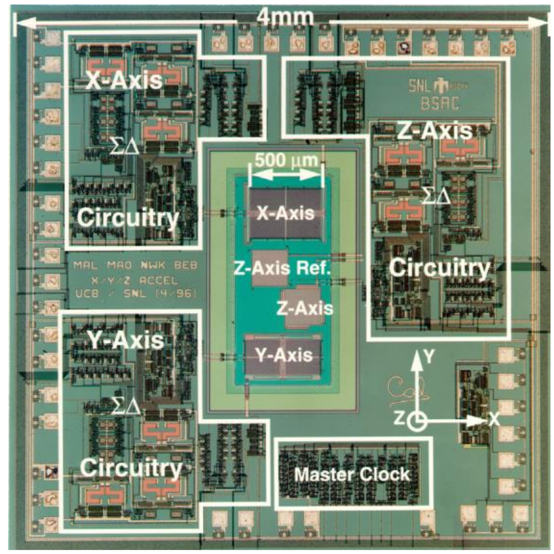
MEMS Inertial and Pressure Sensors

Microelectromechanical system (MEMS) sensors, including accelerometers, gyroscopes, pressure sensors, and microphones, have become a multi-billion dollar market in consumer electronics, automobile, and industrial applications. Sandia helped lay the foundation for these sensors in the 1990s. Sandia fabricated early exploratory designs for accelerometers and gyroscopes from the University of California, Berkeley and Sandia demonstrated a MEMS-first fabrication process for integrating MEMS with supporting CMOS electronics on the same chip. Today, Sandia fills niches in national security, where commercial devices are not available because the technology is too immature or the market is too small.

1.



Sandia fills niches for MEMS inertial sensors in national security, where commercial devices are not available.

Radiation-Hard Inertial Sensors

Sandia focuses on inertial sensors, i.e. accelerometers and gyroscopes, performing in radiation environments. Because the signals are small, a MEMS sensor must be close to its supporting electronics. Sandia develops accelerometers and gyroscopes together with radiation-hard CMOS-7 electronics. One technical path being pursued is the integration of aluminum nitride piezoelectric resonant beam sensors on a CMOS-7 chip above the circuits. The aluminum nitride fabrication process is also used to make radio frequency filters and oscillators at multiple frequencies on the same chip.

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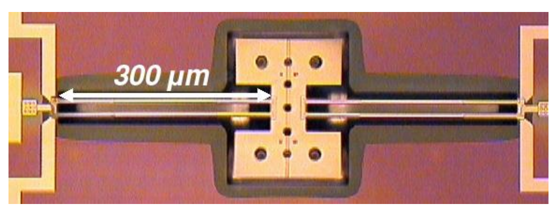

Complex Fabrication for High Performance

Sandia draws upon its many technologies to make high performance inertial sensors using complex fabrication schemes, which would be uneconomical for commercial applications. For example, an accelerometer for low amplitude seismic motions requires a large (for MEMS) proof mass, the measurement of extremely small displacements, ruggedness, and stability. Deep

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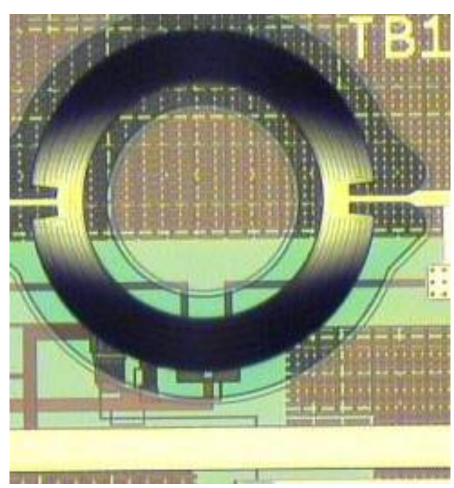

1: An integrated MEMS-CMOS sensor chip designed by the University of California, Berkeley, and fabricated by Sandia.
2: Aluminum nitride resonant beam accelerometer.
3: Radio filter showing oscillator circuits beneath the aluminum nitride

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reactive ion etching completely through the silicon wafer creates the proof mass. Optical interferometry, as is used for calibration standards, measures the displacement. Surface micromachined locks hold the proof mass when not making measurements and make the sensor rugged. Single crystal silicon springs that do not creep lead to long-term stability. The MEMS sensing mass is integrated with a stable laser, optics, gratings, photodiodes, and electronics to make the complete sensor.

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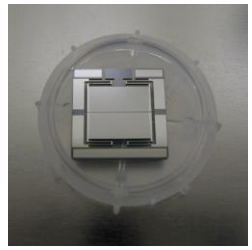

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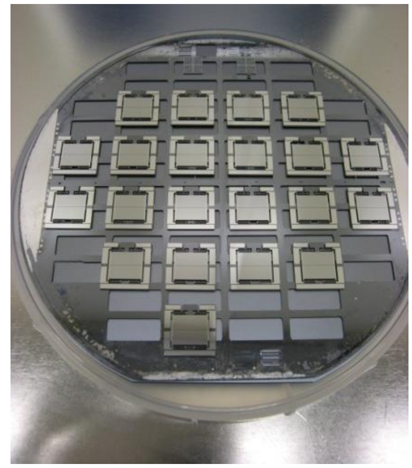
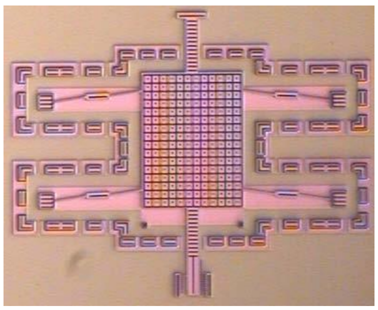
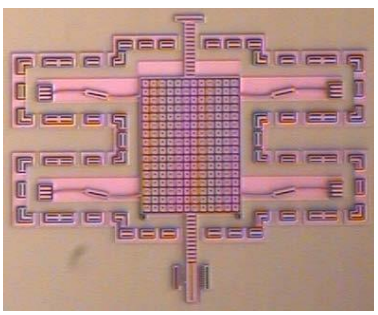


6a.





6b.

Novel Inertial Environment Sensing Devices

Some applications require only the indication that a specified inertial environment has occurred, for example, a rocket achieving a certain velocity. Another example is the occurrence of the sensing of a pyrotechnic event for which Sandia designed and fabricated a switch with a compliant mechanism that is stable in two positions (bi-stable). The switch is moved from electrically open to closed only when the pyrotechnic shockwave accelerates the proof mass. The switch can be integrated with a surface acoustic wave (SAW) device and radio antenna so that its state can be interrogated wirelessly. The sensor is totally passive, drawing no power.

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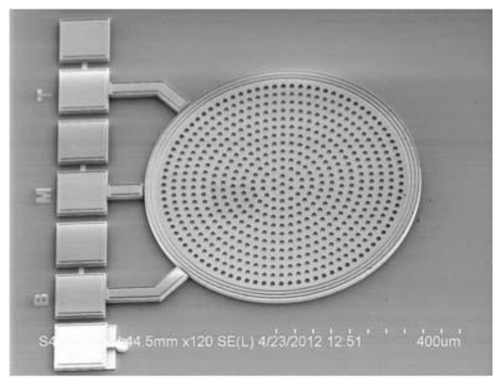
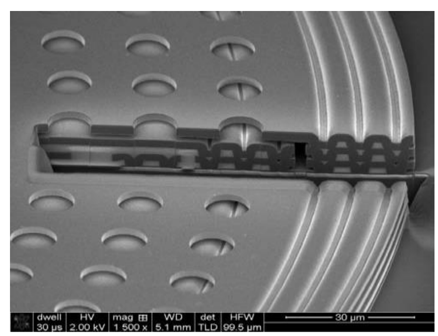


Pressure Sensors and Microphones

In an inertial sensor, a proof mass is moved by acceleration. In a pressure sensor or a microphone, a diaphragm is moved by pressure. Sandia develops pressure sensors for various uncommon environments, for example, munitions penetrating into the ground. Another example is an aeroacoustic microphone designed by the University of Florida, Gainesville, and fabricated by Sandia. This unique design incorporates capacitive sensing of diaphragm position using dual backplates, top and bottom. Its performance is comparable to expensive, industry-standard condenser microphones.



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Contact Us:

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 research and development agreements (CRADA). Sandia may also provide fabrication services in limited amounts when it has unique capabilities.

For additional information, visit our website at:

www.mems.sandia.gov

or email

memsinfo@sandia.gov

4: Single proof mass and its spring suspension.
5: Six-inch wafer with twenty proof masses.
6a, 6b: Pyrotechnic shock sensor in the open[a] and closed[b] positions.
7: Microphone (note the air holes).
8: Partial cross-section revealing the diaphragm and top and bottom capacitor plates.