Model of a Piezoelectric Microaccelerometer Based on Two Piezoelectric Plates Separated by a Layer of Polysilicon

Yurij Kushnir, Mykhaylo Lobur

Abstract - **This paper presents an alternative design solution for a piezoelectric sensor based on two plates separated by a polysilicon solid body.**

Keywords – **MEMS, accelerometer, piezoelectric effect, FEM, ANSYS.**

I. INTRODUCTION

The piezoelectric effect is a widely used physical phenomenon based on polarization of certain materials as a response to deformation or mechanical strain as a result of the influence of an external electric field. The effect is highly linear and demonstrates good response to external forces applied to such materials. The applicability of such materials in the field of MEMS (regardless of their relatively high cost) is explained by their high reliability and ability to preserve their physical properties even when used in the conditions of highly restricted scales.

II. MODELING OF THE SENSOR

This work presents an alternative construction of a piezoelectric sensor that includes two piezoelectric plates fixed on their external facets and separated by a layer of polysilicon [1]. The piezoelectric plates are geometrically flipped against each other in the OXY plane, which allows for accumulation of electric potentials of different signs and similar values on the fixed facets. The advantage of this approach is the ability to have generated voltage on the two facets that can later be connected to a logical analyzing circuit as a fully-functional source of voltage. This may be used to ensure higher reliability of the future device.

Below are presented to two basic equations of the piezoelectric effect in a given material:

$$\{T\} = [c^E]\cdot\{S\} - [e]^T\cdot\{E\} \qquad (1)$$

$$\{D\} = [e]\cdot\{S\} + [\varepsilon^S]\cdot\{E\} \qquad (2)$$

where {T} is the stress vector, [c] is the elastic matrix, {S} is the mechanical strain, [ε] is the dielectric matrix, {E} is the electric field, and {D} is the electric flux vector.

The system used to model the sensor is ANSYS v.10. The application uses the method of finite elements (FEM) and a parallel coupled-field approach to calculate coupled mechanical and electric results in a piezoelectric body. As a highly complex application for automated simulation of physical processes, ANSYS allows the user to not only study the behavior of single physical objects, but also investigate interaction of separate items in a system comprising several such objects. To create a discrete FE model for the traditional piezoelectric equations, the Lagrange mechanical model is used. The Hamilton principle yields a final set of equations that relate the displacement and electric field in a given finite element to the external force applied to it via special element shape functions (that primarily depend on the element type chosen to carry out the simulation).

$$[M]\{\ddot{u}_i\} - [K_{uu}]\{u_i\} - [K_{u\phi}]\{\phi_i\} = \{f_i\} \qquad (3)$$

$$[K_{\phi u}]\{u_i\} - [K_{\phi\phi}]\{\phi_i\} = \{g_i\} \qquad (4)$$

where [M], $[K_{uu}]$, $[K_{u\varphi}]$, $[K_{\varphi\varphi}]$, $[f_i]$ and $[g_i]$ are respectively the modified matrices of mass, elasticity, piezoelectric effect and dielectric permeability, as well as matrices of external forces applied to the body of the sensor (f_i and g_i).

The response of the sensor and the deformed shape of its body when exposed to acceleration are shown below [1].

TABLE 1

SENSOR RESPONSE TO EXTERNAL FORCE

Acceleration (m/s^2)	Electric Voltage (V)
10	0.517e-5
50	0.256e-4
100	0.513e-4
1000	0.498e-3

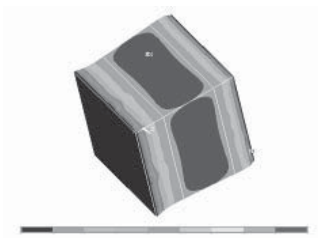

Fig.1. A Deformed Shape of the Sensor

III. CONCLUSION

In this paper an alternative model for a piezoelectric microsensor was considered. As the MEMS technologies evolve, reliability and efficiency of such devices are the key targets of any investigation aimed at improving the performance of microsystems.

REFERENCES

[1] Y. Kushnir and M. Lobur, "Modeling and simulation of piezoelectric microaccelerometers", *Lviv Polytechnic National University*, pp.1-67, Dec. 2009.

Prof. Mykhaylo Lobur - Lviv Polytechnic National University , S. Bandery Str., 28, Lviv, 79013, UKRAINE,
E-mail: ykushnir@yahoo.com