Optoelectronic Digital Holographic Methodologies for Shape and Deformation Measurements

Furlong-Vazquez, C. (Worcester Polytechnic Institute)
Worcester, Massachusetts

Current demanding engineering analysis and design applications require effective experimental methodologies for characterization of surface shape and deformation of components. Such characterization is of primary importance in many applications since shape is directly related to the function of the components and changes in states of deformation to their accurate operation, performance, and integrity.

Recent advances in laser technology, optical sensing, and computer processing of data have led to the development of advanced optical metrology methodologies. These optical methodologies can provide noninvasive, remote, and full field of view information about the components of interest. Such information relates to changes in shape and/or size of the components, characterizes anomalies, and provides tools to enhance fabrication processes. In this paper, optoelectronic digital holographic (OEDH) methodologies that we are developing are described and their capabilities are illustrated with representative applications involving the testing and characterization of microelectromechanical systems (MEMS) [1].

MEMS are micron-sized electrical and mechanical devices fabricated using very large-scale integration (VLSI) techniques adapted from those of the microelectronics industry. MEMS define both, the fabrication process and the devices themselves, and represent one of today's most exciting areas of technological development activity. Recently, MEMS technologies have been developed and applied by a number of industries to produce components with unprecedented sensing and control accuracies and resolutions [2]. As the capabilities of MEMS become more widely recognized, however, it is also recognized that the biggest obstacle to growth of MEMS applications is the design cycle time, which depends on tightly coordinated application of advanced design, analysis, fabrication, and testing. Testing of MEMS involves measurements of their electrical, optical, and/or thermo-mechanical responses to the driving signals and/or environmental loading conditions. Furthermore, in order to understand mechanics of MEMS and materials used for their fabrication, advanced noninvasive testing methodologies, capable of measuring the shape and changes in states of deformation of MEMS packages and materials subjected to actual operating conditions, are required.

There are a number of quantitative methodologies being used to perform testing of MEMS. However, methodologies are either very costly, time-consuming (e.g., use of contact and/or scanning modes), or are not capable of providing the types of measurements that are necessary for the effective testing and characterization of MEMS packages.

This paper will address some of the challenges imposed by the need for super-high resolution measurements, including testing components with

- geometrical discontinuities (e.g., capacitive pickup mechanisms and devices with a high-aspect ratio, including integrated electromechanical components and IC circuits), and
- enabled with mechanisms subjected to 3D motions and high-frequencies of operation (electromechanical components of MEMS can reach very high oscillation frequencies, i.e., larger than a few-hundredths MHz and future requirements call for a few GHz).

Other challenges include:

- the full-field of view measurement capabilities with sub-nanometer measuring accuracy;
- the measurement of a large number of components, e.g., testing at the wafer level;
- the testing at the different levels of the electronic packaging and under realistic operating and loading conditions; and
- the compatibility of the output data with CAD environments that allow the definition of models and conditions suitable for multiphysics computational analyses.

References:

1. Furlong, C. and Pryputniewicz, R. J., “Optoelectronic characterization of shape and deformation of MEMS accelerometers used in transportation applications,” Opt. Eng., 42(5):1223-1231, 2003.
2. Pister, K. S. J., “Frontiers in MEMS design,” 1996 NAE Symp. on Frontiers of Eng., National Academy Press, Washington, D.C., 63-66, 1997.