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Optimization of a down conversion mixer circuit formation in a hetero structure for increasing of elements density dependences of technological process on porosity of the considered materials and stress, which was induced by mismatch of lattice parameters

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Abstract

We consider an analytical approach to model mass and heat transport (with account nonlinearity) with time and space varying parameters has been introduced. Using the approach leads to prediction of heat and mass transport framework a heterostructure. The approach also gives a possibility do not use cross linking of solution on interfaces framework the heterostructure. Based on the approach we analyzed possibility to increase field-effect heterotransistors density in a down conversion mixer circuit. We obtain, that to increase the density of these transistors one shall manufacture them in a heterostructure, which has appropriate composition. Some appropriate areas of the considered heterostructure must be doped by using ion implantation or diffusion. After the doping it should be done of radiation defects annealing optimization, generated during ion implantation, and infused dopant. We also obtained conditions to decrease mismatch-induced stress, which was generated in layers of heterostructure.

Keywords: Down conversion mixer circuit, optimization of manufacturing, increasing of element integration rate.

Introduction

Currently several problems of modern electronics (one of them is increasing of performance of diodes, bipolar transistors, field-effect transistors; another one is increasing of their reliability; the third problem is density increasing of integrated circuits elements) are like billy-oh solving[1-6]. The performance could be increased by choosing of materials with as much as possible charge carriers mobility values[7-10]. Dimensions of integrated circuits elements could be decreased by using thin film heterostructures for manufacturing of the considered integrated circuits[3-5,11]. Using in homogeneity of the above heterostructures with optimization of doping[12] and improvement of epitaxial technology[13-15] leads to decreasing of these dimensions and at the same time to increase the performance[13]. As an alternative approaches, which could be used to decrease these dimensions, one could be used laser or microwave irradiation for annealing[16-18].

In this paper we consider an approach of manufacturing of field-effect transistors in thin film heterostructures, which leads to decreasing of dimensions of the above transistors and increasing of their density comprised a down conversion mixer circuit. We also described decreasing of stress, which was induced by mismatch of lattice parameters, in the considered heterostructure. Framework the paper let us consider a heterostructure. The heterostructure includes into itself an epitaxial layer and a substrate (Figure-1). Let us also consider using of a buffer layer. The buffer layer presents between the considered epitaxial layer and substrate. The consider epitaxial layer includes into itself some sections. Different materials has been used to manufacture by these sections. We consider two types of doping of the above sections: by dopant diffusion and by ion implantation. One can obtain conductivity type (*p* or *n*) in these sections, which were required. After that the considered sections could be used as gates, drains and sources (Figure-1). Using these ways of manufacture of field-effect transistors requires optimization of annealing of radiation defects and/or dopant. Basic aim of this paper is prognosis of radiation defects and dopant redistribution to determine conditions of decreasing of dimensions of considered transistors framework of the oscillator with simultaneous increasing of their density. We also obtained condition for decreasing of mismatch-induced stress in heterostructures. Simultaneous aim of the considered paper is introduction of an analytical approach for prognosis of heat and mass transport in the considered heterostructures during manufacturing of the considered integrated circuit. During the prognosis we take into account nonlinearity of considered processes and mismatch-induced stress. The analytical approach gives us a possibility to analyze heat and mass transport in the heterostructures without stitching of solutions of considered equations on all interfaces between layers of the considered heterostructures. The analytical approach also leads to possibility for taking into account any changing of considered

processes parameters in time and space. Using of the approach gives us a possibility to analyze manufacturing of the considered integrated circuit in more details in comparison with recently published works.

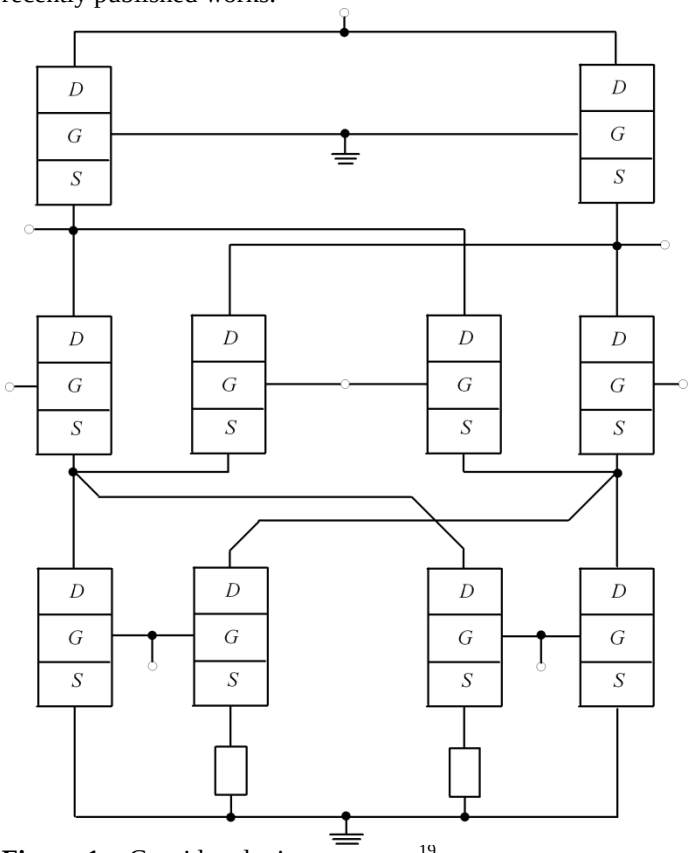

Figure-1a: Considered mixer structure[19].

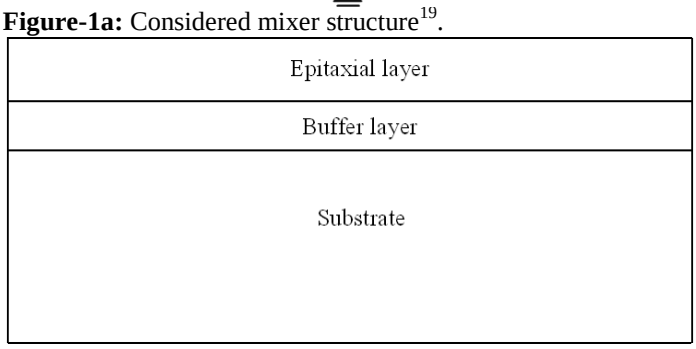

Figure-1b: Considered heterostructure. View from side.

Analysis

We solve the considered aim first of all by calculation of dopant concentration distribution in time and space in the heterostructure, which has been considered in the previous section. After that the distribution will be analyzed to formulate the required conclusions. We calculate the distribution by solving of the second law of Fick[1,20-23].

$$\frac{\partial C(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D\frac{\partial C(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D\frac{\partial C(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D\frac{\partial C(x,y,z,t)}{\partial z}\right]+$$
$$+\Omega\frac{\partial}{\partial x}\left[\frac{D_S}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}C(x,y,W,t)dW\right]+\Omega\frac{\partial}{\partial y}\left[\frac{D_S}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}C(x,y,W,t)dW\right]+ \quad (1)$$
$$+\frac{\partial}{\partial x}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]$$

Initial and boundary conditions for the dopant concentration could be written as

$$\left.\frac{\partial C(x,y,z,t)}{\partial x}\right|_{x=0}=0,\qquad \left.\frac{\partial C(x,y,z,t)}{\partial x}\right|_{x=L_x}=0,$$
$$\left.\frac{\partial C(x,y,z,t)}{\partial y}\right|_{y=0}=0,\qquad \left.\frac{\partial C(x,y,z,t)}{\partial y}\right|_{x=L_y}=0,$$
$$\left.\frac{\partial C(x,y,z,t)}{\partial z}\right|_{z=0}=0,$$
$$\left.\frac{\partial C(x,y,z,t)}{\partial z}\right|_{x=L_z}=0,\ C(x,y,z,0)=f_C(x,y,z).$$

Concentration of dopant distribution has been described by function $C(x,y,z,t)$; volume of atom of considered dopant has been described by symbol Ω; integral $\int_0^{L_z}C(x,y,z,t)dz$ describes the surface dopant concentration near interface between layers of the considered heterostructure (in this situation we consider Z-axis as perpendicular to interface between layers of the considered heterostructure); operator ∇_s describes symbol of the gradient on surface coordinates; function $\mu(x,y,z,t)$ describes the chemical potential, which we considering due to the presence of stress, which was induced by mismatch of lattice parameters, in the considered heterostructure; parameters D and D_S describe coefficients of volumetric and surface diffusions, respectively. Values of the above coefficients of diffusions depend on properties of the considered heterostructure's materials, materials heating and cooling speeds during annealing and distribution of dopant concentration in space and time. We approximate dependences of considered coefficients of diffusions of dopant on considered parameters by relations, which were presented bellow[24-26].

$$D_C=D_L(x,y,z,T)\left[1+\xi\frac{C^\gamma(x,y,z,t)}{P^\gamma(x,y,z,T)}\right]\left[1+\varsigma_1\frac{V(x,y,z,t)}{V^*}+\varsigma_2\frac{V^2(x,y,z,t)}{(V^*)^2}\right],$$

$$D_S=D_{SL}(x,y,z,T)\left[1+\xi_S\frac{C^\gamma(x,y,z,t)}{P^\gamma(x,y,z,T)}\right]\left[1+\varsigma_1\frac{V(x,y,z,t)}{V^*}+\varsigma_2\frac{V^2(x,y,z,t)}{(V^*)^2}\right] \quad (2)$$

Functions $D_L(x,y,z,T)$ and $D_{LS}(x,y,z,T)$ describe dependences of dopant diffusion coefficients the spatial coordinates and temperature of annealing; parameter T describes annealing temperature; function P(x,y,z,T) describes dependence of the limit of solubility of dopant the spatial coordinates and temperature of annealing; parameter γ depends on properties of

materials framework considered heterostructure and is integer $\gamma \in [1,3]$ [24]; distribution of radiation vacancies concentration with the equilibrium distribution V^* described by function V (x,y,z,t). Dependence of diffusion coefficient of dopant on dopant's concentration was described in details[24]. Distributions of concentration of point radiation defects in space and time were calculated as solution of the following system of equations (the first, the second and the third terms describe volumetric diffusion of considered defects in directions, which correspond to spatial coordinates x, y and z; the fourth and the fifth terms describe generation simplest complexes of point defects and recombination of point defects, respectively; the six and the sevens terms describe surface diffusion of dopant in directions, which correspond to spatial coordinates x and y; the surface diffusion of dopant presents near interface between layers of heterostructure under influence of mismatch-induced stress)[20-23,25,26].

$$\frac{\partial I(x,y,z,t)}{\partial t} = \frac{\partial}{\partial x}\left[D_I(x,y,z,T)\frac{\partial I(x,y,z,t)}{\partial x}\right] + \frac{\partial}{\partial y}\left[D_I(x,y,z,T)\frac{\partial I(x,y,z,t)}{\partial y}\right] - k_{I,I}(x,y,z,T)\, I^2(x,y,z,t) +$$
$$+\frac{\partial}{\partial z}\left[D_I(x,y,z,T)\frac{\partial I(x,y,z,t)}{\partial z}\right] + \Omega\frac{\partial}{\partial x}\left[\frac{D_{IS}}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z} I(x,y,W,t)\,dW\right] - k_{I,V}(x,y,z,T)\, I(x,y,z,t)\, V(x,y,z,t) +$$
$$+\frac{\partial}{\partial x}\left[\frac{D_{IS}}{\bar{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right] + \frac{\partial}{\partial y}\left[\frac{D_{IS}}{\bar{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right] + \frac{\partial}{\partial z}\left[\frac{D_{IS}}{\bar{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right] \qquad (3)$$
$$\frac{\partial V(x,y,z,t)}{\partial t} = \frac{\partial}{\partial x}\left[D_V(x,y,z,T)\frac{\partial V(x,y,z,t)}{\partial x}\right] + \frac{\partial}{\partial y}\left[D_V(x,y,z,T)\frac{\partial V(x,y,z,t)}{\partial y}\right] - k_{V,V}(x,y,z,T)\, V^2(x,y,z,t) +$$
$$+\frac{\partial}{\partial z}\left[D_V(x,y,z,T)\frac{\partial V(x,y,z,t)}{\partial z}\right] + \Omega\frac{\partial}{\partial x}\left[\frac{D_{VS}}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z} V(x,y,W,t)\,dW\right] - k_{I,V}(x,y,z,T)\, I(x,y,z,t)\, V(x,y,z,t) +$$
$$+\frac{\partial}{\partial x}\left[\frac{D_{VS}}{\bar{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right] + \frac{\partial}{\partial y}\left[\frac{D_{VS}}{\bar{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right] + \frac{\partial}{\partial z}\left[\frac{D_{VS}}{\bar{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]$$

with boundary and initial conditions

$$\left.\frac{\partial I(x,y,z,t)}{\partial x}\right|_{x=0} = 0,\ \left.\frac{\partial I(x,y,z,t)}{\partial x}\right|_{x=L_x} = 0,\ \left.\frac{\partial I(x,y,z,t)}{\partial y}\right|_{y=0} = 0,\ \left.\frac{\partial I(x,y,z,t)}{\partial y}\right|_{y=L_y} = 0,\ \left.\frac{\partial I(x,y,z,t)}{\partial z}\right|_{z=0} = 0,$$
$$\left.\frac{\partial I(x,y,z,t)}{\partial z}\right|_{z=L_z} = 0,\ \left.\frac{\partial V(x,y,z,t)}{\partial x}\right|_{x=0} = 0,\ \left.\frac{\partial V(x,y,z,t)}{\partial x}\right|_{x=L_x} = 0,\ \left.\frac{\partial V(x,y,z,t)}{\partial y}\right|_{y=0} = 0,\ \left.\frac{\partial V(x,y,z,t)}{\partial y}\right|_{y=L_y} = 0,$$
$$\left.\frac{\partial V(x,y,z,t)}{\partial z}\right|_{z=0} = 0,\ \left.\frac{\partial V(x,y,z,t)}{\partial z}\right|_{z=L_z} = 0,\ V(x_1+V_nt, y_1+V_nt, z_1+V_nt, t) = V_\infty\left(1+\frac{2\ell\omega}{kT\sqrt{x_1^2+y_1^2+z_1^2}}\right), \qquad (4)$$

I (x,y,z,0) =f_I (x,y,z), V (x,y,z,0) =f_V (x,y,z).

Distribution of radiation interstitials concentration with the equilibrium distribution I^* described by function I (x,y,z,t); functions D_I(x,y,z,T), D_V(x,y,z,T), D_{IS}(x,y,z,T), D_{VS}(x,y,z,T) describe dependences of coefficients of volumetric and surface diffusions of interstitials and vacancies on spatial coordinates and temperature; quadric terms V^2(x,y,z,t) and I^2(x,y,z,t) of Equation (3) gives a possibility to take into account generation of diinterstitials and divacancies, respectively[26]; functions $k_{I,V}$(x,y,z,T), $k_{I,I}$(x,y,z,T) and $k_{V,V}$(x,y,z,T) describe dependences of recombination parameters of radiation point defects and of their simplest complexes generation on spatial coordinates and temperature; parameter ω is equal to the third degree of the interatomic distance a; parameter ℓ describes the specific energy of surface. To take into account porosity of material of the considered buffer layers we consider approximately cylindrical porous with average size $r=\sqrt{x_1^2+y_1^2}$ and z_1 before starting of annealing[23]. Small pores decomposing on several vacancies during annealing. The obtained vacancies absorbing by pores with larger size[27]. In this situation volume of large

pores increases by absorbing of the considered vacancies and at the same time became more spherical[27]. Distribution of vacancies concentration in a heterostructure, which existing due to considered porosity, could be determined as a sum on all pores:

$$V(x,y,z,t)=\sum_{i=0}^{l}\sum_{j=0}^{m}\sum_{k=0}^{n}V_p(x+i\alpha,y+j\beta,z+k\chi,t),\ R=\sqrt{x^2+y^2+z^2}\ .$$

Parameters α, β and χ describe the averaged distances between centers of considered pores in all directions, which correspond to spatial coordinates x, y and z, respectively; parameters l, m and n describe quantities of pores in the considered directions.
Distributions of concentrations of diinterstitials $\Phi_I(x,y,z,t)$ and divacancies $\Phi_V(x,y,z,t)$ will be calculated as solution of equations, which are presented bellow[25,26].

$$\begin{aligned}
&\frac{\partial\Phi_I(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial\Phi_I(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial\Phi_I(x,y,z,t)}{\partial y}\right]+k_{I,I}(x,y,z,T)I^2(x,y,z,t)+\\
&+\frac{\partial}{\partial z}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial\Phi_I(x,y,z,t)}{\partial z}\right]+k_I(x,y,z,T)I(x,y,z,t)+\Omega\frac{\partial}{\partial x}\left[\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_I(x,y,W,t)dW\right]+\\
&+\Omega\frac{\partial}{\partial y}\left[\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_I(x,y,W,t)dW\right]+\frac{\partial}{\partial x}\left[\frac{D_{\Phi_I S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{\Phi_I S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\\
&+\frac{\partial}{\partial z}\left[\frac{D_{\Phi_I S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right] \qquad (5)\\
&\frac{\partial\Phi_V(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_V}(x,y,z,T)\frac{\partial\Phi_V(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_{\Phi_V}(x,y,z,T)\frac{\partial\Phi_V(x,y,z,t)}{\partial y}\right]+k_{V,V}(x,y,z,T)V^2(x,y,z,t)+\\
&+\frac{\partial}{\partial z}\left[D_{\Phi_V}(x,y,z,T)\frac{\partial\Phi_V(x,y,z,t)}{\partial z}\right]+k_V(x,y,z,T)V(x,y,z,t)+\Omega\frac{\partial}{\partial x}\left[\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_V(x,y,W,t)dW\right]+\\
&+\Omega\frac{\partial}{\partial y}\left[\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_V(x,y,W,t)dW\right]+\frac{\partial}{\partial x}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\\
&+\frac{\partial}{\partial z}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]
\end{aligned}$$

with initial condition and boundary conditions

$$\left.\frac{\partial\Phi_I(x,y,z,t)}{\partial x}\right|_{x=0}=0,\ \left.\frac{\partial I(x,y,z,t)}{\partial x}\right|_{x=L_x}=0,\ \left.\frac{\partial I(x,y,z,t)}{\partial y}\right|_{y=0}=0,\ \left.\frac{\partial I(x,y,z,t)}{\partial y}\right|_{y=L_y}=0,\ \left.\frac{\partial\Phi_I(x,y,z,t)}{\partial z}\right|_{z=0}=0,$$

$$\left.\frac{\partial I(x,y,z,t)}{\partial z}\right|_{z=L_z}=0,\ \left.\frac{\partial\Phi_V(x,y,z,t)}{\partial x}\right|_{x=0}=0,\ \left.\frac{\partial V(x,y,z,t)}{\partial x}\right|_{x=L_x}=0,\ \left.\frac{\partial V(x,y,z,t)}{\partial y}\right|_{y=0}=0,\ \left.\frac{\partial V(x,y,z,t)}{\partial y}\right|_{y=L_y}=0,$$

$$\left.\frac{\partial V(x,y,z,t)}{\partial z}\right|_{z=0}=0,\ \left.\frac{\partial\Phi_V(x,y,z,t)}{\partial z}\right|_{z=L_z}=0,\ \Phi_I(x,y,z,0)=f_{\Phi I}(x,y,z),\ \Phi_V(x,y,z,0)=f_{\Phi V}(x,y,z). \qquad (6)$$

Dependences $D_{\Phi I}(x,y,z,T)$, $D_{\Phi V}(x,y,z,T)$, $D_{\Phi IS}(x,y,z,T)$ and $D_{\Phi VS}(x,y,z,T)$ describe surficial and volumetric diffusion coefficients of simplest radiation defects complexes on spatial coordinates and temperature. Dependences $k_I(x,y,z, T)$ and $k_V(x,y,z,T)$ describe dependences of the parameters of decay of simplest complexes of radiation defects on coordinates and temperature. Function μ in Equation (1) describes chemical potential. The function could be written as 20

$$\mu = E(z)\Omega\sigma_{ij}\,[u_{ij}(x,y,z,t)+u_{ji}(x,y,z,t)]/2. \qquad (7)$$

Here function $E(z)$ describes dependences of Young modulus on coordinate; value σ_{ij} describes stress tensor; value $u_{ij}=\frac{1}{2}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)$ describes deformation tensor; describe u_i, u_j describes dependences of components $u_x(x,y,z,t)$, $u_y(x,y,z,t)$ and $u_z(x,y,z,t)$ of the displacement vector $\vec{u}(x,y,z,t)$ on coordinates and time; parameters x_i, x_j describe coordinate x, y, z. The Equation (7) could be transform to the following form

$$\mu(x,y,z,t)=\frac{1}{2}\left[\frac{\partial u_i(x,y,z,t)}{\partial x_j}+\frac{\partial u_j(x,y,z,t)}{\partial x_i}\right]\left\{\frac{1}{2}\left[\frac{\partial u_i(x,y,z,t)}{\partial x_j}+\frac{\partial u_j(x,y,z,t)}{\partial x_i}\right]+\frac{\sigma(z)\delta_{ij}}{1-2\sigma(z)}\left[\frac{\partial u_k(x,y,z,t)}{\partial x_k}-3\varepsilon_0\right]-\right.$$
$$\left.-\varepsilon_0\delta_{ij}-K(z)\beta(z)\left[T(x,y,z,t)-T_0\right]\delta_{ij}\right\}\Omega E(z).$$

Here parameter σ describes coefficient of Poisson; parameter $\varepsilon_0=(a_s-a_{EL})/a_{EL}$ describes mismatch parameter; parameters a_{EL} and a_s describe lattice distances of the considered epitaxial layer and substrate; parameter K describes uniform compression modulus; parameter β describes thermal expansion coefficient; parameter T_r describes temperature of the equilibrium state. The temperature coincide with room temperature for our case. Components of the considered displacement vector could be calculated as solution of the next systems of equations[21]

$$\begin{cases}\rho(z)\dfrac{\partial^2 u_x(x,y,z,t)}{\partial t^2}=\dfrac{\partial\sigma_{xx}(x,y,z,t)}{\partial x}+\dfrac{\partial\sigma_{xy}(x,y,z,t)}{\partial y}+\dfrac{\partial\sigma_{xz}(x,y,z,t)}{\partial z}\\ \rho(z)\dfrac{\partial^2 u_y(x,y,z,t)}{\partial t^2}=\dfrac{\partial\sigma_{yx}(x,y,z,t)}{\partial x}+\dfrac{\partial\sigma_{yy}(x,y,z,t)}{\partial y}+\dfrac{\partial\sigma_{yz}(x,y,z,t)}{\partial z}\\ \rho(z)\dfrac{\partial^2 u_z(x,y,z,t)}{\partial t^2}=\dfrac{\partial\sigma_{zx}(x,y,z,t)}{\partial x}+\dfrac{\partial\sigma_{zy}(x,y,z,t)}{\partial y}+\dfrac{\partial\sigma_{zz}(x,y,z,t)}{\partial z}\end{cases}$$

Here $\sigma_{ij}=\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial u_i(x,y,z,t)}{\partial x_j}+\frac{\partial u_j(x,y,z,t)}{\partial x_i}-\frac{\delta_{ij}}{3}\frac{\partial u_k(x,y,z,t)}{\partial x_k}\right]+K(z)\delta_{ij}\times\frac{\partial u_k(x,y,z,t)}{\partial x_k}-\beta(z)\left[T(x,y,z,t)-T_r\right]\times\quad\times K(z).$

Function $\rho(z)$ describes spatial distribution of density of materials of the considered heterostructure; parameter δ_{ij} describes the symbol of Kronecker. Account of the relation for σ_{ij} the previous system of equation could be considered in the present form

$$\rho(z)\frac{\partial^2 u_x(x,y,z,t)}{\partial t^2}=\left\{K(z)+\frac{5E(z)}{6[1+\sigma(z)]}\right\}\frac{\partial^2 u_x(x,y,z,t)}{\partial x^2}+\left\{K(z)-\frac{E(z)}{3[1+\sigma(z)]}\right\}\frac{\partial^2 u_y(x,y,z,t)}{\partial x\partial y}+\frac{E(z)}{2[1+\sigma(z)]}\times$$
$$\times\left[\frac{\partial^2 u_y(x,y,z,t)}{\partial y^2}+\frac{\partial^2 u_z(x,y,z,t)}{\partial z^2}\right]+\left\{K(z)-\frac{E(z)}{3[1+\sigma(z)]}\right\}\frac{\partial^2 u_z(x,y,z,t)}{\partial x\partial z}-K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial x}$$
$$\rho(z)\frac{\partial^2 u_y(x,y,z,t)}{\partial t^2}=\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial^2 u_y(x,y,z,t)}{\partial x^2}+\frac{\partial^2 u_x(x,y,z,t)}{\partial x\partial y}\right]-K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial y}+K(z)\frac{\partial^2 u_y(x,y,z,t)}{\partial x\partial y}+$$
$$+\frac{\partial}{\partial z}\left\{\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial u_y(x,y,z,t)}{\partial z}+\frac{\partial u_z(x,y,z,t)}{\partial y}\right]\right\}+\left\{K(z)-\frac{E(z)}{6[1+\sigma(z)]}\right\}\frac{\partial^2 u_y(x,y,z,t)}{\partial y\partial z}+\frac{\partial^2 u_y(x,y,z,t)}{\partial y^2}\times \quad (8)$$
$$\times\left\{\frac{5E(z)}{12[1+\sigma(z)]}+K(z)\right\}$$
$$\rho(z)\frac{\partial^2 u_z(x,y,z,t)}{\partial t^2}=\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial^2 u_z(x,y,z,t)}{\partial x^2}+\frac{\partial^2 u_z(x,y,z,t)}{\partial y^2}+\frac{\partial^2 u_x(x,y,z,t)}{\partial x\partial z}+\frac{\partial^2 u_y(x,y,z,t)}{\partial y\partial z}\right]+$$
$$+\frac{\partial}{\partial z}\left\{K(z)\left[\frac{\partial u_x(x,y,z,t)}{\partial x}+\frac{\partial u_y(x,y,z,t)}{\partial y}+\frac{\partial u_x(x,y,z,t)}{\partial z}\right]\right\}-K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial z}+$$

$$+\frac{1}{6}\frac{\partial}{\partial z}\left\{\frac{E(z)}{1+\sigma(z)}\left[6\frac{\partial u_z(x,y,z,t)}{\partial z}-\frac{\partial u_x(x,y,z,t)}{\partial x}-\frac{\partial u_y(x,y,z,t)}{\partial y}-\frac{\partial u_z(x,y,z,t)}{\partial z}\right]\right\}.$$

Conditions for the obtained system of Equation (8) could be written as

$$\left.\frac{\partial \vec{u}(x,y,z,t)}{\partial x}\right|_{x=0}=0;\ \left.\frac{\partial \vec{u}(x,y,z,t)}{\partial x}\right|_{x=L_x}=0;\ \left.\frac{\partial \vec{u}(x,y,z,t)}{\partial y}\right|_{y=0}=0;\ \left.\frac{\partial \vec{u}(x,y,z,t)}{\partial y}\right|_{x=L_y}=0;$$

$$\left.\frac{\partial \vec{u}(x,y,z,t)}{\partial z}\right|_{z=0}=0;\ \left.\frac{\partial \vec{u}(x,y,z,t)}{\partial z}\right|_{z=L_z}=0;\ \vec{u}(x,y,z,0)=\vec{u}_0;\ \vec{u}(x,y,z,\infty)=\vec{u}_0.$$

We calculate distributions of dopant and radiation defects concentrations in time and space as solution of the considered Equation (1), Equation (3) and Equation (5) by using standard method of function corrections averaging[28]. Before solving of the considered equations let us transform them to the following forms

$$\frac{\partial C(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D\frac{\partial C(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D\frac{\partial C(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D\frac{\partial C(x,y,z,t)}{\partial z}\right]+\frac{\partial}{\partial x}\left[\frac{D_{CS}}{\bar{V}kT}\frac{\partial \mu_2(x,y,z,t)}{\partial x}\right]+ \quad (1a)$$

$$+\frac{\partial}{\partial y}\left[\frac{D_{CS}}{\bar{V}kT}\frac{\partial \mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{CS}}{\bar{V}kT}\frac{\partial \mu_2(x,y,z,t)}{\partial z}\right]+\Omega\frac{\partial}{\partial x}\left[\frac{D_S}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z}C(x,y,W,t)\,dW\right]+$$

$$+\Omega\frac{\partial}{\partial y}\left[\frac{D_S}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z}C(x,y,W,t)\,dW\right]+f_c(x,y,z)\delta(t)$$

$$\frac{\partial I(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_I(x,y,z,T)\frac{\partial I(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_I(x,y,z,T)\frac{\partial I(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_I(x,y,z,T)\frac{\partial I(x,y,z,t)}{\partial z}\right]+$$

$$+\Omega\frac{\partial}{\partial x}\left[\frac{D_{IS}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}I(x,y,W,t)\,dW\right]+\Omega\frac{\partial}{\partial y}\left[\frac{D_{IS}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}I(x,y,W,t)\,dW\right]+f_I(x,y,z)\delta(t)-$$

$$-k_{I,I}(x,y,z,T)I^2(x,y,z,t)-k_{I,V}(x,y,z,T)I(x,y,z,t)V(x,y,z,t)+f_I(x,y,z)\delta(t) \quad (3a)$$

$$\frac{\partial V(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_V(x,y,z,T)\frac{\partial V(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_V(x,y,z,T)\frac{\partial V(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_V(x,y,z,T)\frac{\partial V(x,y,z,t)}{\partial z}\right]+$$

$$+\Omega\frac{\partial}{\partial x}\left[\frac{D_{VS}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}V(x,y,W,t)\,dW\right]+\Omega\frac{\partial}{\partial y}\left[\frac{D_{VS}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}V(x,y,W,t)\,dW\right]+f_V(x,y,z)\delta(t)-$$

$$-k_{V,V}(x,y,z,T)V^2(x,y,z,t)-k_{I,V}(x,y,z,T)I(x,y,z,t)V(x,y,z,t)+f_V(x,y,z)\delta(t)$$

$$\frac{\partial \Phi_I(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial \Phi_I(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial \Phi_I(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial \Phi_I(x,y,z,t)}{\partial z}\right]+$$

$$+\Omega\frac{\partial}{\partial x}\left[\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_I(x,y,W,t)dW\right]+\Omega\frac{\partial}{\partial y}\left[\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_I(x,y,W,t)dW\right]+f_{\Phi_I}(x,y,z)\delta(t)+$$

$$+\frac{\partial}{\partial x}\left[\frac{D_{\Phi_I S}}{\bar{V}kT}\frac{\partial \mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{\Phi_I S}}{\bar{V}kT}\frac{\partial \mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{\Phi_I S}}{\bar{V}kT}\frac{\partial \mu_2(x,y,z,t)}{\partial z}\right]+k_I(x,y,z,T)I(x,y,z,t)+$$

$$+k_{I,I}(x,y,z,T)I^2(x,y,z,t) \quad (5a)$$

$$\frac{\partial \Phi_V(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_V}(x,y,z,T)\frac{\partial \Phi_V(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_{\Phi_V}(x,y,z,T)\frac{\partial \Phi_V(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_{\Phi_V}(x,y,z,T)\frac{\partial \Phi_V(x,y,z,t)}{\partial z}\right]+$$

$$+\Omega\frac{\partial}{\partial x}\left[\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_V(x,y,W,t)\,dW\right]+\Omega\frac{\partial}{\partial y}\left[\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}\Phi_V(x,y,W,t)\,dW\right]+f_{\Phi_V}(x,y,z)\,\delta(t)+$$

$$+\frac{\partial}{\partial x}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]+k_V(x,y,z,T)V(x,y,z,t)+$$
$$+k_{V,V}(x,y,z,T)V^2(x,y,z,t).$$

Using these forms gives a possibility to account distributions of the required concentrations at initial moment of time. Now let us replace the considered concentrations in right sides of the above Equation (1*a*), Equation (3*a*) and Equation (5*a*) on their average values $\alpha_{1\rho}$, which are not yet known. The replacement gives a possibility to obtain equations to determine the first-order approximations of the considered concentrations

$$\frac{\partial C_1(x,y,z,t)}{\partial t}=\alpha_{1C}\Omega\frac{\partial}{\partial x}\left[z\frac{D_S}{kT}\nabla_S\mu_1(x,y,z,t)\right]+\alpha_{1C}\Omega\frac{\partial}{\partial y}\left[z\frac{D_S}{kT}\nabla_S\mu_1(x,y,z,t)\right]+f_C(x,y,z)\delta(t)+$$
$$+\frac{\partial}{\partial x}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right] \quad (1b)$$

$$\frac{\partial I_1(x,y,z,t)}{\partial t}=\alpha_{1I}z\Omega\frac{\partial}{\partial x}\left[\frac{D_{IS}}{kT}\nabla_S\mu(x,y,z,t)\right]+\alpha_{1I}\Omega\frac{\partial}{\partial y}\left[z\frac{D_{IS}}{kT}\nabla_S\mu(x,y,z,t)\right]-\alpha_{1I}\alpha_{1V}k_{I,V}(x,y,z,T)+f_I(x,y,z)\delta(t)+$$
$$+\frac{\partial}{\partial x}\left[\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]-\alpha_{1I}^2k_{I,I}(x,y,z,T) \quad (3b)$$

$$\frac{\partial V_1(x,y,z,t)}{\partial t}=\alpha_{1V}z\Omega\frac{\partial}{\partial x}\left[\frac{D_{VS}}{kT}\nabla_S\mu(x,y,z,t)\right]+\alpha_{1V}\Omega\frac{\partial}{\partial y}\left[z\frac{D_{VS}}{kT}\nabla_S\mu(x,y,z,t)\right]-\alpha_{1I}\alpha_{1V}k_{I,V}(x,y,z,T)+f_V(x,y,z)\times$$
$$\times f_V(x,y,z)+\frac{\partial}{\partial x}\left[\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]-\alpha_{1V}^2k_{V,V}(x,y,z,T)$$

$$\frac{\partial\Phi_{1I}(x,y,z,t)}{\partial t}=\alpha_{1\Phi_I}z\Omega\frac{\partial}{\partial x}\left[\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,t)\right]+\alpha_{1\Phi_I}z\Omega\frac{\partial}{\partial y}\left[\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,t)\right]+\frac{\partial}{\partial x}\left[\frac{D_{\Phi_I S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+$$
$$+\frac{\partial}{\partial y}\left[\frac{D_{\Phi_I S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{\Phi_I S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]+k_I(x,y,z,T)I(x,y,z,t)+k_{I,I}(x,y,z,T)I^2(x,y,z,t)+$$
$$+f_{\Phi_I}(x,y,z)\delta(t) \quad (5b)$$

$$\frac{\partial\Phi_{1V}(x,y,z,t)}{\partial t}=\alpha_{1\Phi_V}z\Omega\frac{\partial}{\partial x}\left[\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,t)\right]+\alpha_{1\Phi_V}z\Omega\frac{\partial}{\partial y}\left[\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,t)\right]+\frac{\partial}{\partial x}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+$$
$$+\frac{\partial}{\partial y}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{\Phi_V S}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]+k_V(x,y,z,T)V(x,y,z,t)+k_{V,V}(x,y,z,T)V^2(x,y,z,t)+$$
$$+f_{\Phi_V}(x,y,z)\delta(t).$$

Now let us integrate left side and side right of Equation (1*b*), Equation (3*b*) and Equation (5*b*) on time gives. The integration gives us possibility to obtain equations to determine the considered approximation in the next form

$$C_1(x,y,z,t)=\alpha_{1C}\Omega\frac{\partial}{\partial x}\int_0^t D_{SL}(x,y,z,T)\frac{z}{kT}\left[1+\frac{\xi_S\alpha_{1C}^\gamma}{P^\gamma(x,y,z,T)}\right]\left[1+\varsigma_1\frac{V(x,y,z,\tau)}{V^*}+\varsigma_2\frac{V^2(x,y,z,\tau)}{(V^*)^2}\right]\nabla_S\mu_1(x,y,z,\tau)\,d\tau+$$
$$+\alpha_{1C}\Omega\frac{\partial}{\partial y}\int_0^t D_{SL}(x,y,z,T)\frac{z}{kT}\left[1+\frac{\xi_S\alpha_{1C}^\gamma}{P^\gamma(x,y,z,T)}\right]\left[1+\varsigma_1\frac{V(x,y,z,\tau)}{V^*}+\varsigma_2\frac{V^2(x,y,z,\tau)}{(V^*)^2}\right]\nabla_S\mu_1(x,y,z,\tau)\,d\tau+\frac{\partial}{\partial x}\int_0^t\frac{D_{CS}}{\overline{V}kT}\times$$
$$\times\frac{\partial\mu_2(x,y,z,\tau)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial z}d\tau+f_C(x,y,z) \quad (1c)$$

$$I_1(x,y,z,t)=\alpha_{1I}z\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{IS}}{kT}\nabla_S\mu_1(x,y,z,\tau)d\tau+\alpha_{1I}z\Omega\frac{\partial}{\partial y}\int_0^t\frac{D_{IS}}{kT}\nabla_S\mu_1(x,y,z,\tau)\,d\tau+\frac{\partial}{\partial x}\int_0^t\frac{D_{IS}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}d\tau+$$
$$+\frac{\partial}{\partial y}\int_0^t\frac{D_{IS}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{IS}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}d\tau-\alpha_{1I}^2\int_0^t k_{I,I}(x,y,z,T)d\tau-\alpha_{1I}\alpha_{1V}\int_0^t k_{I,V}(x,y,z,T)\,d\tau+$$
$$+f_I(x,y,z) \qquad (3c)$$

$$V_1(x,y,z,t)=\alpha_{1V}z\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{VS}}{kT}\nabla_S\mu_1(x,y,z,\tau)d\tau+\alpha_{1V}z\Omega\frac{\partial}{\partial y}\int_0^t\frac{D_{VS}}{kT}\nabla_S\mu_1(x,y,z,\tau)\,d\tau+\frac{\partial}{\partial x}\int_0^t\frac{D_{VS}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}d\tau+$$
$$+\frac{\partial}{\partial y}\int_0^t\frac{D_{VS}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{VS}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}d\tau-\alpha_{1V}^2\int_0^t k_{V,V}(x,y,z,T)d\tau-\alpha_{1I}\alpha_{1V}\int_0^t k_{I,V}(x,y,z,T)\,d\tau+$$
$$+f_V(x,y,z)$$

$$\Phi_{1I}(x,y,z,t)=\alpha_{1\Phi_I}z\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,\tau)\,d\tau+\alpha_{1\Phi_I}z\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{\Phi_I S}}{kT}\nabla_S\mu_1(x,y,z,\tau)\,d\tau+f_{\Phi_I}(x,y,z)+$$
$$+\frac{\partial}{\partial x}\int_0^t\frac{D_{\Phi_I S}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t\frac{D_{\Phi_I S}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{\Phi_I S}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial z}d\tau+\int_0^t k_I(x,y,z,T)I(x,y,z,\tau)\,d\tau+$$
$$+\int_0^t k_{I,I}(x,y,z,T)I^2(x,y,z,\tau)d\tau+f_{\Phi_I}(x,y,z) \qquad (5c)$$

$$\Phi_{1V}(x,y,z,t)=\alpha_{1\Phi_V}z\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,\tau)\,d\tau+\alpha_{1\Phi_V}z\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{\Phi_V S}}{kT}\nabla_S\mu_1(x,y,z,\tau)\,d\tau+f_{\Phi_V}(x,y,z)+$$
$$+\frac{\partial}{\partial x}\int_0^t\frac{D_{\Phi_V S}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t\frac{D_{\Phi_V S}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{\Phi_V S}}{\overline{V}\,kT}\frac{\partial\mu_2(x,y,z,\tau)}{\partial z}d\tau+\int_0^t k_V(x,y,z,T)V(x,y,z,\tau)\,d\tau+$$
$$+\int_0^t k_{V,V}(x,y,z,T)V^2(x,y,z,\tau)d\tau+f_{\Phi_V}(x,y,z).$$

Considered averaged values of the above approximations of radiation defects and dopant concentrations were calculated by the next standard formula[28]

$$\alpha_{1\rho}=\frac{1}{\Theta L_xL_yL_z}\int_0^\Theta\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}\rho_1(x,y,z,t)d\,z\,d\,y\,d\,x\,d\,t\,. \qquad (9)$$

Accounting of the above relation (1*c*), relation (3*c*) and relation (5*c*) into the relation (9) leads to the next results

$$\alpha_{1C}=\frac{1}{L_xL_yL_z}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_C(x,y,z)d\,z\,d\,y\,d\,x\,,\ \alpha_{1I}=\sqrt{\frac{(a_3+A)^2}{4a_4^2}-4\left(B+\frac{\Theta a_3B+\Theta^2L_xL_yL_za_1}{a_4}\right)}-\frac{a_3+A}{4a_4}\,,$$
$$\alpha_{1V}=\frac{1}{S_{IV00}}\left[\frac{\Theta}{\alpha_{1I}}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_I(x,y,z)\,d\,z\,d\,y\,d\,x-\alpha_{1I}S_{II00}-\Theta L_xL_yL_z\right].$$

Here $S_{\rho\rho\,ij}=\int_0^\Theta(\Theta-t)\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}k_{\rho,\rho}(x,y,z,T)I_1^i(x,y,z,t)V_1^j(x,y,z,t)d\,z\,d\,y\,d\,x\,d\,t$, $a_4=S_{II00}\left(S_{IV00}^2-S_{II00}S_{VV00}\right)$, $a_3=S_{IV00}^2+$ $+S_{IV00}S_{II00}-S_{II00}S_{VV00}$, $a_2=S_{IV00}S_{IV00}^2\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_V(x,y,z)d\,z\,d\,y\,d\,x+2S_{VV00}S_{II00}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_I(x,y,z)\,d\,z\,d\,y\,d\,x+S_{IV00}\Theta L_x^2\times$ $\times L_y^2L_z^2-\Theta L_x^2L_y^2L_z^2S_{VV00}-S_{IV00}^2\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_I(x,y,z)d\,z\,d\,y\,d\,x$, $a_1=S_{IV00}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_I(x,y,z)d\,z\,d\,y\,d\,x$, $A=\sqrt{8y+\Theta^2\frac{a_3^2}{a_4^2}-4\Theta\frac{a_2}{a_4}}$,

$a_0=S_{VV00}\left[\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_I(x,y,z)d\,z\,d\,y\,d\,x\right]^2$, $B=\frac{\Theta a_2}{6a_4}+\sqrt[3]{\sqrt{q^2+p^3}-q}-\sqrt[3]{\sqrt{q^2+p^3}+q}$, $q=\frac{\Theta^3a_2}{24a_4^2}\left(4a_0-\Theta L_xL_yL_z\frac{a_1a_3}{a_4}\right)-$

$$-\frac{a_0\Theta^2}{8a_4^2}\left(4\Theta a_2-\Theta^2\frac{a_3^2}{a_4}\right)-\frac{\Theta^3 a_2^3}{54a_4^3}-L_x^2L_y^2L_z^2\frac{\Theta^4 a_1^2}{8a_4^2},\ \ p=\Theta^2\frac{4a_0a_4-\Theta L_xL_yL_za_1a_3}{12a_4^2}-\frac{\Theta a_2}{18a_4},$$

$$\alpha_{1\Phi_I}=\frac{R_{I1}}{\Theta L_xL_yL_z}+\frac{S_{II20}}{\Theta L_xL_yL_z}+\frac{1}{L_xL_yL_z}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_{\Phi_I}(x,y,z)\,dz\,dy\,dx,$$

$$\alpha_{1\Phi_V}=\frac{R_{V1}}{\Theta L_xL_yL_z}+\frac{S_{VV20}}{\Theta L_xL_yL_z}+\frac{1}{L_xL_yL_z}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}f_{\Phi_V}(x,y,z)\,dz\,dy\,dx.$$

Here $R_{\rho i}=\int_0^{\Theta}(\Theta-t)\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}k_I(x,y,z,T)I_1^i(x,y,z,t)\,dz\,dy\,dx\,dt$.

Now we calculate approximations with the second and higher orders of the considered concentrations by using recently considered iterative procedure of the above approach of function corrections averaging[28]. Based on the procedure we calculate approximations with the *n*-th order of the above concentrations by replacement of the considered concentrations in the Eq. (1*c*), Eq. (3*c*), Eq. (5*c*) on the standard sum $\alpha_{n\rho}+\rho_{n-1}(x,y,z,t)$. This replacement gives a possibility to obtain equations for calculations of the approximations with the second-order of radiation defects and dopant concentrations in the following form

$$\frac{\partial C_2(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left(D_L(x,y,z,T)\left\{1+\xi\frac{[\alpha_{2C}+C_1(x,y,z,t)]^\gamma}{P^\gamma(x,y,z,T)}\right\}\left[1+\varsigma_1\frac{V(x,y,z,t)}{V^*}+\varsigma_2\frac{V^2(x,y,z,t)}{(V^*)^2}\right]\frac{\partial C_1(x,y,z,t)}{\partial x}\right)+$$
$$+\frac{\partial}{\partial y}\left(D_L(x,y,z,T)\left\{1+\xi\frac{[\alpha_{2C}+C_1(x,y,z,t)]^\gamma}{P^\gamma(x,y,z,T)}\right\}\left[1+\varsigma_1\frac{V(x,y,z,t)}{V^*}+\varsigma_2\frac{V^2(x,y,z,t)}{(V^*)^2}\right]\frac{\partial C_1(x,y,z,t)}{\partial y}\right)+$$
$$+\frac{\partial}{\partial z}\left(D_L(x,y,z,T)\left\{1+\xi\frac{[\alpha_{2C}+C_1(x,y,z,t)]^\gamma}{P^\gamma(x,y,z,T)}\right\}\left[1+\varsigma_1\frac{V(x,y,z,t)}{V^*}+\varsigma_2\frac{V^2(x,y,z,t)}{(V^*)^2}\right]\frac{\partial C_1(x,y,z,t)}{\partial z}\right)+f_C(x,y,z)\delta(t)+$$
$$+\frac{\partial}{\partial x}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}\right]+$$
$$+\Omega\frac{\partial}{\partial x}\left\{\frac{D_S}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}[\alpha_{2C}+C(x,y,W,t)]\,dW\right\}+\Omega\frac{\partial}{\partial y}\left\{\frac{D_S}{kT}\nabla_S\mu_1(x,y,z,t)\int_0^{L_z}[\alpha_{2C}+C(x,y,W,t)]\,dW\right\}\quad(1d)$$

$$\frac{\partial I_2(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_I(x,y,z,T)\frac{\partial I_1(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_I(x,y,z,T)\frac{\partial I_1(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_I(x,y,z,T)\frac{\partial I_1(x,y,z,t)}{\partial z}\right]-$$
$$-k_{I,I}(x,y,z,T)[\alpha_{1I}+I_1(x,y,z,t)]^2-k_{I,V}(x,y,z,T)[\alpha_{1I}+I_1(x,y,z,t)][\alpha_{1V}+V_1(x,y,z,t)]+$$
$$+\Omega\frac{\partial}{\partial x}\left\{\frac{D_{IS}}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z}[\alpha_{2I}+I_1(x,y,W,t)]\,dW\right\}+\Omega\frac{\partial}{\partial y}\left\{\frac{D_{IS}}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z}[\alpha_{2I}+I_1(x,y,W,t)]\,dW\right\}+$$
$$+\frac{\partial}{\partial x}\int_0^t\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}d\tau\quad(3d)$$

$$\frac{\partial V_2(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_V(x,y,z,T)\frac{\partial V_1(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_V(x,y,z,T)\frac{\partial V_1(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_V(x,y,z,T)\frac{\partial V_1(x,y,z,t)}{\partial z}\right]-$$
$$-k_{V,V}(x,y,z,T)[\alpha_{1V}+V_1(x,y,z,t)]^2-k_{I,V}(x,y,z,T)[\alpha_{1I}+I_1(x,y,z,t)][\alpha_{1V}+V_1(x,y,z,t)]+$$
$$+\Omega\frac{\partial}{\partial x}\left\{\frac{D_{VS}}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z}[\alpha_{2V}+V_1(x,y,W,t)]\,dW\right\}+\Omega\frac{\partial}{\partial y}\left\{\frac{D_{VS}}{kT}\nabla_S\mu(x,y,z,t)\int_0^{L_z}[\alpha_{2V}+V_1(x,y,W,t)]\,dW\right\}+$$
$$+\frac{\partial}{\partial x}\int_0^t\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2(x,y,z,t)}{\partial z}d\tau$$

$$\frac{\partial\Phi_{2I}(x,y,z,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial\Phi_{1I}(x,y,z,t)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial\Phi_{1I}(x,y,z,t)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_{\Phi_I}(x,y,z,T)\frac{\partial\Phi_{1I}(x,y,z,t)}{\partial z}\right]+$$

$$+\Omega\frac{\partial}{\partial x}\left\{\frac{D_{\Phi_I S}}{kT}\nabla_S\mu\left(x,y,z,t\right)\int_0^{L_z}\left[\alpha_{2\Phi_I}+\Phi_{1I}\left(x,y,W,t\right)\right]dW\right\}+\Omega\frac{\partial}{\partial y}\left\{\frac{D_{\Phi_I S}}{kT}\nabla_S\mu\left(x,y,z,t\right)\int_0^{L_z}\left[\alpha_{2\Phi_I}+\Phi_{1I}\left(x,y,W,t\right)\right]dW\right\}+$$

$$+k_{I,I}\left(x,y,z,T\right)I^2\left(x,y,z,t\right)+k_I\left(x,y,z,T\right)I\left(x,y,z,t\right)+f_{\Phi_I}\left(x,y,z\right)\delta\left(t\right) \qquad (5d)$$

$$\frac{\partial\Phi_{2V}\left(x,y,z,t\right)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_V}\left(x,y,z,T\right)\frac{\partial\Phi_{1V}\left(x,y,z,t\right)}{\partial x}\right]+\frac{\partial}{\partial y}\left[D_{\Phi_V}\left(x,y,z,T\right)\frac{\partial\Phi_{1V}\left(x,y,z,t\right)}{\partial y}\right]+\frac{\partial}{\partial z}\left[D_{\Phi_V}\left(x,y,z,T\right)\frac{\partial\Phi_{1V}\left(x,y,z,t\right)}{\partial z}\right]+$$

$$+\Omega\frac{\partial}{\partial x}\left\{\frac{D_{\Phi_V S}}{kT}\nabla_S\mu\left(x,y,z,t\right)\int_0^{L_z}\left[\alpha_{2\Phi_V}+\Phi_{1V}\left(x,y,W,t\right)\right]dW\right\}+\Omega\frac{\partial}{\partial y}\left\{\frac{D_{\Phi_V S}}{kT}\nabla_S\mu\left(x,y,z,t\right)\int_0^{L_z}\left[\alpha_{2\Phi_V}+\Phi_{1V}\left(x,y,W,t\right)\right]dW\right\}+$$

$$+k_{V,V}\left(x,y,z,T\right)V^2\left(x,y,z,t\right)+k_V\left(x,y,z,T\right)V\left(x,y,z,t\right)+f_{\Phi_V}\left(x,y,z\right)\delta\left(t\right).$$

Now we will integrate the left side and the right side of the above Eq. (1*d*), Eq. (3*d*) and Eq. (5*d*). The result of integration gives a possibility to calculate the approximations with the second-order of radiation defects and dopant concentrations in the next form

$$C_2\left(x,y,z,t\right)=\frac{\partial}{\partial x}\int_0^t D_L\left(x,y,z,T\right)\left\{1+\xi\frac{\left[\alpha_{2C}+C_1\left(x,y,z,\tau\right)\right]^\gamma}{P^\gamma\left(x,y,z,T\right)}\right\}\left[1+\varsigma_1\frac{V\left(x,y,z,\tau\right)}{V^*}+\varsigma_2\frac{V^2\left(x,y,z,\tau\right)}{\left(V^*\right)^2}\right]\frac{\partial C_1\left(x,y,z,\tau\right)}{\partial x}d\tau+$$

$$+\frac{\partial}{\partial y}\int_0^t D_L\left(x,y,z,T\right)\left\{1+\xi\frac{\left[\alpha_{2C}+C_1\left(x,y,z,\tau\right)\right]^\gamma}{P^\gamma\left(x,y,z,T\right)}\right\}\left[1+\varsigma_1\frac{V\left(x,y,z,\tau\right)}{V^*}+\varsigma_2\frac{V^2\left(x,y,z,\tau\right)}{\left(V^*\right)^2}\right]\frac{\partial C_1\left(x,y,z,\tau\right)}{\partial y}d\tau+$$

$$+\frac{\partial}{\partial z}\int_0^t D_L\left(x,y,z,T\right)\left\{1+\xi\frac{\left[\alpha_{2C}+C_1\left(x,y,z,\tau\right)\right]^\gamma}{P^\gamma\left(x,y,z,T\right)}\right\}\left[1+\varsigma_1\frac{V\left(x,y,z,\tau\right)}{V^*}+\varsigma_2\frac{V^2\left(x,y,z,\tau\right)}{\left(V^*\right)^2}\right]\frac{\partial C_1\left(x,y,z,\tau\right)}{\partial z}d\tau+f_C\left(x,y,z\right)+$$

$$+\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_S}{kT}\nabla_S\mu\left(x,y,z,\tau\right)\int_0^{L_z}\left[\alpha_{2C}+C_1\left(x,y,W,\tau\right)\right]dW\,d\tau+\Omega\frac{\partial}{\partial y}\int_0^t\frac{D_S}{kT}\nabla_S\mu\left(x,y,z,\tau\right)\int_0^{L_z}\left[\alpha_{2C}+C_1\left(x,y,W,\tau\right)\right]dW\,d\tau+$$

$$+\frac{\partial}{\partial x}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{CS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial z}\right] \qquad (1e)$$

$$I_2\left(x,y,z,t\right)=\frac{\partial}{\partial x}\int_0^t D_I\left(x,y,z,T\right)\frac{\partial I_1\left(x,y,z,\tau\right)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t D_I\left(x,y,z,T\right)\frac{\partial I_1\left(x,y,z,\tau\right)}{\partial y}d\tau+\frac{\partial}{\partial y}\int_0^t D_I\left(x,y,z,T\right)\frac{\partial I_1\left(x,y,z,\tau\right)}{\partial y}d\tau+$$

$$+\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{IS}}{kT}\nabla_S\mu\left(x,y,z,\tau\right)\int_0^{L_z}\left[\alpha_{2I}+I_1\left(x,y,W,\tau\right)\right]dW\,d\tau+\Omega\frac{\partial}{\partial y}\int_0^t\frac{D_{IS}}{kT}\nabla_S\mu\left(x,y,z,\tau\right)\int_0^{L_z}\left[\alpha_{2I}+I_1\left(x,y,W,\tau\right)\right]dW\,d\tau-$$

$$-\int_0^t k_{I,I}\left(x,y,z,T\right)\left[\alpha_{2I}+I_1\left(x,y,z,\tau\right)\right]^2d\tau-\int_0^t k_{I,V}\left(x,y,z,T\right)\left[\alpha_{2I}+I_1\left(x,y,z,\tau\right)\right]\left[\alpha_{2V}+V_1\left(x,y,z,\tau\right)\right]d\tau+f_I\left(x,y,z\right)+$$

$$+\frac{\partial}{\partial x}\left[\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{IS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial z}\right] \qquad (3e)$$

$$V_2\left(x,y,z,t\right)=\frac{\partial}{\partial x}\int_0^t D_V\left(x,y,z,T\right)\frac{\partial V_1\left(x,y,z,\tau\right)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t D_V\left(x,y,z,T\right)\frac{\partial V_1\left(x,y,z,\tau\right)}{\partial y}d\tau+\frac{\partial}{\partial y}\int_0^t D_V\left(x,y,z,T\right)\frac{\partial V_1\left(x,y,z,\tau\right)}{\partial y}d\tau+$$

$$+\Omega\frac{\partial}{\partial x}\int_0^t\frac{D_{VS}}{kT}\nabla_S\mu\left(x,y,z,\tau\right)\int_0^{L_z}\left[\alpha_{2V}+V_1\left(x,y,W,\tau\right)\right]dW\,d\tau+\Omega\frac{\partial}{\partial y}\int_0^t\frac{D_{VS}}{kT}\nabla_S\mu\left(x,y,z,\tau\right)\int_0^{L_z}\left[\alpha_{2V}+V_1\left(x,y,W,\tau\right)\right]dW\,d\tau-$$

$$-\int_0^t k_{V,V}\left(x,y,z,T\right)\left[\alpha_{2V}+V_1\left(x,y,z,\tau\right)\right]^2d\tau-\int_0^t k_{I,V}\left(x,y,z,T\right)\left[\alpha_{2I}+I_1\left(x,y,z,\tau\right)\right]\left[\alpha_{2V}+V_1\left(x,y,z,\tau\right)\right]d\tau+f_V\left(x,y,z\right)+$$

$$+\frac{\partial}{\partial x}\left[\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{D_{VS}}{\overline{V}kT}\frac{\partial\mu_2\left(x,y,z,t\right)}{\partial z}\right]$$

$$\Phi_{2I}\left(x,y,z,t\right)=\frac{\partial}{\partial x}\int_0^t D_{\Phi_I}\left(x,y,z,T\right)\frac{\partial\Phi_{1I}\left(x,y,z,\tau\right)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t D_{\Phi_I}\left(x,y,z,T\right)\frac{\partial\Phi_{1I}\left(x,y,z,\tau\right)}{\partial y}d\tau+f_{\Phi_I}\left(x,y,z\right)+$$

$$+\frac{\partial}{\partial z}\int_0^t D_{\Phi_I}(x,y,z,T)\frac{\partial \Phi_{1I}(x,y,z,\tau)}{\partial z}d\tau+\Omega\frac{\partial}{\partial x}\int_0^t \frac{D_{\Phi_I S}}{kT}\nabla_S\mu(x,y,z,\tau)\int_0^{L_z}\left[\alpha_{2\Phi_I}+\Phi_{1I}(x,y,W,\tau)\right]dW\,d\tau+$$

$$+\Omega\frac{\partial}{\partial x}\int_0^t \frac{D_{\Phi_I S}}{kT}\nabla_S\mu(x,y,z,\tau)\int_0^{L_z}\left[\alpha_{2\Phi_I}+\Phi_{1I}(x,y,W,\tau)\right]dW\,d\tau+\int_0^t k_{I,I}(x,y,z,T)I^2(x,y,z,\tau)\,d\tau-\int_0^t k_I(x,y,z,T)\times$$

$$\times I(x,y,z,\tau)\,d\tau+\frac{\partial}{\partial x}\int_0^t \frac{D_{\Phi_I S}}{\overline{V}\,kT}\frac{\partial \mu_2(x,y,z,\tau)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t \frac{D_{\Phi_I S}}{\overline{V}\,kT}\frac{\partial \mu_2(x,y,z,\tau)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t \frac{D_{\Phi_I S}}{\overline{V}\,kT}\frac{\partial \mu_2(x,y,z,\tau)}{\partial z}d\tau \quad (5e)$$

$$\Phi_{2V}(x,y,z,t)=\frac{\partial}{\partial x}\int_0^t D_{\Phi_V}(x,y,z,T)\frac{\partial \Phi_{1V}(x,y,z,\tau)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t D_{\Phi_V}(x,y,z,T)\frac{\partial \Phi_{1V}(x,y,z,\tau)}{\partial y}d\tau+f_{\Phi_V}(x,y,z)+$$

$$+\frac{\partial}{\partial z}\int_0^t D_{\Phi_V}(x,y,z,T)\frac{\partial \Phi_{1V}(x,y,z,\tau)}{\partial z}d\tau+\Omega\frac{\partial}{\partial x}\int_0^t \frac{D_{\Phi_V S}}{kT}\nabla_S\mu(x,y,z,\tau)\int_0^{L_z}\left[\alpha_{2\Phi_V}+\Phi_{1V}(x,y,W,\tau)\right]dW\,d\tau+$$

$$+\Omega\frac{\partial}{\partial x}\int_0^t \frac{D_{\Phi_V S}}{kT}\nabla_S\mu(x,y,z,\tau)\int_0^{L_z}\left[\alpha_{2\Phi_V}+\Phi_{1V}(x,y,W,\tau)\right]dW\,d\tau+\int_0^t k_{V,V}(x,y,z,T)V^2(x,y,z,\tau)\,d\tau-\int_0^t k_V(x,y,z,T)\times$$

$$\times V(x,y,z,\tau)\,d\tau+\frac{\partial}{\partial x}\int_0^t \frac{D_{\Phi_V S}}{\overline{V}\,kT}\frac{\partial \mu_2(x,y,z,\tau)}{\partial x}d\tau+\frac{\partial}{\partial y}\int_0^t \frac{D_{\Phi_V S}}{\overline{V}\,kT}\frac{\partial \mu_2(x,y,z,\tau)}{\partial y}d\tau+\frac{\partial}{\partial z}\int_0^t \frac{D_{\Phi_V S}}{\overline{V}\,kT}\frac{\partial \mu_2(x,y,z,\tau)}{\partial z}d\tau\,.$$

We determine the averaged values of the considered approximations by applying the next recently considered relation 28

$$\alpha_{2\rho}=\frac{1}{\Theta L_x L_y L_z}\int_0^{\Theta}\int_0^{L_x}\int_0^{L_y}\int_0^{L_z}\left[\rho_2(x,y,z,t)-\rho_1(x,y,z,t)\right]dz\,dy\,dx\,dt\,. \quad (10)$$

Accounting of the obtained relation (1*e*), relation (3*e*), relation (5*e*) into the above relation (10) leads to the following relations of required averaged values $\alpha_{2\rho}$

$\alpha_{2C}=0$, $\alpha_{2\Phi I}=0$, $\alpha_{2\Phi V}=0$, $\alpha_{2V}=\sqrt{\frac{(b_3+E)^2}{4b_4^2}-4\left(F+\frac{\Theta a_3 F+\Theta^2 L_x L_y L_z b_1}{b_4}\right)}-\frac{b_3+E}{4b_4}$,

$$\alpha_{2I}=\frac{C_V-\alpha_{2V}^2 S_{VV00}-\alpha_{2V}\left(2S_{VV01}+S_{IV10}+\Theta L_x L_y L_z\right)-S_{VV02}-S_{IV11}}{S_{IV01}+\alpha_{2V}S_{IV00}}\,.$$

Here $b_4=\frac{S_{IV00}^2 S_{VV00}-S_{VV00}^2 S_{II00}}{\Theta L_x L_y L_z}$, $b_3=-\frac{S_{II00}S_{VV00}}{\Theta L_x L_y L_z}\left(2S_{VV01}+S_{IV10}+\Theta L_x L_y L_z\right)+\left(S_{IV01}+2S_{II10}+S_{IV01}+\Theta L_x L_y L_z\right)\frac{S_{IV00}}{\Theta L_x}\times$

$$\times\frac{S_{VV00}}{L_y L_z}+S_{IV00}^2\frac{2S_{VV01}+S_{IV10}+\Theta L_x L_y L_z}{\Theta L_x L_y L_z}-\frac{S_{IV00}^2 S_{IV10}}{\Theta^3 L_x^3 L_y^3 L_z^3},\ b_2=\frac{S_{II00}S_{VV00}}{\Theta L_x L_y L_z}\left(S_{VV02}+S_{IV11}+C_V\right)-\left(S_{IV10}-2S_{VV01}+\Theta L_x L_y L_z\right)^2+$$

$$+\frac{S_{IV01}S_{VV00}}{\Theta L_x L_y L_z}\left(\Theta L_x L_y L_z+2S_{II10}+S_{IV01}\right)+S_{IV00}\left(S_{IV01}+2S_{II10}+2S_{IV01}+\Theta L_x L_y L_z\right)\frac{2S_{VV01}+\Theta L_x L_y L_z+S_{IV10}}{\Theta L_x L_y L_z}+\frac{C_I S_{IV00}^2}{\Theta^2 L_x^2 L_y^2 L_z^2}-$$

$$-\frac{S_{IV00}^2}{\Theta L_x L_y L_z}\left(C_V-S_{VV02}-S_{IV11}\right)-2S_{IV10}\frac{S_{IV00}S_{IV01}}{\Theta L_x L_y L_z},\ b_1=S_{II00}\frac{S_{IV11}+S_{VV02}+C_V}{\Theta L_x L_y L_z}\left(2S_{VV01}+S_{IV10}+\Theta L_x L_y L_z\right)+\frac{S_{IV01}}{\Theta L_x L_y L_z}\times$$

$$\times\left(\Theta L_x L_y L_z+2S_{II10}+S_{IV01}\right)\left(2S_{VV01}+S_{IV10}+\Theta L_x L_y L_z\right)-\frac{S_{IV10}S_{IV01}^2}{\Theta L_x L_y L_z}-S_{IV00}\frac{C_V-S_{VV02}-S_{IV11}}{\Theta L_x L_y L_z}\left(3S_{IV01}+2S_{II10}+\Theta L_x L_y L_z\right)+$$

$$+2C_I S_{IV00}S_{IV01},\ b_0=S_{II00}\frac{\left(S_{IV00}+S_{VV02}\right)^2}{\Theta L_x L_y L_z}-S_{IV01}\left(\Theta L_x L_y L_z+2S_{II10}+S_{IV01}\right)\frac{C_V-S_{VV02}-S_{IV11}}{\Theta L_x L_y L_z}-S_{IV01}\frac{C_V-S_{VV02}-S_{IV11}}{\Theta L_x L_y L_z}\times$$

$$\times\left(\Theta L_x L_y L_z+2S_{II10}+S_{IV01}\right)+2C_I S_{IV01}^2,\ C_I=\frac{\alpha_{1I}\alpha_{1V}}{\Theta L_x L_y L_z}S_{IV00}+\frac{\alpha_{1I}^2 S_{II00}}{\Theta L_x L_y L_z}-\frac{S_{II20}S_{II20}}{\Theta L_x L_y L_z}-\frac{S_{IV11}}{\Theta L_x L_y L_z},\ C_V=\alpha_{1I}\alpha_{1V}S_{IV00}+$$

$$+\alpha_{1V}^2 S_{VV00}-S_{VV02}-S_{IV11},\ E=\sqrt{8y+\Theta^2\frac{a_3^2}{a_4^2}-4\Theta\frac{a_2}{a_4}},\ F=\frac{\Theta a_2}{6a_4}+\sqrt[3]{\sqrt{r^2+s^3}-r}-\sqrt[3]{\sqrt{r^2+s^3}+r},\ r=\left(\Theta^2\frac{b_3^2}{b_4}-4\Theta b_2\right)\times$$

$$\times \frac{b_0\Theta^2}{8b_4^2} + \frac{\Theta^3 b_2}{24b_4^2}\left(4b_0 - \Theta L_x L_y L_z \frac{b_1 b_3}{b_4}\right) - \frac{\Theta^3 b_2^3}{54b_4^3} - L_x^2 L_y^2 L_z^2 \frac{\Theta^4 b_1^2}{8b_4^2},\ s = \Theta^2 \frac{4b_0 b_4 - \Theta L_x L_y L_z b_1 b_3}{12b_4^2} - \frac{\Theta b_2}{18b_4}.$$

Now let us determine solutions of Eqs. (8). To obtain the first-order approximations of the considered displacement vector components by using of function corrections averaging approach. To apply the approach one shall replace the considered functions in the right parts of the Eqs. (8) by their averaged means α_i, which are not yet known. The substitution gives a possibility to obtain equations to calculate the approximations with the first-order of the considered vector in the next form

$$\rho(z)\frac{\partial^2 u_{1x}(x,y,z,t)}{\partial t^2} = -K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial x},\ \rho(z)\frac{\partial^2 u_{1y}(x,y,z,t)}{\partial t^2} = -K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial y},$$

$$\rho(z)\frac{\partial^2 u_{1z}(x,y,z,t)}{\partial t^2} = -K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial z}.$$

Further we shall integrate the left side and the right of the above equations on the current time t. The integration gives a possibility to obtain relations of the approximations with the first-order of the vector of displacement in the final form

$$u_{1x}(x,y,z,t) = u_{0x} + K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial x}\int_0^t\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta - K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial x}\int_0^\infty\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta,$$

$$u_{1y}(x,y,z,t) = u_{0y} + K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial y}\int_0^t\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta - K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial y}\int_0^\infty\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta,$$

$$u_{1z}(x,y,z,t) = u_{0z} + K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial z}\int_0^t\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta - K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial z}\int_0^\infty\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta.$$

Approximations of the displacement vector components with the second and higher orders could be calculated by replacement of the considered functions on the standard sums $\alpha_i+u_i(x,y,z,t)$ [28]. This procedure gives a possibility to obtain equations for calculation of the above approximations with the second order in the following form

$$\rho(z)\frac{\partial^2 u_{2x}(x,y,z,t)}{\partial t^2} = \left\{K(z) + \frac{5E(z)}{6[1+\sigma(z)]}\right\}\frac{\partial^2 u_{1x}(x,y,z,t)}{\partial x^2} + \left\{K(z) - \frac{E(z)}{3[1+\sigma(z)]}\right\}\frac{\partial^2 u_{1y}(x,y,z,t)}{\partial x\partial y} +$$

$$+\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial^2 u_{1y}(x,y,z,t)}{\partial y^2} + \frac{\partial^2 u_{1z}(x,y,z,t)}{\partial z^2}\right] + \left\{K(z) + \frac{E(z)}{3[1+\sigma(z)]}\right\}\frac{\partial^2 u_{1z}(x,y,z,t)}{\partial x\partial z} - K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial x}$$

$$\rho(z)\frac{\partial^2 u_{2y}(x,y,z,t)}{\partial t^2} = \frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial^2 u_{1y}(x,y,z,t)}{\partial x^2} + \frac{\partial^2 u_{1x}(x,y,z,t)}{\partial x\partial y}\right] - K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial y} + \frac{\partial^2 u_{1y}(x,y,z,t)}{\partial y^2}\times$$

$$\times\left\{\frac{5E(z)}{12[1+\sigma(z)]} + K(z)\right\} + \frac{\partial}{\partial z}\left\{\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial u_{1y}(x,y,z,t)}{\partial z} + \frac{\partial u_{1z}(x,y,z,t)}{\partial y}\right]\right\} + \left\{K(z) - \frac{E(z)}{6[1+\sigma(z)]}\right\}\frac{\partial^2 u_{1y}(x,y,z,t)}{\partial y\partial z} +$$

$$+K(z)\frac{\partial^2 u_{1y}(x,y,z,t)}{\partial x\partial y}$$

$$\rho(z)\frac{\partial^2 u_{2z}(x,y,z,t)}{\partial t^2} = \frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial^2 u_{1z}(x,y,z,t)}{\partial x^2} + \frac{\partial^2 u_{1z}(x,y,z,t)}{\partial y^2} + \frac{\partial^2 u_{1x}(x,y,z,t)}{\partial x\partial z} + \frac{\partial^2 u_{1y}(x,y,z,t)}{\partial y\partial z}\right] +$$

$$+\frac{\partial}{\partial z}\left\{K(z)\left[\frac{\partial u_{1x}(x,y,z,t)}{\partial x} + \frac{\partial u_{1y}(x,y,z,t)}{\partial y} + \frac{\partial u_{1x}(x,y,z,t)}{\partial z}\right]\right\} - K(z)\beta(z)\frac{\partial T(x,y,z,t)}{\partial z} + \frac{E(z)}{6[1+\sigma(z)]}\times$$

$$\times\frac{\partial}{\partial z}\left[6\frac{\partial u_{1z}(x,y,z,t)}{\partial z} - \frac{\partial u_{1x}(x,y,z,t)}{\partial x} - \frac{\partial u_{1y}(x,y,z,t)}{\partial y} - \frac{\partial u_{1z}(x,y,z,t)}{\partial z}\right].$$

Using integration of both sides of the considered equations on the time current t leads to formulas for the second-order approximations of the vector of displacement components in the following final form

$$u_{2x}(x,y,z,t)=\frac{1}{\rho(z)}\left\{K(z)+\frac{5E(z)}{6[1+\sigma(z)]}\right\}\frac{\partial^2}{\partial x^2}\int_0^t\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{1}{\rho(z)}\frac{\partial^2}{\partial x\partial y}\int_0^t\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta\left\{K(z)-\right.$$

$$\left.-\frac{E(z)}{3[1+\sigma(z)]}\right\}+\frac{E(z)}{2\rho(z)[1+\sigma(z)]}\left[\frac{\partial^2}{\partial y^2}\int_0^t\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{\partial^2}{\partial z^2}\int_0^t\int_0^\vartheta u_{1z}(x,y,z,\tau)\,d\tau\,d\vartheta\right]+\frac{1}{\rho(z)[1+\sigma(z)]}\times$$

$$+\frac{1}{\rho(z)[1+\sigma(z)]}\frac{\partial^2}{\partial x\partial z}\int_0^t\int_0^\vartheta u_{1z}(x,y,z,\tau)d\tau\,d\vartheta\left\{K(z)+\frac{E(z)}{3[1+\sigma(z)]}\right\}-K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial x}\int_0^t\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta-$$

$$-\frac{1}{\rho(z)}\frac{\partial^2}{\partial x^2}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)d\tau\,d\vartheta\left\{K(z)+\frac{5E(z)}{6[1+\sigma(z)]}\right\}-\frac{1}{\rho(z)}\left\{K(z)-\frac{E(z)}{3[1+\sigma(z)]}\right\}\frac{\partial^2}{\partial x\partial y}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)d\tau\,d\vartheta-$$

$$-\frac{E(z)}{2\rho(z)[1+\sigma(z)]}\left[\frac{\partial^2}{\partial y^2}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)d\tau\,d\vartheta+\frac{\partial^2}{\partial z^2}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)d\tau\,d\vartheta\right]+K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial x}\int_0^\infty\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta-$$

$$-\frac{1}{\rho(z)}\left\{K(z)+\frac{E(z)}{3[1+\sigma(z)]}\right\}\frac{\partial^2}{\partial x\partial z}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)d\tau\,d\vartheta+u_{0x}$$

$$u_{2y}(x,y,z,t)=\frac{E(z)}{2\rho(z)[1+\sigma(z)]}\left[\frac{\partial^2}{\partial x^2}\int_0^t\int_0^\vartheta u_{1x}(x,y,z,\tau)d\tau\,d\vartheta+\frac{\partial^2}{\partial x\partial y}\int_0^t\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta\right]+\frac{K(z)}{\rho(z)}\times$$

$$\times\frac{\partial^2}{\partial x\partial y}\int_0^t\int_0^\vartheta u_{1y}(x,y,z,\tau)d\tau\,d\vartheta+\frac{1}{\rho(z)}\left\{\frac{5E(z)}{12[1+\sigma(z)]}+K(z)\right\}\frac{\partial^2}{\partial y^2}\int_0^t\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta+$$

$$+\frac{1}{2\rho(z)}\frac{\partial}{\partial z}\left\{\frac{E(z)}{1+\sigma(z)}\left[\frac{\partial}{\partial z}\int_0^t\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{\partial}{\partial y}\int_0^t\int_0^\vartheta u_{1z}(x,y,z,\tau)d\tau\,d\vartheta\right]\right\}-\int_0^t\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta\times$$

$$\times K(z)\frac{\beta(z)}{\rho(z)}-\frac{1}{\rho(z)}\left\{\frac{E(z)}{6[1+\sigma(z)]}-K(z)\right\}\frac{\partial^2}{\partial y\partial z}\int_0^t\int_0^\vartheta u_{1y}(x,y,z,\tau)d\tau\,d\vartheta-\frac{E(z)}{2\rho(z)}\left[\frac{\partial^2}{\partial x^2}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta+\right.$$

$$\left.+\frac{\partial^2}{\partial x\partial y}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)d\tau\,d\vartheta\right]\frac{1}{1+\sigma(z)}-K(z)\frac{\beta(z)}{\rho(z)}\int_0^\infty\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta-\frac{K(z)}{\rho(z)}\frac{\partial^2}{\partial x\partial y}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta-$$

$$-\frac{1}{2\rho(z)}\frac{\partial}{\partial z}\left\{\frac{E(z)}{1+\sigma(z)}\left[\frac{\partial}{\partial z}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{\partial}{\partial y}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)\,d\tau\,d\vartheta\right]\right\}-\frac{1}{2\rho(z)}\frac{\partial^2}{\partial y^2}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta\times$$

$$\times\left\{K(z)+\frac{5E(z)}{12[1+\sigma(z)]}\right\}-\frac{1}{\rho(z)}\left\{K(z)-\frac{E(z)}{6[1+\sigma(z)]}\right\}\frac{\partial^2}{\partial y\partial z}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta+u_{0y}$$

$$u_z(x,y,z,t)=\frac{E(z)}{2[1+\sigma(z)]}\left[\frac{\partial^2}{\partial x^2}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{\partial^2}{\partial y^2}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{\partial^2}{\partial x\partial z}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta+\right.$$

$$\left.+\frac{\partial^2}{\partial y\partial z}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta\right]\frac{1}{\rho(z)}+\frac{1}{\rho(z)}\frac{\partial}{\partial z}\left\{K(z)\left[\frac{\partial}{\partial x}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta+\frac{\partial}{\partial y}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta+\right.\right.$$

$$\left.\left.+\frac{\partial}{\partial z}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta\right]\right\}+\frac{1}{6\rho(z)}\frac{\partial}{\partial z}\left\{\frac{E(z)}{1+\sigma(z)}\left[6\frac{\partial}{\partial z}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)\,d\tau\,d\vartheta-\frac{\partial}{\partial x}\int_0^\infty\int_0^\vartheta u_{1x}(x,y,z,\tau)\,d\tau\,d\vartheta-\right.\right.$$

$$\left.\left.-\frac{\partial}{\partial y}\int_0^\infty\int_0^\vartheta u_{1y}(x,y,z,\tau)\,d\tau\,d\vartheta-\frac{\partial}{\partial z}\int_0^\infty\int_0^\vartheta u_{1z}(x,y,z,\tau)\,d\tau\,d\vartheta\right]\right\}-K(z)\frac{\beta(z)}{\rho(z)}\frac{\partial}{\partial z}\int_0^\infty\int_0^\vartheta T(x,y,z,\tau)\,d\tau\,d\vartheta+u_{0z}\,.$$

We calculate distributions of dopant concentration, radiation defects concentrations and vector of displacement components in time and space. These distributions were obtained as the approximations with the second-order framework function corrections averaging approach in the standard form. These approximations are usually enough good approximations for qualitative analysis and calculation of some quantitative results. All calculated results were checked by using comparison of them with results of numerical modelling.

Results of analysis

Now let us to make analysis of redistribution of radiation defects and dopant during manufacturing of the considered mixer with account stress, which was induced by mismatch of lattice parameters, and porosity modification. Several distributions of dopant concentrations in the considered heterostructure were presented on Figure-2 (for doping by diffusion) and Figure-3 (for doping by ion implantation). Increasing of number of curve describes larger difference between magnitudes of coefficients of diffusion of dopant in layers of the considered heterostructure. All distributions were calculated for the following situation: diffusion coefficient of dopant in the considered epitaxial layer is larger as opposed to diffusion coefficient of dopant in the substrate. One can find from these figures: inhomogeneity of the considered heterostructure leads to larger values of *p-n*-junction's sharpness. Withal homogeneity of distribution of dopant increased in doped part of epitaxial layer. After increasing of sharpness of the considered *p-n*-junctions one can find decreasing of switching time. Obtained increasing of homogeneity of the considered leads to decreasing of material's local heating during operation of devices or to decrease of dimensions of the considered devices at fixed upper limit of the considered local heating. It should be noted, that using the considered method of manufacturing of the required transistors leads to necessity in annealing optimization of radiation defects and/or dopant. One can find the following reason in the optimization. At smaller value of annealing time dopant cannot achieve nearest interface between materials of the used heterostructure. No modifications of dopant concentration distribution could be finding. Increasing of annealing time leads to larger homogeneity of dopant concentration. In the current situation it is attracted an interest optimization of annealing time to choose compromise time of annealing. We optimize the annealing time by using the approach, which was recently introduced 29-37. To use the considered criterion one shall to approximate real distribution of dopant concentration by step-wise function, which corresponds to required ideal distribution of dopant concentration (Figure-4, 5). Larger numbers of obtained curves correspond to larger value of annealing time. Now let us determine the required compromise time of annealing as time, which corresponds to minimal value of mean-squared error, which is presented bellow

$$U = \frac{1}{L_x L_y L_z} \int_0^{L_x} \int_0^{L_y} \int_0^{L_z} \left[C(x,y,z,\Theta) - \psi(x,y,z) \right] d\,z\,d\,y\,d\,x\,, \qquad (15)$$

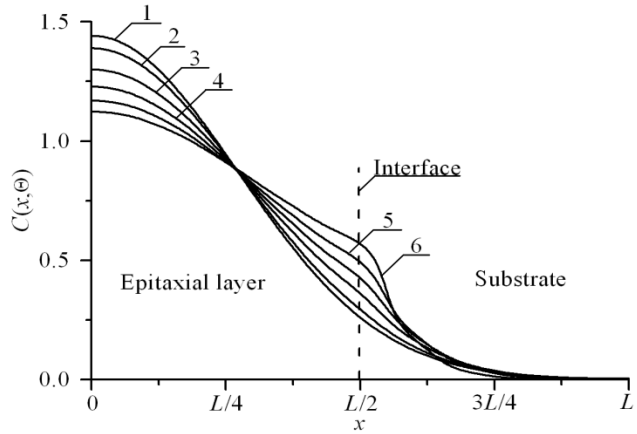

Figure-2: Distributions of infused dopant concentration.

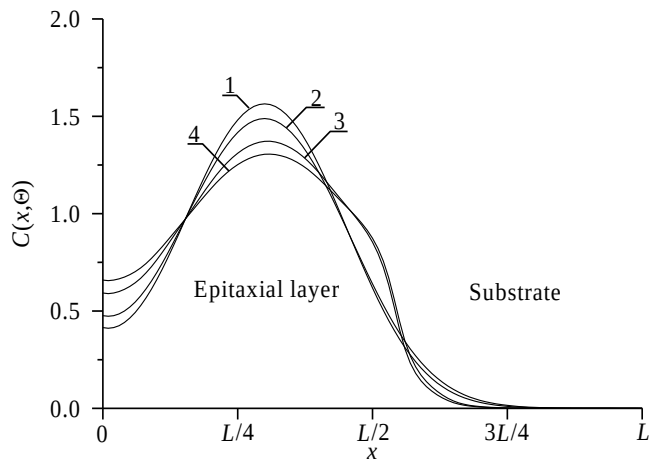

Figure-3: Distributions of implanted dopant concentration. Curve 1 and curve 3 describe distribution of dopant at time of annealing $\Theta = 0.0048(L_x^2+L_y^2+L_z^2)/D_0$. Curve 2 and curve 4 describe distribution of dopant at time of annealing $\Theta = 0.0057(L_x^2+L_y^2+L_z^2)/D_0$

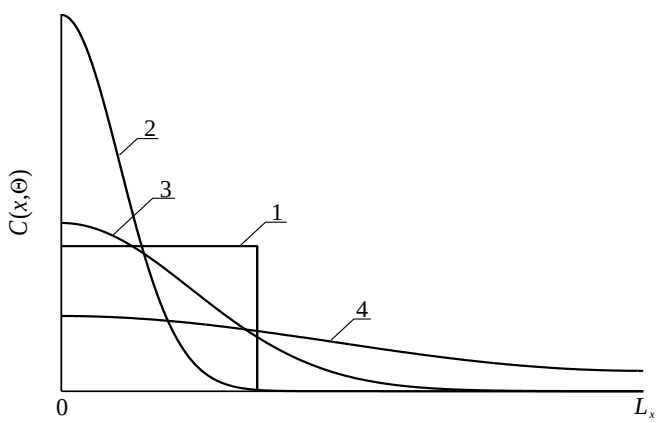

Figure-4: Infused dopant distributions. Curve 1 describes idealized step-wise distribution. Curve 2, curve 3 and curve 4 describe actually existing distributions of concentration of dopant at different means of time of annealing

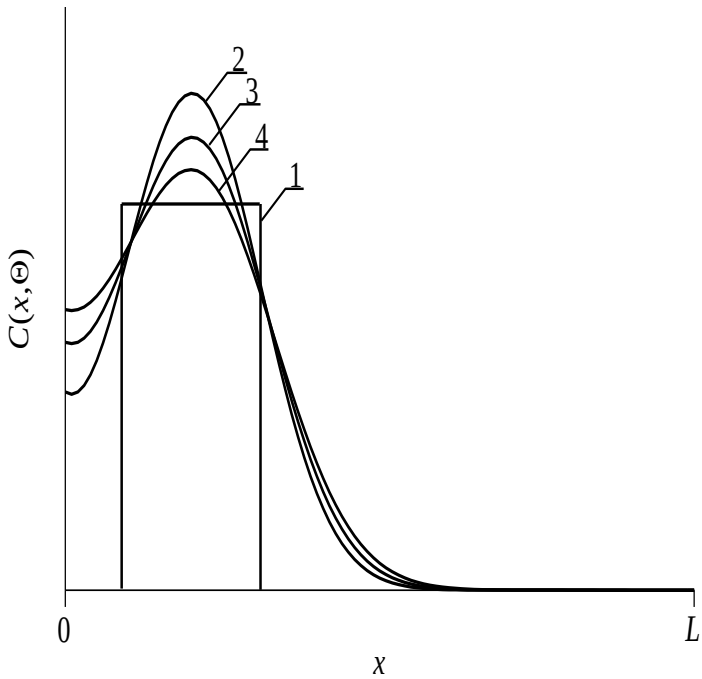

Figure-5: Implanted dopant distributions. Curve 1 describes idealized step-wise distribution. Curve 2, curve 3 and curve 4 describe actually existing distributions of concentration of dopant at different means of time of annealing.

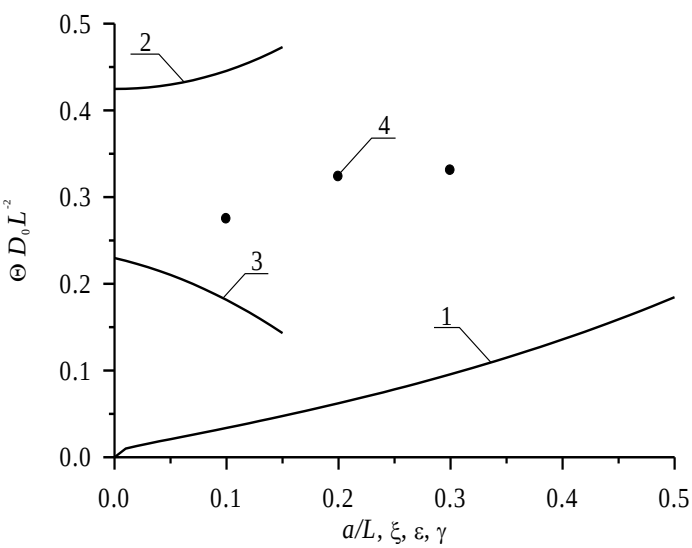

Figure-6: Dimensionless optimized time of annealing of infused dopant as a function of several parameters. Curve 1 as a function of dimensionless optimized time of annealing on relation *a/L* and $\xi = \gamma = 0$ at the equal values to each other of dopant diffusion coefficient in all materials of heterostructure. Curve 2 as a function of dimensionless optimized time of annealing of the parameter ε at *a/L*=1/2 and $\xi = \gamma = 0$. Curve 3 as a function of dimensionless optimized time of annealing on parameter ξ at *a/L*=1/2 and $\varepsilon = \gamma = 0$. Curve 4 as a function of dimensionless optimized time of annealing of parameter γ at *a/L*=1/2 and $\varepsilon = \xi = 0$

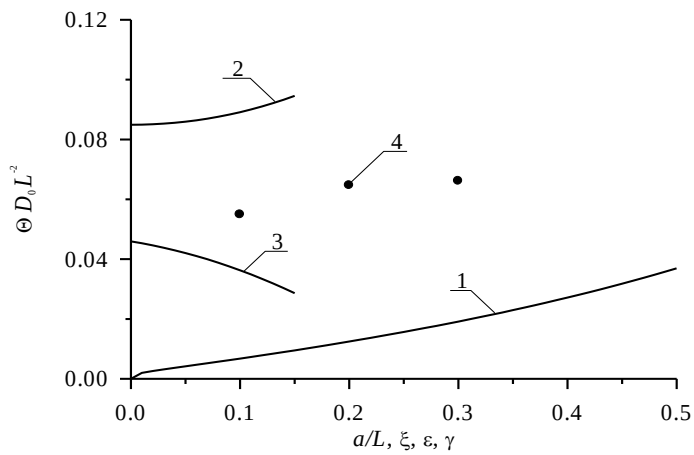

Figure-7: Dimensionless optimized time of annealing of implanted dopant as a function of several parameters. Curve 1 as a function of dimensionless optimized time of annealing on relation *a/L* and $\xi = \gamma = 0$ at the equal values to each other of dopant diffusion coefficient in all materials of heterostructure. Curve 2 as a function of dimensionless optimized time of annealing of the parameter ε at *a/L*=1/2 and $\xi = \gamma = 0$. Curve 3 as a function of dimensionless optimized time of annealing on parameter ξ at *a/L*=1/2 and $\varepsilon = \gamma = 0$. Curve 4 as a function of dimensionless optimized time of annealing of parameter γ at *a/L*=1/2 and $\varepsilon = \xi = 0$

Here function ψ (*x*,*y*,*z*) describes the step-wise approximation. Dependences of optimized time of annealing on different parameters are presented on Figure-6 (for diffusion type of doping) and 7 (for ion type of doping). It must be noted, that annealing of radiation defects required after ion implantation. Annealing of radiation defects and dopant leads to spreading of distribution dopant concentration. Framework the ideal case dopant could achieves nearest interface between materials of the considered heterostructure during radiation defects annealing. In the case, when dopant cannot achieves the nearest interface during radiation defects annealing, than it is necessary to make additional dopant annealing. Framework the situation optimized value of the additional time of annealing of the implanted dopant became smaller in comparison with time of annealing of the infused dopant.

Now let us analyze influence of relaxation of stress, which was induced by mismatch of lattice parameters, on dopant distribution in doped areas of heterostructure. At the condition $\varepsilon_0 < 0$ we find compression of dopant concentration distribution near interfaces in heterostructure. Simultaneously (for $\varepsilon_0 > 0$) we find spreading of dopant concentration distribution in this area. The variation of dopant concentration distribution could partially or fully compensate due to annealing by laser[37]. The annealing by laser leads to acceleration of dopant diffusion and all other processes in the required areas by inhomogeneity of temperature distribution. Accounting relaxation of stress, which was induced by mismatch of lattice parameters, in the considered heterostructure gives a possibility to change

optimized values of time of annealing. Simultaneously porosity modification leads to decreasing of magnitude of stress, which was induced by mismatch of lattice parameters. On the one hand the considered stress could lead to increasing of elements density of the considered integrated circuits. At the same time the stress could generate dislocations of the discrepancy. Figures-8, 9 show vacancies concentration distributions in a materials porosity and component of vector of displacement. The component is perpendicular to internal interfaces in the considered heterostructure.

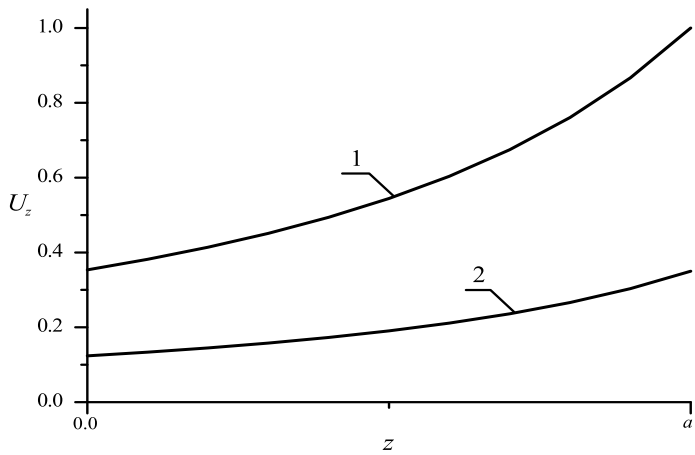

Figure-8: Normalized function of component u_z of the considered vector of displacement on coordinate z for nonporous and porous epitaxial layers (curves 1 and 2, respectively)

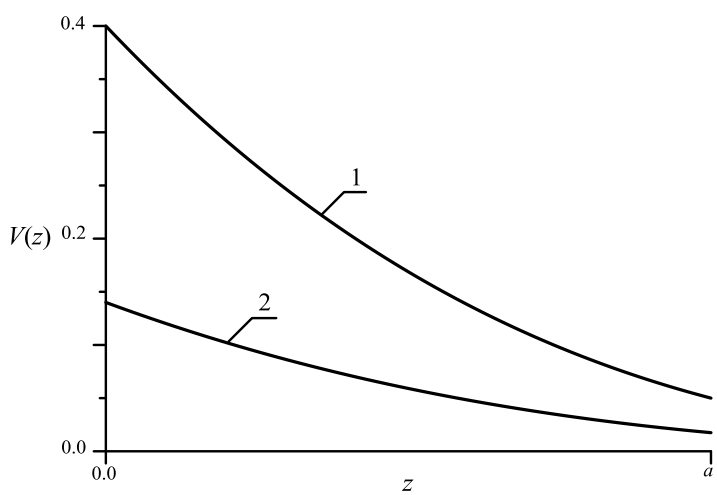

Figure-9: Normalized function of concentration of vacancy on coordinate z in unstressed and stressed epitaxial layers (curves 1 and 2, respectively)

Conclusion

We analyzed implanted and infused dopants redistribution during manufacturing field-effect heterotransistors, which comprises in a down conversion mixer circuit. Framework the modeling we take into account mismatch-induced stress relaxation. We obtain some recommendations to optimization of radiation defects and/or dopant annealing for decreasing of dimensions of field-effect transistors and for increasing of their density. We also obtain recommendations for decreasing of mismatch-induced stress. It has been also introduced an analytical approach for analysis of ion and diffusion types of doping with taking into account changing of parameters of the considered processes simultaneously in time and space. The method also gives a possibility to accounting of nonlinearity of the above processes. The method of manufacturing of integrated circuits leads to increasing of integrated circuits elements density and analysis could be used also for another integrated circuits. At the same time we take into account only some effects to do not overload the considered analysis of technological process. We could consider with time in future larger complexes of radiation defects. However probability of generation of such complexes is smaller in comparison with simplest complexes.

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