Two stage ion beam figuring and smoothing method for shape error correction of ULE® substrates of EUVL multilayer mirrors - Evaluation of surface roughness -

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The ULE® substrates for projection optics of extreme ultra-violet lithography (EUVL) tools are mechanically pre-finished with shape accuracy of several nm rms (Specification: under 0.15 nm rms)[1] and high-spatial frequency roughness (HSFR: Spatial wavelength: under 1 μm) of 0.08 nm rms. Then, ion beam figuring (IBF) is used for final shape error correction of the substrates at low-spatial-wavelength of grater than 1mm using high energy (5-10 keV) ion beam with diameter of 1mm. Our previous researches on ion beam machining of ULE® substrates showed;

- the HSFR of the ULE® substrates machined with Ar^+ ion beam of 5 and 10 keV become 0.15 and 0.17 nm rms, respectively [2] and those values are grater than specification of HFSR of 0.15 nm rms.

Beside;

- the HSFR of the ULE® substrates machined with Ar^+ ion beam of 0.3 keV was 0.10nm rms [3] and is less than the specification of 0.15nm rms.

Therefore, we developed the method in which low energy ion beam of 0.3 or 0.5 keV is used for smoothing the surface of the substrates after figuring the substrates with fine ion beam with high energy of 5 or 10 keV.

Fig.1 shows the AFM images of ULE® substrate before and after ion beam processing. As shown in Fig.1(c) and (d), roughened surface of the ULE® substrate by Ar^+ ion beam of 5 keV was smoothed by ion beam processing with Ar^+ ion beam of 0.3 and 0.5 keV. Fig.2 shows dependence of the HSFR of surface on machined depth. It shows that the HSFR of the substrate processed with 5 keV Ar^+ ion beam becomes 0.18 nm rms at depth of 20 nm. However, the HSFRs of the substrate processed with 0.5 keV Ar^+ ion beam decreases with increasing machined depth and reached to 0.10±0.01 nm rms. Therefore, the proposed method can be applicable to the figuring of the ULE® substrates.

References

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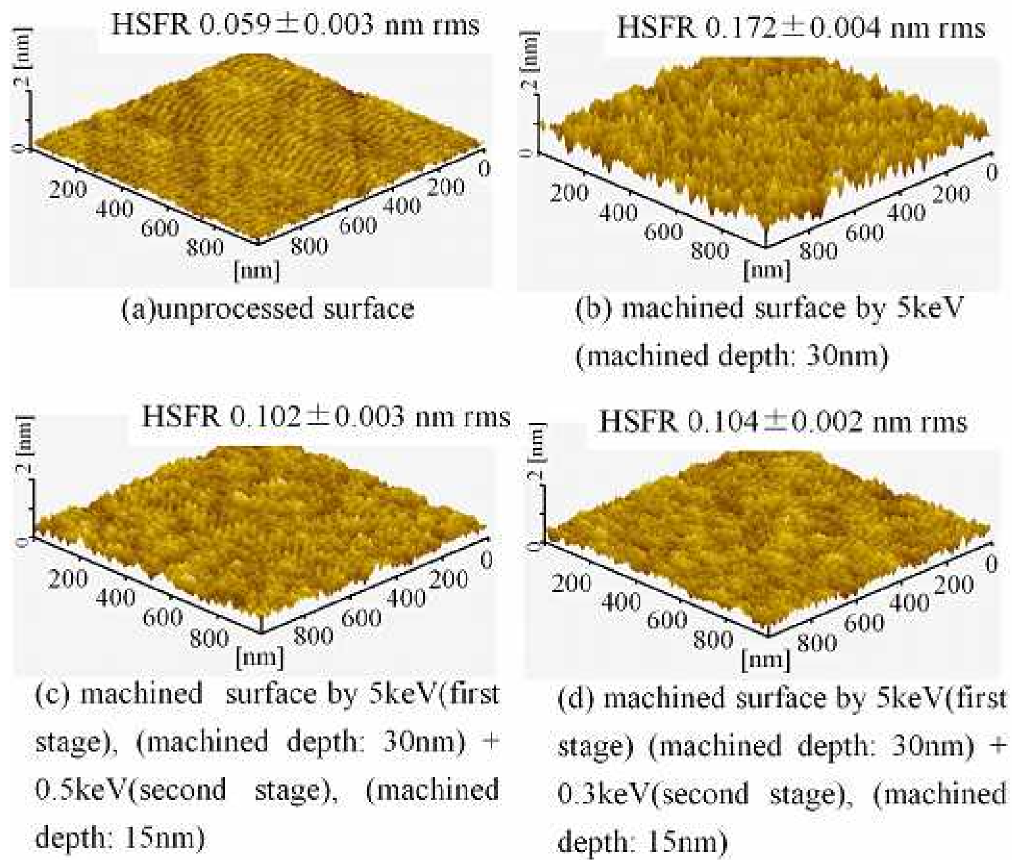

Figure.1. AFM images of ULE® substrate before and after ion beam processing.

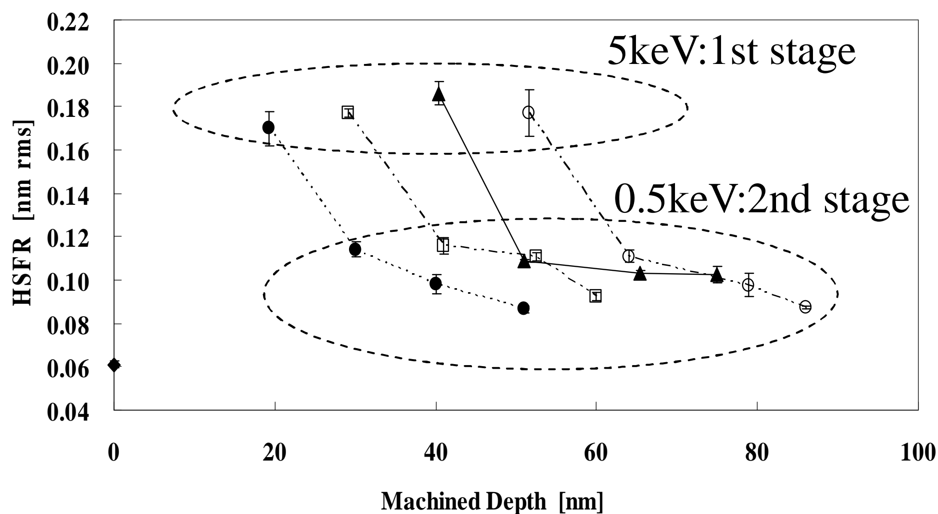

Figure.2. Dependence of the HSFR of surface on machined depth by Ar^+ ion beam energy of 5keV (first stage) +0.5keV (second stage).