RADIATION STABLE ELECTROMECHANICAL TRANSFORMERS ON THE BASIS OF THREAD-LIKE MONOCRYSTALS Ge_{1-x} Si_x

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The investigations of the electromechanical characteristics of the thread-like crystals Ge_{1-x} Si_x subjected to electron and γ- irradiation (Co^{60}) showed their increased radiation stability as compared with the other devices.

The results obtained allow to draw conclusion on perceptivity of application of the transformers based on thread-like monocrystals Ge_{1-x} Si_x for the practical realization of the automatization of the measurement process in different fields of engineering.

The advanced trend in the development of the measuring systems is the use of transformers (transmitters) based on a unique principle. As the experience in designing showed on the basis of the semiconductor thread-like monocrystals of silicon, germanium and $Ge_{1-x}Si_x$ the various types of the measuring transformers characterized by the constructive simplicity, high sensitivity and enlarged functional capability [1-3] could be created.

The unity of a principal solution and unification of devices is achieved due to creation of the base transformers (migrations on thermoresistors and deformations on thermoresistors), in which the sensitive elements are free monocrystals.

With reference to the development of thermoresistive transformers, it should be noted, that with all varieties of the constructions of this class transformers all of them contain a thermoresistor and a heater (thermowire) migrating one relatively another under the action of the parameter to be measured. As a rule, the thermoresistor is made, from the conductive material that eventually determines the construction and metrologic characteristics of the transformer.

The use of the thermoresistors from the semiconductor thread-like monocrystals 1 mm in length and 15 mcm in diameter allows to eliminate defects of the transformers with wire thermosensitive elements.

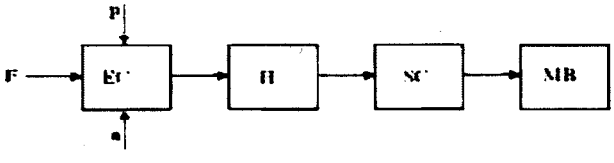

Fig. 1. Structural scheme of thermoresistive transformers. EC – Elastic cell, H – Heater, SC – Sensitive cell, MB – Measuring bringe.

The essence of the proposed method for transforming migration (or the other mechanical value, which can be put into migration) into an electrical signal consists of the possibility for local measurement of temperature by means of a miniature crystal. The transformer structural scheme (fig. 1) can be represented by the successive chain of links with the certain transforming functions and the corresponding error of components: the elastic cell (silphon) perceiving the measured value, cylindrical heater creating the required gradient of the temperature field along its axis; thermosensitive cell-thread-like crystal, mechanically connected with silphon by means of crystal holder and migrating inside the coaxially placed heater; measuring bridge with one or two active arms.

The analysis and calculation of such scheme allowed to determine the functional capabilities of the transformer, its mechanical and electrical parameters.

In the transformer of linear migrations the measuring rod is welded into the silphon- moving element which performs the migration of the crystal holder with the secured on the current outlets crystal relative to the immobile heater. In the given construction two variants of crystal arrangement (longitudinal and transverse) relative to the heater are possible.

By the investigations it was established that in the both cases the linear dependence of resistance change on migration occurs:

$$R(x)=R_o(1+\alpha Mx) \qquad (1)$$

where R_o is an initial resistance of a crystal; M is a coefficient characterizing the gradient of temperature in a heater; α is temperature coefficient of crystal resistance.

Under the action of the migration to be measured the crystal position inside a heater changes and thus its temperature and hence resistance which is transformed by the measuring scheme to analogous electrical signal change.

The transformer sensitivity is represented as

$$S=\frac{dR}{dx}=R_o\alpha\ M \qquad (2)$$

The high sensitivity by voltage allows to measure the output signal by the standard measuring device (digital voltmeter, potentiometer, self-recording device).

In the transformer of pressure the mechanical impact is perceived by the silphon itself which is connected with crystal holder. The inertia mass in the accelerometer is combined with silphon migrating relative to the heater under the action of acceleration.

In design of the thermoresistive transformers a number of the technological peculiarities which permit to decrease the measurement error have been taken into account. The investigations established that the measurement of the above parameters was performed with the main error in the order of 1–1.5%. The temperature error is 0.04%. The fast-response is within the range 0.1–0.3s. The significant advantage is the possibility for interchangeability of the transformers and their low cost.

The use of mechanical resonators opens new perspectives in creation of the tensoresistive transformers.

On the strength of all the properties such vibrating-frequency tensotransformers are the most advanced measuring means providing a number of advantages.

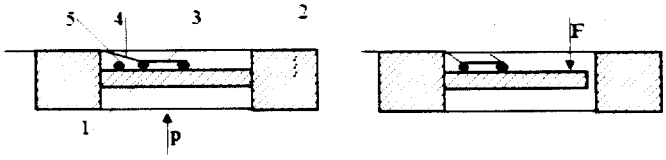

Fig. 2. Functional schemes of vibro-frequency tensotransformers. 1-membrane; 2-supporting fillet; 3-crystal; 4-current-outlets; 5-excitation electrode.

The structural scheme of the transformer (fig. 2) includes: elastic cell transforming the mechanical value (force, pressure, acceleration) into string tension; oscillatory cell (resonator) – monocrystalline structure transforming the tension into the frequency of mechanical oscillations; exciting cell serving for excitation of the string mechanical oscillations; amplifier of the resonator electrical oscillations. In the proposed scheme the functions of the oscillatory and transforming units are combined in one cell – string from thread-like monocrystal. Due to this the direct transforming of the crystal mechanical oscillations to the electrical signal is effected at the expense of its internal properties.

The oscillation exciter as an individual cell is absent, for the oscillation excitation the elastic cell surface adjacent to the string is used.

The string tension is known to lead to the change of its own oscillations frequency and correspondingly to the change of the resistance variable component owing to the strain sensitivity. The relative resistance change is proportional to its deformation

$$\frac{\Delta R}{R} = KE \qquad (3)$$

where K is a coefficient of the crystal tensosensitivity.

If the direct current is passed through the string the tension pulsations will arise in it with frequency doubled with respect to the frequency of the mechanical oscillations. In general view the frequency of this tension can be determined by the formula [4]

$$f = \frac{1}{2l}\sqrt{\frac{\sigma}{\rho}} \qquad (4)$$

where l is a length of the string; σ is a tension of the stretching force acting on string; ρ is a density of the string material.

The functional schemes of vibrating-frequency tensotransformers of different purposes are presented in fig. 2.

In pressure transformer on silicic membrane with supporting fillet the thread-like $Ge_{1-x}Si_x$ monocrystal is rigidly secured in joints. The crystal current-outlets and electrical contact of the oscillations exciter are connected to more rigid contact outlets. In the transformer of forces and accelerometer the crystal is fasten on monocrystalline beam of the equal flexing resistance made by the method of ultrasonic treatment with subsequent chemical etching and polishing.

The maximum simplicity of the construction, consistensy of materials and junction in pick-up points allowed to achieve the high soundness of the string oscillations (10^5). The sensitivity to deformation reaches the value 10^9 Hz/per unit value.

The metrological estimate of the transformers by means of direct comparison with the exemplary measuring means gives the error value in the order of 0.01%. The important advantage of the given transformers is that their operation is not significantly affected by temperature dependencies of the tensosensitivity and resistance coefficient since the parameter to be measured is oscillation frequency which is determined by the crystal geometry, its mechanical properties and applied force.

The investigations of the electromechanical characteristics of the thread-like crystals $Ge_{1-x}Si_x$ subjected to electron and γ – irradiation (Co^{60}) showed their increased radiation stability as compared with Ge or Si crystals which considerably increased with increasing of silicium per cent content in a sample.

The results obtained allow to draw conclusion on perspectivity of application of the transformers based on thread-like monocrystals Ge – Si for the practical realization of the automatization of the measurement process in different fields of engineering.

[1] *R.I. Baitsar.* Pribori i technika eksperimenta, 1980, №3 (in Russian).
[2] Auth. Certif. 960634 USSR. Stringed resonator, B.I. №35, 1982.
[3] *Yu.G. Akhromenko, R.I. Baitsar, E.P. Krasnozhenov.* Phys. Elektronika, Lvov, 1985, Vip.31.
[4] *Sh.M. Abbasov, R.I. Baitsar, Sh.I. Abbasov, E.P. Krasnozhenov.* Izvestiya Natsion. Akad. Nauk Azerbaijana, 2000, v.20, №5, p.45-48.

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SAPŞƏKİLLİ $Ge_{1-x}Si_x$ MONOKRİSTALLARI ƏSASINDA RADİASİYAYADAVAMLI ELEKTROMEXANİKİ ÇEVİRİCİLƏR

Elektron və $\gamma(Co^{60})$ şüalarının təsirinə məruz qalmış sapşəkilli $Ge_{1-x}Si_x$ kristallarının elektromexaniki xassələrinin araşdırılması, onların radiasiyayadavamlılığının başqa cihazlara nisbətən daha yüksək olduğunu göstərmişdir.

Alınmış nəticələr sapşəkilli $Ge_{1-x}Si_x$ monokristalları əsasında radiasiyayadavamlı tenzoçevirici hazırlanmasına imkan verir ki, o da texnikanın müxtəlif sahələrində ölçmə proseslərinin avtomatlaşdırılmasına şərait yaradır.

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РАДИАЦИОННО-СТОЙКИЕ ЭЛЕКТРОМЕХАНИЧЕСКИЕ ПРЕОБРАЗОВАТЕЛИ НА ОСНОВЕ НИТЕВИДНЫХ МОНОКРИСТАЛЛОВ Ge_{1-X} Si_X.

Исследования электромеханических характеристик нитевидных кристаллов $Ge_{1-x}Si_x$, подвергнутых электронному и γ облучению (Co^{60}), показали их повышенную радиационную стойкость по сравнению с другими приборами.

Полученные результаты позволяют сделать вывод о перспективности использования преобразователей на базе нитевидных монокристаллов Ge_{1-x} Si_x для практического осуществления автоматизации процессов измерения в различных областях техники.

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