Fabrication of Transmissive Microshutter Arrays

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A two-dimensional array of transmissive microshutters is designed and fabricated in which light throughput can be digitally modulated at each pixel. This functionality is important for spectroscopy such as the microshutter arrays used in the near-infrared spectrometer on the James Webb Space Telescope [1]. The microshutter may also have applications to microscopes and digital light processors (DLP). This paper provides a new design with significant advantages over the array designed by Goddard Space Flight Center and our previous design [2]. Each pixel in the array contains two layers of lines and spaces of long etch holes that either enable the transmission of light when the two layers of etching holes are fully aligned upon pull-in actuation or block the transmission of light when the two layers of etching holes are fully misaligned at zero state (Figure 1).

We fabricate the microshutter arrays with a standard SOI process (Figure 2). Lines and spaces are fabricated in an SOI wafer's device and handle layers. The probe test indicates the spring structures in the device layer are movable. We can conveniently control the states of each shutter in a large array of microshutters. Each column can be controlled by a V_{dc} line, and each row can be controlled by a V_{ac} line. Only when a row and column are actuated with both V_{ac} and V_{dc} will that one shutter be open. We can reduce the required pull-in voltage significantly by using a sinusoidal input voltage, which dynamically reduces the gap through its amplitude at resonance (Figure 3). Upon pull-in, only a small amount of V_{dc} voltage is required to close and maintain closure. We are searching for the resonant frequency of the structure as well as the optimal combination of V_{ac} and V_{dc} through COMSOL® simulation and experiments.

The devices are electrostatic. Low voltage and power loss are major advantages of the present design compared to conventional transmission arrays.

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[1] M. J. Li et al., "James Webb Space Telescope micro shutter arrays and beyond," *J. of Micro/ Nanolithography, MEMS, and MOEMS*, 16 (2),025501 (2017)

[2] L. Jiang, M. Vangari, and M. Feldman, "Design of Electromechanically Driven Transmission Light Valve Arrays," *Journal of Electronic and Electrical Engineering,* 2(2), 37-41 (2011)

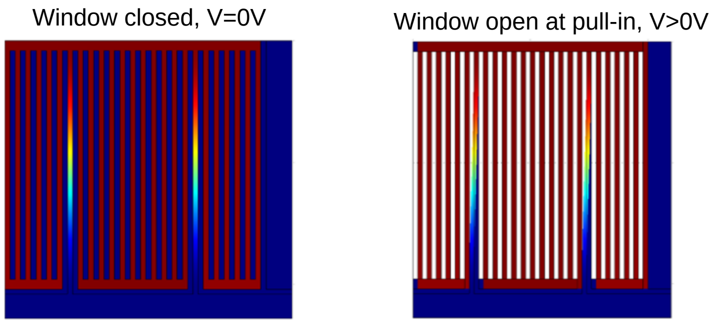

Figure 1: Schematic diagram of different states of the window opening.

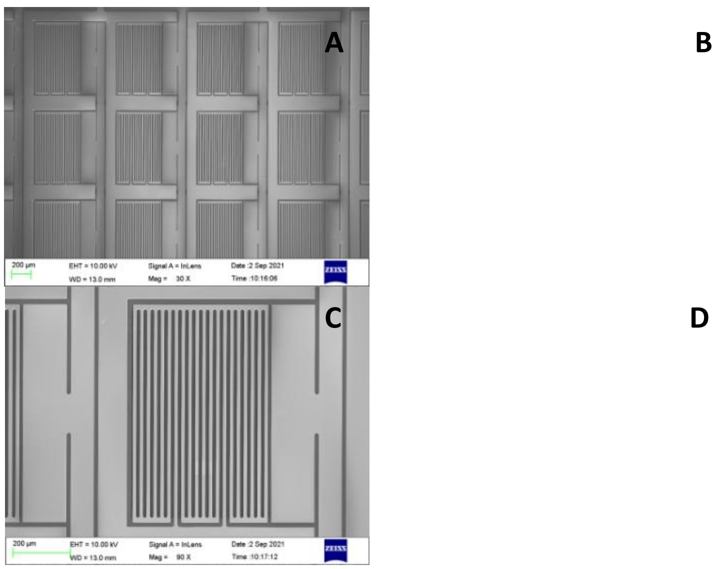

Figure 2: (A) Scanning Electron Microscopy (SEM) image of the device layer. (B) SEM image of the handle layer. (C, D) Magnified image of a single microshutter in (A) and (B) respectively.

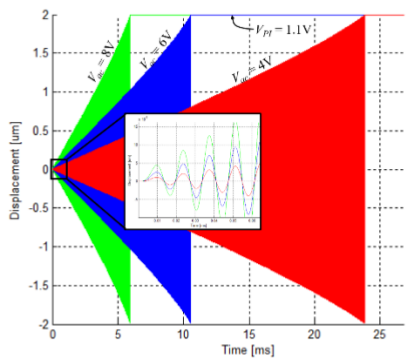

Figure 3: Dynamic simulation of pull-in. The red curve uses a V_{ac} of 4V, followed by a V_{dc} of 1.1V, resulting in a displacement of 2 microns.