

The second technology consists of leveraging, from another project, compact and lightweight $\text{Bi}_{0.87}\text{Sb}_{0.13}/\text{Sb}$ arrayed thermopiles. These detectors consist of 30-layer thermopiles deposited in series upon a silicon nitride membrane. At 300 K, the thermopile arrays are

highly linear over many orders of magnitude of incident IR power, and have a reported specific detectivity that exceeds the requirements imposed on future mission concepts.

The bandpass filter array board is integrated with a thermopile array board by

mounting both boards on a machined aluminum jig.

This work was done by Ari Brown, Shahid Aslam, Wei-Chung Huang, and Rosalind Steptoe-Jackson of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16704-1

Fabrication Methods for Adaptive Deformable Mirrors

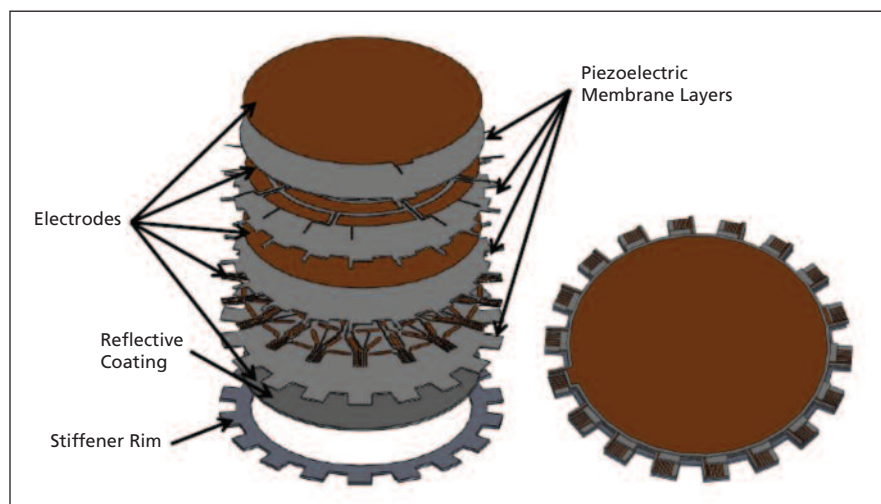
Two methods are presented.

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Previously, it was difficult to fabricate deformable mirrors made by piezoelectric actuators. This is because numerous actuators need to be precisely assembled to control the surface shape of the mirror. Two approaches have been developed. Both approaches begin by depositing a stack of piezoelectric films and electrodes over a silicon wafer substrate. In the first approach, the silicon wafer is removed initially by plasma-based reactive ion etching (RIE), and non-plasma dry etching with xenon difluoride (XeF_2). In the second approach, the actuator film stack is immersed in a liquid such as deionized water. The adhesion between the actuator film stack and the substrate is relatively weak. Simply by seeping liquid between the film and the substrate, the actuator film stack is gently released from the substrate.

The deformable mirror contains multiple piezoelectric membrane layers as well as multiple electrode layers (some are patterned and some are unpatterned). At the piezoelectric layer, polyvinylidene fluoride (PVDF), or its co-polymer, poly(vinylidene fluoride trifluoroethylene) P(VDF-TrFE) is used. The surface of the mirror is coated with a reflective coating. The actuator film stack is fabricated on silicon, or silicon on insulator (SOI) substrate, by repeatedly spin-coating the PVDF or P(VDF-TrFE) solution and patterned metal (electrode) deposition.

In the first approach, the actuator film stack is prepared on SOI substrate. Then, the thick silicon (typically 500-micron thick and called handle silicon) of the SOI wafer is etched by a deep reactive ion etching process tool (SF₆-based plasma etching). This deep RIE stops at the middle SiO₂ layer. The middle SiO₂ layer is etched by either HF-based wet etching or dry plasma etch. The thin silicon layer (generally called a device



The **Deformable Mirror** concept includes electrodes, a reflective coating, stiffener rim, and piezoelectric membrane layers.

layer) of SOI is removed by XeF_2 dry etch. This XeF_2 etch is very gentle and extremely selective, so the released mirror membrane is not damaged. It is possible to replace SOI with silicon substrate, but this will require tighter DRIE process control as well as generally longer and less efficient XeF_2 etch.

In the second approach, the actuator film stack is first constructed on a silicon wafer. It helps to use a polyimide intermediate layer such as Kapton because the adhesion between the polyimide and silicon is generally weak. A mirror mount ring is attached by using adhesive. Then, the assembly is partially submerged in liquid water. The water tends to seep between the actuator film stack and silicon substrate. As a result, the actuator membrane can be gently released from the silicon substrate. The actuator membrane is very flat because it is fixed to the mirror mount prior to the release.

Deformable mirrors require extremely good surface optical quality. In the technology described here, the deformable mirror is fabricated on pris-

tine substrates such as prime-grade silicon wafers. The deformable mirror is released by selectively removing the substrate. Therefore, the released deformable mirror surface replicates the optical quality of the underlying pristine substrate.

This work was done by Risaku Toda, Victor E. White, Harish Manohara, Keith D. Patterson, Namiko Yamamoto, Eleftherios Gdoutos, John B. Steeves, Chiara Daraio, and Sergio Pellegrino of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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