Silicon Mechanical Sensors for High-Temperature Control Systems.
Topicality and scientific novelty as of 1985-1990

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1. Introduction

Relevance is substantiated and scientific novelty is formulated.

2. Relevance of problem

At the present stage of development of our industry, the parameters of control system elements (CS), system control (MS), and system regulation (RS) depend a great deal on the quality of products and the improvement of their technical characteristics. Depending on the purpose of the system, the elements divide into four functional groups of devices:(1) for receiving information about processes and objects;(2) to receive, transform and transmit information;(3) for processing, storing information, and forming control commands;(4) devices for using command information.Information acquisition tools (1) are the largest group and usually make up more than half of the assortment of all technical means of the system. When solving industrial problems, the main components of this group of elements are primary transducers (sensors) of mechanical quantities (pressure, acceleration, impact, etc.). Typical for industry sensors of mechanical quantities VT, LH, ANS, etc. They have significant disadvantages: high weight and overall dimensions, low sensitivity, high labor intensity of manufacture, and driving during operation. Their constructive-technological solutions probably will not allow to significantly improve technical indicators in the future. For this reason, existing primary information transducers do not fundamentally solve a number of current industrial problems, especially in the creation of new products.
One of these tasks relates to the management of research tests of the reusable RD-170 (11D521) and RD-171 (11D520) LPRE units. The problem here comes from obtaining accurate information about the pressure fields in LPRE units. Ranges of measured pressures from$0-1$ atm to$0-10$ atm. In this case, the intrinsic error of the pressure sensors should not exceed$\pm 1\%$. The second problem includes obtaining accurate information about the vibration modes, the dynamic stability parameters, dynamic overloads on the nodes, and the power elements. Measured acceleration ranges from0 ± 1 g to0 ± 10 g, frequency spectrum$0-300$ Hz. The intrinsic error of the accelerometers should not exceed$\pm 5\%$.

3. Methods of research

Theoretical studies use mathematical modeling methods, transport phenomena theories, contact phenomena, and the piezoresistive effect in semiconductors. The author experimentally determined the electrophysical characteristics of the piezoresistive channels, the material of the elastic element, the insulating p-n junction, and the metrological characteristics of the integrated piezoresistive transducer (IPT). Methods of probability theory and mathematical statistics confirmed the results of the experiments.

4. Scientific novelty.

The scientific novelty of the work consists in the development of physical and functional models and principles for constructing integrated monolithic silicon strain resistor transducers with mechanical values of small sensors in the operating temperature range$0-300^{\circ}C$.

5. The new results:

the natural influences of physical and geometric parameters on the temperature dependence of the insulating properties of the IPT p-n junctions at temperatures greater than$0 - +100^{\circ}C$;

a physical and functional model of the primary deformation transducer with a part of the elastic element material electrically connected to the bridge measuring circuit;

The principles of designing a precision monolithic IPT of small pressure and acceleration sensors for the operating temperature range of$0 - 300^{\circ}C$, including minimization of the intrinsic error of the IPT by the identity of the electrical parameters of the bridge measuring circuit;

minimization of the complementary temperature error of the IPT with an insulating p-n junction in the $0 - +200^{\circ}C$ range by using the regular temperature changes of the electrophysical characteristics of silicon piezoresistive p-type channels and passive regulating resistive elements;

minimization of the complementary temperature error of IPT by using a part of the elastic transducer element as a regulating element of the temperature dependence of the output signal for the$0 - 300^{\circ}C$ range.

6. Practical value and implementation of results

Developed unified series of microminiature IPT SIAP408854.001 for small pressure sensors from$0 - 0.1$ atm to $0 - 10$ atm, small-sized LF-accelerometers (LF-Low Frequency) ANPPE SIAP.402139.001 for measurements of low-frequency accelerations from0 ± 1 g to0 ± 30 g in the frequency range$0 - 300$ Hz.

7. Approbation

The All-Union Conference "Methods and means of tensometry and their application in the national economy" in Sverdlovsk 1989 ; Scientific conferences of faculty and postgraduate students of the MSFU (Moscow State Forest University) 1983, 1984, 1985.

8. Publications

The author outlined the main content and results of the work in 9 articles and defended three certificates of authorship.

9. The volume of work

The thesis work consists of an introduction, four chapters, and a conclusion, on 83 pages of typescript, 6 tables, 35 figures, a list of literature comprising 84 titles and applications.

10. The main provisions:

extension of the upper limit of the working temperature range of the integrated silicon strain gauge transducers of mechanical quantities, with an insulating p-n junction, to values greater than$+200^{\circ}C$ by reducing the area, the transition perimeter, and the number of angles in the topological structure of the elements;

The physical and functional model of the mechanical quantity transducer without the insulating p-n junction, allowing at the expense of selection of the electrophysical characteristics of Si piezoresistive channels and the Si elastic element to extend the upper limit of a range of working temperatures to values greater than$300^{\circ}C$;

a method to compensate for the complementary temperature error in the temperature range$-60 - 325^{\circ}C$ of silicon mechanical magnitude sensors by electrically connecting a part of the resilient element material to a bridge circuit and selecting the resistivity of the resilient element material in the range$(0.5 \div 10)\Omega \cdot cm$.