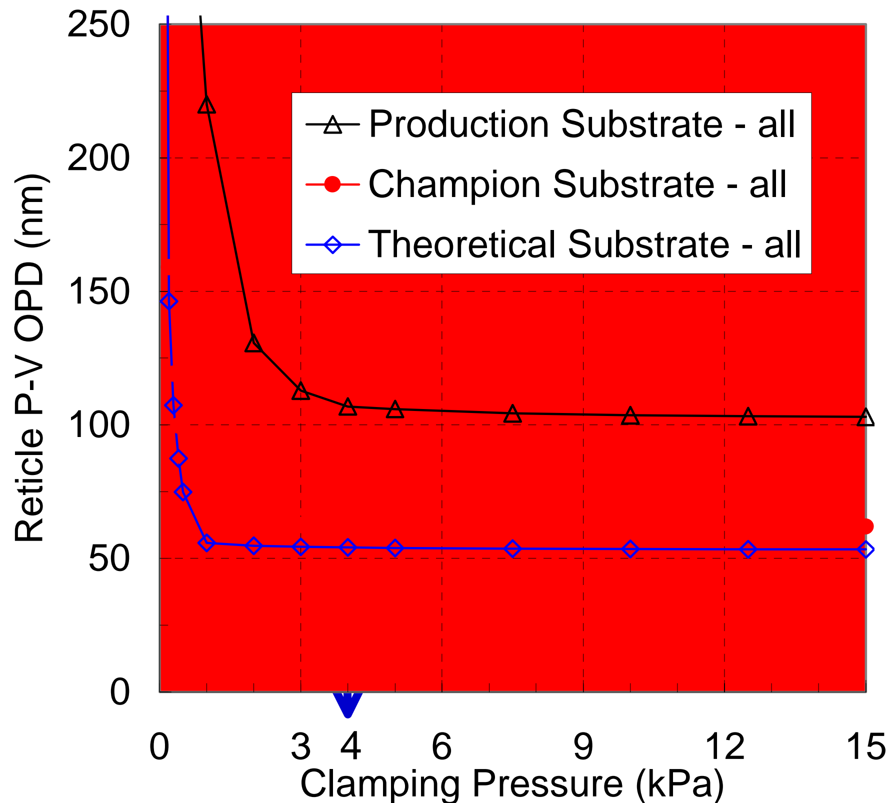


Plot of the maximum chuck *p-v* OPD as a function of clamping pressure.

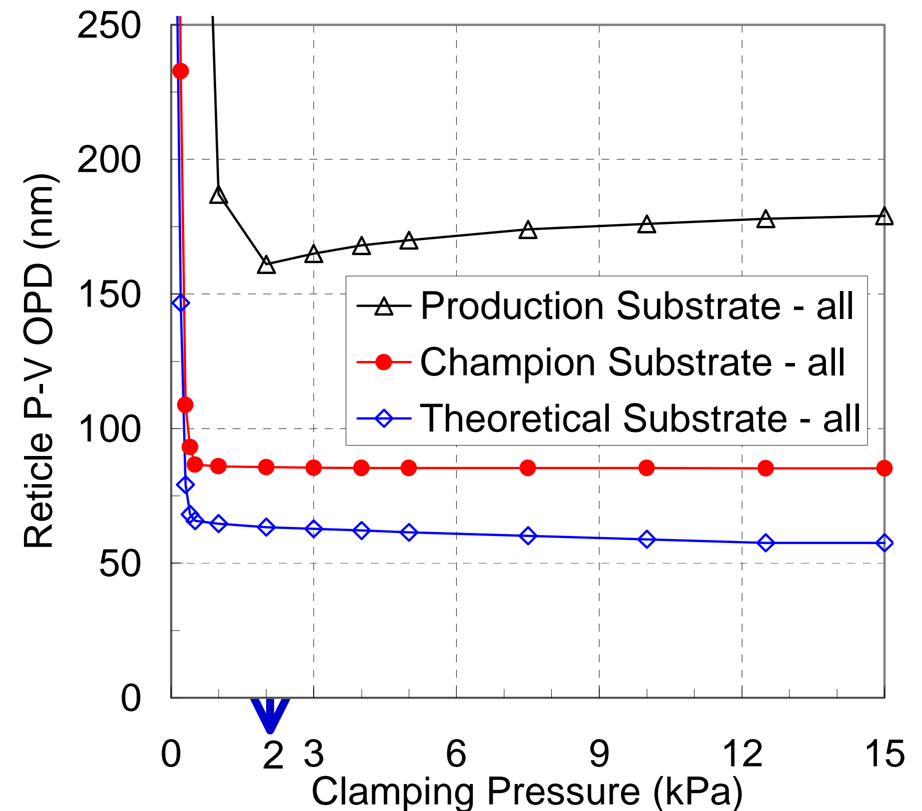
Mask Out-of-Plane Displacement

OPD levels off, since corners and edges have made contact

4.0 mm Thick Substrate



6.35 mm Thick Substrate

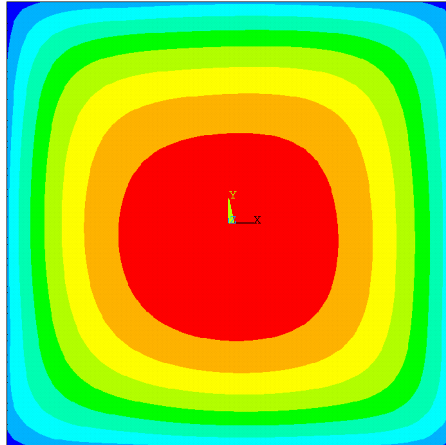


Plot of the mask *p-v* bow over entire patterned surface as a function of pressure.

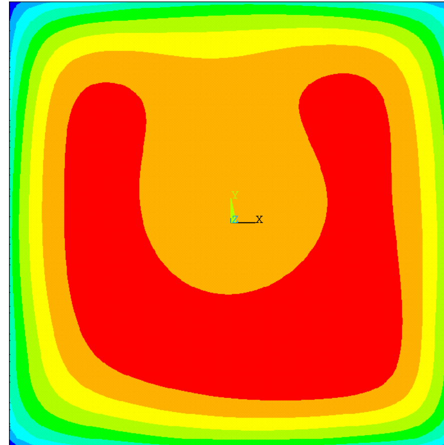
Champion Flatness

6.35 mm Substrate

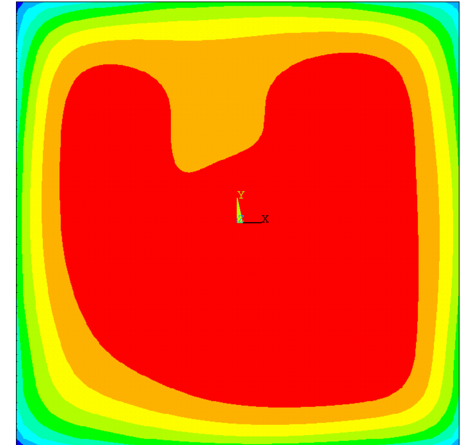
0.2 kPa: bow is 233 nm



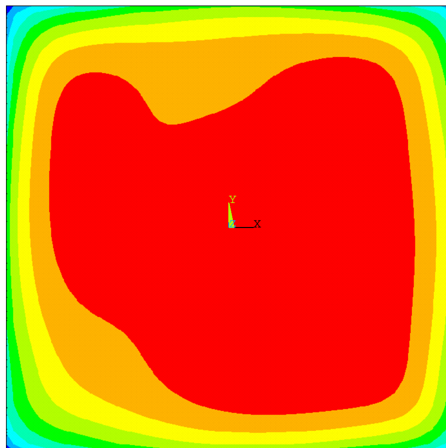
0.3 kPa: bow is 109 nm



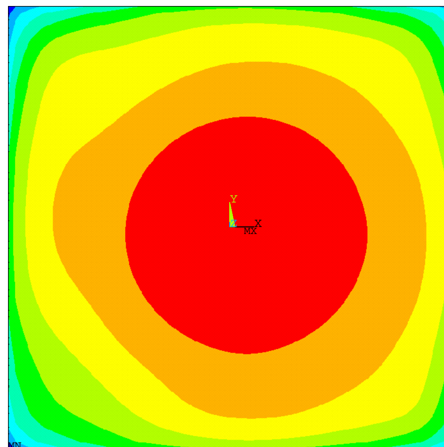
0.4 kPa: bow is 93.1 nm



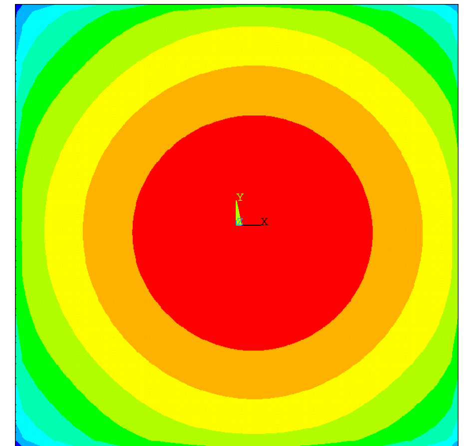
0.5 kPa: bow is 86.6 nm



1.0 kPa: bow is 86.0 nm



15.0 kPa: bow is 86.2 nm



FE scales are different for each plot. “Peaks” are indicated by the red regions and “Valleys” are indicated by the blue regions.

Summary and Conclusions

	Final Mask P-V Bow (nm)			
	Entire Surface		Flatness Quality Area	
Flatness	4.0 mm	6.35 mm	4.00 mm	6.35 mm
Theoretical	53	58	36	41
Champion	62	85	46	65
Production	103	180	80	180

- In each case, **the final chucked flatness can be improved by utilizing a backside layer (with compressive stress)** to offset the effects of the multilayer or by increasing the effective stiffness (thickness) of the chuck.
- However, with the recent developments in polishing and finishing techniques, it seems that **stiffer chucks may not be necessary**. By further refining the most recent finishing techniques and by utilizing a backside layer that can offset the effects of multilayer deposition, many of the issues involving EUVL chucking could be resolved.