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THE PROBLEM OF NON-STATIONARY THERMAL CONDUCTIVITY FOR MULTILAYERED STRUCTURE OF A RADIO-ELECTRONIC COMPONENT

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Abstract*—The article refers to the problem of the information processing and decision-making with faulty elements of digital blocks by the independent automated systems of diagnosing using method of own radiation.*

Index Terms— the diagnostic information; a method of own radiation; a radio-electronic component.

I. INTRODUCTION

Presence of direct communication of a resource of radio-electronic components (REC) with their temperature is feature of a method of intrinsic emission for radio electronics products. Statistical dependences are calculated [1] for a number of components (transistors, diodes, oxide cathodes, resistors). Efficiency of a method of intrinsic emission is visually shown during research of a considerable quantity of the same digital elements.

II. THE ANALYSIS OF SOURCES

The analysis of sources [1]–[3] has shown that thermal fields of the same products were well corelated. The diagnostic parametre (DP) is formed according to way of carrying over of thermal energy (heat conductivity, convection, thermal radiation) during check of a technical condition, and it can be presented not only like a set of numerical values, but also in the form of two-dimensional (three -dimensional) thermogram. Algorithms of images recognition can be applied after formation of a set of informative signs.

The analysis of intrinsic emission method has shown possibility of contactless high-efficiency diagnostics of radio-electronic components with using of computer technics for processing of results [4].

Theoretical and experimental researches allowed to draw conclusions to practical possibility of using method of intrinsic emission not only for identification of a technical condition of the digital block but also for localisation of the faulty REC as a part of the digital block.

III. PROBLEM STATEMENT

Process of malfunction localisation is connected with definition faulty the REC as a part of the digital block by registration and processing of diagnostic parametre – the thermal response to the entrance test sequences, developed for given the REC. Using of intrinsic emission method demands creation of new diagnostic models which display communication DP with the physical and chemical processes occurring in the REC during the service, it is necessary to carry out the analysis of manufacturing techniques of the REC and structure of modern semi-conductor to construct the model of carrying heat from "the warmed up" crystal of the semiconductor to surface of the REC (a problem of non-stationary heat conductivity).

IV. THE BASIC PART

The semiconductor production technology is based on precision processes of processing: the photo – and electrical lithography, oxidation, ionic implantation, diffusion, thermal compression and so on.

The sequence of manufacturing of the planar semiconductor in structure IMC consists of following stages [8]:

– preparation of semi-conductor plates;
– creation of topological picture;
– "cultivation" *p-n*-transitions;
– joining of electric conclusions;
– assemblage and hermetic sealing.

At the first stage, epitaxial structures, for example *n-n*+ -type, or monocrystal linings with electroconductivity *n*- or *p*-type, are clarificated.

The following stage – creation of a topological picture. To generate areas with electroconductivity *p* - type, it is necessary to provide carrying out of local diffusion through windows in a protective mask from a film of silicon dioxide $Si0_2$ in the thickness 0,3–1,0 microns. The sizes of these windows set by means of photolithography process, it is put a layer of photoresist on a film and it is exhibited by an ultraviolet. The lighted sites of photoresist are shown and film $Si0_2$ is deleted.

By precision dispensing of quantity of the impurity, which is entered into a crystal, *p-n*-transitions are received. At area creation *p*-bases – use process of ionic implantation which is in introduction of the

accelerated ions to a crystal surface. Generation of base area and *p-n* - transition a collector-base on necessary depth is received by using further diffuse dispersal of the introduced atoms of a pine forest. The area of base with depth 2–3 microns is as a result formed.

We metallize surfaces of contacts for joining to areas of the emitter, base and a collector of electric conclusions. The film of dioxide is deleted from the necessary sites. We put a metal layer (for example, aluminium, thickness to 1 micron) to all surface of a plate, using a thermal evaporation in vacuum. The following stage is the collection and hermetic sealing. The plate is prepared for assemblage contains a significant amount (ten thousand separate elements). A plate is cut on separate structures – crystals, mount on the holder, carry out distributing – formation of electric wires with contacts and it seals.

Hermetic sealing (creation around a crystal of tight, mechanically strong cover) is intended for protection of a crystal of the semiconductor with from environment influence. The cover is created by covering case bases, with the semi-conductor crystal located on it, plastic.

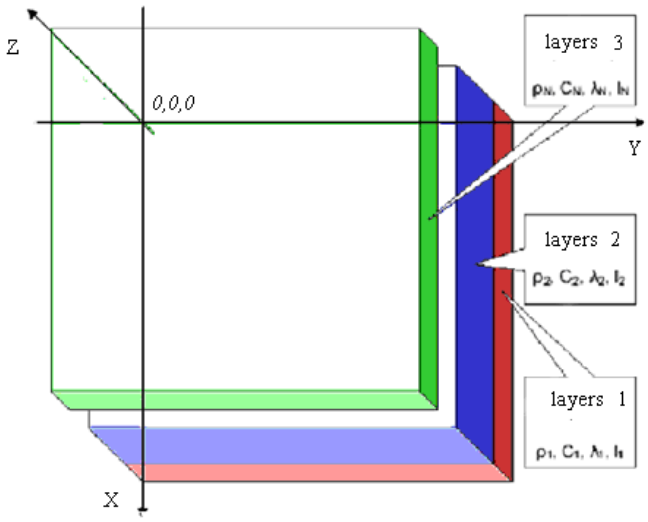
For creation of the plastic case is using different plastic materials: down-pour compound and a press powders on a basis epoxy, silicon of organic and polyester pitches. Cases (the external geometrical sizes) of modern REC are standardised. The analysis of the geometrical sizes of the REC is necessary further for modelling of structure of a thermal field round the REC.

The analysis of manufacturing techniques of the modern semi-conductor REC has shown their multilayered design. It is the holder of a crystal, a lining with "grown up" the REC and tight, mechanically strong cover in the simplified kind.

The decision of a problem of non-stationary heat conductivity in multilayered object (REC) consists in identification of sizes thermal characteristics of layers on set time to dependences of temperature at a surface of the REC and temperature of the surface.

The formulated problem is answered with an one-dimensional direct problem of non-stationary heat conductivity.

Let's present the REC as the multilayered object represented on Figure. We focus axis *Z* to perpendicularly borders between layers of the REC (perpendicularly its surface), and axes *X* і *Y* is the in parallel it. A reference point (0, 0, 0) we will place on one surfaces of a multilayered design (an internal surface). Axis *Z* we will direct to the design opposite side (an external surface) it is necessary for justice of one-dimensional approach, that the size of object in a plane (*XY*) (the width of the REC is long also), exceeded the size along axis *Z* (height of the REC).



Multilayered object

Temperatures of surfaces of the REC change in due course depending on thermal streams which pass through the given surfaces.

The equation of heat conductivity [5]:

$$C(z)\rho(z)=\frac{\partial T(z,t)}{\partial t}=\lambda(z)\frac{\partial^2 T(z,t)}{\partial z^2}.$$

Let's copy in a kind:

$$T(z,t)=\int_0^t C(z)\rho(z)\partial t,$$

where T $(z,\ t)$ dependence of temperature on co-ordinate z and time t; C (z) a thermal capacity; ρ (z) density; λ (z) heat conductivity factor are values thermal characteristics of a material of layers investigated the REC.

Thermal characteristics of materials of layers are considered as constants in each of layers. We will designate value of these functions, on corresponding sites: $C_{n,}$ ρ_n and $\lambda_{n.}$

An Energy sourcein multilayered structure of the REC semi-conductor is the warmed up crystal of the semiconductor.

The temperature of crystal T is defined according to diagnostic model *p-n* transition for a method of intrinsic emission which is based on the analysis of volt-ampere characteristics (VAC) of transition [6]:

$$T = \frac{U - \varphi_{f0}}{\frac{k}{q}\ln\frac{I}{I_{00}} - \varepsilon_3} \qquad (1)$$

where k is the Boltsman constant; T is the temperature; q is the a charge electron; I_{00} is the size independent of temperature; φ_T is the temperature potential; φ_{f0} is the width of the forbidden zone at zero temperature; ε_3 is the temperature sensitivity.

Expression (1) allows to define temperature depending on a current through the semiconductor and physical and chemical processes in the semiconductor.

Having substituted in (1) value of a collector current deduced in [7]:

$$I = -\frac{2qD_n}{L_n}S_n'\operatorname{csch}\frac{W}{L_n}n_1 + \frac{2qD_n}{L_n}S_n'\operatorname{cth}\frac{W}{L_n}n_2.$$

We receive mathematical model of temperature dependence of the semiconductor from physical and chemical properties:

$$T = \frac{U - \varphi_{f0}}{\frac{k}{q}\ln\left(\frac{-\frac{2qD_n}{L_n}S_n^{/}\operatorname{csc}h\frac{W}{L_n}n_1 + \frac{2qD_n}{L_n}S_n^{/}cth\frac{W}{L_n}n_2}{I_{00}}\right) - \varepsilon_f}, \qquad (2)$$

where W is the width of base; L_n is the it is length of diffused displacement electron in base; n_p^0, n_p^w is the concentration of carriers in base on border emitter and collector junction.

Boundary conditions

$$n_1 = n_p^0\left(e^{\lambda U_{b-e}} - 1\right), \quad n_2 = n_p^{\mathrm{w}}\left(e^{\lambda U_{б-c}} - 1\right),$$

U_{b-e}, U_{b-c} are the pressure enclosed to emitter and collector junction accordingly; S is the area of a crystal of the semiconductor; D_n is a concentration factor electron.

Expression (2) is mathematical model of dependence of temperature of a crystal of the semiconductor from its physical and chemical properties.

The received model allows to define semiconductor heating, or quantity of heat, as diagnostic parametre of processes occurring in the REC.

V. Direction of the further researches

Direction of the further researches is the analysis of the mechanism of transfer of heat from "the warmed up" crystal to "surface" of the REC.

Conclusions

The manufacturing techniques and structure of the REC is considered for statement and the solution of a problem of non-stationary heat conductivity of multilayered structure. Reference temperature T is defined "warmed up", under the influence of specially made verifying tests, by a semiconductor crystal. The temperature, according to diagnostic model, depends on a current I through the semiconductor and physical and chemical processes occurring in the REC.

References

[1] Vavilov, V. P. The thermal methods of quality monitoring of composite structures and products of radio electronics. Moscow: Radio and communication, 1984. 162 p. (in Russian).

[2] Kontsevoy, J. A.; Kudin, V. D. The Quality monitoring of the production technology of semi-conductor devices of Moscow: Energy, 1973. 140 p. (in Russian).

[3] Danilin, N. S.; Baklanov, O. D.; Zagorovsky, Ju. I. Theory and methods of not destroying infra-red control of radio-electronic schemes. Moscow: DD the USSR, 1974. 164 p. (in Russian).

[4] Kuzavkov, V. V.; Jankovsky, O. G. "Application of a method of self radiation for technical diagnostics of radio-electronic blocks". *The collection of scientific works*. Odessa state academy of technical regulation and quality. Odessa: OSATR, 2014. Ed. 2 (5). pp. 30–37. (in Ukraine).

[5] Lebedev, N. N.; Skalskaja, I. P.; Ufljand, J. S. The collection of mathematical physics problems. Moscow: Gostechteorizdat, 1955. (it is republished in the USA in 1965). (in Russian).

[6] Zi, S. Semi-conductor devices: In 2 books. Book. 2. Translation from English – the second reprinted. Moscow: Mir. 1984. 456 p. (in Russian).

[7] Kuzavkov, V. V. "Diagnostic model p-n (n-p) transition in a dynamic mode for a contactless induction method of diagnosing". *Collection of scientific works*. Military institute of the Kyiv national university of a name of Tarasa of Shevchenko. Kyiv: VIKNU, 2014. no. 45. pp. 41–47. (in Ukraine).

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М. К. Жердєв, Б. П. Креденцер, В. В. Кузавков. Завдання нестаціонарної теплопровідності для багатошарової структури радіоелектронного компоненту

Вирішено завдання оброблення інформації та прийняття рішень під час локалізації несправних елементів цифрових блоків автономними автоматизованими системами діагностування з використанням методу власного випромінювання.

Ключові слова: діагностична інформація; метод власного випромінювання; радіоелектронний компонент.

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Н. К. Жердев, Б. П. Креденцер, В. В. Кузавков. Задача нестационарной теплопроводности для многослойной структуры радиоэлектронного компонента
Решена задача обработки информации и принятия решений при локализации неисправных элементов цифровых блоков автономными автоматизированными системами диагностирования с использованием метода собственного излучения.
Ключевые слова: диагностическая информация; метод собственного излучения; радиоэлектронный компонент.

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