COTS/MEMS Accelerometers Test Plan

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Introduction

Microelectromechanical systems (MEMS) is one of the fastest growing technologies in microelectronics, and is of great interest for military and aerospace applications. Accelerometers are the earliest and most developed representatives of MEMS. First demonstrated in 1979, micromachined accelerometers were used in automobile industry for air bag crash-sensing applications since 1990. In 1999, MEMS accelerometers were used in NASA-JPL Mars Microprobe [1].

The most developed accelerometers for airbag crash-sensing are rated for a full range of ± 50 G. The range of sensitivity for accelerometers required for military or aerospace applications is much larger, varying from 20,000 G (to measure acceleration during gun and ballistic munition launches), and to 10^{-6} G, when used as guidance sensors (to measure attitude and position of a spacecraft). The presence of moving parts on the surface of chip is specific to MEMS, and particularly, to accelerometers. This characteristic brings new reliability issues to micromachined accelerometers, including cyclic fatigue cracking of polysilicon cantilevers and springs, mechanical stresses that are caused by packaging and contamination in the internal cavity of the package. Studies of fatigue cracks initiation and growth in polysilicon [2, 3] showed that the fatigue damage may influence MEMS device performance, and the presence of water vapor significantly enhances crack initiation and growth.

Environmentally induced failures, particularly, failures due to thermal cycling and mechanical shock are considered as one of major reliability concerns in MEMS [1]. These environmental conditions are also critical for space applications of the parts. For example, the Mars pathfinder mission had experienced 80 mechanical shock events during pyrotechnic separation processes [4].

In general, most of the analyses of the failure mechanisms in MEMS have been performed using test structures. However, a comprehensive qualification of MEMS, requires experimental data obtained using real parts. In this respect, endurance characteristics of the accelerometers with respect to temperature cycling and mechanical shock is of great interest in their evaluation for space applications.

In the present study, thermo-mechanical stability of commercially available, mass production accelerometers (ADXL250) available from Analog Devices was evaluated, by subjecting them to multiple temperature cycles in the range from –65 °C to +150 °C and mechanical shocks of 2000 G in X and Z directions.

Part Description

Analog Devices ADXL250 is a dual-axis, surface micromachined accelerometer rated for ± 50 G and packaged in a hermetic 14-lead surface mount cerpack. The operating temperature range of the part is from –55 °C to +125 °C and the storage temperature range is from –65 °C to +150 °C. The part can withstand acceleration up to 2000 G.

The device is fabricated using a proprietary surface micromachining process that has been in high volume production at Analog Devices, since 1993. The two sensitive axes of the ADXL250 are orthogonal (90°) to each other and in the same plane as the silicon chip. The differential capacitor sensor consists of fixed plates (stationary polysilicon fingers) and moving plates attached to the beam (inertial mass) that shifts in response to the acceleration. Movement of the beam changes the differential capacitance, which is measured by the on-chip circuitry (the clock frequency of the capacitance meter is 1 MHz). Figures 1 and 2 show overall views of the chip and the capacitive sensor. Figures 3 and 4 show close up views of the elements of the sensor such as spring attachment and polysilicon finger attachment..

The sensor has 12-unit capacitance cells for electrostatically forcing the beam during a self-test. During a logic high on the self-test input pin, an electrostatic force acts on the beam equivalent to approximately 20% of the full-scale acceleration input, activating both the entire mechanical structure and the electrical circuitry. The polysilicon electrodes have a thickness of 2 μm and are suspended approximately 1 μm over the surface by means of two long and folded polysilicon beams acting as suspension springs. The overall capacitance of the sensor is small, typically in the order of 0.1 pF and during acceleration, the capacitance variation, which is measured by the on-chip electronics, ranges from 0.001 to 0.01 pF [5].

Electrical Tests

The ADXL250 has limited number of parameters specified, including sensitivity for X and Y channels (specified as 38 ±5 mV/G), self-test for X and Y channels measured as output voltage change (0.25 V< V_{out} < 0.6 V), and quiescent supply current, ICC (5 mA max). The sensitivity was calculated using a self-calibration technique, which is based on output measurements at four different orientations of the part in the gravity field of the Earth.

A resonant frequency of polysilicon stationary fingers and/or springs is sensitive to the presence of microcracks [3]. Therefore, changes in the resonant frequency caused by mechanical or thermal cycling could be used as a precursor of fatigue failures. For this reason, the resonant frequency of the capacitor sensor will be determined using the self-test response at different self-test input frequencies.

Temperature cycling.

Temperature cycling will be performed on 10 samples in the range from – 65 °C to +150 °C with 15 minutes dwell time at each temperature extreme. Measurements will be taken after 100, 200, 400, 700, and 1000 temperature cycles.

Mechanical shock.

Mechanical shock testing will be performed on two groups of devices with 10 samples in each group. The first group will be subjected to 2000 G shocks in the X-direction and the second group to 2000 G shocks in the Z direction. Measurements will be taken after 100, 300, 1000, 3,000, 10,000, and 30,000 shocks.

Internal Examination and Failure Analysis.

Failure analysis will be performed on all failed parts. Several good parts from different groups will be decapsulated after testing, and will be examined using optical and SEM microscopes for any evidence of microcracks or other defects, which would indicate fatigue-related damage in the sensors.

References

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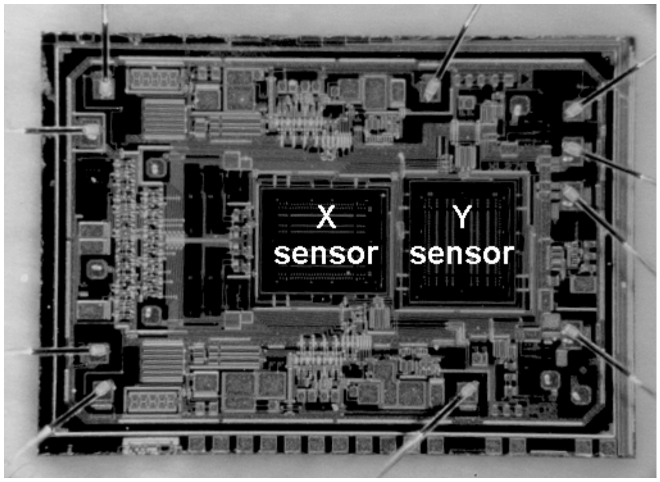

Figure 1. Overall view of the ADXL250 chip.

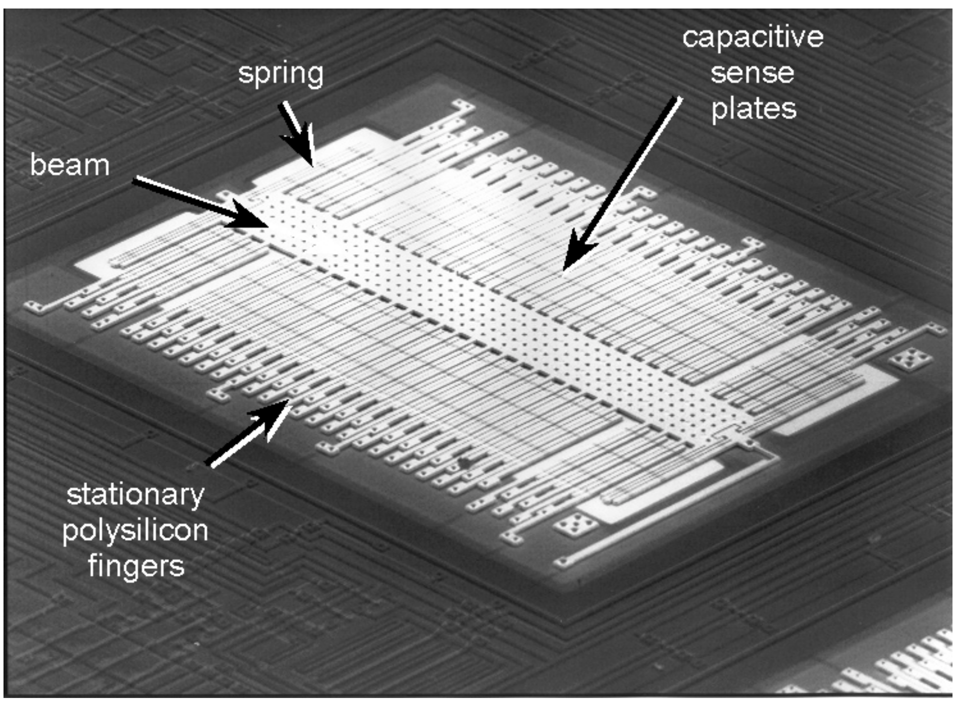

Figure 2. Overall view of the capacitive sensor.

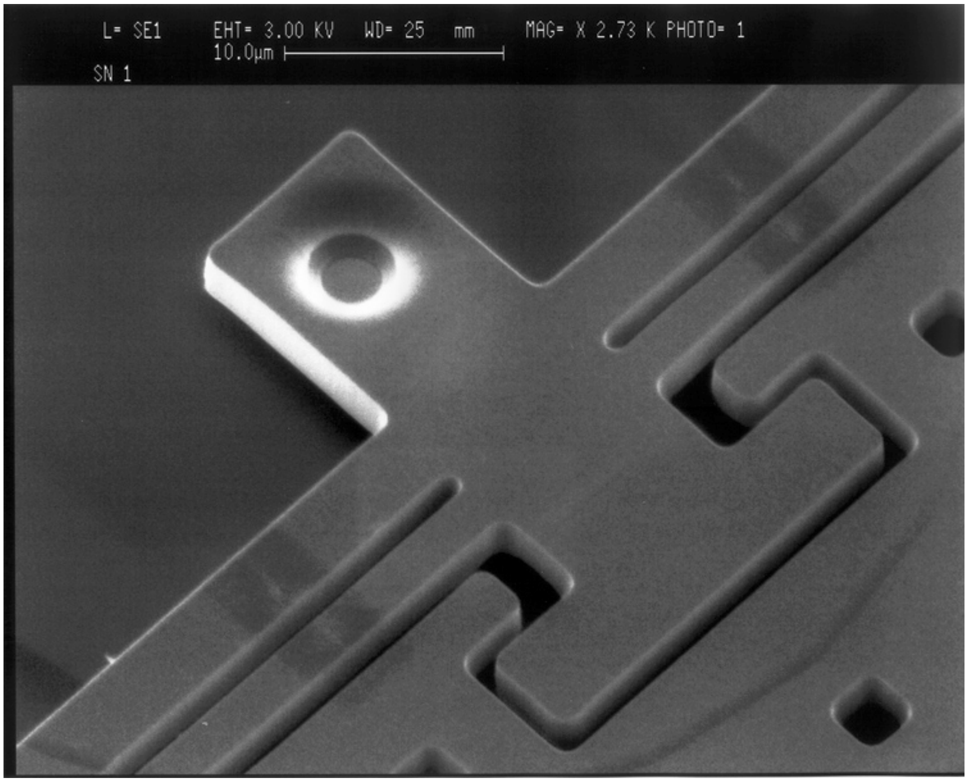

Figure 3. Close up of the spring attachment.

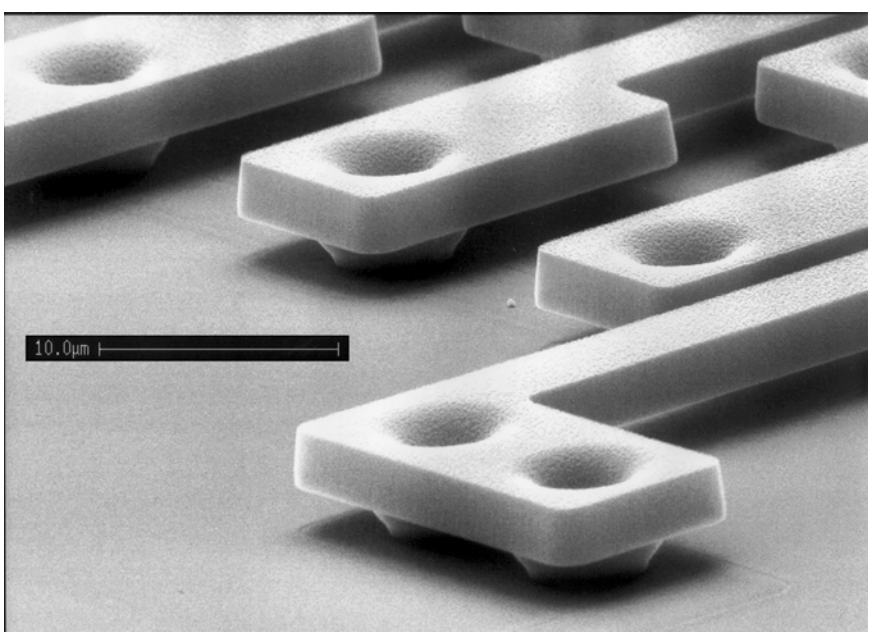

Figure 4. Close up of the stationary polysilicon finger attachment.

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