

# **Deformation of EUVL Mask due to Multilayer and Absorber-Pattern Stress**

**ASET-EUVL Laboratory**

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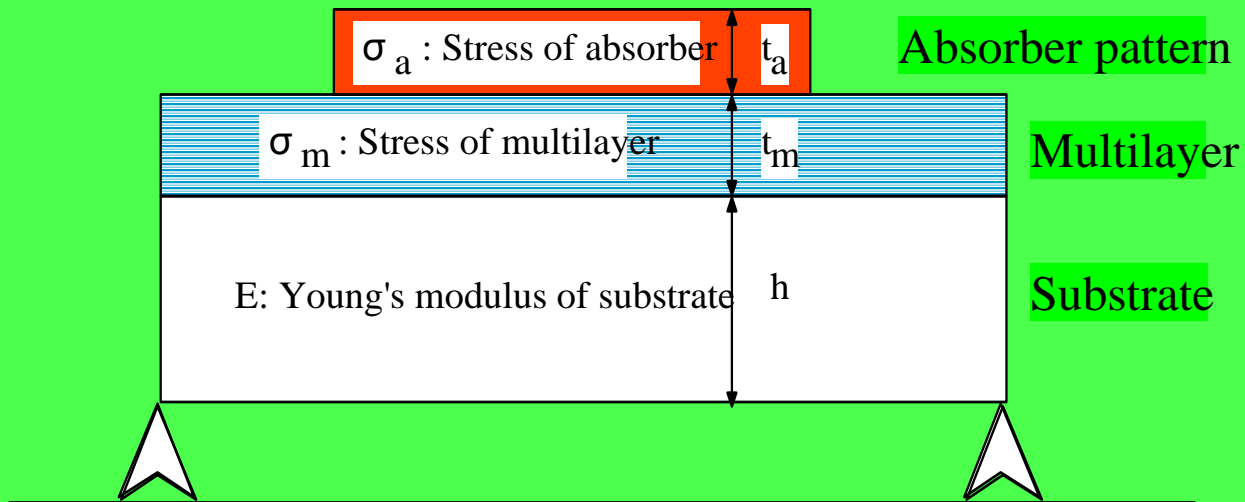
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# *EUVL mask structure*



## 2. Deformation model of Multilayer mask due to film stress

Basic equation

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)w = \frac{p}{D} - \frac{1}{D(1-\nu)}(f_m \nabla^2 M_m + f_a \nabla^2 M_a)$$

$$M_m = \frac{h}{2} \sigma_m t_m$$

$$M_a = \frac{h}{2} \left(1 + 2 \frac{t_m}{h}\right) \sigma_a t_a$$

$$f_m = 1 + \frac{t_m}{h}$$

$$f_a = 1 + \left(1 + 2 \frac{t_m}{h}\right)^{-1} \frac{t_a}{h}$$

$M_m$  : bending moment of multilayer

$M_a$  : bending moment of absorber

$t_m$  : thickness of multilayer

$t_a$  : thickness of absorber

$h$  : thickness of substrate

$\nu$  : poisson's ratio

$D$  : bending rigidity

How to solve the equation

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\phi = \frac{p}{D}$$

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)w = \phi - \frac{f_m M_m + f_a M_a}{D(1-\nu)}$$

How to solve: Finite difference method

Successive over relaxation method

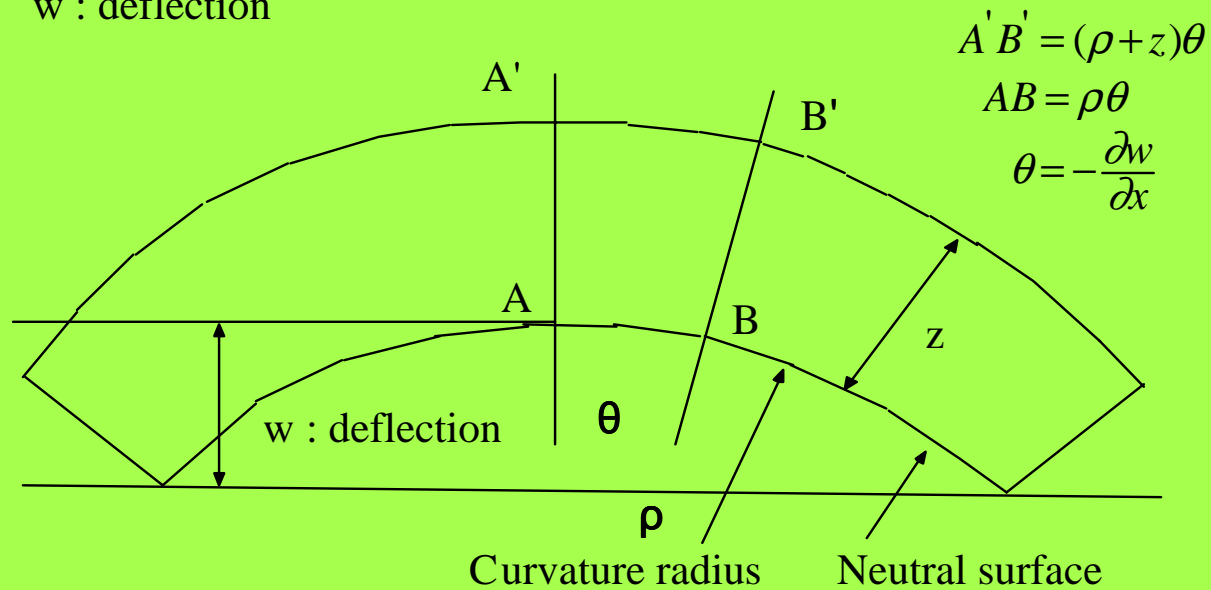
# Displacement on mask surface due to deflection

Placement error ← Displacement

Displacement :  $A'B' - AB = z\theta$

$z$  : distance from neutral surface to substrate surface

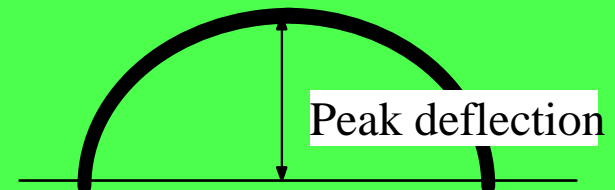
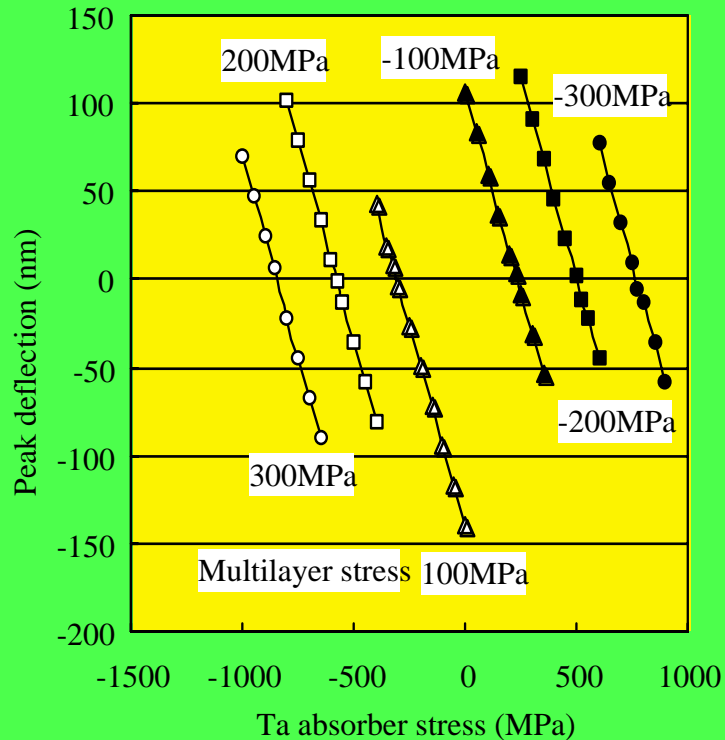
$w$  : deflection



# Table I Physical parameter used for calculation

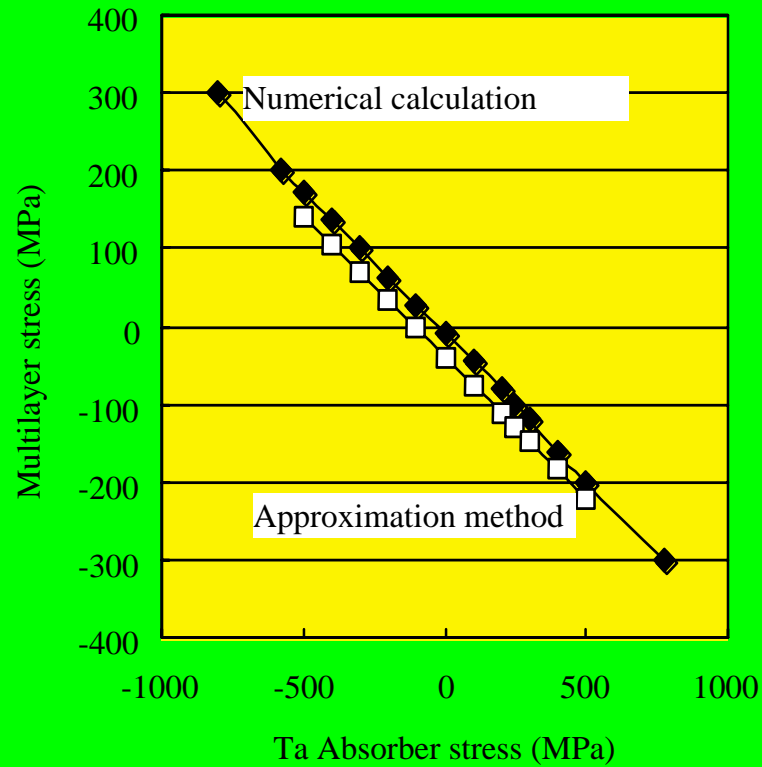
Substrate Density [g/cm <sup>3</sup> ]	2.2
Substrate Young's Modulus [MN/cm <sup>2</sup> ]	7.3
Substrate Poisson's Ratio	0.3
Substrate Thickness [mm]	6.25
Substrate Size [mm <sup>2</sup> ]	150x150
Absorber Thickness [nm]	100
Multilayer thickness [nm]	272
Segment Size $\Delta x = \Delta y$ [mm]	7.5

# *Peak deflection of EUVL mask blank*



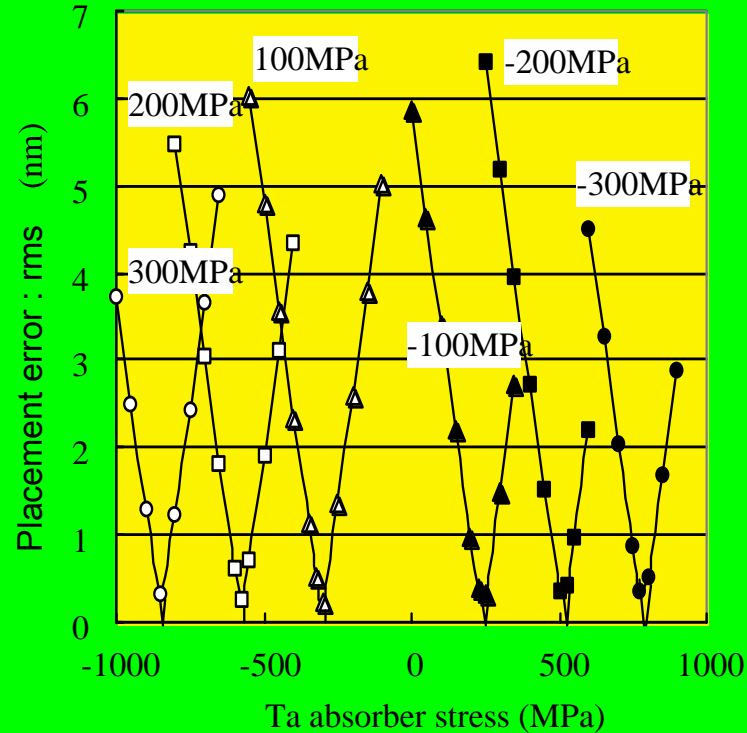
Absorber coverage is 100%  
Curvature parameter is multilayer stress  
Substrate is 6025 quartz substrate

# *Relation satisfying critical stress*



6025 quartz substrate is used

# *Placement error on EUVL mask blank*



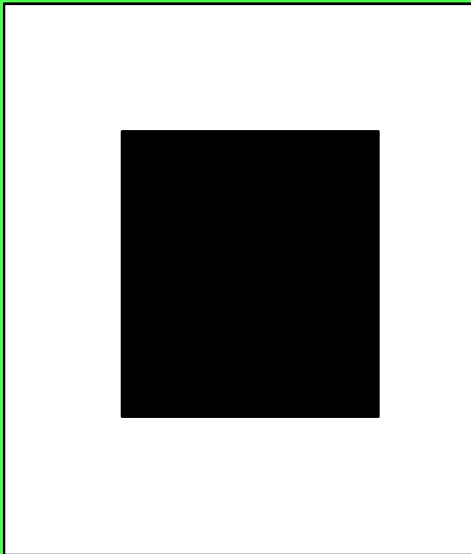
Absorber coverage is 100%

Curvature parameter is multilayer stress

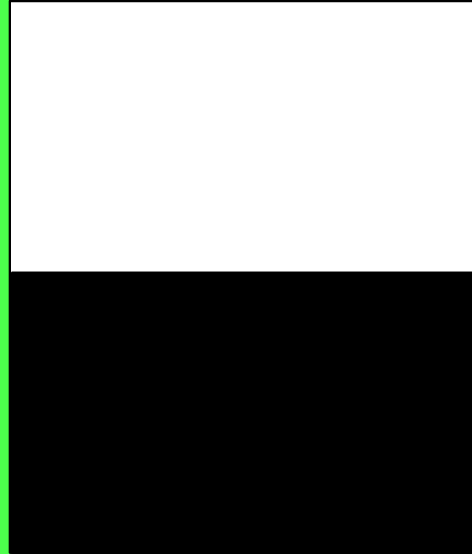
Substrate is 6025 quartz substrate

# *Three types of EUVL mask with coverage 50%*

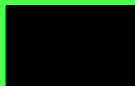
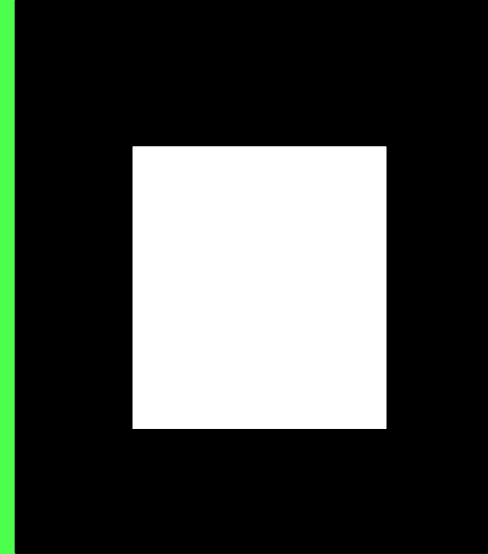
Case-1



Case-2



Case-3



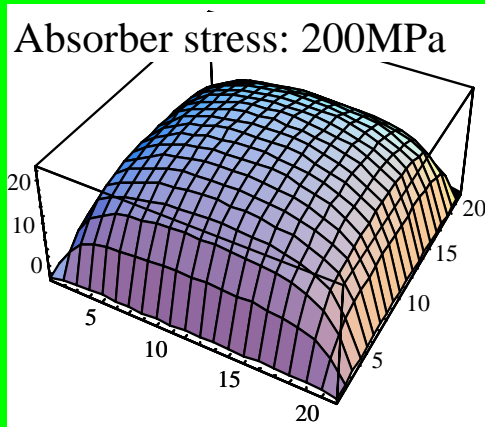
Absorber : 100 nm thick



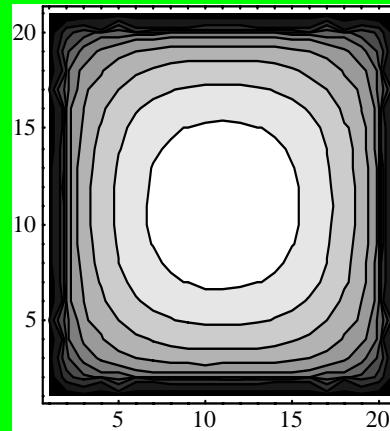
ReflectiveSurface with compressive stress of 100MPa

# Deflection, Contour Plot & Displacement Vector Field for Case-1

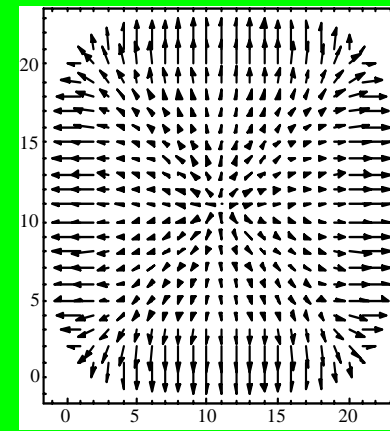
Bird's view



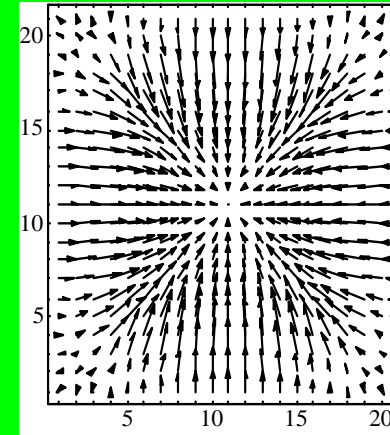
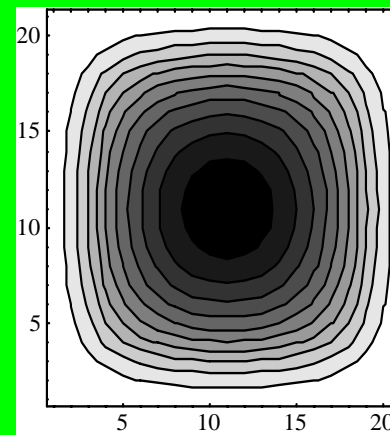
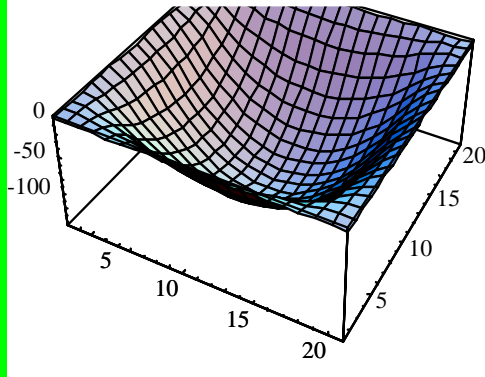
Contour plot



Vector field of displacement



Absorber stress: 500MPa

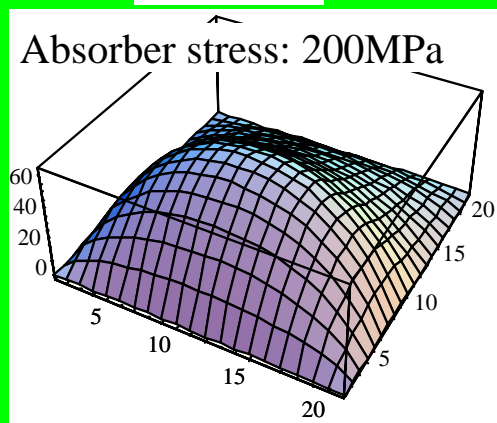


Multilayer stress: -100MPa on 6025 Qz substrate, Coverage: 50%

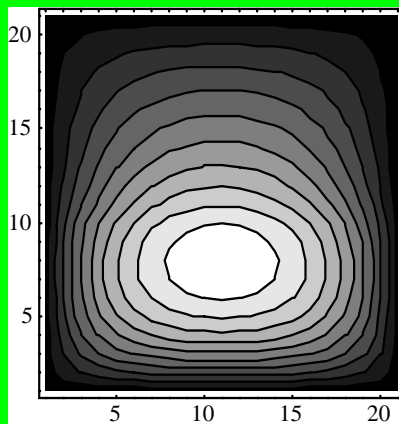
図6 ケース1におけるEUVLマスクブランク変形計算例

# Deflection, Contour Plot & Displacement Vector Field for Case-2

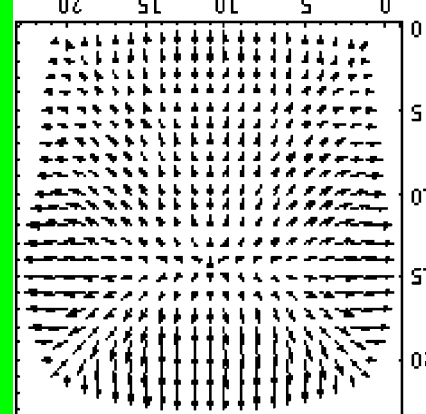
Bird's view



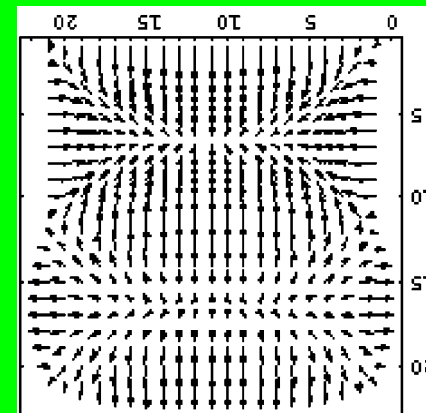
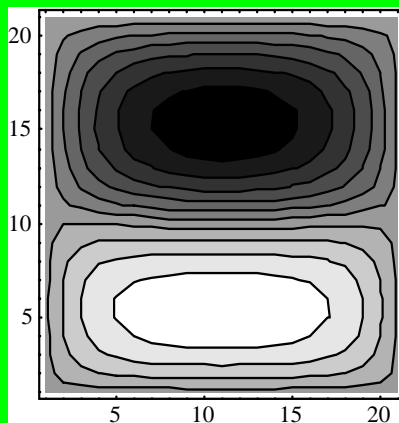
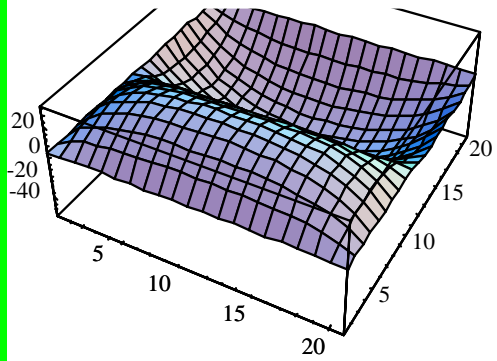
Contour plot



Vector field of displacement



Absorber stress: 500MPa

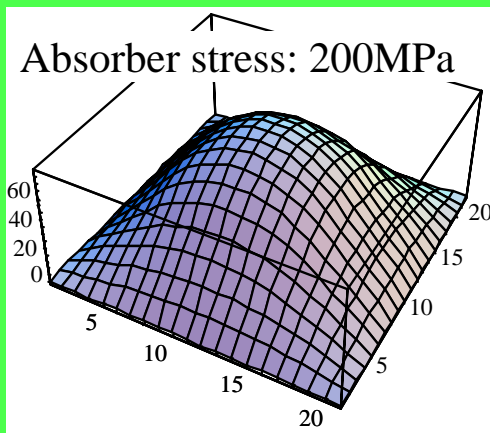


Multilayer stress: -100MPa on 6025 Qz substrate, Coverage: 50%

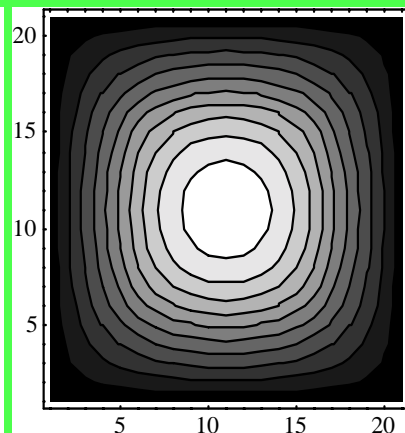
図7 ケース2におけるEUVLマスクブランク変形計算例

# Deflection, Contour Plot & Displacement Vector Field for Case-3

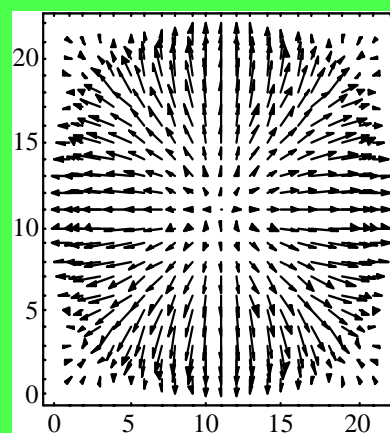
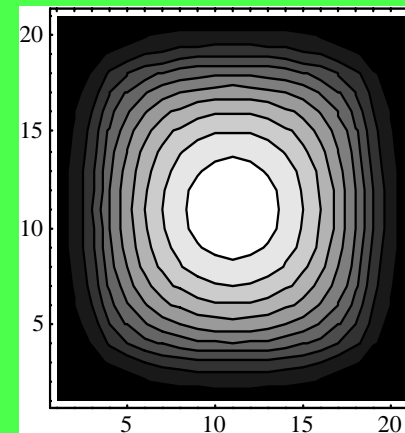
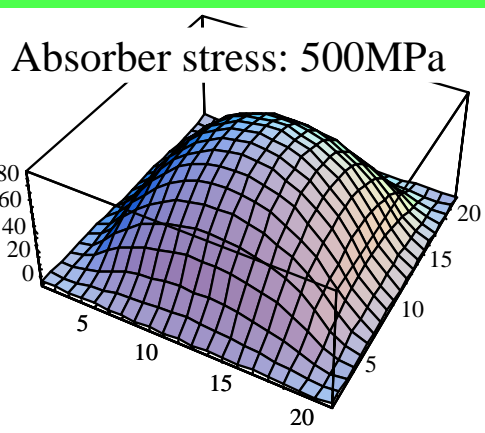
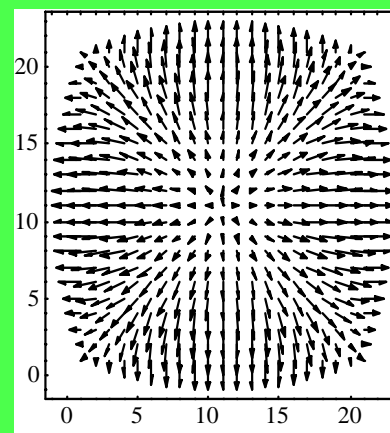
Bird's view



Contour plot



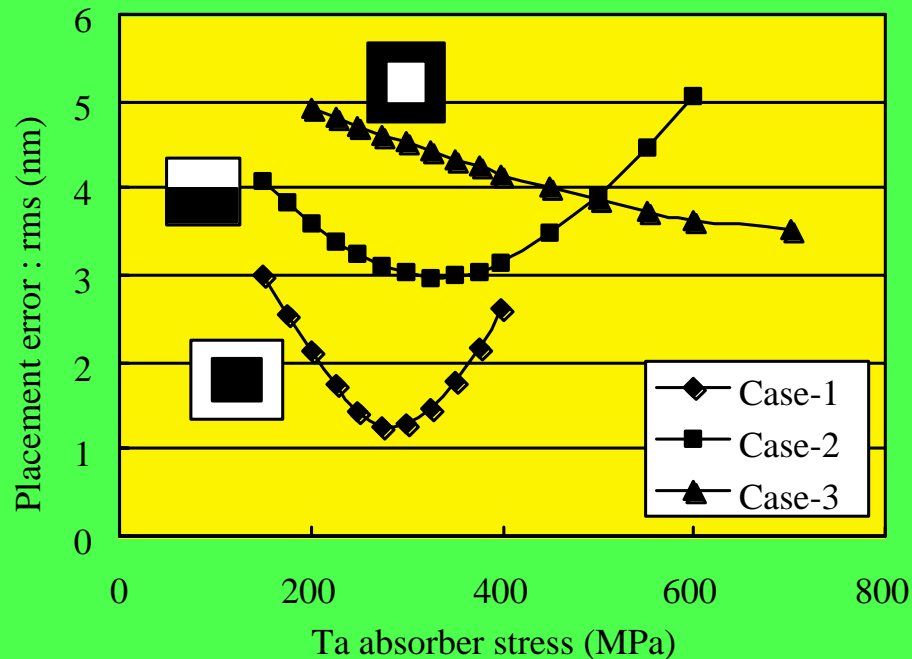
Vector field of displacement



Multilayer stress: -100MPa on 6025 Qz substrate, Coverage: 50%

図8 ケース3におけるEUVLマスクブランク変形計算例

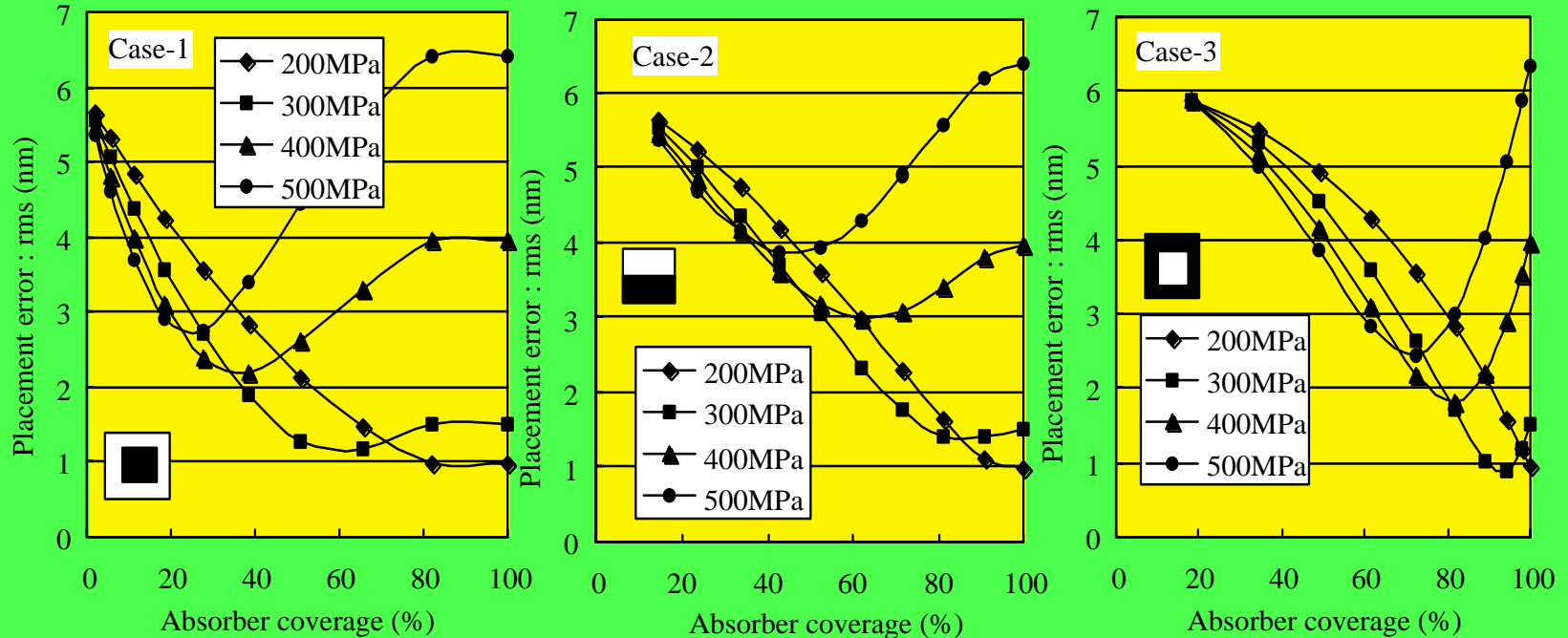
# *Comparison of placement error on mask under absorber coverage 50%*



Absorber coverage is 50%

Multilayer stress of -100MPa is on 6025 quartz substrate

# *Absorber coverage and placement error on mask*



Mo/Si multilayer on 6025 quartz substrate has stress of -100MPa

Curvature parameter is absorber stress

Case 1,2 and 3 indicate 3 kinds of absorber arrangement

## Conclusion

1. Deformation model of EUVL mask was developed for calculating the deflection and placement error due to film stress both multilayer and absorber pattern.
2. Placement error less than 10 nm rms is possible under the setting of absorber critical stress against multilayer stress.
3. The optimum film stress depends on the distribution of absorber pattern, it's value is determined by the numerical calculation every pattern.

## Further works

1. Thermal distortion during exposure
2. Deformation due to chucking
3. And so on.