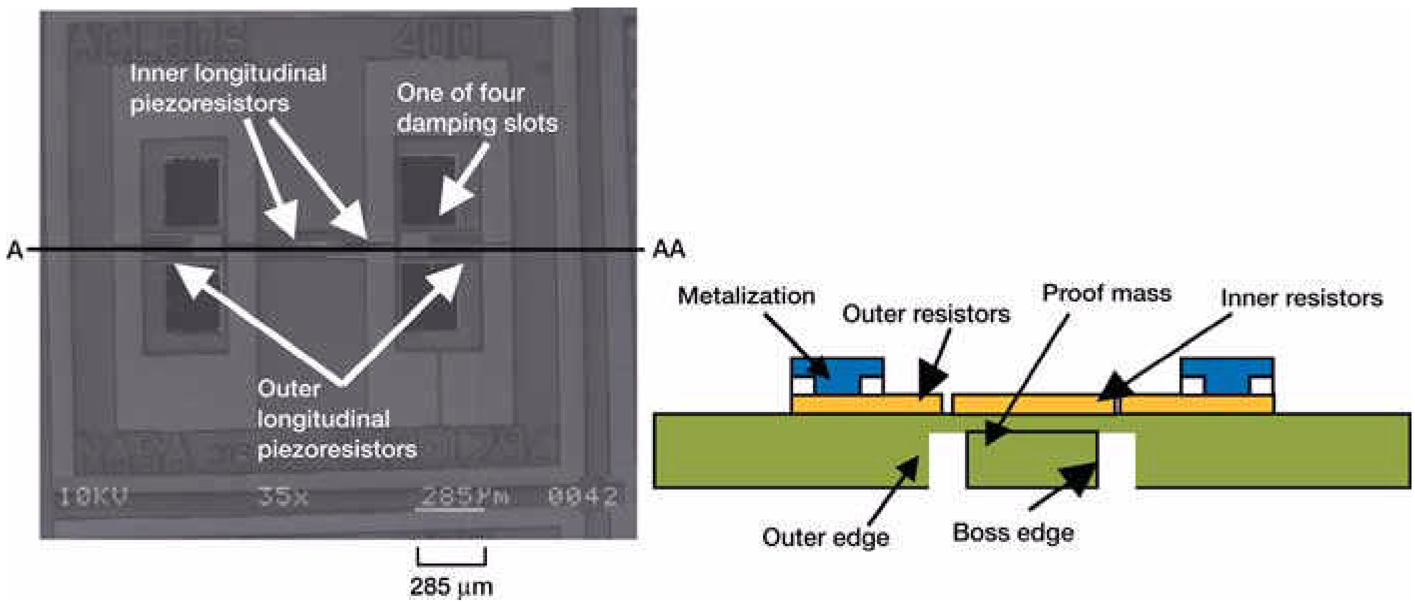
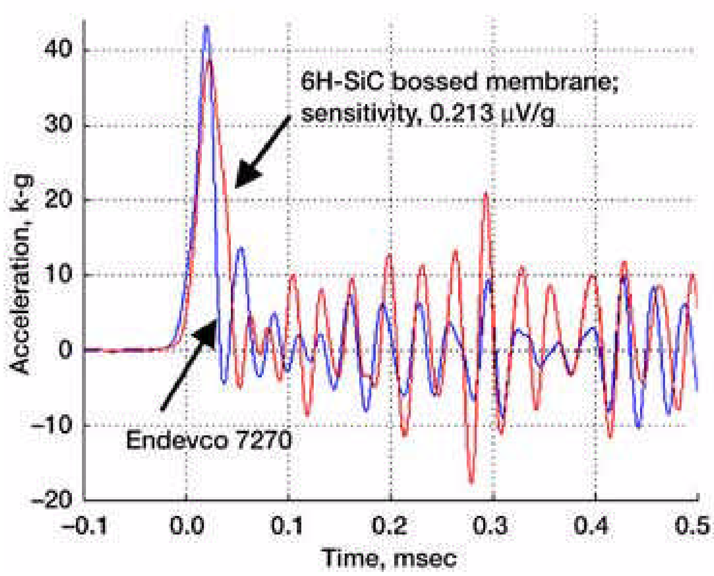
Bulk Micromachined 6H-SiC High-g Piezoresistive Accelerometer Fabricated and Tested

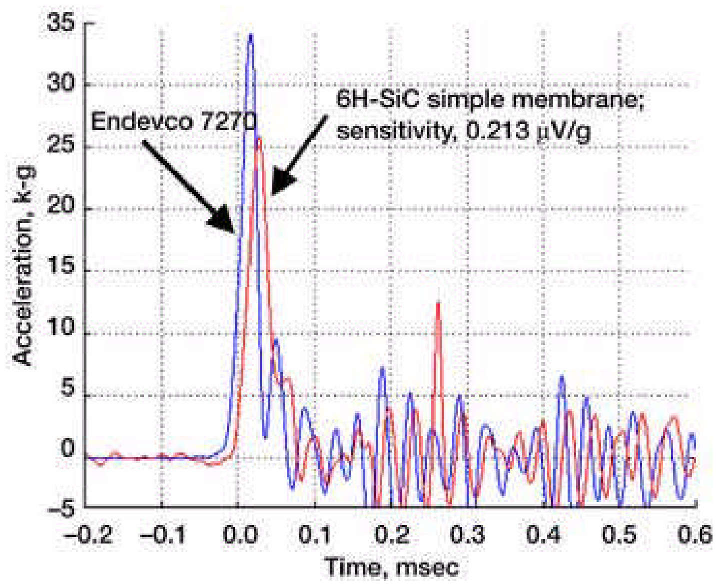
High-g accelerometers are needed in certain applications, such as in the study and analysis of high-g impact landings and projectiles. Also, these accelerometers must survive the high electromagnetic fields associated with the all-electric vehicle technology needed for aerospace applications. The choice of SiC is largely due to its excellent thermomechanical properties over conventional silicon-based accelerometers, whose material properties inhibit applicability in high electromagnetic radiation and high temperatures (>150 °C) unless more complex and sometimes costly packaging schemes are adopted (refs. 1 and 2). This work was the outcome of a NASA Glenn Research Center summer internship program, in collaboration with Cornell University and the Munitions Directorate of the U.S. Air Force in Eglin, Florida. It aimed to provide the enabling technology infrastructure (modeling, fabrication, and validation) for the implementation of SiC accelerometers designed specifically for harsh environments.



Left: Scanning electron micrograph of an accelerometer depicts the four longitudinal piezoresistors and twin suspension beams. Right: A-AA cross section of the illustration on the left indicates the relative locations of the inner and outer resistors on the narrow suspension beams.

We batch-fabricated the first-generation single-crystal, 6H-SiC piezo-resistive accelerometers at Glenn's Sensors and Electronics Branch and successfully tested them at the Fuzes Branch of the Munitions Directorate of the Air Force Research Laboratory at the Eglin Air Force Base. The as-fabricated 6H-SiC accelerometer chip sizes ranged from 4 to 6.25 mm^2 in area, with Wheatstone-bridge-configured piezoresistive mesa elements that were dry-etched in an *n*-type 6H-SiC epilayer grown on a *p*-type 6H-SiC substrate. A scanning electron microscope micrograph of one design concept is shown on the left, and a cross section is shown on the right to depict the relative positions of the resistors. The four sensing elements were placed longitudinally on the narrow beams, each located on the inner edge of the peripheral rigid structure and at the opposite edges of the centered inertial proof mass. The beams were fabricated by a deep reactive ion-etching process. The two wide beams control the overall stiffness and deflection of the structure. The two narrow beams that carry the piezoresistors transfer strain into the piezoresistors, effecting a change in output voltage from the Wheatstone bridge. The wider beams can be adjusted during design to control the strain level transferred to the narrow beams. Representative results from selected design concepts are shown in the following graphs. The responses of the SiC-bossed circular membrane and the simple membrane to acceleration were compared with a benchmark Endevco 7270 accelerometer (Endevco Corporation, 30700 Rancho Viejo Road, San Juan Capistrano, CA 92675).





The impulse responses of the 6H-SiC for bossed (left) and simple membrane (right) accelerometers in red are compared with the response of the benchmark Endevco 7520 accelerometer in blue.

Although both designs tracked the benchmark very well (to within 6 μsec for the bossed membrane and 12 μsec for the simple membrane), issues such as nonlinearity, steady-state quiescence, and packaging will be investigated as ongoing work. The finite element modeling predicts SiC accelerometer operation at 300 kg (15 percent of 6H-SiC fracture strength).

This work is of significance to NASA's goal to revolutionize aviation, with objectives that include increasing aviation safety and reducing noise. The SiC accelerometers can be inserted in closer proximity than before in the hot sections of engines, rockets, and the space shuttles for in situ monitoring of extreme vibration loads. These accelerometers may also find application in high-impact landers.

In the next phase of work, we plan to streamline the design parameters based on previous results with the goal of optimizing the accelerometer performance characteristics.

Find out more about this research. http://www.grc.nasa.gov/WWW/SiC/SiC.html

References

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2. Katulka, G.L., et al.: Characterization of Silicon Carbide and Commercial-Off-The-Shelf (COTS) Components for High-g Launch and EM Applications. IEEE Trans. Magn., vol. 37, no. 1, part 1, 2001, pp. 248-251.

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