MICROMECHANICAL PIEZORESISTIVE TACTILE SENSOR

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The tactile sensors are widely used in the areas of robotics, human identification etc.

Especially in human identification, the biometric data of person could be used as input data. By using sensors, the physical parameters of the shape of the ear, the iris of eye, the shape of the hand, the image of veins, fingerprints etc. could be obtained and processed. The most widely used method of identification and biometric sign of the person is the tactile processing.

In Micro Electro Mechanical Systems (MEMS), piezoresistive sensors could be designed and built by using elements with different shapes, such as bridges, cantilevers, membranes.

A Micromechanical Piezoresistive Tactile Sensor has been successfully designed. With the aim to be compatible with the current technological processes in microelectronics, the technological sequence for manufacturing of this device includes some of the typical standard processes for making of Selfaligned Polysilicon Unipolar Transistors and Integrated Circuits.

1. INTRODUCTION

One of the basic aims of the microengineering is the integration of microelectronic circuit with the micromechanical threedimensional structures. Many laboratories and universities in the world are occupied with studies and development of such type of detectors.

The tactile sensors have a large application in the areas of robotics and human identification. As input data for the identification, biometric features of the different people can be used. By such detectors, the physical parameters of the shape of the ear, the iris of eye, the shape of the hand, the image of veins, fingerprints etc. can be obtained and processed. The mostly used method of identification and biometric sign of the person it is the tactile processing and especially the human fingerprints (48%).

The tactile feeling is defined as registration and transformation of energies in the limits 0.5-5 N at the place of contact of the sensor with other body [3].

The tactile data could be obtained and used in two situations – passive and active sensibility. Passive sensibility is defined as situation in which the object is identified from fixed, immobilized sensor.

During active sensibility, the sensor is moved and touches the object's surface to determine its form, in the same way like systems for technical visualization [3]. This type of identification is more widespread, mainly in the robotic sphere.

2. DESIGN OF TACTILE SENSOR

The tactile sensors can be made by using a variety of sensitive elements, such as capacitors, piezoresistors or piezoelectric devices.

The piezoresistive sensors represent different structures, in which, piezoresistors are used. During the application of pressure, the sensitive element changes its volume. Such structures can be designed and built by using elements with different shapes, such as bridges, cantilevers, membranes. Fig.1 shows a sensor of such type, in which several microcantilevers are used, in the beginning of which, the sensitive elements are put.

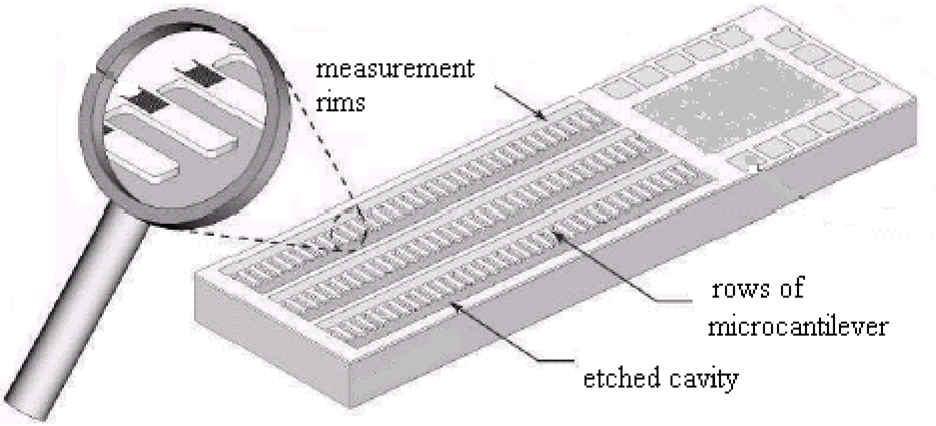


Fig.1

The designed tactile sensor includes a matrix of microcantilevers, placed on a distance one from the other. On each of the cantilevers, a sensitive element (piezoresistor), which will register the changes in the position of the microstructure is built.

First we will choose the dimensions of one cantilever, after which we will use the same dimensions for the other cantilevers:

Length of cantilever: L_G=100 μm;

Width of cantilever: l_G=30 μm;

Following many experiments, it is known, that the most suitable place, for implanting a piezoresistor is the fixed end of the cantilever (fig.2). Applying a force to the free end, the strain forces at fixed end are with the biggest value.

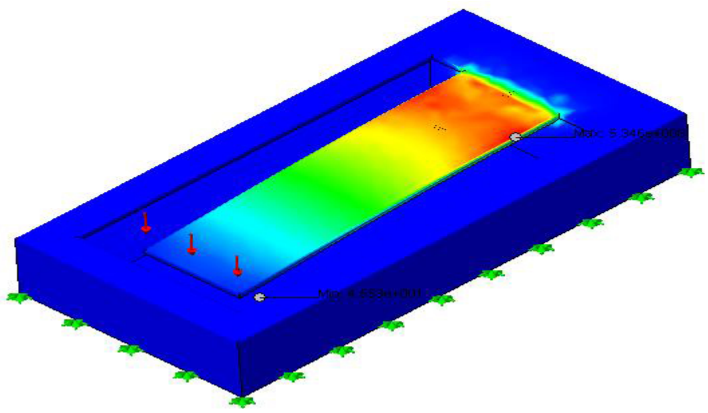


Fig.2

A small part of the piezoresistor, with a length of x_1 is placed on the frame of the structure. In this part, the forces are with negative values. The remaining length is marked with x_2.

For the piezoresistor we use n-type polysilicon, whose value of the specific resistance is $\rho = 8.10^{-4}\Omega.cm$. In case of immovable cantilever, the resistance will be:

(1) $R = \rho \frac{L}{l.e}$

Applying some pressure, the resistance of the microstructure will be changed. This change can be defined in this way:

(2) $$\frac{\Delta R}{R} = \frac{G_l.F}{2.E.I.L}\left(\frac{h_2 + h_1}{2} - \bar{z}\right).[x_1.H(x_1) - x_2].[x_1.H(x_1) + x_2 - 2L_G]$$

where: h_1=0.6 μm - thickness of SiO_2 ,
h_2=1.2 μm - the total thickness of SiO_2 and PolySi,
H – Hevisate's function: $H(x) = \begin{cases} 1, if x \geq 0 \\ 0, if x < 0 \end{cases}$

G_1 is the factor of the piezoresistor during unidirectional pressure. It depends on Poisson's coefficient: $\nu = 0{,}22 \div 0{,}28$, Young's module: E= 170 GPa and the resistanse coefficient π_1, which is:

(3) $$\pi_l = \pi_{11} + 0{,}504(\pi_{44} + \pi_{12} - \pi_{11}) =$$
$$=-1042.10^{-12}+0{,}504.[-138.10^{-12}+544.10^{-12}-(-1042.10^{-12})]=-312{,}2.10^{-12}\ Pa^{-1}$$

the value on π_{l1}, π_{l2} and π_{44} are shown in tabl. 1:

	π_{11} [$10^{-12}Pa^{-1}$]	π_{12} [$10^{-12}Pa^{-1}$]	π_{44} [$10^{-12}Pa^{-1}$]
p-type Si	+67,1	-10,8	+1408
n-type Si	-1042	+544	-138

Tabl.1

The factor G_1 is given by:

(4) $G_l = \pi_l.E + 1 + 2.\nu = (-312{,}2.10^{-12}).170.10^9+1+2.0{,}25= -53$.

The coefficient β is 0.213. The level on neutral line: $\bar{z}$ could be found as:

(5) $\bar{z}$=3,1266-0,1021. β = 3,1266-0,1021.0,213 = 3,1 μm.

In this way we can find the inertness on the microstructure I:

	L ,m	l ,m	e ,m	ρ ,Ω.m	R ,Ω
I variant	**25.10^{-6}**	**4.10^{-6}**	**0.6.10^{-6}**	**8.10^{-6}**	**83,33**
II variant	**50.10^{-6}**	**6.10^{-6}**	**0.6.10^{-6}**	**8.10^{-6}**	**111,1**
III variant	**150.10^{-6}**	**8.10^{-6}**	**0.6.10^{-6}**	**8.10^{-6}**	**166,7**

Table 2

(6) $I \cong 7{,}0632+0{,}9459.0{,}213 = 7{,}3.$

Having in mind, that the applied force F is in the range 0,5 – 5 N, several variants for the size of the resistor are shown in table 2.

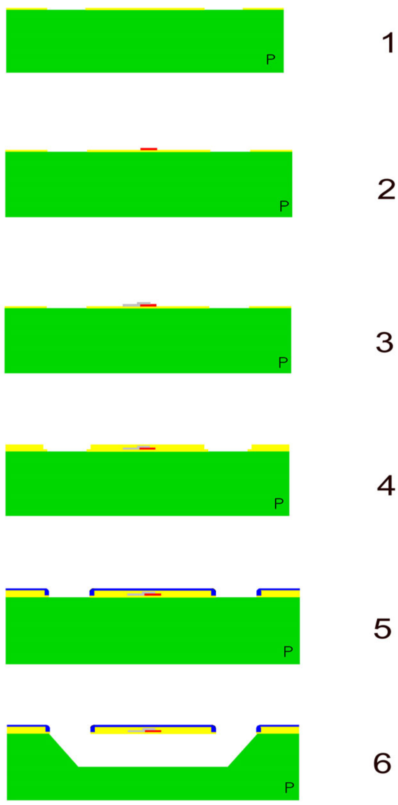
In table 3, the corresponding values of the relative error during the change of the resistance $\frac{\Delta R}{R}$ are given. We assume a force F = 2 N.

	L , m	x_2 , m	Δ R/R	Δ R/R.100%
I variant	**25.10^{-6}**	**24.3.10^{-6}**	**0,01605**	**16%**
II variant	**50.10^{-6}**	**44.10^{-6}**	**0,0129**	**13%**
III variant	**150.10^{-6}**	**144.10^{-6}**	**0,00758**	**8%**

Table 3

Having in mind that the admissible error is about 20%, then we can choose the piezoresistor with L=25 μm (first variant).

The maximal deviation of the cantilever d will depend on force F and immobility of the cantilever k, whose value will be:



(7) $$k = \frac{3.E.I}{L_G^3} = \frac{3.170.10^9.7{,}3.10^{-18}}{\left(100.10^{-6}\right)^3} = 3{,}7.10^6 \text{ N/m}$$

Then, the deviation d will be:

(8) $$d = \frac{F}{k} = \frac{2}{3{,}7.10^6} = 0{,}54 \ \mu\text{m}.$$

This expression is useful for finding the deviation of the cantilever before breaking.

The layers, deposit on the Si substrate, are SiO_2; PolySi - for piezoresistors; Al - for resistors; second SiO_2 – for passivation of metalized surface, this SiO_2 must be thermal; Si_3N_4 - like mask with isotropic etch to get microcantilever.

Fig.3

The piezoresistor of PolySi is made by using of the standard technological sequence for making of Selfaligned Polysilicon Unipolar Transistors and Integrated Circuits. In the present work, the circuit is not developed, but we use this method to get the PoliSi - layer. The technology includes also an Ion Implantation for reducing the resistivity of the layer.

The technological sequence, which could be used for making the sensor is shown on fig. 3, as follows:

1. Deposition of SiO_2 - photolithography – etching of SiO_2;
2. Deposition of PolySi - photolithography – etching of PolySi;
3. Deposition of Al - photolithography – etching of Al ;
4. Deposition of SiO_2 - photolithography – etching of SiO_2;
5. Deposition of Si_3N_4 - photolithography – etching of Si_3N_4;
6. Anisotropic etching.

The horizontal (top) and side views of one cell of the sensor array are shown on Fig. 4 and Fig. 5

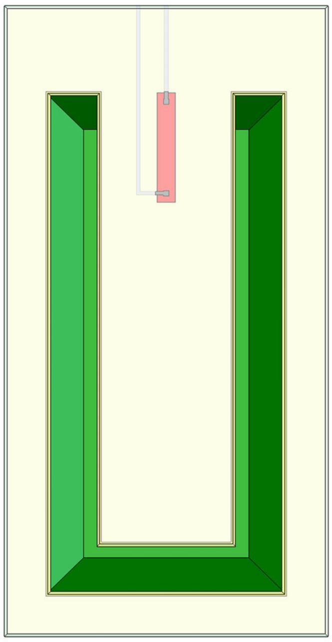


Fig. 4

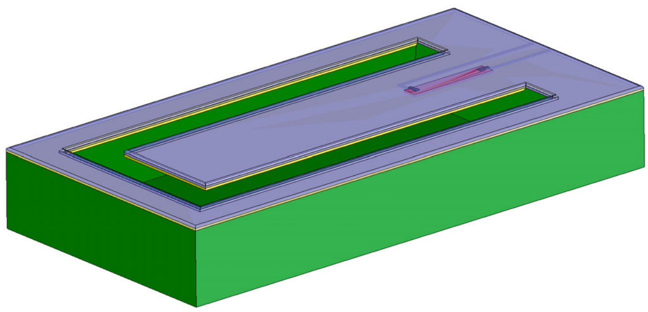


Fig.5

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