Prevention effect of insulator substrate charge-up during ion beam figuring

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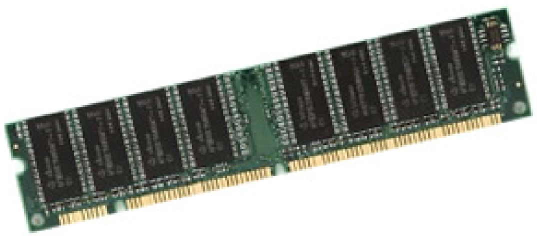
Introduction

Faster and more complex integrated circuits were manufactured by reducing the size of features patterned on the semiconductor wafer by 30% every years.

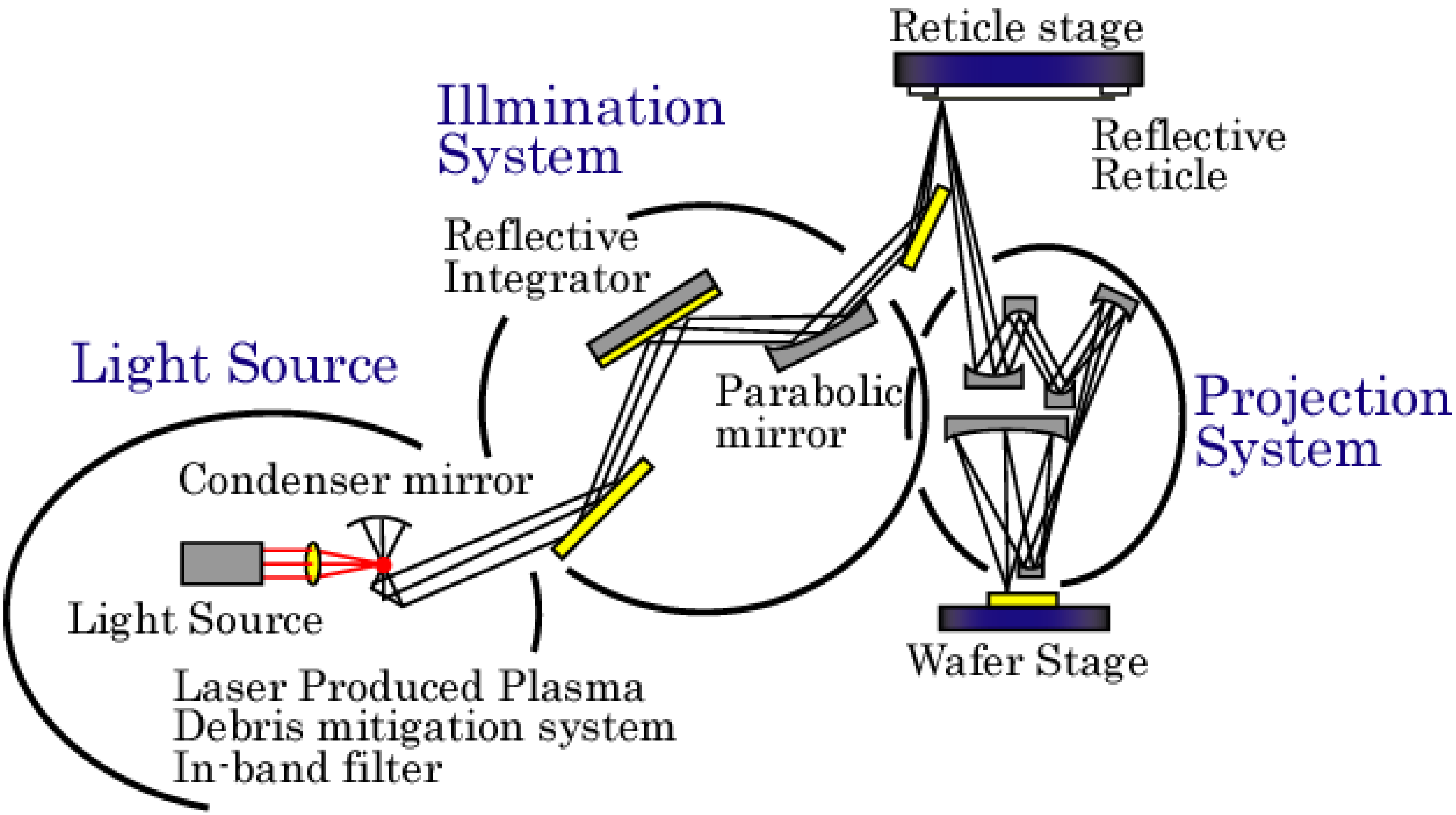


future

In 2009, 45nm pitch DRAM will be appear.

For manufacturing this DRAM, EUVL stand must be developed until 2009.

Schematic Optical System for EUV Lithography



The Spatial frequency roughness requirement of EUV aspherical mirror

0.20[nm] RMS

High spatial frequency roughness

HSFR

（ ＜1μm ）

0.20[nm] RMS

mid spatial frequency roughness

MSFR

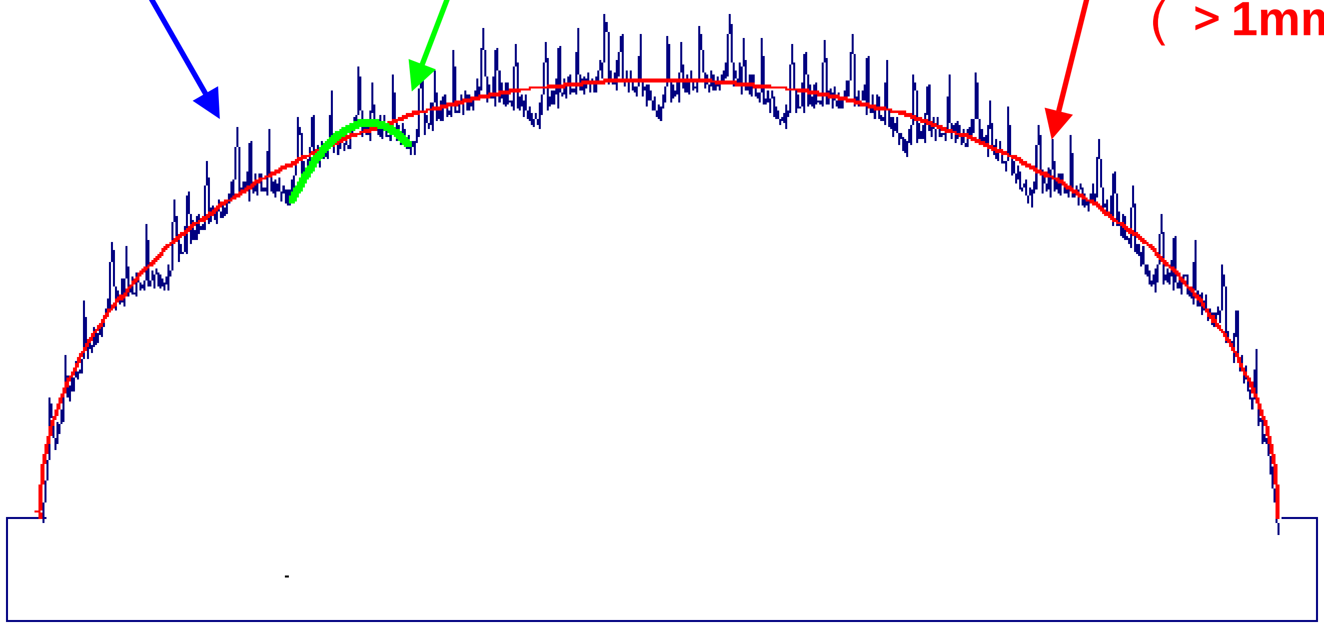
（ 1μm ~ 1mm ）

0.20[nm] RMS

Shape accuracy

HSFR

（ ＞1mm ）



High and Mid Spatial Frequency Roughness, and shape

Problems of mechanical polishing of aspherical mirror

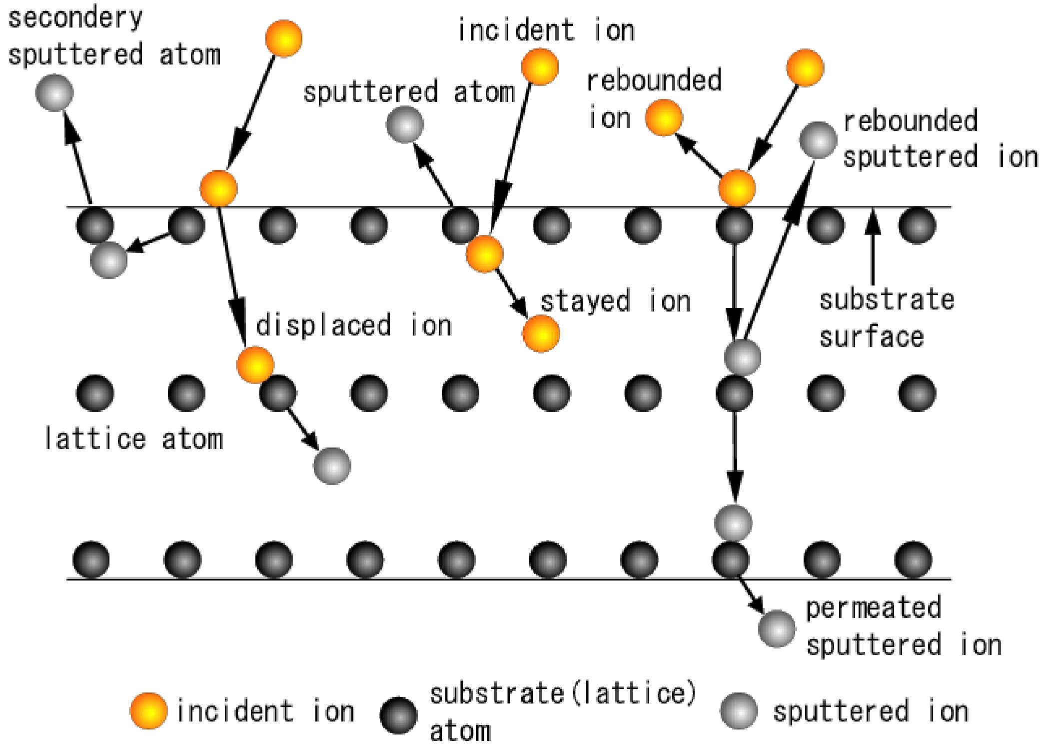
1) At the edge of a work-piece, it is difficult to control the shape of the work-piece.
2) The shape of polishing tool will be changed during polishing the mirror. So, more stability or long life time tool is required.
3) The removal rate is not constant, when the compounding material or hard-brittle material is polished.

↓ Solve these problem

Ion beam figuring (IBF) is promising method for fine finishing of EUV mirror.

Advantages of IBF (1)

1) Etching mechanism of IBF is based on physical sputtering. Therefore, atomic order machining of the work-piece is possible.

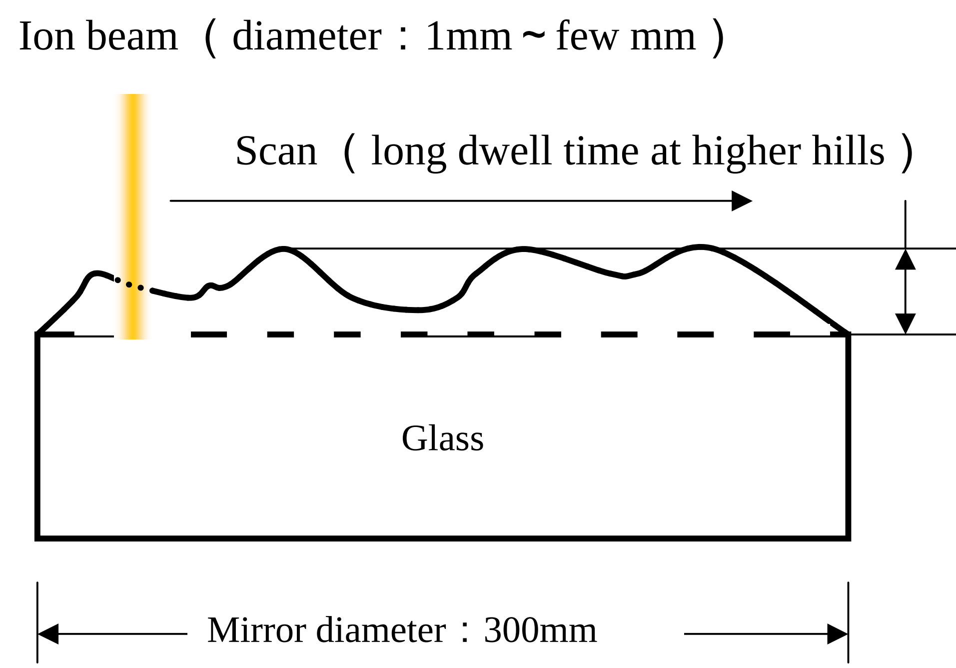


2) Ease of electrical control of ion beam is suitable for dwell time control of machining.

Advantages of IBF (2)

3) The machining tool is ion beam, so wear of tool and changing the tool shape do not occur. But stability of ion beam current sometimes become problem.

4) IBF is performed in a vacuum chamber, so clean surface will be maintained.



Dwell time control using IBF

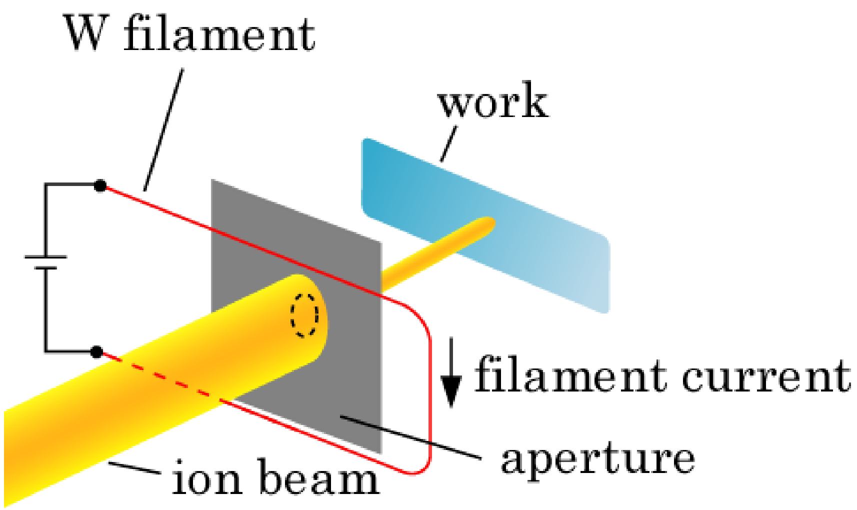
Adverse effect of charge up

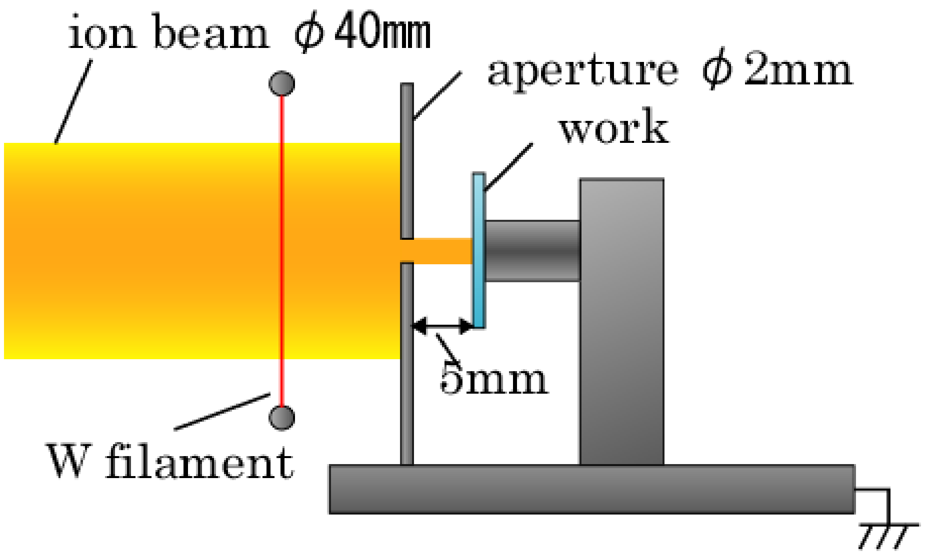
- Shape of etched holes become unstable.
- Volume of holes become unstable.

It is necessary to neutralize charge of ion beam to eliminate charging up of substrate.

How to neutralize ion beam

Neutralize positive charge of ion beam by thermal electron emitted from heated W filament.



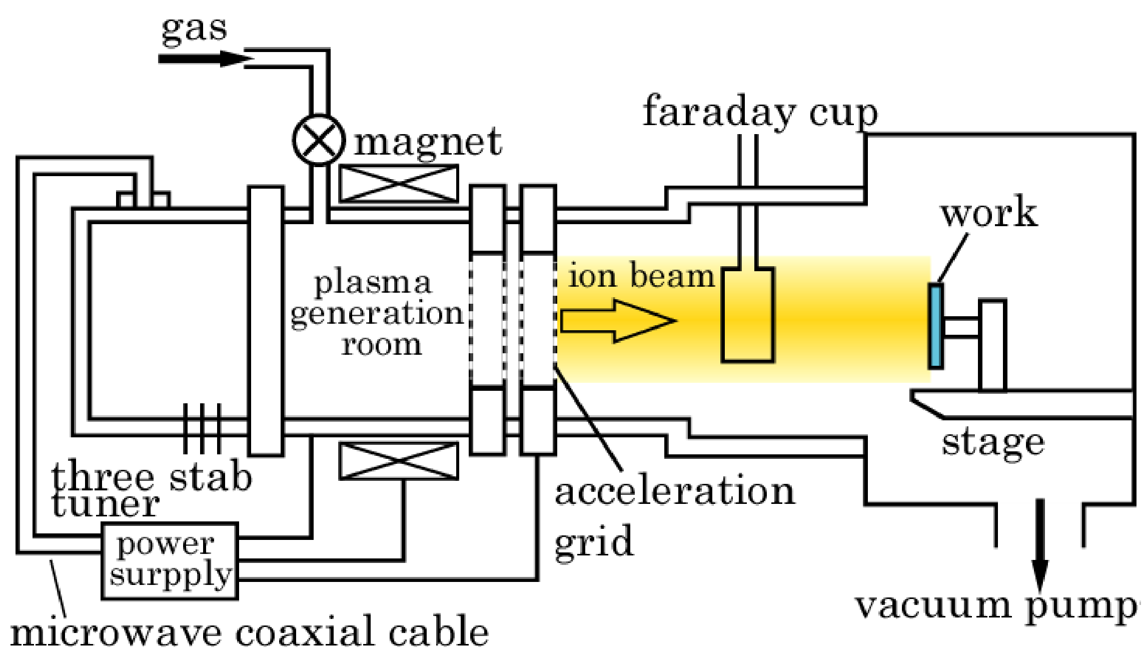


Layout

Experimental procedure

Slide glasses were etched for 30min with Neutralized Ar ion beam by electrons from heated W filament.

After etching, we measured the hole shape using 3-D Surface Profiler (New view).

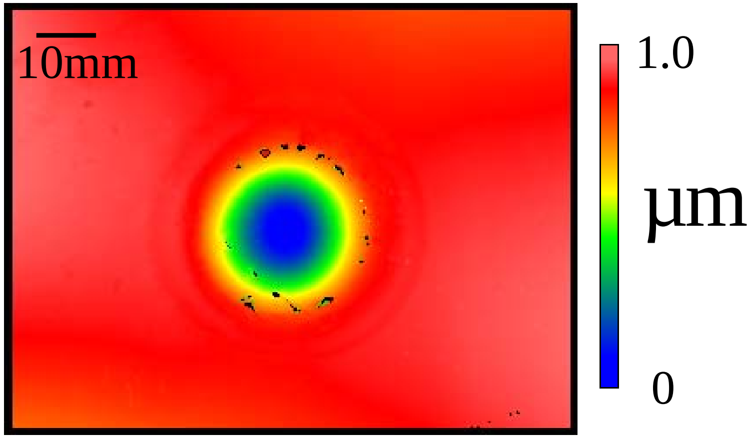


ECR Ion beam figuring apparatus

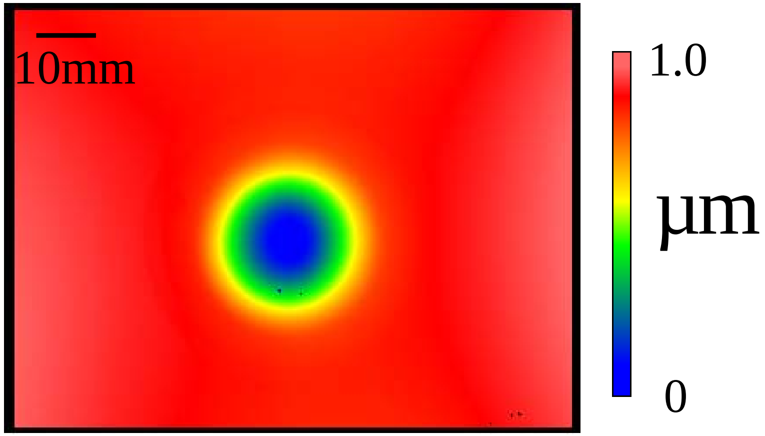
IBF conditions

Gas	Ar; 3.00 sccm
Acceleration Voltage	1000V
Process time	30min
Microwave power	100W
Filament current	0.5, 1.0, 1.5, 2.0 A
Base vacuous degree	2.36×10^{-2} Pa
Ar vacuous degree	$3.5\times10^{-1}\sim3.7\times10^{-1}$ Pa
Ion current density	$0.84\sim0.93$ mA/cm^2

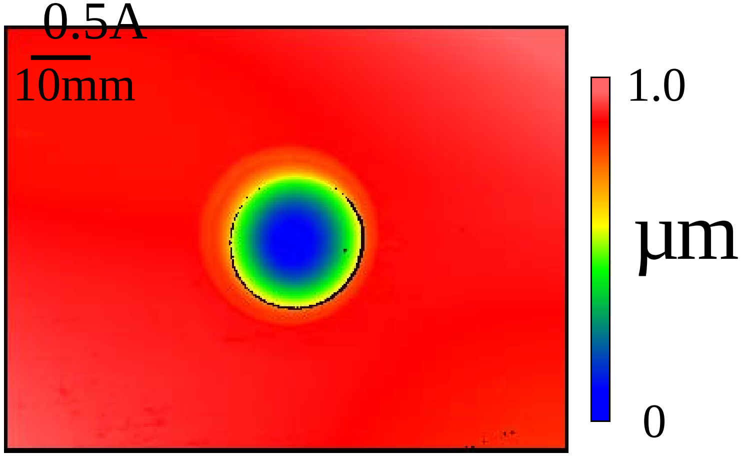
Ion beam etched holes (Top view)



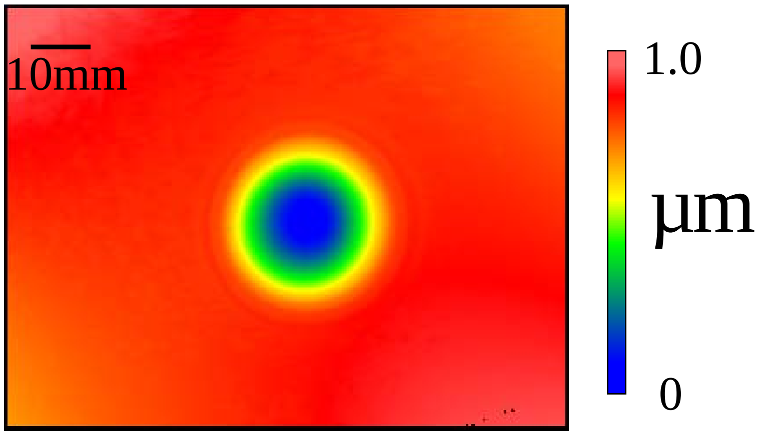
Filament current：0.5A



Filament current ：1.0A

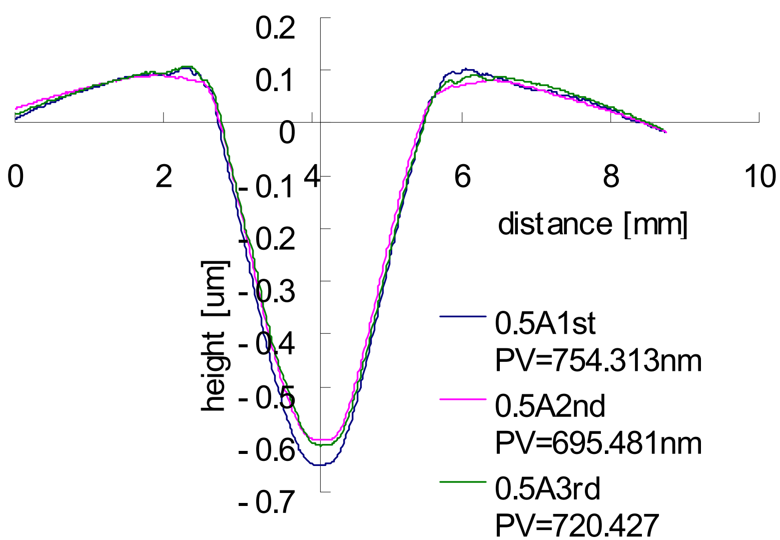


Filament current ：1.5A

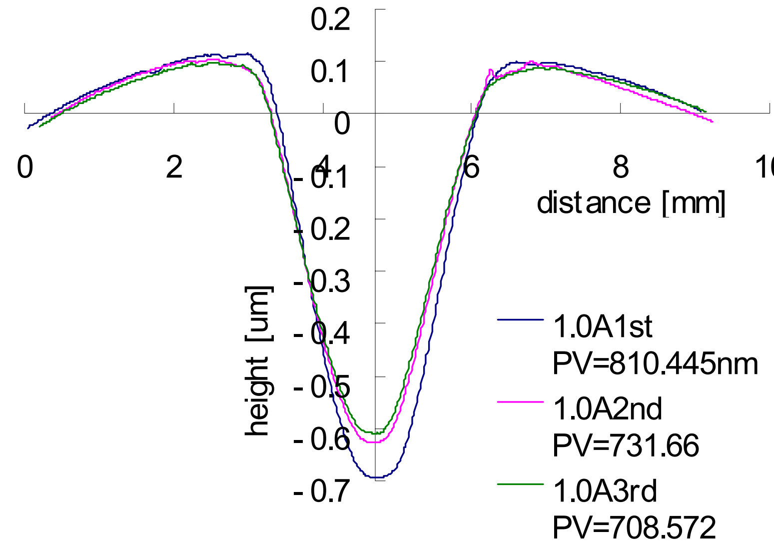


Filament current ：2.0A

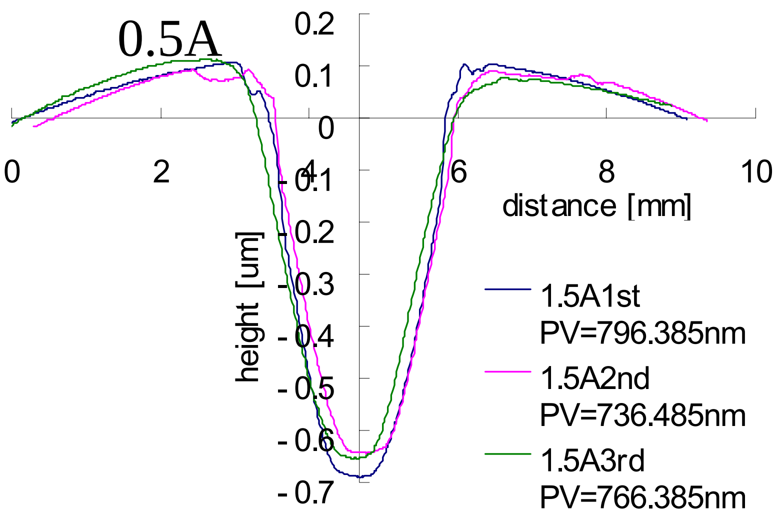
Shape of etched holes (Cross section)



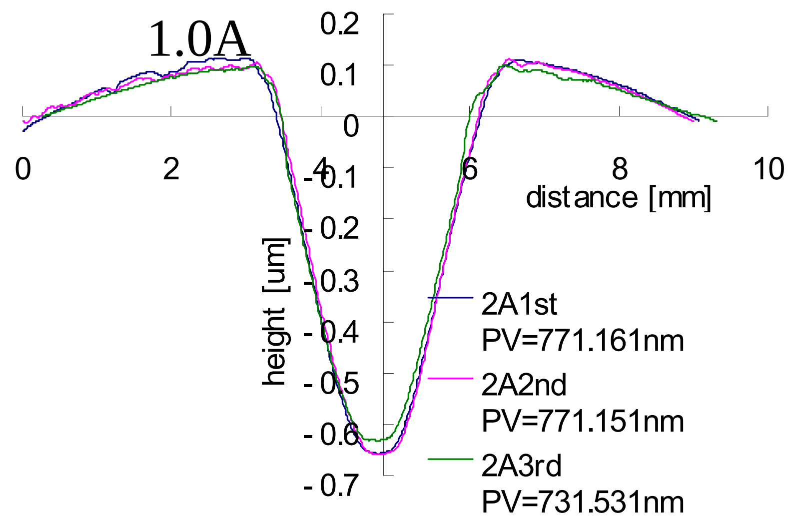
Filament current：
0.5A



Filament current：
1.0A

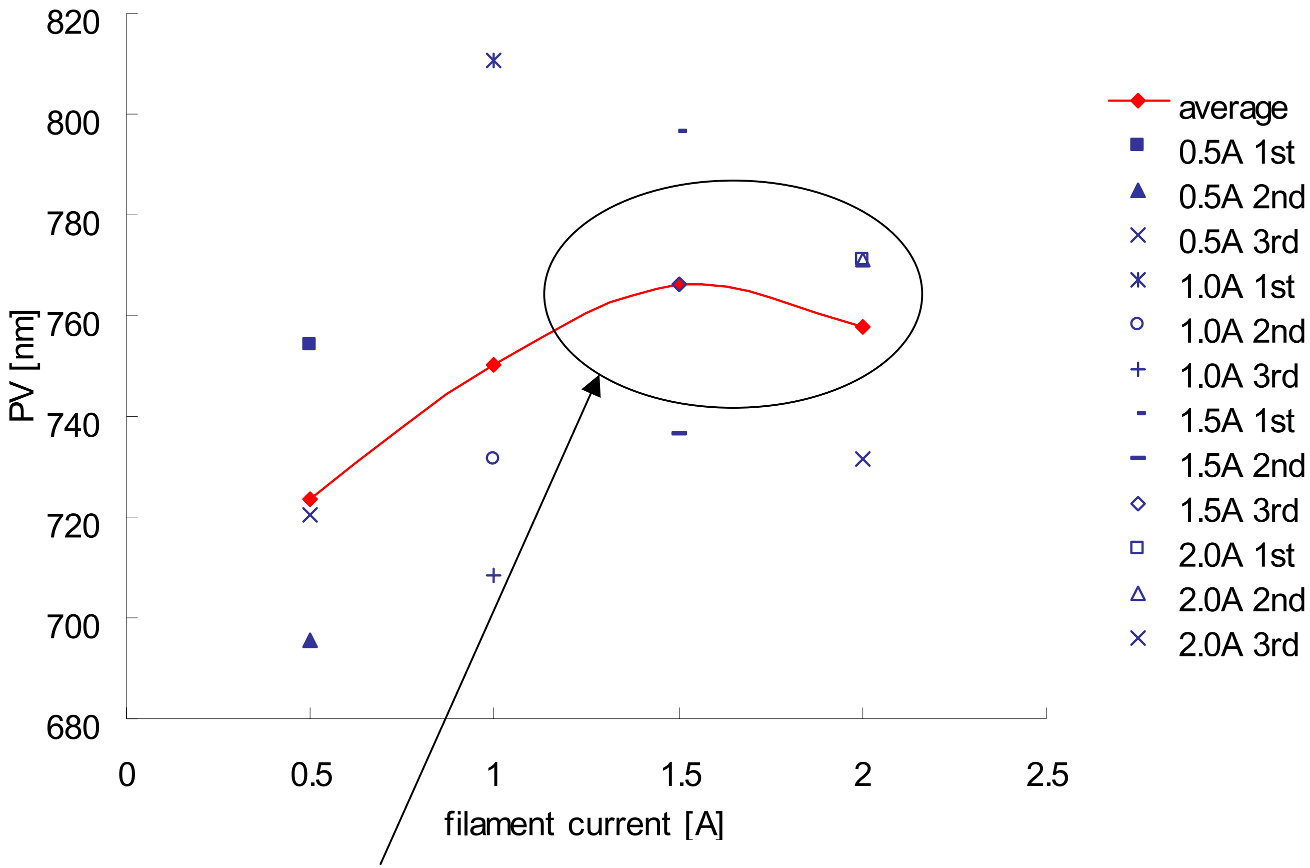


Filament current：



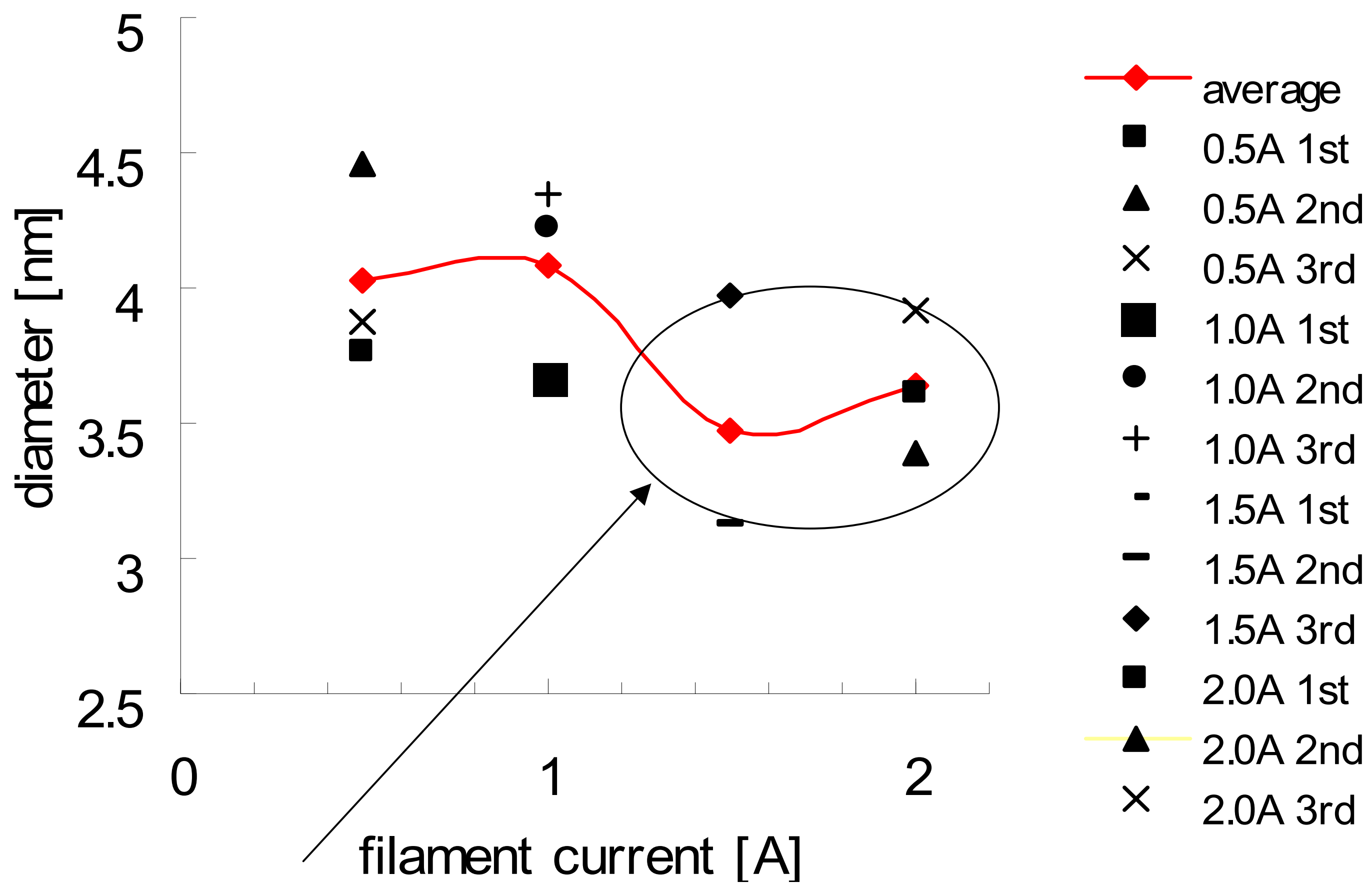
Filament current：

Relation between filament current and depth of etched hole



Etched depth of hole becomes maximum at filament current of 1.5A.

Relation between filament current and removal diameter



Hole diameter becomes minimum at filament current of 1.5A.

conclusion

Insulator substrate will be charged up during ion beam etching. That gives adverse effects such as surface contamination, increase in surface roughness, distortion of unit removal shape, and unsteady of ion beam impact area.

We confirmed that these adverse effects can be eliminate by neutralization of ion beam using heated W filament.

We found that optimum filament current value is about 1.5A, and then removal depth become maximum, and beam spread (beam diameter) become minimum.

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