On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

E.L. Pankratov

Nizhny Novgorod State University, 23 Gagarin avenue, Nizhny Novgorod, Russia
Nizhny Novgorod State Technical University, 24 Minin Street, Nizhny Novgorod, Russia

Abstract: In this paper we introduce an approach to increase density of field-effect transistors framework a three stage nested miller compensated amplifier in transistor model. Framework the approach we consider manufacturing the inverter in heterostructure with specific configuration. Several required areas of the heterostructure should be doped by diffusion or ion implantation. After that dopant and radiation defects should by annealed framework optimized scheme. We also consider an approach to decrease value of mismatch-induced stress in the considered heterostructure. We introduce an analytical approach to analyze mass and heat transport in heterostructures during manufacturing of integrated circuits with account mismatch-induced stress.

Keywords: three stage nested miller compensated amplifier; optimization of manufacturing; influence of mismatch-induced stress; influence of porosity of materials; analytical approach for modelling.

INTRODUCTION

Currently density of elements of integrated circuits and their performance intensively increasing [1-15]. Simultaneously with increasing of the density of the elements of integrated circuit their dimensions decreases. One way to decrease dimensions of these elements of these integrated circuit is manufacturing of these elements in thin-film heterostructures. An alternative approach to decrease dimensions of the elements of integrated circuits is using laser and microwave types annealing [12,16-18]. Using these types of annealing leads to generation inhomogeneous distribution of temperature. Due to Arrhenius law the inhomogeneity of the diffusion coefficient and other parameters of process [12]. The inhomogeneity gives us possibility to decrease dimensions of elements of integrated circuits. Changing of properties of electronic materials could be obtain by using radiation processing of these materials.

In this paper we consider a heterostructure. The heterostructure includes into itself some epitaxial layers and a substrate. Some sections have been manufactured in the epitaxial layers. Further we consider doping of these sections by diffusion or ion implantation. The doping gives a possibility to manufacture field-effect transistors framework a current source circuit [19] so as it is shown on Figs. 1. After the doping we consider annealing of dopant and/or radiation defects. The annealing should be optimized to manufacture more compact distributions of concentrations of dopant. Framework the paper we determine conditions to increase density of elements of current source [4] and at the same time to increase of homogeneity of distribution of concentration of dopant in enriched area.
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

Method of Solution

We calculate distribution of concentration of dopant in space and time as solution of the following boundary problem [1,20-23]

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

with boundary and initial conditions

\[
\left.\frac{\partial C(x,y,z,t)}{\partial x}\right|_{x=0} = 0, \quad \left.\frac{\partial C(x,y,z,t)}{\partial x}\right|_{x=L_x} = 0, \quad \left.\frac{\partial C(x,y,z,t)}{\partial y}\right|_{y=0} = 0, \quad C(x,y,z,0) = f_C(x,y,z),
\]

Fig 1a. Structure of the considered amplifier [19]

Fig 1b. Heterostructure with a substrate, epitaxial layers and buffer layer (view from side)
Here $C(x,y,z,t)$ is the spatio-temporal distribution of concentration of dopant; $\Omega$ is the atomic volume of dopant; $\nabla_i$ is the symbol of surficial gradient; $\int_0^{L_z} C(x,y,z,t)dz$ is the surficial concentration of dopant on interface between layers of heterostructure (in this situation we assume, that Z-axis is perpendicular to interface between layers of heterostructure); $\mu_0(x,y,z,t)$ and $\mu_2(x,y,z,t)$ are the chemical potential due to the presence of mismatch-induced stress and porosity of material; $D$ and $D_3$ are the coefficients of volumetric and surficial diffusions. Dopant diffusion coefficient will be changed with changing materials of heterostructure. Dopant diffusion coefficient will be also changed with changing speed of heating and cooling of heterostructure (with account Arrhenius law). Dependences of dopant diffusion coefficient on concentration of dopant and radiation defects [24-26]

$$D_c = D_L(x,y,z,T) \left[ 1 + \xi C'(x,y,z,t) \right] \left[ 1 + \xi_1 V(x,y,z,t) \frac{V}{V^*} + \xi_2 \frac{V^2(x,y,z,t)}{(V^*)^2} \right],$$

$$D_s = D_{sl}(x,y,z,T) \left[ 1 + \xi_s C'(x,y,z,t) \right] \left[ 1 + \xi_1 V(x,y,z,t) \frac{V}{V^*} + \xi_2 \frac{V^2(x,y,z,t)}{(V^*)^2} \right].$$

Here $D_L(x,y,z,T)$ and $D_{sl}(x,y,z,T)$ are the spatial (due to accounting all layers of heterostructure) and temperature (due to Arrhenius law) dependences of dopant diffusion coefficients; $T$ is the temperature of annealing; $P(x,y,z,T)$ is the limit of solubility of dopant; parameter $\gamma$ depends on properties of materials and could be integer in the following interval $\gamma \in [1,3]$ [24]; $V(x,y,z,t)$ is the spatio-temporal distribution of concentration of radiation vacancies; $V^*$ is the equilibrium distribution of vacancies. Concentrational dependence of dopant diffusion coefficient has been described in details in [24]. Spatio-temporal distributions of concentration of point radiation defects have been determined by solving the following system of equations [20-23,25,26]

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

$$+ \frac{\partial}{\partial z} \left[ D_L(x,y,z,T) \frac{\partial I(x,y,z,t)}{\partial z} \right] - k_{l_1}(x,y,z,T) I^1(x,y,z,t) - k_{l_3}(x,y,z,T) I^3(x,y,z,t) \times$$

$$\times I(x,y,z,t)V(x,y,z,t) + \Omega \frac{\partial}{\partial x} \left[ \frac{D_{ls}}{kT} \nabla \mu(x,y,z,t) \int_0^{L_z} I(x,y,W,t)dW \right] +$$

$$+ \Omega \frac{\partial}{\partial y} \left[ \frac{D_{ls}}{kT} \nabla \mu(x,y,z,t) \int_0^{L_z} I(x,y,W,t)dW \right] + \frac{\partial}{\partial x} \left[ \frac{D_{ls}}{V^2kT} \frac{\partial \mu(y,x,z,t)}{\partial x} \right] +$$

$$+ \frac{\partial}{\partial y} \left[ \frac{D_{ls}}{V^2kT} \frac{\partial \mu(y,x,z,t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{ls}}{V^2kT} \frac{\partial \mu(y,x,z,t)}{\partial z} \right]$$

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

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

International Journal of Research Studies in Electrical and Electronics Engineering (IJRSEEE)  Page | 42
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

\[ + \frac{\partial}{\partial z} \left[ D_v(x, y, z, T) \frac{\partial V(x, y, z, t)}{\partial z} \right] - k_{V, V}(x, y, z, T) V^2(x, y, z, t) - k_{I, V}(x, y, z, T) \times \]

\[ \times I(x, y, z, t) V(x, y, z, t) + \Omega \frac{\partial}{\partial x} \left[ \frac{D_{V,S}}{k T} \nabla_s \mu_s (x, y, z, t) \int_0^t V(x, y, W, t) dW \right] + \]

\[ + \frac{\partial}{\partial y} \left[ \frac{D_{V,S}}{k T} \nabla_z \mu_z (x, y, z, t) \int_0^t V(x, y, W, t) dW \right] + \frac{\partial}{\partial z} \left[ \frac{D_{V,S}}{k T} \frac{\partial \mu_z (x, y, z, t)}{\partial z} \right] + \]

\[ + \frac{\partial}{\partial y} \left[ \frac{D_{V,S}}{k T} \frac{\partial \mu_z (x, y, z, t)}{\partial y} \right] \]

with boundary and initial conditions

\[ \left. \frac{\partial I(x, y, z, t)}{\partial x} \right|_{x=0} = 0, \quad \left. \frac{\partial I(x, y, z, t)}{\partial x} \right|_{x=L_x} = 0, \quad \left. \frac{\partial I(x, y, z, t)}{\partial y} \right|_{y=0} = 0, \quad \left. \frac{\partial I(x, y, z, t)}{\partial y} \right|_{y=L_y} = 0, \quad \left. \frac{\partial I(x, y, z, t)}{\partial z} \right|_{z=0} = 0, \quad \left. \frac{\partial I(x, y, z, t)}{\partial z} \right|_{z=L_z} = 0, \quad I(x, y, z, 0) = \]

\[ f_I(x, y, z), \quad V(x, y, z, 0) = f_V(x, y, z), \quad V(x_1 + V_x t, y_1 + V_y t, z_1 + V_z t, t) = V_n \left( 1 + \frac{2 \ell \omega}{k T \sqrt{x_1^2 + y_1^2 + z_1^2}} \right). \]

Here \( I(x, y, z, t) \) is the spatio-temporal distribution of concentration of radiation interstitials; \( \Gamma \) is the equilibrium distribution of interstitials; \( D(x, y, z, T), D_{V,S}(x, y, z, T), D_{V,S}(x, y, z, T), D_{V,S}(x, y, z, T) \) are the coefficients of volumetric and surficial diffusions of interstitials and vacancies, respectively; terms \( V^2(x, y, z, t) \) and \( f_I(x, y, z, t) \) correspond to generation of divacancies and diinterstitials, respectively (see, for example, [26] and appropriate references in this book); \( k_{I, V}(x, y, z, T), k_{I, V}(x, y, z, T), k_{I, V}(x, y, z, T) \) and \( k_{I, V}(x, y, z, T) \) are the parameters of recombination of point radiation defects and generation of their complexes; \( k \) is the Boltzmann constant; \( \omega = a^3 \), \( a \) is the interatomic distance; \( \ell \) is the specific surface energy. To account porosity of buffer layers we assume, that porous are approximately cylindrical with average values \( r = \sqrt{x_1^2 + y_1^2} \) and \( z_1 \) before annealing [23]. With time small pores decomposing on vacancies. The vacancies absorbing by larger pores [27]. With time large pores became larger due to absorbing the vacancies and became more spherical [27]. Distribution of concentration of vacancies in heterostructure, existing due to porosity, could be determined by summing on all pores, i.e.

\[ V(x, y, z, t) = \sum_{i=0}^l \sum_{j=0}^m \sum_{k=0}^n V_p (x + i \alpha, y + j \beta, z + k \chi, t), \quad R = \sqrt{x^2 + y^2 + z^2}. \]
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

Here $\alpha$, $\beta$ and $\chi$ are the average distances between centers of pores in directions $x$, $y$ and $z$; $l$, $m$ and $n$ are the quantity of pores inapposite directions.

Spatio-temporal distributions of divacancies $\Phi_i(x,y,z,t)$ and diinterstitials $\Phi_t(x,y,z,t)$ could be determined by solving the following system of equations [25,26]

$$
\frac{\partial \Phi_i(x,y,z,t)}{\partial t} = \frac{\partial}{\partial x} \left[ D_{\Phi_i} (x,y,z,T) \frac{\partial \Phi_i(x,y,z,t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ D_{\Phi_i} (x,y,z,T) \frac{\partial \Phi_i(x,y,z,t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ D_{\Phi_i} (x,y,z,T) \frac{\partial \Phi_i(x,y,z,t)}{\partial z} \right] + \Omega \frac{\partial}{\partial x} \left[ \frac{D_{\Phi_i} \mu_i(x,y,z,t)}{kT} \nabla_s \mu_i(x,y,z,t) \int_0^L \Phi_i(x,y,W,t) dW \right] + \Omega \frac{\partial}{\partial y} \left[ \frac{D_{\Phi_i} \mu_i(x,y,z,t)}{kT} \nabla_s \mu_i(x,y,z,t) \int_0^L \Phi_i(x,y,W,t) dW \right] + \Omega \frac{\partial}{\partial z} \left[ \frac{D_{\Phi_i} \mu_i(x,y,z,t)}{kT} \nabla_s \mu_i(x,y,z,t) \int_0^L \Phi_i(x,y,W,t) dW \right] + k_{ij}  \Phi_i(x,y,z,t) + k_{ij}  \Phi_i(x,y,z,t) \nabla^2 \Phi_i(x,y,z,t)
$$

$$
\frac{\partial \Phi_t(x,y,z,t)}{\partial t} = \frac{\partial}{\partial x} \left[ D_{\Phi_t} (x,y,z,T) \frac{\partial \Phi_t(x,y,z,t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ D_{\Phi_t} (x,y,z,T) \frac{\partial \Phi_t(x,y,z,t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ D_{\Phi_t} (x,y,z,T) \frac{\partial \Phi_t(x,y,z,t)}{\partial z} \right] + \Omega \frac{\partial}{\partial x} \left[ \frac{D_{\Phi_t} \mu_t(x,y,z,t)}{kT} \nabla_s \mu_t(x,y,z,t) \int_0^L \Phi_t(x,y,W,t) dW \right] + \Omega \frac{\partial}{\partial y} \left[ \frac{D_{\Phi_t} \mu_t(x,y,z,t)}{kT} \nabla_s \mu_t(x,y,z,t) \int_0^L \Phi_t(x,y,W,t) dW \right] + \Omega \frac{\partial}{\partial z} \left[ \frac{D_{\Phi_t} \mu_t(x,y,z,t)}{kT} \nabla_s \mu_t(x,y,z,t) \int_0^L \Phi_t(x,y,W,t) dW \right] + k_{ij}  \Phi_t(x,y,z,t) \nabla^2 \Phi_t(x,y,z,t)
$$

with boundary and initial conditions

$$
\frac{\partial \Phi_i(x,y,z,t)}{\partial x} \Bigg|_{x=0} = 0, \quad \frac{\partial \Phi_i(x,y,z,t)}{\partial x} \Bigg|_{x=L_x} = 0, \quad \frac{\partial \Phi_t(x,y,z,t)}{\partial x} \Bigg|_{x=0} = 0, \quad \frac{\partial \Phi_t(x,y,z,t)}{\partial x} \Bigg|_{x=L_x} = 0, \quad \frac{\partial \Phi_i(x,y,z,t)}{\partial y} \Bigg|_{y=0} = 0, \quad \frac{\partial \Phi_i(x,y,z,t)}{\partial y} \Bigg|_{y=L_y} = 0, \quad \frac{\partial \Phi_t(x,y,z,t)}{\partial y} \Bigg|_{y=0} = 0, \quad \frac{\partial \Phi_t(x,y,z,t)}{\partial y} \Bigg|_{y=L_y} = 0, \quad \frac{\partial \Phi_i(x,y,z,t)}{\partial z} \Bigg|_{z=0} = 0, \quad \frac{\partial \Phi_i(x,y,z,t)}{\partial z} \Bigg|_{z=L_z} = 0, \quad \frac{\partial \Phi_t(x,y,z,t)}{\partial z} \Bigg|_{z=0} = 0, \quad \frac{\partial \Phi_t(x,y,z,t)}{\partial z} \Bigg|_{z=L_z} = 0,
$$

$$
\Phi_i(x,y,z,0) = f_{\Phi_i}(x,y,z), \quad \Phi_t(x,y,z,0) = f_{\Phi_t}(x,y,z).
$$

Here $D_{\Phi_i}(x,y,z,T), D_{\Phi_t}(x,y,z,T), D_{\Phi_t}(x,y,z,T)$ and $D_{\Phi_s}(x,y,z,T)$ are the coefficients of volumetric and surficial diffusions of complexes of radiation defects; $k_i(x,y,z)$ and $k_v(x,y,z)$ are the parameters of the process.
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

decay of complexes of radiation defects.
Chemical potential $\mu_i$ in Eq.(1) could be determine by the following relation [20]
\[ \mu_i = E(z)\Omega \sigma_j [u_i(x,y,z,t)+u_j(x,y,z,t)]/2, \]
(7)

where $E(z)$ is the Young modulus, $\sigma_j$ is the stress tensor; $u_i, u_j$ are the components $u_i(x,y,z,t)$, $u_j(x,y,z,t)$ and $u_i(x,y,z,t)$ of the displacement vector $\mathbf{u}(x, y, z, t)$; $x, y, z$ are the coordinate $x, y, z$. The Eq. (3) could be transform to the following form
\[ \mu(x, y, z, t) = \frac{1}{2} \left[ \frac{\partial u_i(x, y, z, t)}{\partial x_j} + \frac{\partial u_j(x, y, z, t)}{\partial x_i} \right] \]
\[ -\epsilon_0 \delta_{ij} - \frac{\sigma(z) \delta_{ij}}{1-2\sigma(z)} \left[ \frac{\partial u_k(x, y, z, t)}{\partial x_j} - 3 \epsilon_0 \right] - K(z) \beta(z) [T(x, y, z, t) - T_0] \delta_{ij} ] \Omega/2 E(z), \]

where $\sigma$ is Poisson coefficient; $\omega = (a_i - a_{EL})/a_{EL}$ is the mismatch parameter; $a_i, a_{EL}$ are lattice distances of the substrate and the epitaxial layer; $K$ is the modulus of uniform compression; $\beta$ is the coefficient of thermal expansion; $T_0$ is the equilibrium temperature, which coincide (for our case) with room temperature. Components of displacement vector could be obtained by solution of the following equations [21]
\[ \rho(z) \frac{\partial^2 u_i(x, y, z, t)}{\partial t^2} = \frac{\partial \sigma_{xx}(x, y, z, t)}{\partial x} + \frac{\partial \sigma_{xy}(x, y, z, t)}{\partial y} + \frac{\partial \sigma_{xz}(x, y, z, t)}{\partial z} \]
\[ \rho(z) \frac{\partial^2 u_y(x, y, z, t)}{\partial t^2} = \frac{\partial \sigma_{xy}(x, y, z, t)}{\partial x} + \frac{\partial \sigma_{yy}(x, y, z, t)}{\partial y} + \frac{\partial \sigma_{yz}(x, y, z, t)}{\partial z} \]
\[ \rho(z) \frac{\partial^2 u_z(x, y, z, t)}{\partial t^2} = \frac{\partial \sigma_{xz}(x, y, z, t)}{\partial x} + \frac{\partial \sigma_{yz}(x, y, z, t)}{\partial y} + \frac{\partial \sigma_{zz}(x, y, z, t)}{\partial z} \]

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

$\rho(z)$ is the density of materials of heterostructure, $\delta_{ij}$ is the Kronecker symbol. With account the relation for $\sigma_{ij}$ last system of equation could be written as

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

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

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

\[ + \frac{\partial^2 u_z(x, y, z, t)}{\partial y \partial z} + \frac{\partial}{\partial z} \left\{ K(z) \left[ \frac{\partial u_x(x, y, z, t)}{\partial x} + \frac{\partial u_y(x, y, z, t)}{\partial y} + \frac{\partial u_z(x, y, z, t)}{\partial z} \right] \right\} + \]

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

Conditions for the system of Eq. (8) could be written in the form

\[ \frac{\partial \bar{u}(0, y, z, t)}{\partial x} = 0; \frac{\partial \bar{u}(L_x, y, z, t)}{\partial x} = 0; \frac{\partial \bar{u}(x, 0, z, t)}{\partial y} = 0; \frac{\partial \bar{u}(x, L_y, z, t)}{\partial y} = 0; \]

\[ \frac{\partial \bar{u}(x, y, 0, t)}{\partial z} = 0; \frac{\partial \bar{u}(x, y, L_z, t)}{\partial z} = 0; \bar{u}(x, y, z, 0) = \bar{u}_0; \bar{u}(x, y, z, \infty) = \bar{u}_0. \]

We determine spatio-temporal distributions of concentrations of dopant and radiation defects by solving the Eqs.(1), (3) and (5) framework standard method of averaging of function corrections [28]. Previously we transform the Eqs.(1), (3) and (5) to the following form with account initial distributions of the considered concentrations

\[ \frac{\partial C(x, y, z, t)}{\partial t} = \frac{\partial}{\partial x} \left[ D_x \frac{\partial C(x, y, z, t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ D_y \frac{\partial C(x, y, z, t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ D_z \frac{\partial C(x, y, z, t)}{\partial z} \right] + (1a) \]

\[ + \frac{\partial}{\partial x} \left[ \frac{D_{cs}}{V k T} \frac{\partial z_2(x, y, z, t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ \frac{D_{cs}}{V k T} \frac{\partial z_2(x, y, z, t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{cs}}{V k T} \frac{\partial z_2(x, y, z, t)}{\partial z} \right] \]

\[ + \frac{\partial}{\partial z} \left[ \frac{D_{cs}}{V k T} \frac{\partial z_2(x, y, z, t)}{\partial z} \right] + \Omega \frac{\partial}{\partial x} \left[ \frac{D_{cs}}{V k T} \nabla_s \mu \left( x, y, z, t \right) \int_x^l C(x, y, W, t) dW \right] \]

\[ + \Omega \frac{\partial}{\partial y} \left[ \frac{D_{cs}}{V k T} \nabla_s \mu \left( x, y, z, t \right) \int_y^l C(x, y, W, t) dW \right] \]

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

\[ + \frac{\partial}{\partial z} \left[ \frac{D}{z} \frac{\partial I(x, y, z, t)}{\partial z} \right] + \frac{\partial}{\partial x} \left[ \frac{D_{cs}}{V k T} \nabla_s \mu \left( x, y, z, t \right) \int_x^l I(x, y, W, t) dW \right] + \]
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

\[ + \frac{\partial}{\partial y} \left[ \frac{D_{\Phi}}{kT} \nabla \mu_i(x, y, z, t) I(x, y, W, t) \right] I^2(x, y, z, t) \frac{\partial}{\partial y} \left[ \frac{D_{\Phi}}{kT} \nabla \mu_i(x, y, z, t) \right] - k_{I,I}(x, y, z, T) I(x, y, z, t) + f_{I}(x, y, z) \delta(t) \]

\[ \frac{\partial V(x, y, z, t)}{\partial t} = \frac{\partial}{\partial x} \left[ D_{\psi} \nabla \psi(x, y, z, t) \right] + \frac{\partial}{\partial y} \left[ D_{\psi} \nabla \psi(x, y, z, t) \right] + \frac{\partial}{\partial z} \left[ D_{\psi} \nabla \psi(x, y, z, t) \right] + \Omega \frac{\partial}{\partial x} \left[ \frac{D_{\Phi}}{kT} \nabla \mu_i(x, y, z, t) \right] V(x, y, W, t) \right] dW \]

Further we replace concentrations of dopant and radiation defects in right sides of Eqs. (1a), (3a) and (5a) on their not yet known average values \( \alpha_{\psi, \Phi} \). In this situation we obtain equations for the first-order
approximations of the required concentrations in the following form

\[
\frac{\partial C_i(x, y, z, t)}{\partial t} = \alpha_{iC}^\varOmega \frac{\partial}{\partial x} \left[ z \frac{D_{Ss}}{kT} \nabla_s \mu_i(x, y, z, t) \right] + \alpha_{iC}^\varOmega \frac{\partial}{\partial y} \left[ z \frac{D_{Ss}}{kT} \nabla_s \mu_i(x, y, z, t) \right] + \frac{f_c(x, y, z)\delta(t)}{\partial t} \left[ \frac{D_{cs}}{\sqrt{kT}} \frac{\partial \mu_c(x, y, z, t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ \frac{D_{cs}}{\sqrt{kT}} \frac{\partial \mu_c(x, y, z, t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{cs}}{\sqrt{kT}} \frac{\partial \mu_c(x, y, z, t)}{\partial z} \right]
\]

\[
(1b)
\]

\[
\frac{\partial I_i(x, y, z, t)}{\partial t} = \alpha_{iI}^\varOmega \frac{\partial}{\partial x} \left[ z \frac{D_{Is}}{kT} \nabla_s \mu_i(x, y, z, t) \right] + \alpha_{iI}^\varOmega \frac{\partial}{\partial y} \left[ z \frac{D_{Is}}{kT} \nabla_s \mu_i(x, y, z, t) \right] + \frac{\partial}{\partial x} \left[ \frac{D_{Is}}{\sqrt{kT}} \frac{\partial \mu_i(x, y, z, t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ \frac{D_{Is}}{\sqrt{kT}} \frac{\partial \mu_i(x, y, z, t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{Is}}{\sqrt{kT}} \frac{\partial \mu_i(x, y, z, t)}{\partial z} \right] + f_i(x, y, z)\delta(t) - \alpha_{iI}^2 k_{i, i}(x, y, z, T) - \alpha_{iI} \alpha_{iV} k_{i, V}(x, y, z, T)
\]

\[
(3b)
\]

\[
\frac{\partial V_i(x, y, z, t)}{\partial t} = \alpha_{iV}^\varOmega \frac{\partial}{\partial x} \left[ z \frac{D_{Vs}}{kT} \nabla_s \mu_i(x, y, z, t) \right] + \alpha_{iV}^\varOmega \frac{\partial}{\partial y} \left[ z \frac{D_{Vs}}{kT} \nabla_s \mu_i(x, y, z, t) \right] + \frac{\partial}{\partial x} \left[ \frac{D_{Vs}}{\sqrt{kT}} \frac{\partial \mu_i(x, y, z, t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ \frac{D_{Vs}}{\sqrt{kT}} \frac{\partial \mu_i(x, y, z, t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{Vs}}{\sqrt{kT}} \frac{\partial \mu_i(x, y, z, t)}{\partial z} \right] + f_i(x, y, z)\delta(t) - \alpha_{iV}^2 k_{V, i}(x, y, z, T) - \alpha_{iI} \alpha_{iV} k_{i, V}(x, y, z, T)
\]

\[
(5b)
\]

Integration of the left and right sides of the Eqs. (1b), (3b) and (5b) on time gives us possibility to obtain relations for above approximation in the final form

\[
C_i(x, y, z, t) = \alpha_{iC}^\varOmega \frac{\partial}{\partial x} \int_0^t \frac{D_{Sl}}{kT} \frac{\partial}{\partial x} \left[ z \frac{V(x, y, z, t)}{V^*} \right] 1 + \frac{V(x, y, z, t)}{V^*} + \frac{V^2(x, y, z, t)}{(V^*)^2} \times \frac{1}{V^*}
\]
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

\[
\times \nabla_s \mu_i(x, y, z, \tau) \left[ 1 + \frac{\xi_s \alpha_{ic}^p}{P^p(x, y, z, T)} \right] d \tau \right] + \alpha_{ic} \frac{\partial}{\partial y} \left[ D_{SL}(x, y, z, T) \left[ 1 + \frac{\xi_s \alpha_{ic}^p}{P^p(x, y, z, T)} \right] \right] + \\
\times \nabla_s \mu_i(x, y, z, \tau) \frac{z}{k T} \left[ 1 + \xi_1 \frac{V(x, y, z, \tau)}{V^*} + \xi_2 \frac{V^2(x, y, z, \tau)}{(V^*)^2} \right] d \tau + \frac{\partial}{\partial x} \left[ D_{CS} \frac{\partial \mu_i(x, y, z, \tau)}{\partial z} \right] d \tau + f_c(x, y, z) \]

\[
I_i(x, y, z, \tau) = \alpha_{iz} \Omega \frac{\partial}{\partial x} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau + \alpha_{iz} \Omega \frac{\partial}{\partial y} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau + \\
+ \frac{\partial}{\partial x} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial y} d \tau + \\
+ \frac{\partial}{\partial z} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial z} d \tau + f_i(x, y, z) - \alpha_{iz} \alpha_{iw} \int_0^T \mu_i(x, y, z, \tau) d \tau \]

\[
V_i(x, y, z, \tau) = \alpha_{iv} \Omega \frac{\partial}{\partial x} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau + \alpha_{iv} \Omega \frac{\partial}{\partial y} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau + \\
+ \frac{\partial}{\partial x} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial y} d \tau + \\
+ \frac{\partial}{\partial z} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial z} d \tau + f_i(x, y, z) - \alpha_{iv} \alpha_{iw} \int_0^T \mu_i(x, y, z, \tau) d \tau \]

\[
\Phi_i(x, y, z, \tau) = \alpha_{iv} \Omega \frac{\partial}{\partial x} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau + \Omega \frac{\partial}{\partial x} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau \times \\
\times \alpha_{iv} \mu + f_{iv}(x, y, z) + \frac{\partial}{\partial x} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial y} d \tau + \\
+ \frac{\partial}{\partial z} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial z} d \tau + \int_0^T k_i(x, y, z, \tau) d \tau + \int_0^T k_i(x, y, z, \tau) d \tau d \tau + \\
\Phi W(x, y, z, \tau) = \alpha_{iv} \Omega \frac{\partial}{\partial x} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau + \Omega \frac{\partial}{\partial x} \int_0^T \nabla_s \mu_i(x, y, z, \tau) d \tau \times \\
\times \alpha_{iv} \mu + f_{iv}(x, y, z) + \frac{\partial}{\partial x} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial y} d \tau + \\
+ \frac{\partial}{\partial z} \int_0^T \frac{D_{IS}}{k T} \frac{\partial \mu_i(x, y, z, \tau)}{\partial z} d \tau + \int_0^T k_i(x, y, z, \tau) d \tau + \int_0^T k_i(x, y, z, \tau) d \tau d \tau + \\
\int_0^T k_i(x, y, z, \tau) d \tau + \int_0^T k_i(x, y, z, \tau) d \tau d \tau + \\
\int_0^T k_i(x, y, z, \tau) d \tau + \int_0^T k_i(x, y, z, \tau) d \tau d \tau +
\]
\begin{equation}
+ \int_{0}^{t} k_{VY}(x, y, z, T) V^2(x, y, z, \tau) d \tau.
\end{equation}

We determine average values of the first-order approximations of concentrations of dopant and radia-
tion defects by the following standard relation [28]

\begin{equation}
\alpha_{ip} = \frac{1}{\Theta L_{x} L_{y} L_{z}} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} \rho_{i}(x, y, z, t) d z \ d y \ d x \ d t.
\end{equation}

Substitution of the relations (1c), (3c) and (5c) into relation (9) gives us possibility to obtain required
average values in the following form

\begin{equation}
\alpha_{iC} = \frac{1}{L_{x} L_{y} L_{z}} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{C}(x, y, z) d z \ d y \ d x,
\end{equation}

\begin{equation}
\alpha_{ii} = \sqrt{(a_{3} + A)^{2} - 4 \left[ B + \frac{\Theta a_{d} B + \Theta^{2} L_{x} L_{y} L_{z} a_{1}}{a_{4}} \right] - \frac{a_{3} + A}{4 a_{4}}}.
\end{equation}

\begin{equation}
\alpha_{iv} = \frac{1}{S_{IV00}} \left[ \frac{\Theta L_{x} L_{y} L_{z}}{\alpha_{ii}} \right] \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{i}(x, y, z) d z \ d y \ d x - \alpha_{i2} S_{H00} - \Theta L_{x} L_{y} L_{z},
\end{equation}

where

\begin{equation}
S_{IV0j} = \int_{0}^{\Theta} \int_{0}^{L_{x}} \int_{0}^{L_{y}} k_{p_{j}}(x, y, z, T) I_{i}(x, y, z, T) V_{i}(x, y, z, T) d z \ d y \ d x, \quad a_{4} = S_{H00} \times
\end{equation}

\begin{equation}
\times \left( S_{V0} - S_{H00} S_{V00} \right), \quad a_{3} = S_{IV0} S_{H00} + S_{IV0} S_{V00} - S_{H00} S_{V00}, \quad a_{2} = \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{V}(x, y, z) d z \ d y \ d x \times
\end{equation}

\begin{equation}
\times S_{IV0} S_{IV0} + S_{IV0} \Theta L_{x} L_{y} L_{z} + 2 S_{V00} S_{H00} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{i}(x, y, z) d z \ d y \ d x - \Theta L_{x} L_{y} L_{z} S_{V00} -
\end{equation}

\begin{equation}
- S_{IV0} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{i}(x, y, z) d z \ d y \ d x, \quad a_{1} = S_{IV0} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{i}(x, y, z) d z \ d y \ d x, \quad a_{0} = S_{V00} \times
\end{equation}

\begin{equation}
\times \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}, \quad A = \sqrt{8 \ y + \Theta^{2} \frac{a_{3}^{2}}{a_{4}^{2}} - 4 \Theta a_{3} a_{4}}, \quad B = \Theta a_{3} + \frac{\sqrt{q^{2} + p^{2}}}{q - q} -
\end{equation}

\begin{equation}
- \frac{3 \sqrt{q^{2} + p^{2}} + q}{q}, \quad q = \Theta^{3} a_{3}^{2} \left( 4 a_{0} - \Theta L_{x} L_{y} L_{z} a_{4} a_{3} \right) a_{4} - \Theta^{2} a_{0} \left( 4 a_{3} a_{4} - a_{3}^{2} \right) -
\end{equation}

\begin{equation}
- \frac{\Theta a_{2}^{2}}{54 a_{4}^{7}} - L_{x} L_{y} L_{z} \frac{\Theta^{2} a_{0}^{2}}{8 a_{4}^{2}}, \quad p = \Theta^{2} a_{4} a_{0} - \Theta L_{x} L_{y} L_{z} a_{4} a_{1}, \quad \alpha_{i0}, \quad
\end{equation}

\begin{equation}
\alpha_{i0} = \frac{R_{i1}}{\Theta L_{x} L_{y} L_{z}} + \frac{S_{H20}}{\Theta L_{x} L_{y} L_{z}} + \frac{1}{L_{x} L_{y} L_{z}} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{0}(x, y, z) d z \ d y \ d x,
\end{equation}

\begin{equation}
\alpha_{i0} = \frac{R_{i1}}{\Theta L_{x} L_{y} L_{z}} + \frac{S_{V20}}{\Theta L_{x} L_{y} L_{z}} + \frac{1}{L_{x} L_{y} L_{z}} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} f_{0}(x, y, z) d z \ d y \ d x,
\end{equation}

where

\begin{equation}
R_{p} = \Theta \int_{0}^{\Theta} \int_{0}^{L_{x}} \int_{0}^{L_{y}} k_{j}(x, y, z, T) I_{j}(x, y, z, T) d z \ d y \ d x \ d t.
\end{equation}
We determine approximations of the second and higher orders of concentrations of dopant and radiation defects framework standard iterative procedure of method of averaging of function corrections [28]. Framework this procedure to determine approximations of the n-th order of concentrations of dopant and radiation defects we replace the required concentrations in the Eqs. (1c), (3c), (5c) on the following sum \( \alpha_{0} + \rho_{n1}(x,y,z,t) \). The replacement leads to the following transformation of the appropriate equations:

\[
\frac{\partial C_{z}(x, y, z, t)}{\partial t} = \frac{\partial}{\partial x} \left[ 1 + \xi \left[ \alpha_{zc} + C_{z}(x, y, z, t) \right] \right] \left[ 1 + \xi_{1} \frac{V(x, y, z, t)}{V^{*}} + \xi_{2} \frac{V^{2}(x, y, z, t)}{(V^{*})^{2}} \right] \times
\]

\[
\times D_{t}(x, y, z, T) \frac{\partial C_{z}(x, y, z, t)}{\partial x} + \frac{\partial}{\partial y} \left[ 1 + \xi_{1} \frac{V(x, y, z, t)}{V^{*}} + \xi_{2} \frac{V^{2}(x, y, z, t)}{(V^{*})^{2}} \right] \frac{\partial C_{z}(x, y, z, t)}{\partial y} \times
\]

\[
\times D_{t}(x, y, z, T) \frac{\partial C_{z}(x, y, z, t)}{\partial z} \left[ 1 + \xi \left[ \alpha_{zc} + C_{z}(x, y, z, t) \right] \right] \left[ 1 + \xi_{1} \frac{V(x, y, z, t)}{V^{*}} + \xi_{2} \frac{V^{2}(x, y, z, t)}{(V^{*})^{2}} \right] \times
\]

\[
f_{c}(x, y, z, t) \]

\[
+ \frac{\partial}{\partial x} \left[ \frac{D_{cs}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ \frac{D_{cs}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{cs}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial z} \right] +
\]

\[
\frac{\Omega}{\bar{V} kT} \left[ \frac{D_{cs}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial y} \right] \left[ \alpha_{zc} + C_{z}(x, y, z, t) \right] dW + \frac{\Omega}{\bar{V} kT} \left[ \frac{D_{cs}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial y} \right] \left[ \alpha_{zc} + C_{z}(x, y, z, t) \right] dW \] (1d)

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

\[
+ \frac{\partial}{\partial z} \left[ D_{y}(x, y, z, T) \frac{\partial I_{z}(x, y, z, t)}{\partial z} \right] - k_{1,t}(x, y, z, t) \left[ \alpha_{11} + I_{1}(x, y, z, t) \right] - k_{1,v}(x, y, z, T) \times
\]

\[
\times \left[ \alpha_{11} + I_{1}(x, y, z, t) \right] \left[ \alpha_{11} + I_{1}(x, y, z, t) \right] + \Omega \frac{\partial}{\partial x} \left[ \nabla_{s} \left[ \alpha_{21} + I_{1}(x, y, z, t) \right] \right] dW \times
\]

\[
\frac{D_{is}}{kT} + \frac{\partial}{\partial y} \left[ \frac{D_{is}}{kT} \nabla_{s} \left[ \alpha_{21} + I_{1}(x, y, z, t) \right] \right] dW + \frac{\partial}{\partial x} \left[ \frac{D_{is}}{kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial x} \right] dW \times
\]

\[
\frac{D_{is}}{\bar{V} kT} d\tau + \frac{\partial}{\partial y} \left[ \frac{D_{is}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial y} \right] d\tau + \frac{\partial}{\partial z} \left[ \frac{D_{is}}{\bar{V} kT} \frac{\partial \mu_{c}(x, y, z, t)}{\partial z} \right] d\tau \] (3d)

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

\[
+ \frac{\partial}{\partial z} \left[ D_{v}(x, y, z, T) \frac{\partial V_{z}(x, y, z, t)}{\partial z} \right] - k_{v,v}(x, y, z, T) \left[ \alpha_{11} + V_{1}(x, y, z, t) \right] - k_{1,v}(x, y, z, T) \times
\]
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

\[
\times \left[ \alpha \mu + I_1(x, y, z, t) \right] [\alpha_1 + V_1(x, y, z, t)] + \Omega \frac{\partial}{\partial x} \left\{ V_s \mu \left( x, y, z, t \right) \left[ \alpha_2 + V_1(x, y, W, t) \right] \right\} dW \times
\]

\[
\times \frac{D_{VS}}{kT} + \Omega \frac{\partial}{\partial y} \left\{ \frac{D_{VS}}{kT} V_s \mu \left( x, y, z, t \right) \left[ \alpha_2 + V_1(x, y, W, t) \right] \right\} dW + \frac{\partial}{\partial x} \left\{ \frac{D_{VS}}{kT} \mu_2 \left( x, y, z, t \right) \right\} dW \times
\]

\[
\times \frac{D_{VS}}{V kT} \frac{d\tau}{\frac{\partial}{\partial y} \left\{ \frac{D_{VS}}{V kT} \mu_2 \left( x, y, z, t \right) \right\} d\tau \times
\]

\[
\frac{\partial}{\partial t} \Phi_{2l}(x, y, z, t) = \frac{\partial}{\partial x} \left\{ D_{\phi_1} \left( x, y, z, T \right) \frac{\partial}{\partial x} \Phi_{2l}(x, y, z, t) \right\} + \frac{\partial}{\partial y} \left\{ D_{\phi_1} \left( x, y, z, T \right) \frac{\partial}{\partial y} \Phi_{2l}(x, y, z, t) \right\} + \frac{\partial}{\partial z} \left\{ D_{\phi_2} \left( x, y, z, T \right) \frac{\partial}{\partial z} \Phi_{2l}(x, y, z, t) \right\} + f_{\phi_1}(x, y, z) \delta(t)
\]

\[
\frac{\partial}{\partial t} \Phi_{2u}(x, y, z, t) = \frac{\partial}{\partial x} \left\{ D_{\phi_1} \left( x, y, z, T \right) \frac{\partial}{\partial x} \Phi_{2u}(x, y, z, t) \right\} + \frac{\partial}{\partial y} \left\{ D_{\phi_1} \left( x, y, z, T \right) \frac{\partial}{\partial y} \Phi_{2u}(x, y, z, t) \right\} + \frac{\partial}{\partial z} \left\{ D_{\phi_2} \left( x, y, z, T \right) \frac{\partial}{\partial z} \Phi_{2u}(x, y, z, t) \right\} + f_{\phi_2}(x, y, z) \delta(t).
\]

Integration of the left and the right sides of Eqs. (1d), (3d) and (5d) gives us possibility to obtain relations for the required concentrations in the final form

\[
C_2(x, y, z, t) = \frac{\partial}{\partial x} \left\{ 1 + \int_{t_0}^{t} \left[ \alpha_2 + C_1(x, y, z, T) \right] \right\} \left[ 1 + \int_{t_0}^{t} \frac{V(x, y, z, T)}{V^*} + \int_{t_0}^{t} \frac{V^2(x, y, z, T)}{(V^*)^2} \right] \times
\]

International Journal of Research Studies in Electrical and Electronics Engineering (IJRSEEE)  Page | 52
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

\[ \times D_L(x, y, z, T) \frac{\partial C_i(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int D_L(x, y, z, T) \left[ 1 + \zeta_1 \frac{V(x, y, z, \tau)}{V'} + \zeta_2 \frac{V^2(x, y, z, \tau)}{(V')^2} \right] \times \]

\[ \times \frac{\partial C_i(x, y, z, \tau)}{\partial y} \left[ 1 + \zeta_1 \frac{\nu_{2c} + C_i(x, y, z, \tau)}{P'}(x, y, z, T) \right] \int + \frac{\partial}{\partial z} \int \left[ 1 + \zeta_1 \frac{V(x, y, z, \tau)}{V'} + \zeta_2 \frac{V^2(x, y, z, \tau)}{(V')^2} \right] \times \]

\[ \times D_L(x, y, z, T) \frac{\partial C_i(x, y, z, \tau)}{\partial z} \left[ 1 + \zeta_1 \frac{\nu_{2c} + C_i(x, y, z, \tau)}{P'}(x, y, z, T) \right] d \tau + f_c(x, y, z) + \]

\[ + \Omega \frac{\partial}{\partial x} \int D_s \nabla_s \mu (x, y, z, \tau) [\alpha_{2c} + C_i(x, y, W, \tau)] dW d \tau + \frac{\partial}{\partial y} \int \nabla_s \mu (x, y, z, \tau) \times \]

\[ \times \frac{\partial D_s}{kT} \left[ \alpha_{2c} + C_i(x, y, W, \tau) \right] dW d \tau + \frac{\partial}{\partial x} \left[ \frac{D_{cs}}{kT} \frac{\partial \mu_2(x, y, z, \tau)}{\partial x} \right] + \]

\[ + \frac{\partial}{\partial y} \left[ \frac{D_{cs}}{kT} \frac{\partial \mu_2(x, y, z, \tau)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{cs}}{kT} \frac{\partial \mu_2(x, y, z, \tau)}{\partial z} \right] \]

\[ I_2(x, y, z, \tau) = \frac{\partial}{\partial x} \int D_j(x, y, z, T) \frac{\partial I_1(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int D_j(x, y, z, T) \frac{\partial I_1(x, y, z, \tau)}{\partial y} d \tau + \]

\[ + \frac{\partial}{\partial z} \int D_j(x, y, z, T) \frac{\partial I_1(x, y, z, \tau)}{\partial z} d \tau - \int_0^T k_{j, 1} (x, y, z, T) [\alpha_{21} + I_1(x, y, z, \tau)]^2 d \tau - \]

\[ - \int_0^T k_{j, 1} (x, y, z, T) [\alpha_{21} + I_1(x, y, z, \tau)] [\alpha_{2y} + V_j(x, y, z, \tau)] d \tau + \frac{\partial}{\partial x} \int \nabla_s \mu (x, y, z, \tau) \times \]

\[ \times \frac{\partial D_s}{kT} \left[ \alpha_{2y} + I_1(x, y, W, \tau) \right] dW d \tau + \frac{\partial}{\partial y} \int \nabla_s \mu (x, y, z, \tau) \int \left[ \alpha_{2y} + I_1(x, y, W, \tau) \right] \times \]

\[ \times \frac{\partial D_s}{kT} \int [\alpha_{2y} + I_1(x, y, W, \tau)] dW d \tau + \frac{\partial}{\partial x} \left[ \frac{D_{is}}{kT} \frac{\partial \mu_2(x, y, z, \tau)}{\partial x} \right] + \]

\[ + \frac{\partial}{\partial y} \left[ \frac{D_{is}}{kT} \frac{\partial \mu_2(x, y, z, \tau)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{is}}{kT} \frac{\partial \mu_2(x, y, z, \tau)}{\partial z} \right] \]

\[ V_2(x, y, z, \tau) = \frac{\partial}{\partial x} \int D_v(x, y, z, T) \frac{\partial V_1(x, y, z, \tau)}{\partial x} d \tau + \frac{\partial}{\partial y} \int D_v(x, y, z, T) \frac{\partial V_1(x, y, z, \tau)}{\partial y} d \tau + \]

\[ + \frac{\partial}{\partial z} \int D_v(x, y, z, T) \frac{\partial V_1(x, y, z, \tau)}{\partial z} d \tau - \int_0^T k_{v, 2} (x, y, z, T) [\alpha_{2y} + V_1(x, y, z, \tau)]^2 d \tau - \]

\[ - \int_0^T k_{v, 2} (x, y, z, T) [\alpha_{2y} + V_1(x, y, z, \tau)] [\alpha_{2y} + V_1(x, y, z, \tau)] d \tau + \frac{\partial}{\partial x} \int \nabla_s \mu (x, y, z, \tau) \times \]
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements, On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

\[ \times \Omega \frac{D_{VS}}{kT} \int_0^L \left[ \alpha_{2v} + V_1(x,y,W,\tau) \right] dW d\tau + \frac{\partial}{\partial y} \int_0^L \nabla_5 \mu \left( x,y,z,\tau \right) \int_0^L \left[ \alpha_{2v} + V_1(x,y,W,\tau) \right] \times \]

\[ \times \frac{D_{VS}}{kT} \int_0^L dW d\tau + \frac{\partial}{\partial x} \left[ \frac{D_{VS}}{kT} \frac{\partial \mu_s(x,y,z,\tau)}{\partial x} \right] + \frac{\partial}{\partial y} \left[ \frac{D_{VS}}{kT} \frac{\partial \mu_s(x,y,z,\tau)}{\partial y} \right] + \frac{\partial}{\partial z} \left[ \frac{D_{VS}}{kT} \frac{\partial \mu_s(x,y,z,\tau)}{\partial z} \right] + f_v(x,y,z) \]

\[ \Phi_{2V} (x,y,z,\tau) = \frac{\partial}{\partial x} \int_0^L D_{V_1} (x,y,z,T) \frac{\partial \Phi_{IV} (x,y,z,\tau)}{\partial x} d\tau + \frac{\partial}{\partial y} \int_0^L \frac{\partial \Phi_{IV} (x,y,z,\tau)}{\partial y} d\tau \times \]

\[ \times D_{V_1} (x,y,z,T) d\tau + \frac{\partial}{\partial z} \int_0^L D_{V_1} (x,y,z,T) \frac{\partial \Phi_{IV} (x,y,z,\tau)}{\partial z} d\tau + \Omega \frac{\partial}{\partial x} \int_0^L \nabla_5 \mu (x,y,z,\tau) \times \]

\[ \times \frac{D_{VS}}{kT} \int_0^L \left[ \alpha_{2v} + \Phi_{IV} (x,y,W,\tau) \right] dW d\tau + \Omega \frac{\partial}{\partial y} \int_0^L \left[ \alpha_{2v} + \Phi_{IV} (x,y,W,\tau) \right] dW \times \]

\[ \times \nabla_5 \mu (x,y,z,\tau) d\tau + \int_0^L k_{IV} (x,y,z,T) I^2 (x,y,z,\tau) d\tau + \frac{\partial}{\partial x} \int_0^L \frac{\partial \mu_s (x,y,z,\tau)}{\partial x} d\tau + \Phi_{2V} (x,y,z,\tau) + \int_0^L k_{IV} (x,y,z,T) I (x,y,z,\tau) d\tau \]  

\[ \Phi_{2V} (x,y,z,\tau) = \frac{\partial}{\partial x} \int_0^L D_{V_1} (x,y,z,T) \frac{\partial \Phi_{IV} (x,y,z,\tau)}{\partial x} d\tau + \frac{\partial}{\partial y} \int_0^L \frac{\partial \Phi_{IV} (x,y,z,\tau)}{\partial y} d\tau \times \]

\[ \times D_{V_1} (x,y,z,T) d\tau + \frac{\partial}{\partial z} \int_0^L D_{V_1} (x,y,z,T) \frac{\partial \Phi_{IV} (x,y,z,\tau)}{\partial z} d\tau + \Omega \frac{\partial}{\partial x} \int_0^L \nabla_5 \mu (x,y,z,\tau) \times \]

\[ \times \frac{D_{VS}}{kT} \int_0^L \left[ \alpha_{2v} + \Phi_{IV} (x,y,W,\tau) \right] dW d\tau + \Omega \frac{\partial}{\partial y} \int_0^L \left[ \alpha_{2v} + \Phi_{IV} (x,y,W,\tau) \right] dW \times \]

\[ \times \nabla_5 \mu (x,y,z,\tau) d\tau + \int_0^L k_{IV} (x,y,z,T) V^2 (x,y,z,\tau) d\tau + \frac{\partial}{\partial x} \int_0^L \frac{D_{VS}}{kT} \frac{\partial \mu_s (x,y,z,\tau)}{\partial x} d\tau + \phi_v (x,y,z) + \int_0^L k_{IV} (x,y,z,T) V (x,y,z,\tau) d\tau. \]

Average values of the second-order approximations of required approximations by using the following standard relation [28]
$$\alpha_{2p} = \frac{1}{\Theta L_{x} L_{y} L_{z}} \int_{0}^{L_{x}} \int_{0}^{L_{y}} \int_{0}^{L_{z}} \left[ \rho_{2}(x, y, z, t) - \rho_{1}(x, y, z, t) \right] d z d y d t .$$  \hspace{1cm} (10)$$

Substitution of the relations (1e), (3e), (5e) into relation (10) gives us possibility to obtain relations for required average values $\alpha_{2p}$

$$\alpha_{2c}=0, \alpha_{2q}=0, \alpha_{2v}=0, \alpha_{2i} = \frac{C_{v} - \alpha_{2v} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right) - S_{V_{V}V_{0}} - S_{V_{V}V_{11}}}{\sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)} ,$$

$$\alpha_{2i} = \frac{C_{v} - \alpha_{2v} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right) - S_{V_{V}V_{0}} - S_{V_{V}V_{11}}}{\sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)} ,$$

where $b_{4} = \frac{1}{\Theta L_{x} L_{y} L_{z}} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right),$ $b_{3} = \frac{S_{V_{V}V_{0}} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)}{\Theta L_{x} L_{y} L_{z}} (2S_{V_{V}V_{0}} + S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z})$,

$$+ \Theta L_{x} L_{y} L_{z}) \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right) + \frac{S_{V_{V}V_{0}} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)}{\Theta L_{x} L_{y} L_{z}} (2S_{V_{V}V_{0}} + S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z})$$

$$+ \Theta L_{x} L_{y} L_{z}) \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right),$$

$$b_{2} = \frac{S_{V_{V}V_{0}} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)}{\Theta L_{x} L_{y} L_{z}} (2S_{V_{V}V_{0}} + S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z})$$

$$+ \Theta L_{x} L_{y} L_{z}) \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right),$$

$$b_{1} = \frac{S_{V_{V}V_{0}} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)}{\Theta L_{x} L_{y} L_{z}} (2S_{V_{V}V_{0}} + S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z})$$

$$+ \Theta L_{x} L_{y} L_{z}) \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right),$$

$$b_{0} = \frac{S_{V_{V}V_{0}} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right)}{\Theta L_{x} L_{y} L_{z}} (2S_{V_{V}V_{0}} + S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z}).$$

$$C_{V} = \alpha_{2i} a_{2i} S_{V_{V}V_{0}} + a_{2v} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right) - S_{V_{V}V_{0}} - S_{V_{V}V_{11}},$$

$$E = \sqrt{8 y + \Theta a_{3} a_{4} \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} \left( S_{V_{V}V_{0}} + \Theta L_{x} L_{y} L_{z} \right) b_{1} b_{4}} + \frac{\Theta a_{3} a_{4} b_{2}}{6 a_{4}} + \frac{\Theta a_{3} a_{4} b_{2}}{54 a_{4} b_{4}^2} - b_{0} \Theta^2 a_{4} + \frac{\Theta a_{3} a_{4} b_{2}}{8 a_{4}^2} .$$
\[
\times \left( 4 \Theta b_2 - \Theta^2 \frac{b_3^2}{b_4} \right) - L_i^2 L_i^2 \Theta^4 b_2^2 \frac{8 b_4^2}{12 b_4^2} - \Theta b_2^2 \frac{18 b_4}{18 b_4}. 
\]

Further we determine solutions of Eqs.(8), i.e. components of displacement vector. To determine the first-order approximations of the considered components framework method of averaging of function corrections we replace the required functions in the right sides of the equations by their not yet known average values \( \alpha \). The substitution leads to the following result

\[
\rho(z) \frac{\partial^2 u_{ix}(x, y, z, t)}{\partial t^2} = -K(z) \beta(z) \frac{\partial T(x, y, z, t)}{\partial x}, \quad \rho(z) \frac{\partial^2 u_{iy}(x, y, z, t)}{\partial t^2} = -K(z) \beta(z) \frac{\partial T(x, y, z, t)}{\partial y}, \\
\rho(z) \frac{\partial^2 u_{iz}(x, y, z, t)}{\partial t^2} = -K(z) \beta(z) \frac{\partial T(x, y, z, t)}{\partial z}. 
\]

Integration of the left and the right sides of the above relations on time \( t \) leads to the following result

\[
u_{ix}(x, y, z, t) = u_{0x} + K(z) \beta(z) \frac{\partial}{\rho(z) \partial x} \int_0^t \int_0^t T(x, y, z, \tau) d \tau d \theta - K(z) \beta(z) \frac{\partial}{\rho(z) \partial x} \int_0^t \int_0^t T(x, y, z, \tau) d \tau d \theta, \\
u_{iy}(x, y, z, t) = u_{0y} + K(z) \beta(z) \frac{\partial}{\rho(z) \partial y} \int_0^t \int_0^t T(x, y, z, \tau) d \tau d \theta - K(z) \beta(z) \frac{\partial}{\rho(z) \partial y} \int_0^t \int_0^t T(x, y, z, \tau) d \tau d \theta, \\
u_{iz}(x, y, z, t) = u_{0z} + K(z) \beta(z) \frac{\partial}{\rho(z) \partial z} \int_0^t \int_0^t T(x, y, z, \tau) d \tau d \theta - K(z) \beta(z) \frac{\partial}{\rho(z) \partial z} \int_0^t \int_0^t T(x, y, z, \tau) d \tau d \theta.
\]

Approximations of the second and higher orders of components of displacement vector could be determined by using standard replacement of the required components on the following sums \( \alpha + u_{i}(x, y, z, t) \) [28]. The replacement leads to the following result

\[
\rho(z) \frac{\partial^2 u_{ix}(x, y, z, t)}{\partial t^2} = \left\{ K(z) + \frac{5E(z)}{6[1 + \sigma(z)]} \right\} \frac{\partial^2 u_{ix}(x, y, z, t)}{\partial x^2} + \left\{ K(z) + \frac{E(z)}{3[1 + \sigma(z)]} \right\} \frac{\partial^2 u_{iy}(x, y, z, t)}{\partial x \partial y} + \\
\times \frac{\partial^2 u_{ix}(x, y, z, t)}{\partial x \partial y} + \frac{E(z)}{2[1 + \sigma(z)]} \left[ \frac{\partial^2 u_{iy}(x, y, z, t)}{\partial y^2} + \frac{\partial^2 u_{iz}(x, y, z, t)}{\partial z^2} \right] - \frac{\partial T(x, y, z, t)}{\partial x} \times \\
\times K(z) \beta(z) + \left\{ K(z) + \frac{E(z)}{3[1 + \sigma(z)]} \right\} \frac{\partial^2 u_{iz}(x, y, z, t)}{\partial x \partial z} + \\
\rho(z) \frac{\partial^2 u_{iy}(x, y, z, t)}{\partial t^2} = \frac{E(z)}{2[1 + \sigma(z)]} \left[ \frac{\partial^2 u_{iy}(x, y, z, t)}{\partial x^2} + \frac{\partial^2 u_{iz}(x, y, z, t)}{\partial x \partial y} \right] - \frac{\partial T(x, y, z, t)}{\partial y} \times \\
\times K(z) \beta(z) + \frac{\partial}{\partial z} \left\{ \frac{E(z)}{2[1 + \sigma(z)]} \left[ \frac{\partial u_{iy}(x, y, z, t)}{\partial z} + \frac{\partial u_{iz}(x, y, z, t)}{\partial y} \right] \right\} + \frac{\partial^2 u_{iz}(x, y, z, t)}{\partial y^2} \times 
\]
\[ u_{2x}(x, y, z, t) = \frac{1}{\rho(z)} \left[ K(z) + \frac{5E(z)}{6[1+\sigma(z)]} \right] \frac{\partial^2 u_{1x}(x, y, z, \tau)}{\partial x^2} \int_0^\tau d\tau d\theta + \frac{1}{\rho(z)} \left[ K(z) - \frac{E(z)}{2[1+\sigma(z)]} \right] \frac{\partial^2 u_{1x}(x, y, z, \tau)}{\partial y^2} \int_0^\tau d\tau d\theta \]

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

Integration of the left and right sides of the above relations on time \( t \) leads to the following result

\[ u_{2y}(x, y, z, t) = \frac{E(z)}{2\rho(z)[1+\sigma(z)]} \left[ \frac{\partial^2}{\partial x^2} \int_0^\tau d\tau d\theta \left[ K(z) + \frac{5E(z)}{6[1+\sigma(z)]} \right] \frac{\partial^2 u_{1x}(x, y, z, \tau)}{\partial x^2} \int_0^\tau d\tau d\theta + \frac{1}{\rho(z)} \frac{\partial^2}{\partial y^2} \int_0^\tau d\tau d\theta \left[ K(z) - \frac{E(z)}{2[1+\sigma(z)]} \right] \frac{\partial^2 u_{1x}(x, y, z, \tau)}{\partial y^2} \int_0^\tau d\tau d\theta \right] + \frac{1}{1+\sigma(z)} \frac{K(z)}{\rho(z)} \frac{\partial^2}{\partial x^2} \int_0^\tau d\tau d\theta \left[ K(z) + \frac{5E(z)}{6[1+\sigma(z)]} \right] \frac{\partial^2 u_{1x}(x, y, z, \tau)}{\partial x^2} \int_0^\tau d\tau d\theta + \frac{1}{\rho(z)} \frac{\partial^2}{\partial y^2} \int_0^\tau d\tau d\theta \left[ K(z) - \frac{E(z)}{2[1+\sigma(z)]} \right] \frac{\partial^2 u_{1x}(x, y, z, \tau)}{\partial y^2} \int_0^\tau d\tau d\theta \]
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

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

u_{z}(x, y, z, \tau) = \frac{E(z)}{2[1 + \sigma(z)]} \left[ \frac{\partial^2}{\partial y^2} \int_0^\infty u_{1z}(x, y, z, \tau) \, d\tau \, d\theta \right] + \frac{\partial^2}{\partial y^2} \int_0^\infty u_{1z}(x, y, z, \tau) \, d\tau \, d\theta + \frac{\partial^2}{\partial y^2} \int_0^\infty u_{1z}(x, y, z, \tau) \, d\tau \, d\theta + \frac{\partial}{\partial y} \left[ K(z) \frac{\beta(z)}{\rho(z)} \int_0^\infty T(x, y, z, \tau) \, d\tau \, d\theta \right] \times \frac{1}{\rho(z)} + \frac{1}{\rho(z)} \times \times \frac{\partial}{\partial z} \left[ K(z) \frac{\partial}{\partial y} \int_0^\infty u_{1y}(x, y, z, \tau) \, d\tau \, d\theta \right] + \frac{\partial}{\partial y} \left[ K(z) \frac{\beta(z)}{\rho(z)} \int_0^\infty T(x, y, z, \tau) \, d\tau \, d\theta \right] - \frac{K(z)}{\rho(z)} \frac{\beta(z)}{\rho(z)} \int_0^\infty T(x, y, z, \tau) \, d\tau \, d\theta + u_{0y}, \right.

Order approximation framework method of match and to obtain some quantitative results. All obtained results have been checked by comparison with results of numerical simulations.

International Journal of Research Studies in Electrical and Electronics Engineering (IJRSEE)  Page | 58
DISCUSSION

In this section we analyzed spatio-temporal distributions of concentrations of dopants. Figs. 2 shows typical spatial distributions of concentrations of dopants in neighborhood of interfaces of heterostructures. We calculate these distributions of concentrations of dopants under the following condition: value of dopant diffusion coefficient in doped area is larger, than value of dopant diffusion coefficient in nearest areas. In this situation one can find increasing of compactness of field-effect transistors with increasing of homogeneity of distribution of concentration of dopant at one time. Changing relation between values of dopant diffusion coefficients leads to opposite result (see Figs. 3). We optimize annealing time framework recently introduces approach [29-37]. The optimization based on approximation real distribution by step-wise function (see Figs. 4 and 5). Farther we determine optimal values of annealing time by minimization of the following mean-squared error

![Fig. 2. Distributions of concentration of infused dopant in heterostructure from Fig. 1 in direction, which is perpendicular to interface between epitaxial layer substrate. Increasing of number of curve corresponds to increasing of difference between values of dopant diffusion coefficient in layers of heterostructure under condition, when value of dopant diffusion coefficient in epitaxial layer is larger, than value of dopant diffusion coefficient in substrate.](image1)

![Fig. 3. Distributions of concentration of implanted dopant in heterostructure from Fig. 1 in direction, which is perpendicular to interface between epitaxial layer substrate. Curves 1 and 3 corresponds to annealing time $\Theta = 0.0048(L_x^2+L_y^2+L_z^2)/D_0$. Curves 2 and 4 corresponds to annealing time $\Theta = 0.0057(L_x^2+L_y^2+L_z^2)/D_0$. Curves 1 and 2 corresponds to homogenous sample. Curves 3 and 4 corresponds to heterostructure under condition, when value of dopant diffusion coefficient in epitaxial layer is larger, than value of dopant diffusion coefficient in substrate.](image2)
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

Fig. 4. Spatial distributions of dopant in heterostructure after dopant infusion. Curve 1 is idealized distribution of dopant. Curves 2-4 are real distributions of dopant for different values of annealing time. Increasing of number of curve corresponds to increasing of annealing time

\[
U = \frac{1}{L_x L_y L_z} \int_0^{L_x} \int_0^{L_y} \int_0^{L_z} [C(x, y, z, \Theta) - \psi(x, y, z)] dz dy dx,
\]

where \( \psi(x, y, z) \) is the approximation function. Dependences of optimal values of annealing time on parameters are presented on Figs. 6 and 7 for diffusion and ion types of doping, respectively. It should be noted, that it is necessary to anneal radiation defects after ion implantation. One could find spreading of concentration of distribution of dopant during this annealing. In the ideal case distribution of dopant achieves appropriate interfaces between materials of heterostructure during annealing of radiation defects. If dopant did not achieves any interfaces during annealing of radiation defects, it is practicably to additionally anneal the dopant. In this situation optimal value of additional annealing time of implanted dopant is smaller, than annealing time of infused dopant.

Fig. 5. Spatial distributions of dopant in heterostructure after ion implantation. Curve 1 is idealized distribution of dopant. Curves 2-4 are real distributions of dopant for different values of annealing time. Increasing of number of curve corresponds to increasing of annealing time
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

Fig.6. Dependences of dimensionless optimal annealing time for doping by diffusion, which have been obtained by minimization of mean-squared error, on several parameters. Curve 1 is the dependence of dimensionless optimal annealing time on the relation $a/L$ and $\xi = \gamma = 0$ for equal to each other values of dopant diffusion coefficient in all parts of heterostructure. Curve 2 is the dependence of dimensionless optimal annealing time on value of parameter $\varepsilon$ for $a/L=1/2$ and $\xi = \gamma = 0$. Curve 3 is the dependence of dimensionless optimal annealing time on value of parameter $\xi$ for $a/L=1/2$ and $\varepsilon = \gamma = 0$. Curve 4 is the dependence of dimensionless optimal annealing time on value of parameter $\gamma$ for $a/L=1/2$ and $\xi = \varepsilon = 0$.

Farther we analyzed influence of relaxation of mechanical stress on distribution of dopant in doped areas of heterostructure. Under following condition $\varepsilon_0 < 0$ one can find compression of distribution of concentration of dopant near interface between materials of heterostructure. Contrary (at $\varepsilon_0 > 0$) one can find spreading of distribution of concentration of dopant in this area. This changing of distribution of concentration of dopant could be at least partially compensated by using laser annealing [37]. This type of annealing gives us possibility to accelerate diffusion of dopant and another processes in annealed area due to inhomogenous distribution of temperature and Arrhenius law. Accounting relaxation of mismatch-induced stress in heterostructure could leads to changing of optimal values of annealing time. At the same time modification of porosity gives us possibility to decrease value of mechanical stress. On the one hand mismatch-induced stress could be used to increase density of elements of integrated circuits. On the other hand could leads to generation dislocations of the discrepancy. Figs. 8 and 9 show distributions of concentration of vacancies in porous materials and component of displacement vector, which is perpendicular to interface between layers of heterostructure.

Fig.7. Dependences of dimensionless optimal annealing time for doping by ion implantation, which have been obtained by minimization of mean-squared error, on several parameters. Curve 1 is the dependence of dimensionless optimal annealing time on the relation $a/L$ and $\zeta = \gamma = 0$ for equal to each other values of dopant diffusion coefficient in all parts of heterostructure. Curve 2 is the dependence of dimensionless optimal annealing time on value of parameter $\varepsilon$ for $a/L=1/2$ and $\xi = \gamma = 0$. Curve 3 is the dependence of dimensionless optimal annealing time on value of parameter $\xi$ for $a/L=1/2$ and $\varepsilon = \gamma = 0$. Curve 4 is the dependence of dimensionless optimal annealing time on value of parameter $\gamma$ for $a/L=1/2$ and $\xi = \varepsilon = 0$. 

International Journal of Research Studies in Electrical and Electronics Engineering (IJRSEEE)  Page | 61
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

Fig. 8. Normalized dependences of component $u_z$ of displacement vector on coordinate $z$ for nonporous (curve 1) and porous (curve 2) epitaxial layers

Fig. 9. Normalized dependences of vacancy concentrations on coordinate $z$ in unstressed (curve 1) and stressed (curve 2) epitaxial layers

CONCLUSION

In this paper we model redistribution of infused and implanted dopants with account relaxation mismatch-induced stress during manufacturing field-effect heterotransistors framework a three stage nested miller compensated amplifier in transistor model. We formulate recommendations for optimization of annealing to decrease dimensions of transistors and to increase their density. We formulate recommendations to decrease mismatch-induced stress. Analytical approach to model diffusion and ion types of doping with account concurrent changing of parameters in space and time has been introduced. The approach also gives a possibility to take into account nonlinearity of mass transport.

REFERENCES

[1] V.I. Lachin, N.S. Savelov. *Electronics*. Rostov-on-Don: Phoenix, 2001.
[2] A. Polischuk. Modern Electronics. Issue 12. P. 8-11 (2004).
[3] G. Volovich. Modern Electronics. Issue 2. P. 10-17 (2006).
[4] A. Kerentsev, V. Lanin, Power Electronics. Issue 1. P. 34 (2008).
[5] A.O. Ageev, A.E. Belyaev, N.S. Boltovets, V.N. Ivanov, R.V. Konakova, Ya.Ya. Kudrik, P.M. Litvin, V.V. Milenin, A.V. Sachenko. *Semiconductors*. Vol. 43 (7). P. 897-903 (2009).
[6] Jung-Hui Tsai, Shao-Yen Chiu, Wen-Shiung Lour, Der-Feng Guo. *Semiconductors*. Vol. 43 (7). C. 971-974 (2009).
[7] O.V. Alexandrov, A.O. Zakhar’in, N.A. Sobolev, E.I. Shek, M.M. Makoviychuk, E.O. Parshin. *Semiconductors*. Vol. 32 (9). P. 1029-1032 (1998).
[8] I.B. Ermolovich, V.V. Milenin, R.A. Red’ko, S.M. Red’ko. *Semiconductors*. Vol. 43 (8). P. 1016-1020 (2009).
On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress

[9] P. Sinsermsuksakul, K. Hartman, S.B. Kim, J. Heo, L. Sun, H.H. Park, R. Chakraborty, T. Buonassisi, R.G. Gordon. Appl. Phys. Lett. Vol. 102 (5). P. 053901-053905 (2013).
[10] J.G. Reynolds, C.L. Reynolds, Jr.A. Mohanta, J.F. Muth, J.E. Rowe, H.O. Everitt, D.E. Aspnes. Appl. Phys. Lett. Vol. 102 (15). P. 152114–152118 (2013).
[11] N.I. Volokobinskaya, I.N. Komarov, T.V. Matyukhina, V.I. Reshetnikov, A.A. Rush, I.V. Falina, A.S. Yastrebov. Semiconductors. Vol. 35 (8). P. 1013-1017 (2001).
[12] E.L. Pankratov, E.A. Bulaeva. Reviews in Theoretical Science. Vol. 1 (1). P. 58-82 (2013).
[13] S.A. Kukushkin, A.V. Osipov, A.I. Romanychev. Physics of the Solid State. Vol. 58 (7). P. 1448-1452 (2016).
[14] E.M. Trukhanov, A.V. Kolesnikov, I. D. Loshkarev. Russian Microelectronics. Vol. 44 (8). P. 552-558 (2015).
[15] E.L. Pankratov, E.A. Bulaeva. Reviews in Theoretical Science. Vol. 3 (4). P. 365-398 (2015).
[16] K.K. Ong, K.L. Pey, P.S. Lee, A.T.S. Wee, X.C. Wang, Y.F. Chong, Appl. Phys. Lett. Vol. 89 (17). P. 172111-172114 (2006).
[17] H.T. Wang, L.S. Tan, E. F. Chor. J. Appl. Phys. Vol. 98 (9). P. 094901-094905 (2006).
[18] Yu.V. Bykov, A.G. Yeremeev, N.A. Zharova, I.V. Plotnikov, K.I. Rybakov, M.N. Drozdov, Yu.N. Drozdov, V.D. Skupov. Radiophysics and Quantum Electronics. Vol. 43 (3). P. 836-843 (2003).
[19] M. Shokouhifar, A. Jalali. Analog. Integr. Circ. Sig. Process. Vol. 86. P. 189-205 (2016).
[20] Y.W. Zhang, A.F. Bower. Journal of the Mechanics and Physics of Solids. Vol. 47 (11). P. 2273-2297 (1999).
[21] L.D. Landau, E.M. Lifshits. Theoretical physics. 7 (Theory of elasticity) (Physmatlit, Moscow, 2001).
[22] M. Kitayama, T. Narushima, W.C. Carter, R.M. Cannon, A.M. Glaeser. J. Am. Ceram. Soc. Vol. 83. P. 2561 (2000); M. Kitayama, T. Narushima, A.M. Glaeser. J. Am. Ceram. Soc. Vol. 83. P. 2572 (2000).
[23] P.G. Cheremskoy, V.V. Slesov, V.I. Betekhtin. Pore in solid bodies (Energoatomizdat, Moscow, 1990).
[24] Z.Yu. Gotra, Technology of microelectronic devices (Radio and communication, Moscow, 1991).
[25] P.M. Fahey, P.B. Griffin, J.D. Plummer. Rev. Mod. Phys. 1989. Vol. 61 (2). P. 289-388.
[26] V.L. Vinetskiy, G.A. Kholodar', Radiative physics of semiconductors. ("Naukova Dumka", Kiev, 1979).
[27] M.G. Mynbaeva, E.N. Mokhov, A.A. Lavrent'ev, K.D. Mynbaev, Techn. Phys. Lett. Vol. 34 (17). P. 13 (2008).
[28] Yu.D. Sokolov. Applied Mechanics. Vol.1 (1). P. 23-35 (1955).
[29] E.L. Pankratov. Russian Microelectronics. Vol. 36 (1). P. 33-39 (2007).
[30] E.L. Pankratov. Int. J. Nanoscience. Vol. 7 (4-5). P. 187-197 (2008).
[31] E.L. Pankratov, E.A. Bulaeva. Reviews in Theoretical Science. Vol. 1 (1). P. 58-82 (2013).
[32] E.L. Pankratov, E.A. Bulaeva. Int. J. Micro-Nano Scale Transp. Vol. 3 (3). P. 119-130 (2012).
[33] E.L. Pankratov, E.A. Bulaeva. International Journal of Modern Physics B. Vol. 29 (5). P. 1550023-1-1550023-12 (2015).
[34] E.L. Pankratov. J. Comp. Theor. Nanoscience. Vol. 14 (10). P. 4885–4899 (2017).
[35] E.L. Pankratov, E.A. Bulaeva. Materials science in semiconductor processing. Vol. 34. P. 260-268 (2015).
[36] E.L. Pankratov, E.A. Bulaeva. Int. J. Micro-Nano Scale Transp. Vol. 4 (1). P. 17-31 (2014).
[37] E.L. Pankratov. Nano. Vol. 6 (1). P. 31-40 (2011).

Citation: E.L. Pankratov (2020). “On Optimization of Manufacturing of a three Stage Nested Miller Compensated Amplifier in Transistor Model Based on Heterostructures to Increase Density of their Elements. On Variation of Technological Process under Influence of Porosity of Materials and Mismatch-Induced Stress”, International Journal of Research Studies in Electrical and Electronics Engineering (IJRSEEE), 6(3), pp.40-63, DOI: http://dx.doi.org/10.20431/2454-9436.0603004.

Copyright: © 2020 E.L. Pankratov. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited