MEMS Microshutter Array System for James Webb Space Telescope


NASA Goddard Space Flight Center, Greenbelt MD 20771

ABSTRACT

A complex MEMS microshutter array system has been developed at NASA Goddard Space Flight Center (GSFC) for use as a multi-object aperture array for a Near-Infrared Spectrometer. The NIRSpec is one of the four major instruments carried by the James Webb Space Telescope (JWST), the next generation of space telescope after the Hubble Space Telescope retires. The microshutter arrays (MSAs) are designed for the selective transmission of light with high efficiency and high contrast. The MSA assembly is one of three major innovations on JWST and the first major MEMS devices serving observation missions in space.

The MSA system developed at NASA GSFC is assembled with four quadrant fully addressable 365x171 shutter arrays that are actuated magnetically, latched and addressed electrostatically. As shown in Figure 2, each MSA is fabricated out of a 4" silicon-on-insulator (SOI) wafer using MEMS bulk-micromachining technology. Individual shutters are close-packed silicon nitride membranes with a pixel size close to 100x200 μm (Figure 3). Shutters are patterned with a torsion flexure permitting shutters to open 90 degrees with a minimized mechanical stress concentration. In order to prevent light leak, light shields are made on to the surrounding frame material. A shutter image shown in Figure 6 was taken at room temperature, presenting shutters slightly bowing down as expected. Shutter become flat when the temperature decreases to 35K. The MSAs are then bonded to silicon substrates that are fabricated out of 6" single-silicon wafers in the thickness of 2mm. The bonding is conducted using a novel single-sided indium flip-chip bonding technology. Indium bumps fabricated on a substrate are shown in Figure 7. There are 180,000 indium bumps for bonding a flight-format MSA array to its substrate. Besides a MSA, each substrate houses five customer-designed ASIC (Application Specific Integrated Circuit) multiplexer/address chips for 2-dimensional addressing, twenty capacitors, two temperature sensors, numbers of resistors and all necessary interconnects, as shown in Figure 8. Complete MSA quadrant assemblies have been successfully manufactured and fully functionally tested. The assemblies have passed a series of critical reviews required by JWST in satisfying all the design specifications. The qualification tests cover programmable 2-D addressing, life tests, optical contrast tests, and environmental tests including radiation, vibration, and acoustic tests. A 2-D addressing pattern with "ESA" letters programmed in a MSA is shown in Figure 9. The MSAs passed 1 million cycle life tests and achieved high optical contrast over 10,000. MSA teams are now making progress in final fabrication, testing and assembly (Figure 10). The delivery of flight-format MSA system is scheduled at the end of 2008 for being integrated to the focal plane of the NIRSpec detectors.

KEYWORDS: microshutter, MEMS, RIE, DRIE, micro-optics, near infrared, space telescope, flip chip bonding

REFERENCES


Figure 1. Demonstration of a microshutter array used as an aperture (right) to select multiple objects from sky (left).

Figure 2. A flight-format 365x171 microshutter array (right) is fabricated out of a 4" SOI wafer (left).

Figure 3. Shutters in 100x200um pixel size on front side of MSA (left), and silicon frame on backside of MSA (right).

Figure 4. Light shields are patterned to cover the gaps between shutters and frame; and sub-micron-bumps on light shields (left).

Figure 5. Micron-ribs are made on back walls to prevent sticktion (right).
Figure 6. Shutters are slightly bowing down at room temperature and will become flat when the temperature reaches 35K.

Figure 7. Indium bumps (top) are patterned on a MSA substrate (bottom) for flip-chip bonding between MSAs and their substrates.

Figure 8. A MSA quadrant assembly consists of a MSA array (top right), a silicon substrate populated with ASIC 2-D addressing components, a daughter board (left), and a flexure (underneath the substrate).

Figure 9. A 2-D addressing pattern from a flight-format 365x171 microshutter array showing "ESA" letters.

Figure 10. Final design of a microshutter array assembly with four MSA quadrants located in the center, a permanent magnet (pink) in up-down motion programmed to synchronize shutter open and close, step motors, and harnesses connected to the NIRSpec instrument.

Word Count: 598
Contact Information: Mary Li, NASA Goddard Space Flight Center, Code 553, Greenbelt Rd, Greenbelt, MD 20771
Phone: (301) 286-9921 email: mary.j.li@nasa.gov