Stress-Balancing in Piezoelectric Adjustable X-ray Optics

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Abstract

Next generation X-ray observatories require lightweight, high throughput optics that maintain a < 0.5 arcsecond resolution in order to probe the physics of black holes and gain understanding of the early universe. Thin adjustable X-ray mirrors can correct deformations generated from fabrication errors, gravity release, mounting stresses, and thermal variations, maintaining the high angular resolution (< 0.5 arcsecond) and large effective area (> 2 m^2) required for future X-ray missions. This paper describes fabrication of adjustable mirrors for the Lynx X-ray observatory mission concept. One potential type of X-ray mirror consists of a 400 µm thick curved *Corning EAGLE XG®* glass substrate with a Cr/Ir X-ray mirror coating deposited on the front (concave) side, and an array of radio frequency (RF) sputtered $Pb_{0.995}(Zr_{0.52}Ti_{0.48})_{0.99}Nb_{0.01}O_3$ (PZT) piezoelectric thin film actuators on the back (convex) side to enable correction of figure errors. Piezoelectric actuator arrays were fabricated on the convex side of precision slumped glass or curved silicon mirror segments using a 1.5 µm thick (PZT) film. A two-layer metal routing scheme with a polymeric insulator was used to independently address 288 actuators on the mirror. The two-layer metal allows narrow kerfs between actuators and increased actuator density. A chrome-iridium layer was deposited on the concave side to function as the X-ray reflective coating and provide stress balancing for the films deposited on the convex side. Anisotropic conductive film was used to bond thin flexible copper cables to flat edges of the mirror to interface with external control electronics. An alternative stress balancing process was developed to correct the figure distortion arising from thin film stresses in the actuator layers. Compressively stressed SiO_2 films were deposited on the convex side of the mirror to balance the tensile integrated stress of the actuator array while also matching the film thickness distribution. Finite element methods were used to assess the impact of film thickness distributions on the convex and concave substrate surfaces. The resulting models show peak-to-valley figure errors of 105 nm, well within the 1 µm peak-to-valley dynamic range of the piezoelectric adjusters. In contrast, when stress compensation was done with the iridium mirror film that had a mismatched thickness distribution, the peak-to-valley figure errors.

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