Stress-balancing in Piezoelectric Adjustable X-ray Optics

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Next-generation x-ray observatories require lightweight, high throughput optics that maintain a <0.5 arcsec resolution to probe the physics of black holes and gain understanding of the early universe. 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 sputtered $Pb_{0.995}(Zr_{0.52}Ti_{0.48})_{0.99}Nb_{0.01}O_3$ piezoelectric thin film actuators on the back (convex) side to enable correction of figure errors. A 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 an iridium mirror film deposited on the front side, the mismatched thickness distribution results in peak-to-valley figure errors over 3 µm.