Shutter Speed Function of Shortest Elapsed Time in Thickness Distribution Controlled Multilayer Deposition

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For wavelength matching in soft X-ray multilayer fabrication for imaging optics, the Research Center for Soft X-ray Microscopy developed an ion beam sputtering deposition system with a shutter moving at a programmed speed in front of the spinning substrate[1]. Figure 1 shows a view from the sputtering target toward the substrate. The shape of the shutter is triangular for a longer exposure near the edge of the substrate than at the center. The sector angle ψ was tentatively chosen as 60°.

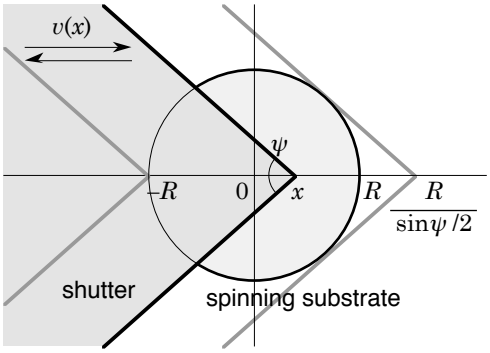

Fig. 1. Front view of a spinning substrate and a programmable shutter for thickness distribution control in multilayer deposition.

The theoretical description on the derivation of the shutter speed function was given in ref. 1. It was found that switching the function at the center enables an accurate thickness control on whole area of the substrate. If the inverse of the speed function is expressed by a third polynomial, switching increases the degree of freedom by 3, which can be used for a shorter elapsed time within limitations of the shutter driving mechanics. In this study the procedure to obtain the shutter speed function of the shortest elapsed time was found and its sector angle dependence was estimated with deposition parameters of our system assumed. Open squares and closed circles in fig. 2 show the shortest elapsed times for one layer deposition of alternative materials. A Mo/Si multilayer for a wavelength of 13.5 nm on a concave substrate of a 300 mm radius of curvature and a 100 mm size in diameter was assumed. The solid line shows the stroke of the shutter in a unit of the radius of the substrate. In the range of ψ < 90° the elapsed time is almost the same while the stroke rapidly increases toward ψ = 0°.

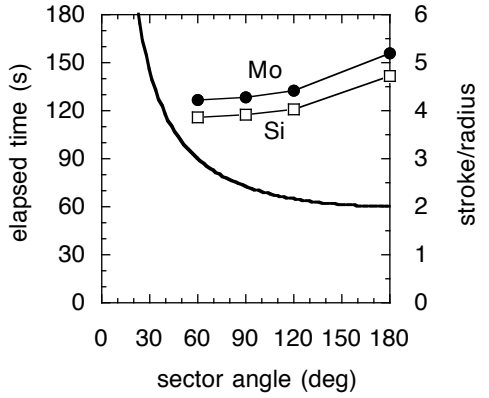

Fig. 2. Sector angle dependent shortest elapsed times for one layer deposition in a Mo/Si multilayer and stroke of the shutter.

[1] T. Hatano, H. Umetsu and M. Yamamoto, *Precision Science and Technology for Perfect Surfaces, JSPE Publication Series No. 3* (JSPE, Tokyo, 1999) pp. 292−297.