Low energy Ar^+ ion beam machining of Si thin layer deposited on a Zerodur® substrate for EUVL optics

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Aspherical substrates for Extreme ultra violet lithography (EUVL) optics require ultra high shape accuracy of approximately 0.15 nm rms and high-spatial frequency roughness (HSFR: Spatial wavelength: under 1 μm) of 0.15 nm rms [1]. However, it is very difficult to obtain such shape accuracy using mechanical machining methods. Therefore, ion beam figuring (IBF) may be adapted to final shape correction of the substrates of ultra-low-expansion material such as Zerodur® and ULE®

In the case of the Zerodur® substrate, surface of the substrate was roughened to 0.70 nm rms by 3-10 keV Ar^+ ion beam bombardment [2]. In order to prevent roughening and charge-built-up on Zerodur® substrates, we have proposed a method in which a thin Si layer was deposited on Zerodur® substrates and figuring the deposited Si layer. Previous research shows that the surface roughness of machined Si layer decreases with decreasing the ion beam energy (3-10 keV) [3]. Therefore, we carried out experiments on ion beam machining of Si deposited Zerodur® substrates by Ar^+ ion beam with energy of less than 3 keV and evaluate the HSFR of the substrates.

In this experiment, the Si layer was deposited by ion beam sputtering on the mechanically pre-finished Zerodur® substrates. The experiments were conducted in an ion beam machining apparatus which has an ECR discharge type ion source. To evaluate the HSFR quantitatively, the surfaces were observed by an atomic force microscope (AFM).

Fig.1 shows AFM images of unprocessed Zerodur®, deposited Si layer on Zerodur® substrates and machined Si layer on that. As shown in Fig.1-(b), some sharp protrusions seen in Fig.1-(a) were smoothed due to Si thin layer deposition. Fig.2 shows ion beam energy dependence of the HSFRs of Si layer on Zerodur®. Results conclude that the HSFRs tend to increase with increasing the ion beam energy, but the HSFR can be kept less than 0.15 nm rms up to 1keV and 0.10 nm rms up to 0.5keV. The proposed processing method using Ar^+ ion beam within 1 keV can be applicable for the figuring of substrates for projection optics of mass production exposure tool which requires the HSFR of less than 0.10 nm rms.

References:

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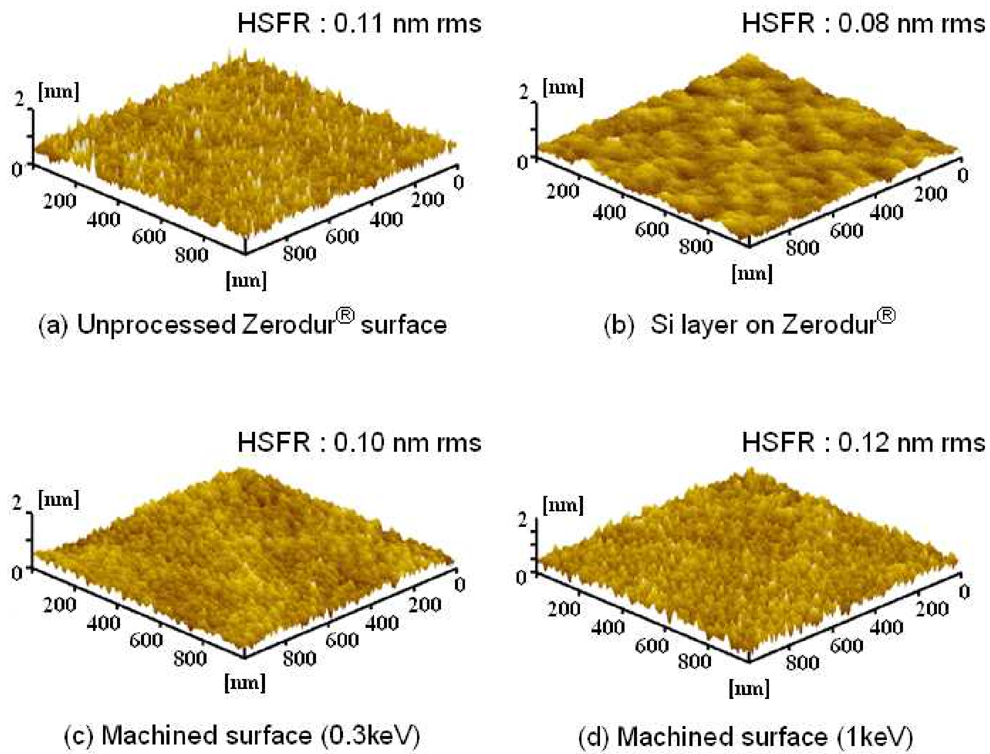

Figure 1. AFM images of (a) unprocessed Zerodur® surface, the (b) surface of deposited Si layer on Zerodur® (about 196 nm), and (c),(d) surface of machined Si layer by 0.3 keV and 1 keV beam energy (about 50 nm). The scale of these images is 1μm × 1μm and the axis of ordinate is 0.2 nm

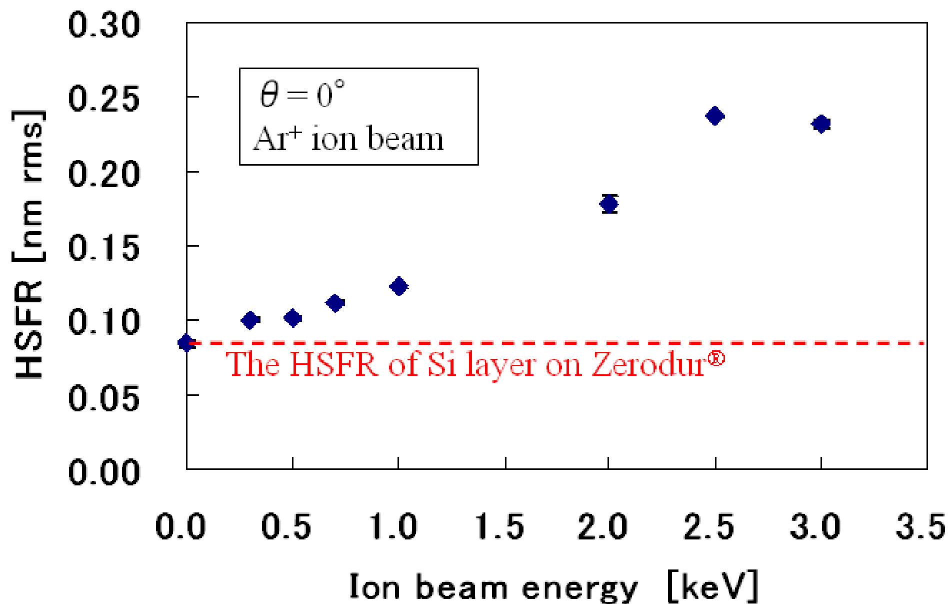

Figure 2. Dependence of Ion beam energy on High-spatial frequency roughness (HSFR) of machined Si layer (machined depth about 50 nm).