

Microelectromechanical Systems (MEMS)

Sandia's efforts in MEMS began in the early 1990s with a unique collaboration between the semiconductor fabrication facility and mechanical mechanism designers and a goal of miniaturizing mechanical switches. This unusual collaboration led to the development of unique capabilities, particularly in the deposition and surface micromachining of multiple layers of polycrystalline silicon (polysilicon).

Sandia's initial efforts were in inertial sensors and micro-scale mechanisms. For example, Sandia fabricated early prototype accelerometers and gyroscopes designed by the University of California, Berkeley, to demonstrate the potential of surface micromachining technology. Sandia also developed a MEMS-first process to integrate MEMS with CMOS electronics and demonstrated it with a Berkeley six-axis inertial sensor design.

Sandia was the first to apply chemical mechanical polishing (CMP) to MEMS to create flat polysilicon surfaces. A standard fabrication process called SUMMiT V™ (Sandia Ultraplanar, Multilevel MEMS Technology with 5 polysilicon layers) was developed to make machine parts, such as, gears, hubs, and hinges. This allowed Sandia to make mechanisms that move and precisely position objects, such as, mirrors, over relatively long displacements.

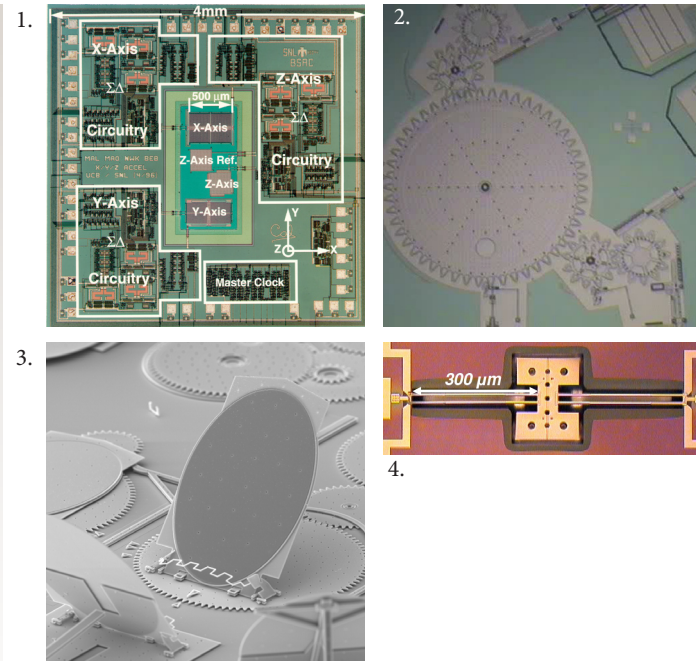
Today, MEMS is a rapidly growing, multi-billion dollar industry driven by the cost advantages of parallel processing. Sandia remains focused on its national security mission and develops advanced MEMS technologies and devices for high value, limited volume products that commercial suppliers will not pursue.

Inertial Sensors

Inertial sensors have emerged as the most significant MEMS product in consumer electronics. Sandia continues to develop MEMS inertial sensors with an emphasis on nuclear and space environments where radiation hardness is required.



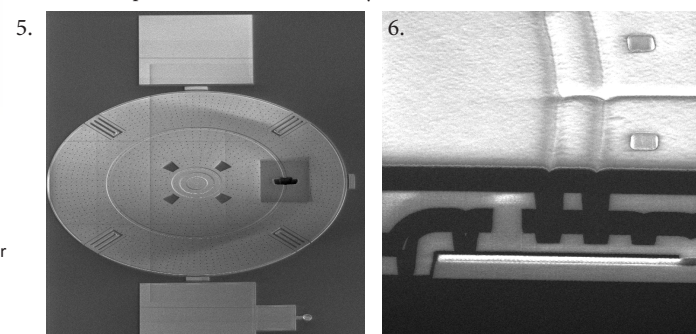
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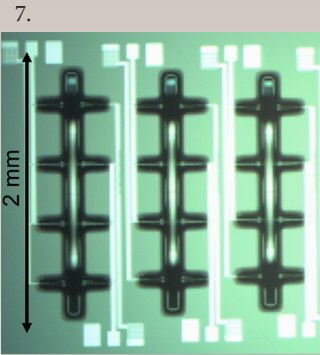


Sandia develops advanced MEMS technologies, devices, and systems for national security.

For additional information, visit our website at: www.mems.sandia.gov or email memsinfo@sandia.gov

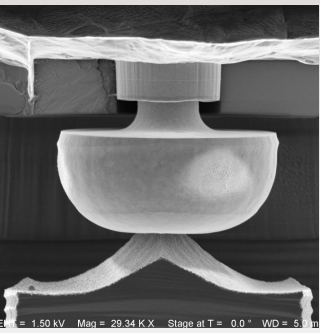
- 1: An integrated MEMS-CMOS sensor chip designed by the University of California, Berkeley, and fabricated by Sandia.
- 2: Gear drive fabricated in SUMMiT V™
- 3: Rotating mirror fabricated in SUMMiT V™
- 4: Aluminum nitride resonant beam accelerometer.
- 5: Active valve for Micro Gas Analyzer (MGA).
- 6: Close-up of valve cross-sectioned by a focused ion beam cut.





Microfluidic Actuators

The common inkjet printer uses MEMS microfluidic devices to precisely dispense picoliter drops of ink. Sandia has fabricated various microfluidic devices, including inkjet dispensers and micro-nozzles for experimental jet propulsion. For another application, Sandia's high-pressure valves enable the two-stage Micro Gas Analyzer (MGA) by precisely controlling high-pressure gas sample flow with an extremely low leak rate and without the use of polymer coatings in the seals.



Electronics

Commercial electronic products are beginning incorporate MEMS oscillators and clocks. Sandia is developing the next generation of MEMS electronic devices, namely, radio frequency filters. Sandia has developed a fabrication technology using aluminum nitride for piezoelectric transducers that can be integrated with CMOS electronics. RF filter frequency characteristics are determined by photolithographically defined geometries rather than film thicknesses. This enables whole filter banks to be fabricated on a single chip.

Vacuum Electronics

Sandia is exploring vacuum electronic devices based upon field emitter tips. In the example shown, a sharp Spindt tip is formed by wet etching; a conformal sacrificial layer is deposited; the counter-electrode is deposited at a uniform distance determined by the sacrificial layer; the sacrificial layer is released; and the device is sealed in a vacuum. We expect this technology to be useful for radiation-hard, high-frequency applications.

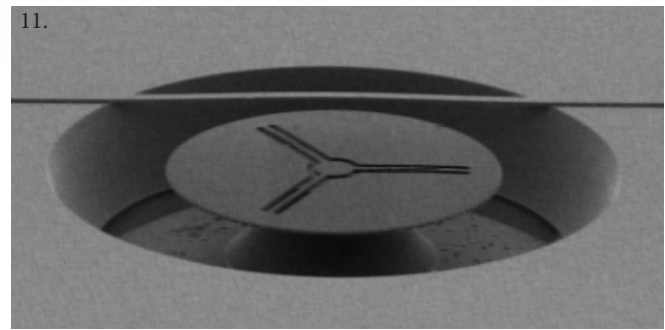
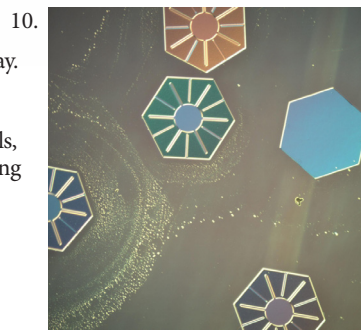
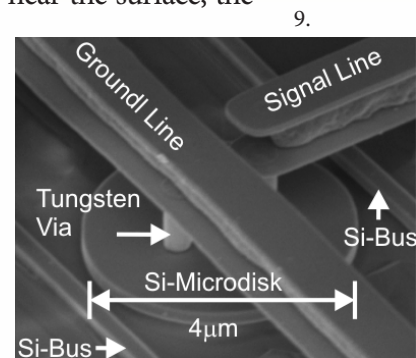
Photonics and Waveguides

Silicon photonics is an exciting area of research for high-speed optical interconnects and signal processing. Fundamental components include low-loss optical waveguides and optical micro-disk resonators. Sandia has produced world record, low-loss waveguides.

Photovoltaic Cells and Radiation Detection

As we have explored the application of MEMS technologies to new problems, we have discovered disruptive new approaches to solving old problems. For example, in traditional radiation sensors, radiation interacts with matter to create free charged particles that must travel long distances to be collected. We invert this paradigm by making the detecting volume small and integrating it with electrodes; then we make large arrays of these pixels. Similarly, the interactions of photons in a photovoltaic cell occur in the tens of microns near the surface; the rest of the silicon wafer thickness is unnecessary for functionality. We are developing PV cell technology where individual micro-sized cells are released from the substrate wafer, assembled into arbitrary arrays, and individually connected. This leads to extremely efficient use of expensive single crystal silicon and many system-level advantages.

Sandia conducts research and development in MEMS technologies for the benefit of the United States of America. Various business arrangements are possible, including contract R&D, joint R&D for government sponsors, and R&D through cooperative R&D agreements (CRADA). Sandia may also provide fabrication services in limited amounts when it has unique capabilities.



- 7: Aluminum nitride radio frequency filter array.
- 8: Vacuum diode using Spindt tip.
- 9: Silicon microdisk signal modulator.
- 10. "Solar glitter": free floating photovoltaic cells, four showing backside contacts and one showing top, "sunny," side.
- 11. Silicon optical waveguide and microdisk.