

MEMS Reliability and Testing

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Abstract

There are several factors that influence the reliability of MEMS devices. The types of materials used and the shape of the device affect the probability and type of failure. The three types of failure mechanisms that can be encountered are: packaging defects, packaging interfering with the device, and device defects. Cracks in the package can allow moisture in which will contaminate the MEMS device. The gap between the package and the device could collapse, interfering with the function of the device. Finally, the device can have flaws that lead to residual stress build up, eventually causing bowing and shorting. One of the issues with testing the reliability of MEMS devices is that there are few standardized tests since most are application specific. A software tool called CAMEL was developed to model the effects of contamination to the device. Also, shock tests have been run that demonstrate that the shape of the microsystem affects the intensity of stresswaves.

Introduction

Micro-electromechanical systems (MEMS) are divided into classes depending on how they interact with their environment. There are four classes:

- Class I – No moving parts. (Figure 1)
- Class II – Moving parts, no rubbing or impacting surfaces. The accelerometer is a good example of a class II MEMS. (Figure 2)
- Class III – Moving parts with impacting surfaces. (Figure 3)
- Class IV – Moving parts with impacting and rubbing surfaces. [1] (Figure 4)

These devices can be applied to a large range of markets from the health industry to the automotive industry. In order for these devices to be of use, there needs to be a certain level of inherent reliability and methods for testing as the reliability of MEMS is defined by the application. There are not as many standardized tests for the reliability as with other electronic devices. [2] As with other electronic devices, it should be possible to define standardized tests for each class of MEMS. This will be difficult because the failure modes of the device will change based on the usage, unlike analog or digital components. [3] Figure 5 illustrates a general methodology for evaluating MEMS reliability prediction and assumes normal working conditions under a normal environment. [4] Discussed in this paper are the failure mechanisms for the packaging associated with the MEMS device and the interaction between the device and package as well as the different tests currently used for testing reliability.

Failure Mechanisms

There are three failure mechanisms for a MEMS system: the packaging, the packaging interfering with the device, and the device. Any of these would cause the MEMS system to fail. The most important of the three failure mechanisms with respect to reliability is the package interfering with the device. [1]

Packaging Defects

The packaging can fail by the packaging cracking or fracturing. The packaging for a typical MEMS device is silicon. When silicon fractures, it mainly depends on how it was processed, meaning whether it was ground or etched. The maximum principle stress is predicted from which it can be calculated the probability that the protective cap will fail due to cracking. [5]

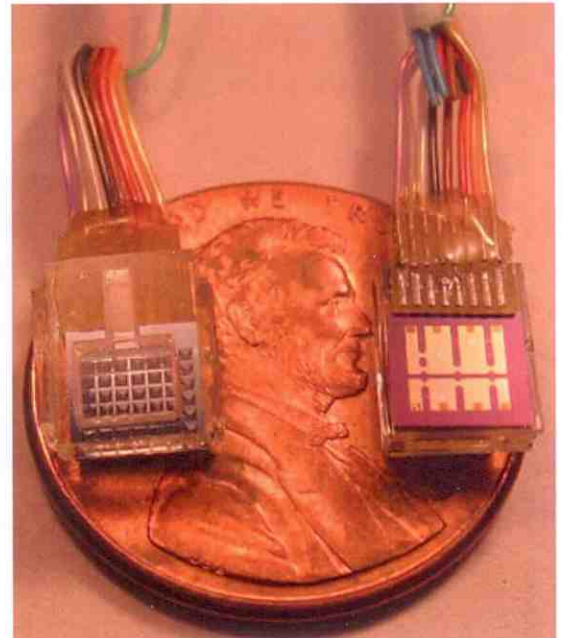


Figure 1: Class I MEMS

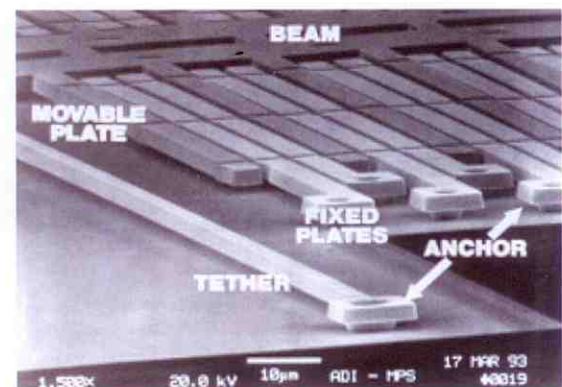


Figure 2: Class II MEMS (analog.com)

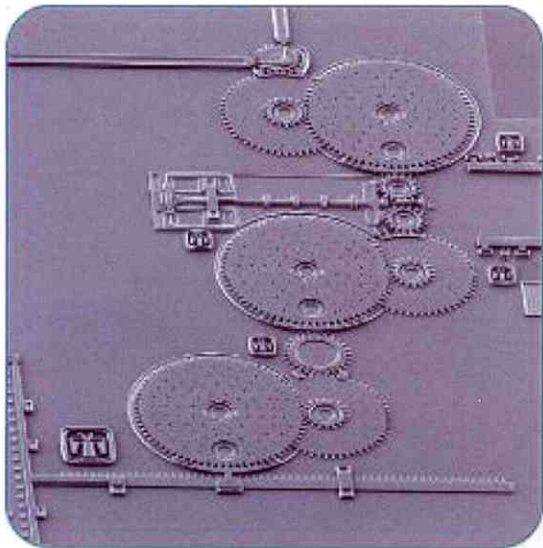


Figure 3: Class III MEMS (semiconductors.net)



Figure 4: Class IV MEMS

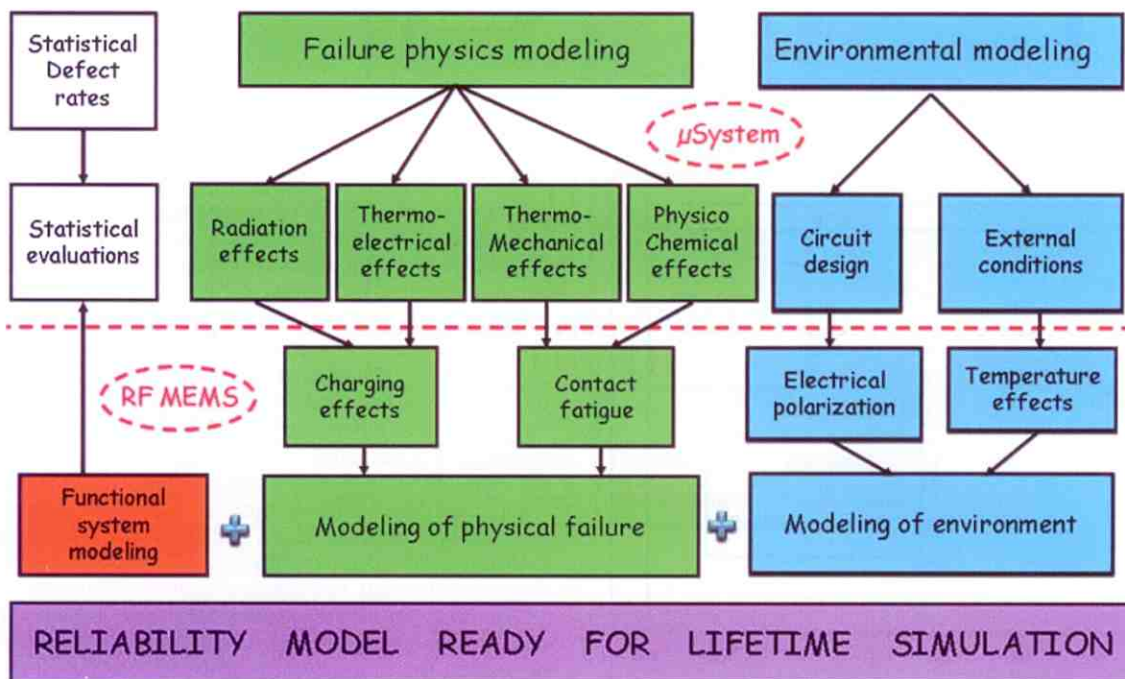


Figure 5: Current approach to reliability modeling [4]

Packaging Interfering with Device

There are several ways in which the package can interfere with the device to cause failure. Perhaps the most common is when the cavity that surrounds the MEMS device collapses and eliminates the necessary gap between the packaging and the device. Improper over-molding is a common cause of interference with the device that can cause failure due to added pressure or friction. [5] Figure 6 illustrates an FEA model prediction of the cavity collapse due to the over-molding process. The model predicts a maximum collapse of 9.8mm that matched closely with the verification experiment that produced a maximum deflection of 10.5mm. [5]

Moisture can penetrate through the packaging and cause damage to the device. The moisture can “pressurize the cavity and change the electrical performance” or it could corrode and add mass. [5] The graph in Figure 7 shows that the over-molding process increases resistance to moisture penetration. The die-free condition has maximum percentage moisture content reached within 10 hours while the over-molded condition does not reach the same level of moisture within 160 hours.

Device Defects

MEMS devices, especially class III and IV, are very sensitive to distortion and can fail by too much residual stress which will cause it to bow and short. These devices are

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