[Shikulskaya* *et al.*, 6(4): April, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

THE METHODS ANALYSIS OF ACHIEVEMENT OF THE REQUIRED OPERATIONAL CHARACTERISTICS OF MICROELECTRONIC PRESSURE SENSORS

Olga Shikulskaya *, Irina Petrova, Mikhail Shikulskiy
* Dept. of research activities, Astrakhan state university of architecture and civil engineering, Russian Federation

DOI: 10.5281/zenodo.556244

ABSTRACT

In paper it is shown that acceleration of sensors production rates requires design process automation, especially at the initial stage which main objectives are synthesis and the choice of design solutions of sensors sensitive elements on the basis of the comparative analysis of a large number of alternative options. For automated synthesis of new technical devices, it is necessary to fill in the database on the basis of the analysis of the known constructions. Based on the analysis of patent and scientific and technical literature the class of sensors for implementation of the drafted theoretical provisions is defined. These are microelectronic pressure sensors. By results of the analysis of patent and scientific and technical literature microelectronic sensors of pressure are classified by the following signs: the improved operational characteristics (precision, responsivity, constancy, reliability, functionality, gabarit, price) and methods of their achievement. It is established that more attention is paid to processing and materials research methods. Basic type designs of pressure microelectronic sensors are defined. The most perspective constructive methods, the required operational characteristics allowing to reach at the same time the maximum quantity and insufficiently studied directions of achievement of the required operational characteristics are revealed. The research has allowed to reveal the most perspective methods of improvement of operational characteristics of pressure microelectronic sensors. Research results are intended for formation of the database containing the formalized description of elementary objects for synthesis of new technical solutions.

KEYWORDS: microelectronic sensor of pressure, sensitive element, operational characteristic, patent search, classification.

INTRODUCTION

The market of the sensors in the most developed countries for the last decades has one of the highest rates of growth rates in instrument making. On average the microelectronic sensors production in the USA, Japan and Germany annually doubles. Sensors are used in many industries.

Acceleration of rates of production of sensors by quantity and the nomenclature requires design process automation.

Quality of design decisions in many respects is defined by results of the initial stages of design (a stage of the specification and the technical offer) on which fundamental decisions on structure and the principle of operation of the developed device are made. The initial stages of design are characterized by processing of considerable volumes of information, a large number of the studied realization options. The solution of these tasks in many respects is defined by how the developer will be provided with the new information technologies strengthening his intellectual opportunities, allowing to automate processes of search and information processing on the basis of use of system approach to development of sensors and their elements on the basis of general concept about a class of objects.

Researches [1-4] are devoted to creation of such technologies.

According to the main stages of fractal interpretation and structural and parametric synthesis of primary transformers it is necessary to fill in the database on the basis of the analysis of the known technical devices with use of the developed methods [5] in the beginning. Only after that it is possible to start synthesis of new technical solutions.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Based on the analysis of patent and scientific and technical literature the class of sensors for implementation of the drafted theoretical provisions — microelectronic pressure sensors is defined. The choice is caused by relevance of the task of measurement of pressure (the sensors intended for measurement of pressure are dominating in the market of measuring instruments their share makes 25%), prospects and unique opportunities given by micro technology application, impossibility of automation of synthesis of such technical devices on the basis of the known methods of retrieval design, universality of the conversion methods realized in constructions (14 thousand different constructions of pressure sensors realize eight main methods of conversion).

MATERIALS AND METHODS

The most worked technique of information researches allowing to reveal and analyse tendencies of development of scientific and technical decisions is the research of patent information.

Properties of the array of patent information make it the most preferable for the purposes of the tendencies analysis in the scientific and technical sphere:

- completeness – the vast majority of the new scientific and technical ideas are described in patent documents, the patent fund covers all scientific and technical activity of the person;
- efficiency – according to the international legal status of patent documents they are the first advancing publications;
- authenticity – real feasibility of the technical solution proposed in the patent and a possibility of obtaining the promised effect are confirmed by non-departmental examination, and for them the patentee bears legal and liability;
- checklist information – the patent fund of all main countries is classified by the international classification of inventions, uniform for them.

According to theoretical provisions of informatics, the material object containing the fixed scientific information, intended for its transfer in time and space and used in public practice is considered the scientific document. As it is possible to see from the above-stated points, this definition can be completely referred to patent information.

The analysis of patent information has allowed to classify microelectronic sensors of pressure by the methods used at their designing for improvement of various operational characteristics [6-29].

IDENTIFICATION OF PERSPECTIVE METHODS FOR ACHIEVEMENT OF THE REQUIRED OPERATIONAL CHARACTERISTICS OF MICROELECTRONIC SENSORS OF PRESSURE

For detection of basic methods of achievement of the required operational characteristics of microelectronic pressure sensors the analysis of patent literature for the last 30 years [6-29] as the main methods can be used in earlier patents is made.

The made analysis of patent and scientific and technical information showed that pressure sensors of the following types generally are issued: capacity sensors, resistive strain gage with semiconductor tensoresistors, frequency probes with miniature silicon force sensing resonators, piezoresistive and optical ones. The following tendencies of enhancement of pressure sensors are revealed: lowering of dimensional and weight indices, increase in accuracy and reliability, support of conjugation to standard international types of information transfer, increase in "intellectuality", implementation during creation of microelectronic pressure sensors of micromechanical constructions and technologies – the new scientific and technical direction which arose for the last decade.

The analysis allowed to classify microelectronic sensors of pressure by the methods used in case of their constructioning for improving of different operational characteristics (table 1-4).

Table 1-4 display the analysis of patent and scientific and technical literature on pressure sensors by the following signs:

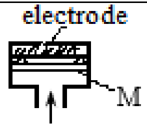
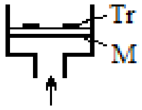
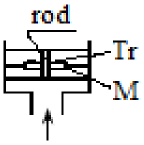
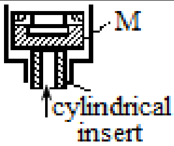
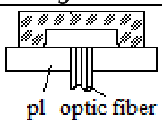
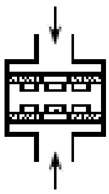
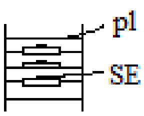
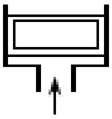
1. the improved operational characteristics (aprecision, sensitivity, constancy, reliability, manufacturability, gabarit, price);
2. method by means of which they are reached (constructive, technological, use of new materials).

On figures in tables 1-4 the following designations are applied:

M - membrane; D - diaphragm; Tr - transistor; C - crosspiece; Th - thread; pl - plate; SE - a sensitive element; R-resonator; S – string.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table 1. Constructive methods of achievement of the required operational characteristics (membrane sensors)

Decisions	Objects of an invention						
	Increase of					Decrease of	
	precision	sensitivity	stability	reliability	manufacturability	gabarit	price
Single-membrane devices							
 ***Figure 1***	+		+	+			
 ***Figure 2***	+		+	+			
 ***Figure 3***		+	+	+			+
 ***Figure 4***				+			
 ***Figure 5***			+	+			
Double-membrane devices							
 ***Figure 6***		+				+	+
Multiple-membrane device							
 ***Figure 7***							+
Sensing element in the form of a box							
 ***Figure 8***		+				+	+

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Table 2. Constructive methods of achievement of the required operational characteristics (vibration sensors)

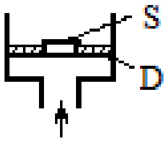
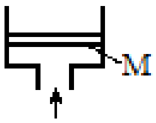
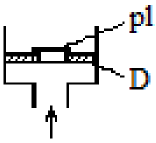
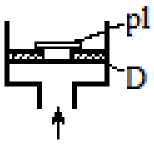
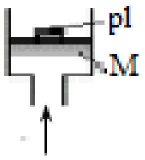
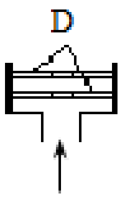
Decisions	Objects of an invention						
	Increase of					Decrease of	
	precision	sensitivity	stability	reliability	manufacturability	gabarit	price
 ***Figure 9***		+					
 ***Figure 10***			+			+	
 ***Figure 11***		+	+	+			
 ***Figure 12***		+	+	+			+
 ***Figure 13***			+				
 ***Figure 14***	+	+					

Table 3. Technological methods of achievement of the required operational characteristics

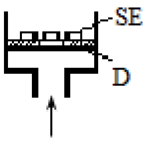
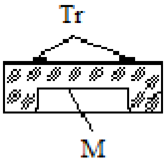
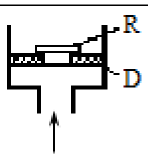
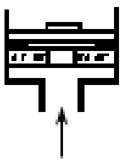
Decisions	Objects of an invention						
	Increase of					Decrease of	
	precision	sensitivity	stability	reliability	manufacturability	gabarit	price
 ***Figure 15***	+						
 ***Figure 16***				+			+
Cutting tensoresistors from a semiconductor monocrystal							+
Cultivation of monocrystals in the form of thin films by means of condensation of vapors				+			
Cultivation of monocrystals in the form of whiskers, by means of condensation of vapors				+			
Drawing on some types of substrates of thin films with properties of monocrystals				+			
Manufacture of semiconductors from the germanic arborescent tape which is drawn out from strongly overcooled melts on a special seed				+			+
Formation of p/n of transitions by diffusion of impurity			+		+		

Таблица 4. Methods of achievement of the required operational characteristics by means of the choice of new materials

Decisions	Objects of an invention						
	Increase of					Decrease of	
	precision	sensitivity	stability	reliability	manufacturability	gabarit	price
 ***Figure 17***				+	+		
 ***Figure 18***	+						
Gallium-arsenide			+				

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

RESULTS AND DISCUSSION

According to table 1 microelectronic pressure sensors at which design constructive methods are used can conditionally be subdivided into the following groups: Single-membrane devices (table 1 fig. 1-5), Double-membrane devices (table 1. fig. 6), multi-membrane devices (table 1 fig. 7), microelectronic pressure sensors with a sensitive element in the form of the closed silicon box (table 1 figs. 8) and microelectronic pressure sensors with a vibration sensitive element (table 1 fig. 9-14).

In capacitor sensors of pressure between mobile and motionless electrodes there is a gap which size changes depending on pressure (table 1. fig.1). The design of the elementary resistive-strain sensor of pressure represents a silicon plate in which the internal cavity with a membrane and tensoresistors on her surface is executed (table 1. fig.2).

In other known design of the sensor of the specified type core from strong material runs through a hole in the center of a round membrane and it is rigid connected to membrane. Application of such design provides not only high to reliability, but also sensitivity, stability, and also low price (table 1. fig.3).

For increase in resistance to overloads the system of increase in mechanical resistance of knot of a receiving membrane is used. This knot is produced in the form of a small glass with reinforced sidewalls which central part performs functions of a receiving membrane (table 1. fig.4).

Fiber-optical sensors (table 1. fig.5) provide reliability and stability.

Membrane sensors can be executed from two tiny silicon plates about 1 micron and 0.6 microns thick with two membranes and tensoresistors. Limits of measurement of pressure of such sensors are made by 0.07-420 kg / sq. cm (table 1 fig.6).

For the purpose of ensuring technological effectiveness of production sensors can be executed in the form of a package of plates (two external are made of the isolating materials, and 3 internal are made of silicon in the form of a framework with the engraved sensitive elements on each frame) (table 1. fig.7).

There is a kind of performance of sensitive elements in the form of the closed silicon box. Such sensors have high sensitivity, small dimensions, small thermal coefficient and low cost (table 1. fig.8).

The principle of operation of the frequency pressure sensors is that oscillations are excited in resonators. Oscillation frequency changes in case of deformation of the diaphragm arising under the influence of pressure.

There are different systems of excitation of the resonator: piezoelectric, capacity, vibrooptical ones. The vibrooptical system uses the laser ray modulated on excitement transferred on an optical fiber.

In frequency sensors the vibration frequency element can be executed in the form of the tiny force-sensitivity beam resonators (table 1. fig.12), it can represent an oscillatory string (table 1. fig.9), single-crystal silicon thread which tension depends on a diaphragm deflection (table 1. fig. 11), the crossbeam leaning on a diaphragm (table 1. fig.12), a vacuum cavity with a silicon cover (table 1. fig.13). At last, the membrane (table 1. fig.10) or a diaphragm (table 1. fig. 14) can carry out a resonator role.

For the purpose of increase in sensitivity of devices the matrix silicon sensors containing several sensitive elements on one diaphragm are used (tab. 3.1 fig.15). The matrix of such sensor is made on a silicon plate by method of anisotropic pressure. Formation of an epithelial layer is applied to a stop of etching process for the purpose of obtaining the necessary thickness of a diaphragm (technologic method).

At production of membrane sensors from structures "silicon on sapphire" for the purpose of ensuring high reliability and depreciation the technologic method of plasma etch chemistry of sapphire is applied to creation of the profiled sensitive elements (table 1. fig. 16).

Improvement of sensors characteristics is reached also by the material choice.

At production of the vibration sensor (table 1 fig.17) for formation of a sensitive element of the set thickness it is used unilateral diffusion of boracium which presence in a blanket of a sensitive element sharply slows down the process of chemical etching which is carried out from the opposite side.

For minimization of influence of the efforts arising at assembly to characteristics of the sensor it is mounted by means of the viscous silicon paste which is a mechanical outcome (table 1. fig.18).

CONCLUSION

The analysis of scientific and technical and patent literature, directories of firms' manufacturers of sensors and metering equipment allowed to reveal the following perspective directions:

- use in sensitive elements of composite semiconductor structures (silicon on dielectric, the pyezoplenka created on the semiconductor or the insulator, etc.);
- use of high-temperature semiconductors and semiconductor connections (diamond, silicon carbide, gallium arsenide);

- use in technological process of high-energy technological operations (the ion implantation, processing by the ionic bundles, plasma etching, etc.);
- implementation of multifunctional performance of measurements in case of which the microelectronic sensor at the same time measures different parameters (pressure and temperature, pressure and vibration, concentration and composition of different gases or the liquid environments and so forth). Multifunctional performance allows to reduce significantly the nomenclature of the used sensors and to increase informtiveness of their measurements;
- use in the developed microelectronic sensors of micromechanical constructions and technologies.

For the purpose of the database filling used for synthesis of new technical devices results of patent methods of achievement of the presented operational characteristics of microelectronic pressure sensors are classified. Results are performed in tables 1-4. The analysis of tables allowed to draw the following conclusions:

- it is set that more attention is paid to technologic and materials research methods;
- the list of utilization properties used earlier is added by the new characteristic — functionality;
- basic typical constructions of microelectronic pressure sensors are defined (capacity, resistive strain gage, resonator and piezoresistive ones) which can be used for synthesis of new technical devices are defined;
- the most perspective constructive methods, allowing to reach at the same time the maximum quantity of the required operational characteristics are revealed;
- insufficiently investigated directions of achievement of the required operational characteristics are revealed (underutilization of technologic and materials research methods for increase of sensitivity and materials research — for reduction of price).

Results of a research are intended for formation of the database containing the formalized description of elementary objects for synthesis of new technical solutions.

REFERENCES

[1] Shikul'skya O. M., Konstantinova O. S., “Synthesis of new designs based on modern technologies” in Measurement techniques, No 8, Vols. 52, pp. 829-832, 2009.
[2] Shikul'skaya O. M., Nezametdinova E. R., Modernization of a conceptual model of a data bank for physicotechnical effects based on contemporary information technology in Measurement techniques, No 1, Vol. 50, pp. 7-9, 2009.
[3] Zaripova, V., Petrova, I., Lezhnina, Y., “Designing the module “Methods for activating engineering creativity” on basis of competence approach” in Recent Patents on Computer Science, Vol. 9. No 2. pp. 160-165, 2016.
[4] Zaripova, V.M., Petrova, I.Y., Kravets, A., Evdoshenko, O., “Knowledge bases of physical effects and phenomena for method of energy-informational models by means of ontologies” in Communications in Computer and Information Science, JCKBSE 2014, No 1, Vols. 466, pp. 521-532, 2014.
[5] I. Petrova, O. Shikulskaya, M. Shikulskiy, "Conceptual Modeling Methodology of Multifunction Sensors on the Basis of a Fractal Approach" in Advanced Materials Research, Vols. 875-877, pp. 951-956, 2014
[6] R. Balzar, E. Krasnogenov, S. Abbasov “Semiconductor vibrational frequency response sensor for pressure measurement: Pap. 30 Annu. Meet. Eur. High Pressure Res. group.” In Physics and technic of high pressures, No 2. pp. 25-27, 1993.
[7] Kovacich John A., Hoinsky Christopher C. “Diaphragm mounting system for a pressure transducer”, patent 5264820 USA, 1993
[8] Van Vessm Peter D., Rado Ricardo A.; Eaton Corp. patent No 860860; appl. 31.3.92, publ. 23.11.93.
[9] Electronics, Vol. 63, No 1. -P. 86-87, 1990.
[10] Zhao Ganming, Huang Yiping, Bao Minhang “SOI structure pressure transducer formed by oxibized porous silicon”, in Transducers’ 89.: Proc. 5th Int. Conf. Solid-State Sensors and Actuators and Eurosensors III, Montreux”, Vol. 2., Lausanne. - pp. 840-843, 25-30 June 1989.
[11] Massayoshi Esashl, Matsumoto Yoshlnorl, Sojl Shulchi. “Absolute pressure sensor by air-tight electrical feed-through structure” in Transuders’89 Lausame, pp. 1048-1052, 1990.
[12] Bao Min-Hang, Yu Lian-Zhong, Wang Yan. “Micromachined beam-diaphragm strukture improves performances of pressure transducer” in Transducers’ 89.: Proc. 5th Int. Conf. Solid-State Sensors and Actuators and Eurosensors III, Montreux, Vol. 2. - Lausanne, pp. 137-141, 25-30 June 1989.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

[13] Bai-zar R., Voronin V., Krasnogenov E., Bogdanova N. "Operation of monocrystalline silicon resonator ina measuring circuit" Pap. East-West Workshop Microelectron. Sens, Sozopol, in Sens. and Actuators. A., Vol. 30, No 1-2. - pp. 175-178. 7-9 May 1991

[14] V. E.Prilutskii, Yu. K. Pylaev, A. G. Gubanov, Yu. N. Korkishko, V. A. Fedorov, E. M. Paderin, "Precision fiber optical gyroscope with linear digital output", 9 Saint Petersburg International Conference on Integrated Navigation Systems. - St. Petersburg. 27-29 May, 2002, - St. Petersburg: Elektropribor, pp. 333-342, 2002.

[15] Zook James D., Burns David W. "Resonant gauge with microbeam driven in constant electric field" Patent 5275055 USA,; Honeywell Inc. - No 937068; Appl. 31.08.92; publish. 04.01.94;

[16] Tilmans Hendricus A.C. "Resonant mechanical sensor" Patent 5165289 USA, Johnson Service Co. - No 551523; appl. 10.07.90; publish. 24.11.92.

[17] Rippert, L. Rippert Laurent, Papy Jean-Michel, Wevers Martine, Van Huffel Sabine, "The touch device with fiber-optical elements" in Fibre optic sensor for continuous health monitoring in CFRP composite materials: Conference on Smart Structures and Materials: Modeling, Signal Processing, and Control", Proc. SPIE, 2002, 4693. - pp. 312-323, 2002

[18] Karl Ryan, Janusz Bryzek "Sensor with new configuration of a touch element. Flexible miniature packaging from Lucas Nova Sensor provides low-cost pressure senson solutions to a wide variety of hostile media applications, Electron. Compon. News, 39, No 4. - pp. 118-120, 1995.

[19] Tokuji Saigusa, Michiaki Yamagata "Converters of pressure of rezonator type" Keisoku to migyo.= J. Soc. Instrum. And Contr. Eng., 31, No 6, 1992.

[20] Frische Richard H. "Semiconductor pressure sensor" Patent 5142912 USA, МКИ5 G 01 L 9/06. Honeywell Inc. No 538956; Patent 15.06.90; publish. 01.09.92.

[21] Shimaoka Keiichi, Tabata Osamu, Sugiyama Susumu; K. K. Toyota Chuo Kenkyusho. "Semiconductor pressure sensor" Patent 5163329 USA, No 635953; Patent 28.12.90; publish. 17.11.92.; НКИ 73/721

[22] Eric Stemme, Goran Stemme "A balanced resonant pressurre sensor" in Transducers' 89.: Proc. 5th Int. Conf. Solid-State Sensors and Ac-tuators and Eurosensors III, Montreux. - 1989. - 25-30 June. - Vol. 2. Lau-sanne. pp. 336-341, 1990.

[23] S. Terry J.S. Eckerle, R.D. Kornbluh, T.Low, C. M. Ablow. "Silicon pressure transducer arrays for blood-pressure measurement" in Transducers' 89.: Proc. 5th Int. Conf. Solid-State Sensors and Actuators and Eu-rosensors III, Montreux, 1989. - 25-30 June. - Vol. 2. - Lausanne. pp. 1070-1079, 1990.

[24] Fujii Tetsuo, Gotoh Yoshitaka, Kuroyanagi Susumu. "Fabrication of microdiaphragm pressure sensor utilizing micromachining" in Sens. and Actuators. A. - 1992. - 34, No 3. - pp. 217-224.

[25] r.Tehn. Mess Werthschutzky. "Silizium sensoren inprozeB-meBgeraten", Zar Druckmessung- Stand and Tendenzen, 1992, No9. 340-346

[26] Germer Wilfried, Kovalski Gunter "Mechanical decoupling of monolithic pressure sensor in small plastic encapc" in "Transducers'89", Prog. 5th Int. Conf. Solid-State Sensor and Actuators and Eurusensors III, Montreux, 1989. - Vol. 2. - Lausane. - 1990. - pp. 1065-1069.

[27] Wang Yaoling, Liu Litan, Zheng Xinyu, Li Zhijian "A novel pressure sensor structure for integrated sensors" in Transducers' 89.: Proc. 5th Int. Conf. Solid-State Sensors and Actuators and Eurosensors III, Montreux. June 25-30. Vol. 2. - Lausanne. pp. 62-64. Appl. 2235773 1989, 1990.

[28] Parsons Philip, Willson Joison Peter, Metcalf Eric. "Indirectly excited resonant element sensor", Great Britain, Schlumberger Ind. Ltd. - No 90170820; Patent 03.08.90; publish. 13.03.91.

[29] Isabelle Thomas, Pierre Olivier Lefort; Sextant Avionique S.A., Appl 2664979 France, No 9009468; Patent 20.7.90; publish. 24.1.92