Mechanical and Thermal Strains in RF MEMS Microbridge Structures

Background

An interferometer is an optical device that is used to measure changes in position with great accuracy using interference fringes. These fringes are a result of the Moiré effect, in which patterns of light and dark bands are observed when two arrays of speckle patterns are superimposed. A reference image is compared to the deformed image, and the displacements can be measured both in and out of plane. These displacements can be used to determine values of strain. In my research, I am using electronic speckle pattern interferometry (ESPI), which generates fringes based on digital images of speckle patterns using digital subtraction (Figure 1).

Research & Future Work

At this point in my research, I have worked with the GOM ESPi software program to develop specific protocol and techniques for measuring deformations and strains using the laser interferometer system. After I have developed a detailed procedure for obtaining accurate values for strain based of the deformation of surfaces, future steps will lead to analyzing strains on a much smaller scale. The laser ESPi system will be used to measure deformations of radio frequency microelectromechanical systems (RF MEMS) devices caused by thermal loads. The capability of measuring thermal strains in MEMS is crucial to the development of smaller electrical and mechanical products. For now, I will continue to perfect the measurement techniques for various materials and additional bending conditions, becoming more confident and familiar with the accuracy of the system.

Bending Test Results

In order to refine the protocol for determining strain using the ESPi system, I tested a Lexan plexiglass beam and an aluminum 6061 alloy beam (Figure 2) under cantilever and three-point bending conditions (Figure 3). Based on the stress equation, \( \sigma = \frac{Mc}{I} \), where \( \sigma \) is stress, \( M \) is the moment, \( c \) is the distance from the centroid, and \( I \) is the moment of inertia, the theoretical strain can be calculated using the equation, \( \varepsilon = \frac{E \sigma}{E} \), if the material is of known Young’s Modulus, \( E \). These equations can also be used to solve for the elastic modulus. The calculated values can be compared to the strains produced from the ESPi system based of deformations and fringe patterns. Thus far, the ESPi system has been able to determine strain within 10% of theory.

The GOM ESPi 4.7 System

This Electronic Speckle Pattern Interferometer system (Figure 4) allows the user to view real time surface deformations using digital subtraction, and can determine deformations as small as a few micrometers with high accuracy using the Pisa Optical software. The system consists of a class 3B laser which is converted to a class 1B laser when delivered through the mirror system. The laser intensity can be adjusted as needed, along with the type of lens and extension. The interferometer can be shifted in three directions (X, Y, Z) in order to obtain the appropriate field of view. When the interferometer is properly adjusted, the system can determine displacements and strain very accurately (Figure 5).

References


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Figure 1. An example of X (left) and Y (right) fringes for a Lexan beam exposed to cantilever bending.

Figure 2. The Lexan plexiglass beam (top) and the aluminum 6061 alloy beam (bottom).

Figure 3. The set-up for cantilever and three-point bending tests, respectively.

Figure 4. The GOM ESPi 4.7 system and experimental set-up.

Figure 5. Figures representing strain (center) and displacement in both the X (left) and Y (right) direction for the Lexan beam under cantilever bending.