Measurement of nanometric deformations of microsystems

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This paper gives a description of the measurement uncertainties when coherent techniques (digital holography, electronic speckle pattern interferometry) are used for the investigation of out-of-plane and in-plane deformation of microsystems.

1 Introduction

The increasing trends towards miniaturization in many different application fields, from optical communications to medicine, have produced in the past few years a dramatic progress in the development of microelectromechanical systems (MEMS) and microoptomechanical systems (MOEMS) [1]. Miniature robots, micro mirrors, micro actuators, optical scanners are some examples of MEMS devices. New applications are emerging as the existing technology is applied to the miniaturization and integration of conventional devices. The reliability of such systems is an important issue that still requires advanced research. For the quality inspection, it is necessary to know not only their geometry but also the displacements or deformations due to the mechanical, thermal or electrostatic loads. The measurement of the deformation of micromechanical systems may be used for the calculation of strain and, along with the evaluation of applied forces, allows for obtaining stresses and consequently extraction of material parameters [2]. This information may in turn be used for the validation of FEM models and eventually detect defects in microsystems. Since the structures themselves exhibit typical dimensions of the order of some micrometers, it is necessary to measure the deformation with accuracies in the nanometer range.

Digital holography [3] and speckle techniques [4]-[5] are well suited for the measurement of deformations or vibrations and have been extensively used for the investigation of both large and microscopic objects. Since these are interferometric techniques and use coherent light there is the appearance of speckle that from one side are carrier of information but from the other side due to their statistical nature produce noise and thus inaccuracies in the measurements, it is thus necessary to know if the set-ups can guaranty precision in the nanometer range. Preliminary results where optical techniques have been used for the measurement of in-plane displacements of Microsystems, have been presented in Ref. [6]. At first reference test objects, from which we know exactly how they deform when submitted to loading, have been developed. The references have then been measured by using interferometric systems and the uncertainty of the measurement is determined according to internationally recognized guidelines [7].

2 . Digital holography for the measurement of out-of-plane deformations

The out of-plane deformations have been measured by using a set-up based on digital holographic interferometry (see Fig. 1). The test object (Fig.2.a), is a MEMS designed to have a very accurate out of plane displacement (parallel to the observation direction) that is produced by applying an electrical voltage to the structure. The deformation can be controlled with the accuracy of 1 nm or better. The uniaxial, displacement is insured by geometrical constraints and is given by $d = cV^2$, where V is the applied voltage, c is a constant that depend on material properties and the device geometry. Digital holography is a full field technique able to measure the deformation of the whole surface of the MEMS; in Fig. 2.b we show the deformation at a point only, where "+" indicate the measured deformation and the solid line show the expected theoretical behavior. The difference between measured and expected deformation is reported in Fig.2.c, the standards deviation is 1.4 nm, thus very small compared with the total deformation which is 2 µm.

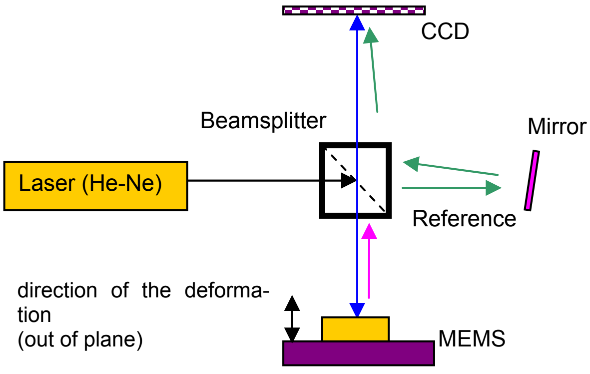

Fig. 1. *Digital holography set-up.*

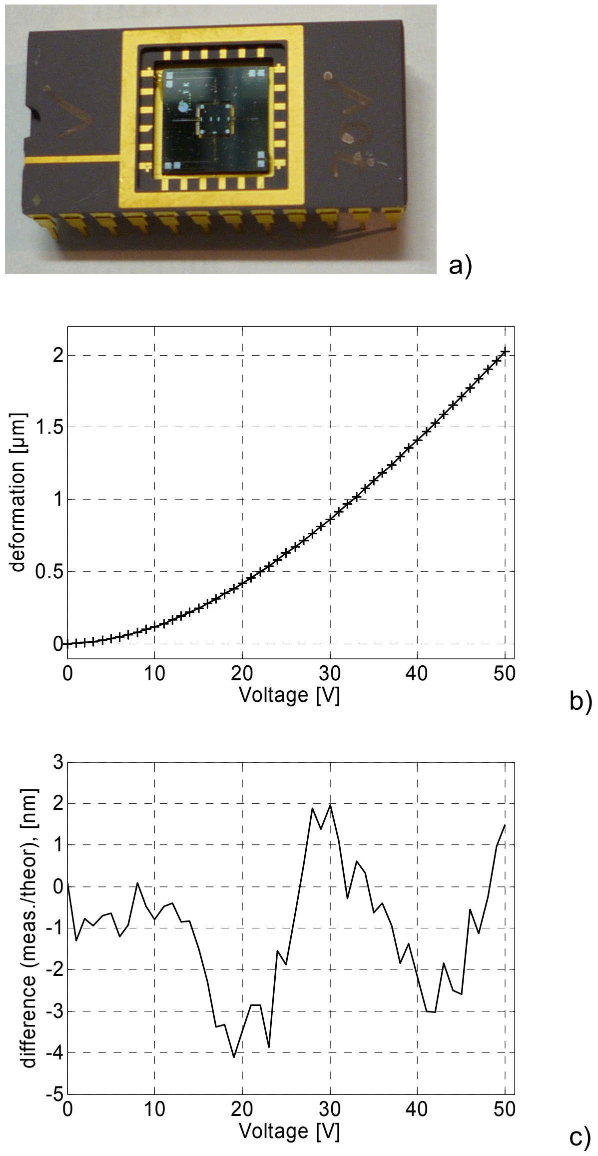

Fig. 2 *Reference MEMS (a), measured deformation as a function of the applied voltage (b) and comparison between measured and expected results (c).*

3 . Electronic Speckle Interferometry for the measurement of in-plane deformations

The ESPI arrangement used for the measurement of the in-plane deformations is shown in Fig.3. The reference MEMS is similar to that one shown in Fig. 2.a but in this case its deformation is perpendicular to the observation direction.

The result of the measurement of the MEMS at a point of its surface is presented in Fig. 4, it shows a quadratic behaviour as expected. The error increases with the object deformation (3 nm incertitude for a displacement of 90 nm), this can be easily explained with the decorrelation due to the in plane translation.

Acknowledgment

The authors gratefully acknowledge the support of the DFG

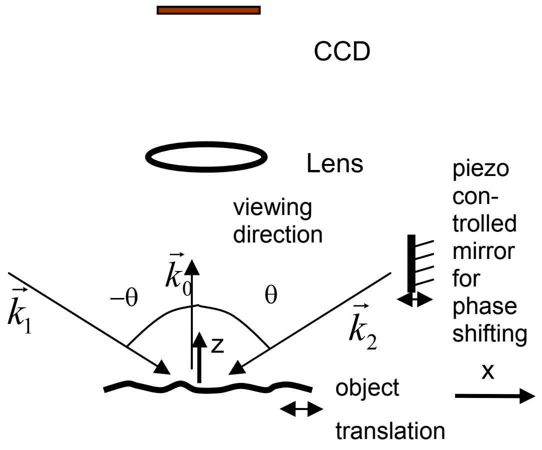

Fig.3 *ESPI set-ups for the measurement of in-plane deformation.*

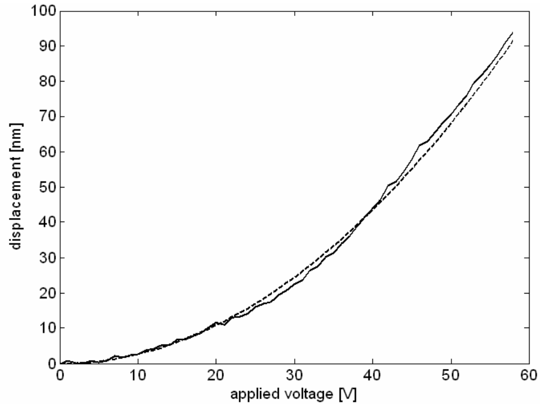

Fig. 4. *In-plane displacement of the MEMS when the applied voltage is increased from 0 to 59 V. The solid line indicate the measured displacement and the dashed line the theoretical expected values.*

4 References

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