FABRICATION OF MEMS MICROSHUTTER ARRAYS FOR CRYOGENIC APPLICATIONS

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Abstract: Two-dimensional MEMS microshutter arrays are being developed for use as a high contrast field selector for the Near Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope (JWST). We present details of microshutter array fabrication and give results of work done to optimize the flatness of microshutter elements through film stress control for both room temperature and cryogenic (35K) operation.

Keywords: microshutter, cryogenic, magnetic actuation, thin film stress

INTRODUCTION

The primary mission of the James Webb Space Telescope is to reveal the origins of galaxies, clusters, and large-scale structures in the universe [1]. In order to observe galaxies at the peak of the star-forming era, JWST operation requires a spectroscopic coverage in the near-infrared (NIR) wavelength region, from 0.6 to 5 μm. A MEMS microshutter has been developed at Goddard Space Flight Center that is suited as a highly efficient field object selector for the NIRSpec. The microshutter is not only light and close-packed, but also makes possible programmable access addressing, large optical field of view, high fill factor, high resolution and high contrast ratio. Following, we present an overview of microshutter array fabrication and give results of work done to optimize flatness of microshutter elements through film stress control for both room temperature and cryogenic (35K) operation.

FABRICATION

The microshutter array operates through a combination of magnetic and electrostatic actuation. Magnetic actuation provides a large enough force to rotate the shutter 90 degrees out of plane to the open (transmissive) position. Once rotated out of plane, a DC voltage between the vertical electrode and the front electrode is used to latch the microshutter in the open state. A cross section of a unit cell is shown in figure 1. When the DC voltage is released the torsion bar returns it to the closed state. Microshutter array actuation is discussed in detail in [2].

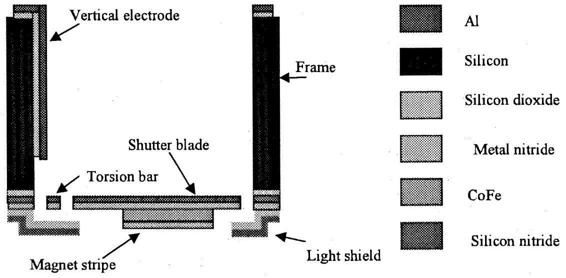

Figure 1. Cross section of microshutter unit showing shutter blade in the closed state.

The array consists of 175x384 microshutter array elements with each element 100um x 200um. The microshutter elements are a sandwich of a 5000A Si_3N_4 structural layer plus 2200A CoFe layer covered with 4000A of a metal nitride. The element is supported by a 2um wide Si_3N_4 torsion bar as shown in figure 2.

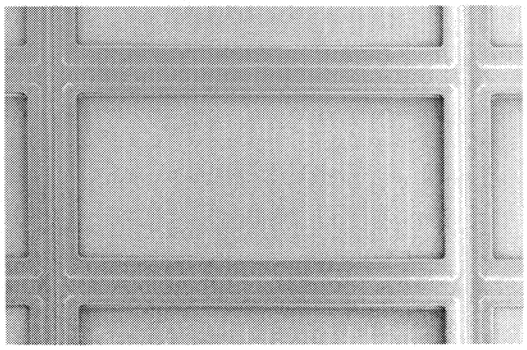

Figure 2. SEM micrograph of front side of microshutter showing light shields and CoFe pads. Long dimension bowing can be seen in the photo.

Shown in Figure 3. is a SEM micrograph of the microshutter array from the back side. The shutter element is shown in the closed state. The 2um torsion bar can be seen in the top of the image closest to the vertical electrode.

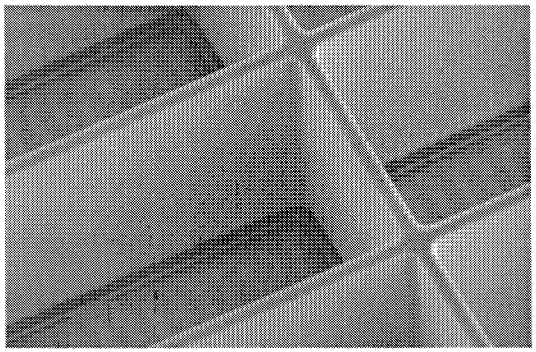

Figure 3. SEM micrograph of closed microshutter from backside.

Fabrication includes wafer bonding and thinning and an anisotropic DRIE to form the mechanical supporting grids along with an off normal angle evaporation for forming the vertical back electrode.

RESULTS

The metal nitride film stress is tuned to maintain optimal microshutter flatness and high contrast ratio. Figure 4. is a plot of room temperature (300K) bowing versus the difference between the prestress in the two nitride films. Prestress is measured by measuring the radius of curvature of the wafer both prior to and after film deposition and using Stoney's equation to calculate stress. Microshutter long and short dimension bowing is measured using a confocal microscope that is fitted cryogenic and room temperature operation.

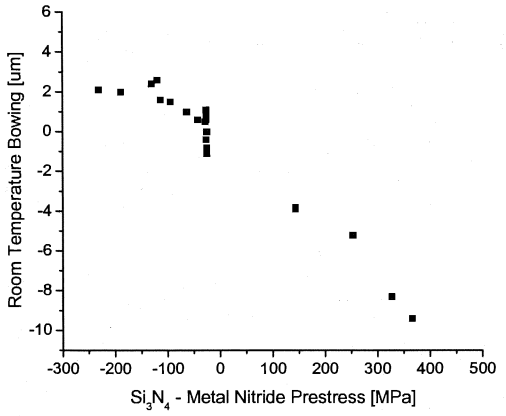

Figure 4. Plot of room temperature long dimension bowing versus difference between metal nitride prestress and silicon nitride prestress

We see a stiffness of approximately 100MPa per micron of bowing. A directionally dependent prestress of as deposited films allows us to tune the initial shape of the microshutter such that the shorter dimension is bowed slightly up (toward the light shields) while the long dimension is relatively flat. We have found that this cylindrical shape significantly stiffens the long dimension of the microshutter element from bowing up. The effect is shown in figure 5. For short dimension bowing greater than 0.5um the long dimension bowing is less than 1um. For negative initial short dimension bowing the long dimension bowing is as large as 5um. The result is due to a bifurcation in the deflection versus stress for large bowing displacements [3].

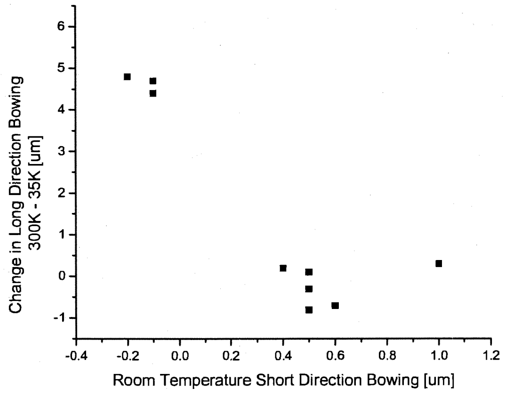

Figure 5. Change in long direction bowing versus initial bowing in the short direction. Microshutters are mechanically stiffer when fabricated with an initial cylindrical shape.

CONCLUSIONS

Microshutter array fabrication has been demonstrated. Results on microshutter element stress control are given. It is shown that a small initial cylindrical curvature in the short dimension can significantly reduce the amount of bowing due to CTE mismatch from 300K to 35K. Future work will include developing a finite element model of the effect of asymmetrical stress distribution on microshutter bowing behavior.

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