Basic examinations of shape correction machining of minute area by ion beam figuring

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Principle of IBF

Numerical control stage

Work-piece

Sputtering

Surface atoms

Ar^+ ions

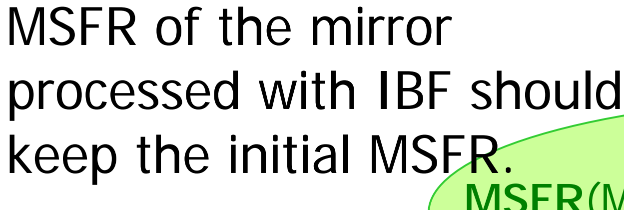
Work-piece

Ion beam

Ion-gun

Work-piece surface is atomically removed by physical sputtering with Ar^+ ions. Ion beam processing point of the work-piece is scanned by a numerical control stage.

Specifications of mirrors for EUVL machine



0.1nmRMS

MSFR(Mid Spatial Frequency Roughness)
Spatial wavelength is 1mm~1µm.

Design shape

Aim of the IBF is to correct LSFR of the mirrors with in the required accuracy.

EUVL mirror

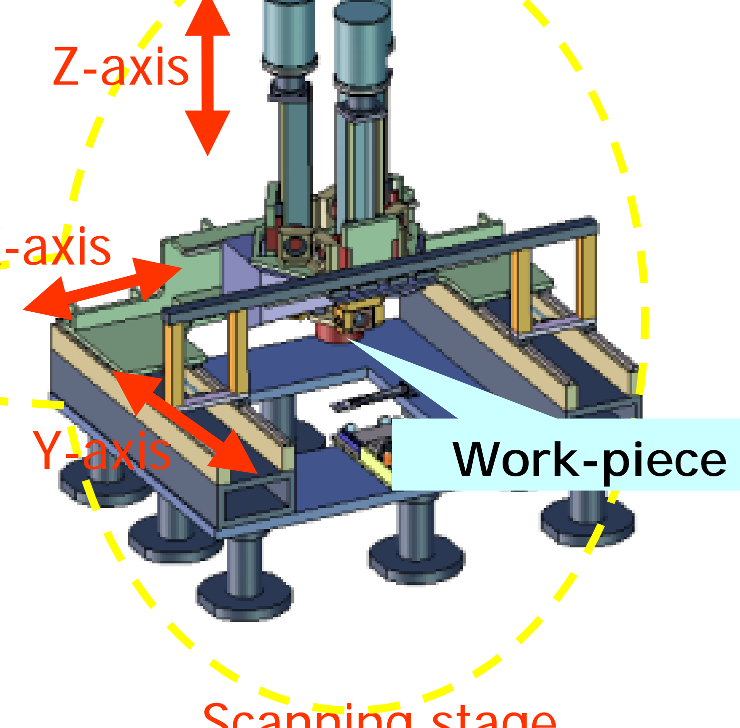
0.1~0.2nmRMS

LSFR(Low Spatial Frequency Roughness)
Spatial wavelength is more than 1mm.

HSFR(High Spatial Frequency Roughness)
Spatial wavelength is less than 1µm

0.1nmRMS

Developed IBF system and accuracy of scanning stage



Scanning stage

Stage is in the vacuum chamber.
Accuracy of 3 dimensional positioning of work-piece is about ±30μm.

Vacuum chamber

Volume : more than 10m^3
Achieved vacuum pressure:
1x10^{-4}(within 5 hours)

Ion-gun

Seting upward on the base plate of the camber
Diameter of ion beam : 1~3mm

EUVA Profiles of ion beam current density and etched spot

ion accelerating voltage : 5kV
processing time : 30min
work-piece : Si

Profile of ion beam current density measured with Faraday cup of 200 μm diameter

0.101mA/cm²

X-axis (mm)

Y-axis (mm)

Profile of processed spot measured with 3-D surface profiler

291nm

2.0mm

Profiles of ion beam current density and that of processed spot agree well.

Linearity of the removal rate

Removal depth (nm)

1400
1200
1000
800
600
400
200
0

No.1
No.2
No.3
No.4

[Spot processing]
ion accelerating voltage : 20kV
work-piece : Si
measurement : 3-D Surface profiler

0 2 4 6 8 10 12

Processing time (min)

Removal volume increases proportionally with the processing time.
IBF is suitable for dwell time control of removal process.

Profile of ion beam current density & processed track with line scanning

EUVA

ion accelerating voltage : 20kV
scanning velocity : 0.6mm/min
work-piece : Si
measurement : 3-D Surface profiler

0.5mm(FWHM)

Profile of ion beam current density

5.4mm

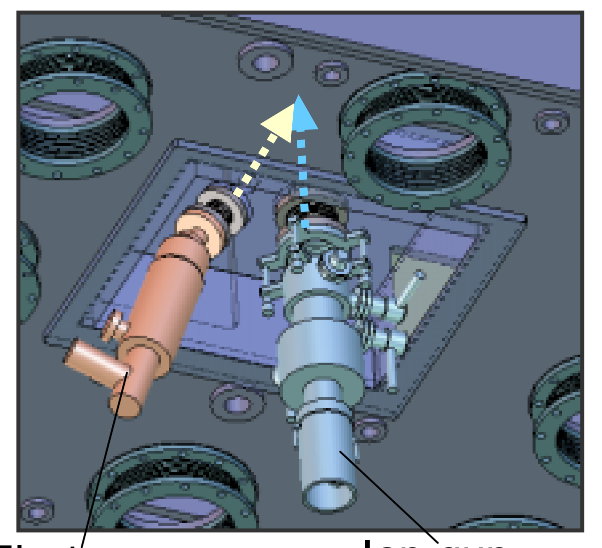
0.5mm (FWHM)

(depth of processed track : 140nm)

Shape of processed track

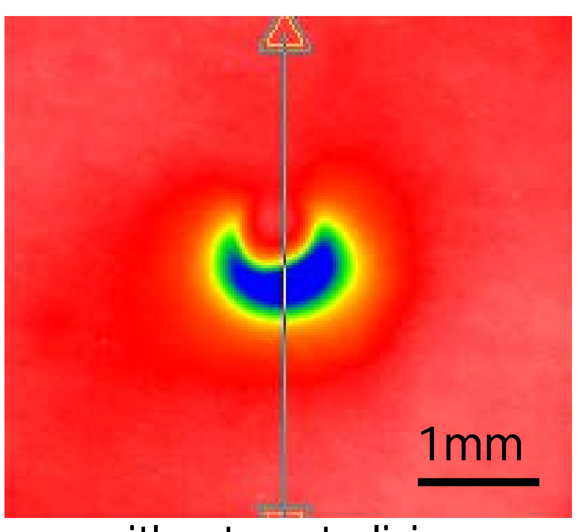
Profile of ion beam agrees well to the cross-sectional profile of processed track.

EUVA Neutralizing Effect of ion beam with electron beam

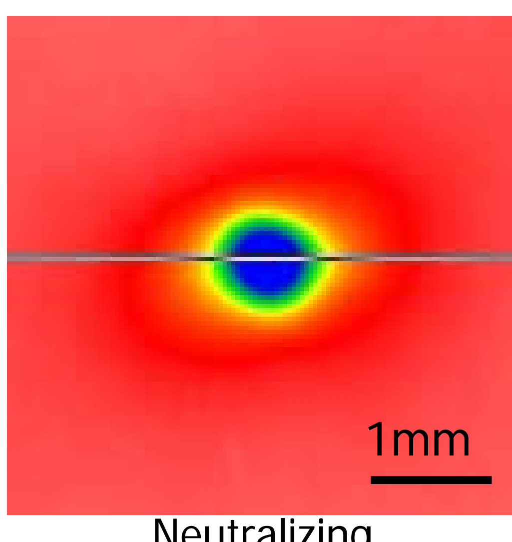


Electron-gun Ion-gun

Set-up for neutralization of ion beam



without neutralizing



Neutralizing

Processed spot shapes (3D-Surface profiler)

Electron-gun is set near the ion-gun for delivering electrons to ion beam processing point at the work-piece.

Ion accelerating voltage : 20kV
Work-piece : Low-thermal expansion glass

In the case of ion processing dielectric insulator, etched shapes differ from the ion beam shape.

Neutralize process with electron beam irradiation by the Electron gun is very useful for IBF processing of dielectric insulator.

Effect of the electron beam current on neutralization of ion beam

[Spot processing]
ion accelerating voltage : 20kV
work-piece : Low-thermal expansion glass

Electron beam current (μA)	1.0	2.0	3.5
Unit removal volume / Ion beam current density $(mm^3/hour)/(mA/cm^2)$	5.78e-4	5.97e-4	6.01e-4

deviation: 3.8%

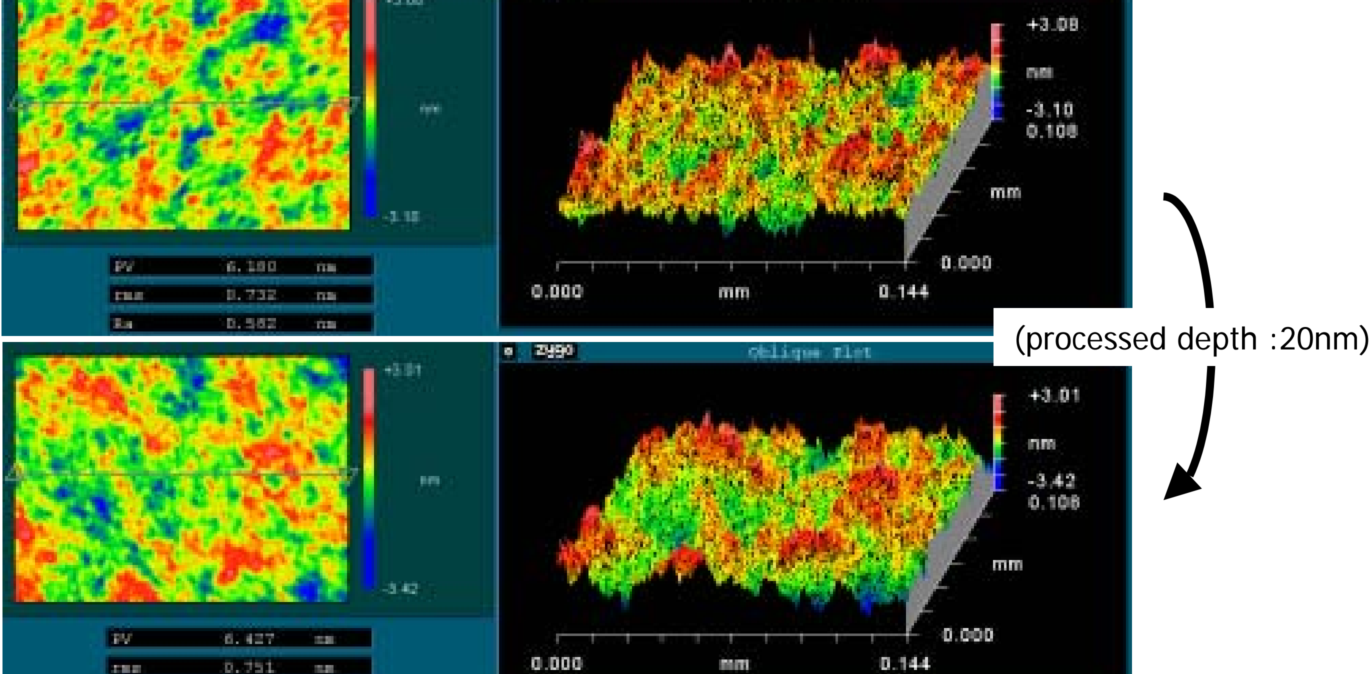
Neutralizing effect of ion beam with electron beam does not depend on an electron beam current at range from 1.0μA to 3.5μA.

MSFR of work piece before and after ion beam processing

[raster scan processing of 15mm x 15mm]
ion accelerating voltage : 20kV
scanning velocity : 0.25mm/sec
work-piece : Low-thermal expansion glass
feed pitch : 0.1mm

Before processing

After processing



Average of 8 points before : 0.780 nm RMS
after : 0.745 nm RMS

MSFR of the work piece processed with ion beam at raster scanning can keep the initial value.

Time stability of the removal volume

removal volume(mm3/hour)

0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0

ion accelerating voltage : 20kV
work-piece : Low-thermal expansion glass

0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00

time(from start of Machinig) (h:m)

Deviation of removal volume is within ±5.4% for 7 hours IBF processing time.

Conclusion

Performance of the developed IBF system was evaluated.
Results were good enough to try profile correction processes.

Profiles of ion beam current density agree well that of IBF processed spot.

Removal volume increases proportionally with the processing time.
It is suitable for dwell time control removal process.

In case of processing dielectric materials, spot profile is deformed.
Adding neutralize process (electron beam irradiation by the EB-gun), normal spot profile is realized.

Neutralizing effect of ion beam with electron beam does not depend on an electron beam current at range from 1.0μA to 3.5μA.

MSFR of the work piece processed with ion beam at raster scanning can keep the initial value.

Deviation of removal volume is within ±5.4% for 7 hours processing time.

Canon

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