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About analysis of influence of radiation dose on charge carrier mobility value

EL Pankratov

Abstract
In this paper we analyze dependence of charge carriers mobility on value of radiation dose during ion implantation. Based on model, introduced framework the paper, we determine conditions to decrease radiation damage in the irradiated materials. Also we introduce an analytical approach to analyze mass transfer. The approach gives a possibility to take into account nonlinearity of the considered process, as well as changes in the considered parameters in space and simultaneously in time.

Keywords: Radiation damage, charge carriers mobility, influence of value of radiation dose

Introduction
Currently, an actual point of solid-state electronic is development of new and improvement of characteristics of previously developed devices [1-5]. To solve these problems both the technological processes, which were used to manufacture the considered devices, and the characteristics of already manufactured devices attracted an interest. In this paper we consider a two-layer structure. The structure consist of a substrate and an epitaxial layer (see Fig. 1). We assume that a dopant was implanted into the considered structure to generate the required type of conductivity (*n* or *p*) in the doped are (for example, during manufacturing of a *p*-*n*-junction). Main aim of this paper is analysis of dependence of charge carriers mobility on radiation dose. An accompanying aim of this work is development of an analytical approach for analysis of mass transfer, which simultaneously takes into account of nonlinearity of the considered process, as well as changes of the considered parameters in space and time.

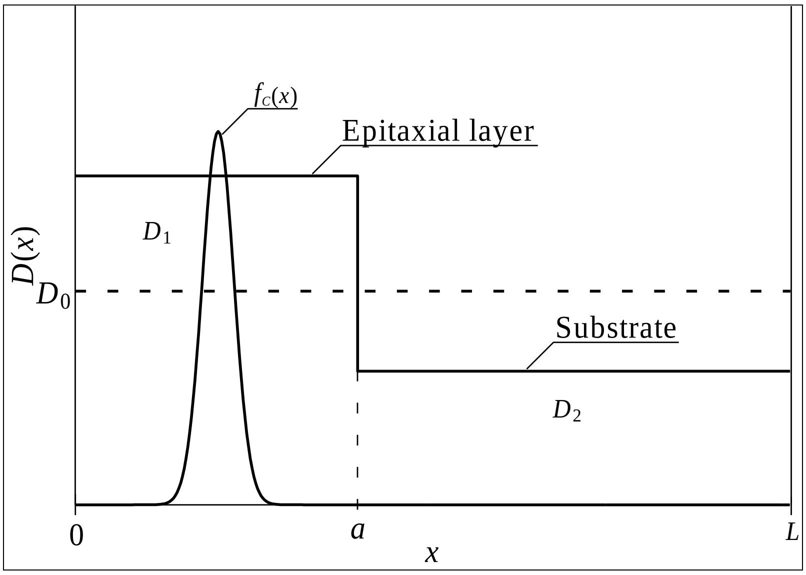

Fig 1: Two-layer structure with a substrate and an epitaxial layer

Method of solution
To solve our aim we determine and analyzed spatio-temporal distribution of concentration of dopant in the considered heterostructure. We determine the distribution by solving the second Fick's law in the following form [6-9].

$$\frac{\partial C(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_C\frac{\partial C(x,t)}{\partial x}\right] \quad (1)$$

With boundary and initial conditions

$$\left.\frac{\partial C(x,t)}{\partial x}\right|_{x=0}=0,\ \left.\frac{\partial C(x,t)}{\partial x}\right|_{x=L}=0,\ C(x,0)=f_C(x).$$

Here $C(x, t)$ is the spatio-temporal distribution of concentration of dopant; D is the dopant diffusion coefficient. Values of dopant diffusion coefficient depends on properties of materials of multilayer structure, speed of heating and cooling of materials during annealing and spatio-temporal distribution of concentration of dopant. Dependences of dopant diffusions coefficients on parameters could be approximated by the following relation [7-9].

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

Here $D_L(x,T)$ is the spatial (due to accounting all layers of multilayer structure) and temperature (due to Arrhenius law) dependences of dopant diffusion coefficient; T is the temperature of annealing; $P(x, T)$ is the limit of solubility of dopant; parameter γ depends on properties of materials and could be integer in the following interval $\gamma \in$ [1, 3, 7]; $V(x,t)$ is the spatio-temporal distribution of concentration of radiation vacancies with the equilibrium distribution V^*. Concentrational dependence of dopant diffusion coefficient has been described in details in [7]. Spatio-temporal distributions of concentration of point radiation defects have been determined by solving the following system of equations [7-9].

$$\begin{cases}\frac{\partial I(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_I(x,T)\frac{\partial I(x,t)}{\partial x}\right]-k_{I,I}(x,T)I^2(x,t)-k_{I,V}(x,T)I(x,t)V(x,t)\\ \frac{\partial V(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_V(x,T)\frac{\partial V(x,t)}{\partial x}\right]-k_{V,V}(x,T)V^2(x,t)-k_{I,V}(x,T)I(x,t)V(x,t)\end{cases} \quad (3)$$

with boundary and initial conditions

$$\left.\frac{\partial I(x,t)}{\partial x}\right|_{x=0}=0,\ \left.\frac{\partial I(x,t)}{\partial x}\right|_{x=L}=0,\ \left.\frac{\partial V(x,t)}{\partial x}\right|_{x=0}=0,\ \left.\frac{\partial V(x,t)}{\partial x}\right|_{x=L}=0,\ I(x,0)=f_I(x),\ V(x,0)=f_V(x) \quad (4)$$

Here $I(x,t)$ is the spatio-temporal distribution of concentration of radiation interstitials with the equilibrium distribution I^*; $D_I(x,T)$ and $D_V(x,T)$ are the diffusion coefficients of interstitials and vacancies, respectively; terms $V^2(x,t)$ and $I^2(x,t)$ correspond to generation of divacancies and diinterstitials, respectively (see, for example, [9] and appropriate references in this book); $k_{I,V}(x,T)$, $k_{I,I}(x,T)$ and $k_{V,V}(x,T)$ are the parameters of recombination of point radiation defects and generation of their complexes. Spatio-temporal distributions of divacancies $\Phi_V(x,t)$ and diinterstitials $\Phi_I(x,t)$ could be determined by solving the following system of equations [8, 9].

$$\begin{cases}\frac{\partial \Phi_I(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_I}(x,T)\frac{\partial \Phi_I(x,t)}{\partial x}\right]+k_I(x,T)I(x,t)+k_{I,I}(x,T)I^2(x,t)\\ \frac{\partial \Phi_V(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_V}(x,T)\frac{\partial \Phi_V(x,t)}{\partial x}\right]+k_V(x,T)V(x,t)+k_{V,V}(x,T)V^2(x,t)\end{cases} \quad (5)$$

with boundary and initial conditions

$$\left.\frac{\partial \Phi_I(x,t)}{\partial x}\right|_{x=0}=0,\quad \left.\frac{\partial \Phi_I(x,t)}{\partial x}\right|_{x=L}=0,\quad \left.\frac{\partial \Phi_V(x,t)}{\partial x}\right|_{x=0}=0,\quad \left.\frac{\partial \Phi_V(x,t)}{\partial x}\right|_{x=L}=0, \tag{6}$$

$\Phi_I(x,0)=f_{\Phi I}(x)$, $\Phi_V(x,0)=f_{\Phi V}(x)$.

Here $D_{\Phi I}(x, T)$ and $D_{\Phi V}(x, T)$ are the diffusion coefficients of simplest of complexes of radiation defects; $k_I(x,T)$ and $k_V(x,T)$ are the parameters of decay of these complexes of radiation defects.
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 [10-12]. Previously we transform the Eqs. (1), (3) and (5) to the following form with account initial distributions of the considered concentrations.

$$\frac{\partial C(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_C\frac{\partial C(x,t)}{\partial x}\right]+f_C(x)\delta(t) \tag{1a}$$

$$\begin{cases}\dfrac{\partial I(x,t)}{\partial t}=\dfrac{\partial}{\partial x}\left[D_I(x,T)\dfrac{\partial I(x,t)}{\partial x}\right]-\\ \qquad -k_{I,I}(x,T)I^2(x,t)-k_{I,V}(x,T)I(x,t)V(x,t)+f_I(x)\delta(t)\\ \dfrac{\partial V(x,t)}{\partial t}=\dfrac{\partial}{\partial x}\left[D_V(x,T)\dfrac{\partial V(x,t)}{\partial x}\right]-\\ \qquad -k_{V,V}(x,T)V^2(x,t)-k_{I,V}(x,T)I(x,t)V(x,t)+f_V(x)\delta(t)\end{cases} \tag{3a}$$

$$\begin{cases}\dfrac{\partial \Phi_I(x,t)}{\partial t}=\dfrac{\partial}{\partial x}\left[D_{\Phi_I}(x,T)\dfrac{\partial \Phi_I(x,t)}{\partial x}\right]+\\ \qquad +k_I(x,T)I(x,t)+k_{I,I}(x,T)I^2(x,t)+f_{\Phi_I}(x)\delta(t)\\ \dfrac{\partial \Phi_V(x,t)}{\partial t}=\dfrac{\partial}{\partial x}\left[D_{\Phi_V}(x,T)\dfrac{\partial \Phi_V(x,t)}{\partial x}\right]+\\ \qquad +k_V(x,T)V(x,t)+k_{V,V}(x,T)V^2(x,t)+f_{\Phi_V}(x)\delta(t)\end{cases} \tag{5a}$$

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

$$\frac{\partial C_1(x,t)}{\partial t}=f_C(x)\delta(t) \tag{1b}$$

$$\begin{cases}\dfrac{\partial I_1(x,t)}{\partial t}=f_I(x)\delta(t)-\alpha_{1I}^2k_{I,I}(x,T)-\alpha_{1I}\alpha_{1V}k_{I,V}(x,T)\\ \dfrac{\partial V_1(x,t)}{\partial t}=f_V(x)\delta(t)-\alpha_{1V}^2k_{V,V}(x,T)-\alpha_{1I}\alpha_{1V}k_{I,V}(x,T)\end{cases} \tag{3b}$$

$$\begin{cases} \frac{\partial \Phi_{1I}(x,t)}{\partial t} = f_{\Phi_I}(x)\delta(t) + k_I(x,T)I(x,t) + k_{I,I}(x,T)I^2(x,t) \\ \frac{\partial \Phi_{1V}(x,t)}{\partial t} = f_{\Phi_V}(x)\delta(t) + k_V(x,T)I(x,t) + k_{V,V}(x,T)V^2(x,t) \end{cases} \qquad (5b)$$

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

$$C_1(x,t) = f_C(x) \qquad (1c)$$

$$\begin{cases} I_1(x,t) = f_I(x) - \alpha_{1I}^2 \int\limits_0^t k_{I,I}(x,T)\,d\tau - \alpha_{1I}\alpha_{1V} \int\limits_0^t k_{I,V}(x,T)\,d\tau \\ V_1(x,t) = f_V(x) - \alpha_{1V}^2 \int\limits_0^t k_{V,V}(x,T)\,d\tau - \alpha_{1I}\alpha_{1V} \int\limits_0^t k_{I,V}(x,T)\,d\tau \end{cases} \qquad (3c)$$

$$\begin{cases} \Phi_{1I}(x,t) = f_{\Phi_I}(x) + \int\limits_0^t k_I(x,T)I(x,\tau)\,d\tau + \int\limits_0^t k_{I,I}(x,T)I^2(x,\tau)\,d\tau \\ \Phi_{1V}(x,t) = f_{\Phi_V}(x) + \int\limits_0^t k_V(x,T)V(x,\tau)\,d\tau + \int\limits_0^t k_{V,V}(x,T)V^2(x,\tau)\,d\tau \end{cases} \qquad (5c)$$

We determine average values of the first-order approximations of concentrations of dopant and radiation defects by the following standard relation [10-12].

$$\alpha_{1\rho} = \frac{1}{\Theta L} \int\limits_0^\Theta \int\limits_0^L \rho_1(x,t)\,d\,x\,d\,t \qquad (7)$$

Substitution of the relations (1*c*), (3*c*) and (5*c*) into relation (7) gives us possibility to obtain required average values in the following form

$$\alpha_{1C} = \frac{1}{L}\int\limits_0^L f_C(x)\,d\,x, \quad \alpha_{1I} = \sqrt{\frac{(a_3+A)^2}{4a_4^2} - 4\left(B + \frac{\Theta a_3 B + \Theta^2 L a_1}{a_4}\right)} - \frac{a_3 + A}{4a_4},$$

$$\alpha_{1V} = \frac{1}{S_{IV00}}\left[\frac{\Theta}{\alpha_{1I}} \int\limits_0^{L_x} f_I(x)\,d\,x - \alpha_{1I} S_{II00} - \Theta L\right],$$

Where

$$S_{\rho\rho\, ij} = \int\limits_0^\Theta (\Theta - t) \int\limits_0^L k_{\rho,\rho}(x,T) I_1^i(x,t) V_1^j(x,t)\,d\,x\,d\,t, \quad a_4 = S_{II00}\left(S_{IV00}^2 - S_{II00} S_{VV00}\right),$$

$$a_3 = S_{IV00} S_{II00} + S_{IV00}^2 - S_{II00} S_{VV00}, \quad a_2 = S_{IV00} S_{IV00}^2 \int\limits_0^L f_V(x)\,d\,x + 2 S_{VV00} S_{II00} \int\limits_0^L f_I(x)\,d\,x +$$

$$+ S_{IV00}\Theta L^2 - \Theta L^2 - S_{IV00}^2 \int\limits_0^L f_I(x)\,d\,x, \quad a_1 = S_{IV00} \int\limits_0^L f_I(x)\,d\,x, \quad a_0 = S_{VV00}\left[\int\limits_0^L f_I(x)\,d\,x\right]^2,$$

$$A=\sqrt{8y+\Theta^2\frac{a_3^2}{a_4^2}-4\Theta\frac{a_2}{a_4}},\quad B=\frac{\Theta a_2}{6a_4}+\sqrt[3]{\sqrt{q^2+p^3}-q}-\sqrt[3]{\sqrt{q^2+p^3}+q},\quad q=\frac{\Theta^3 a_2}{24a_4^2}\times$$

$$\times\left(4a_0-\Theta L\frac{a_1a_3}{a_4}\right)-\Theta^3\frac{a_0}{8a_4^2}\left(4a_2-\Theta\frac{a_3^2}{a_4}\right)-\frac{\Theta^3a_2^3}{54a_4^3}-L^2\frac{\Theta^4a_1^2}{8a_4^2},\quad p=\Theta^2\frac{4a_0a_4-\Theta L a_1a_3}{12a_4^2}-$$

$$-\Theta a_2/18a_4,$$

$$\alpha_{1\Phi_I}=\frac{R_{I1}}{\Theta L}+\frac{S_{II20}}{\Theta L}+\frac{1}{L}\int_0^L f_{\Phi_I}(x)dx,\quad \alpha_{1\Phi_V}=\frac{R_{V1}}{\Theta L}+\frac{S_{VV20}}{\Theta L}+\frac{1}{L}\int_0^L f_{\Phi_V}(x)dx,$$

Where

$$R_{\rho i}=\int_0^\Theta(\Theta-t)\int_0^L k_I(x,T)I_1^i(x,t)dx\,dt$$

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 [10-12]. 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. (1*c*), (3*c*), (5*c*) on the following sum $\alpha_{n\rho}+\rho_{n-1}(x,t)$. The replacement leads to the following transformation of the appropriate equations.

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

$$+f_C(x)\delta(t) \qquad (1d)$$

$$\begin{cases}\frac{\partial I_2(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_I(x,T)\frac{\partial I_1(x,t)}{\partial x}\right]-k_{I,I}(x,T)[\alpha_{1I}+I_1(x,t)]^2-\\ \qquad -k_{I,V}(x,T)[\alpha_{1I}+I_1(x,t)][\alpha_{1V}+V_1(x,t)]\\ \frac{\partial V_2(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_V(x,T)\frac{\partial V_1(x,t)}{\partial x}\right]-k_{V,V}(x,T)[\alpha_{1V}+V_1(x,t)]^2-\\ \qquad -k_{I,V}(x,T)[\alpha_{1I}+I_1(x,t)][\alpha_{1V}+V_1(x,t)]\end{cases} \qquad (3d)$$

$$\begin{cases}\frac{\partial \Phi_{2I}(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_I}(x,T)\frac{\partial \Phi_{1I}(x,t)}{\partial x}\right]+k_{I,I}(x,T)I^2(x,t)+\\ \qquad +k_I(x,T)I(x,t)+f_{\Phi_I}(x)\delta(t)\\ \frac{\partial \Phi_{2V}(x,t)}{\partial t}=\frac{\partial}{\partial x}\left[D_{\Phi_V}(x,T)\frac{\partial \Phi_{1V}(x,t)}{\partial x}\right]+k_{V,V}(x,T)V^2(x,t)+\\ \qquad +k_V(x,T)V(x,t)+f_{\Phi_V}(x)\delta(t)\end{cases} \qquad (5d)$$

Integration of the left and the right sides of Eqs. (1*d*), (3*d*) and (5*d*) gives us possibility to obtain relations for the required concentrations in the final form $C_2(x,t)=f_C(x)+$

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

$$\begin{cases} I_2(x,t)=\frac{\partial}{\partial x}\int_0^t D_I(x,T)\frac{\partial I_1(x,\tau)}{\partial x}d\tau+f_I(x)-\int_0^t k_{I,I}(x,T)\,[\alpha_{2I}+I_1(x,\tau)]^2 d\tau- \\ \qquad -\int_0^t k_{I,V}(x,T)\,[\alpha_{2I}+I_1(x,\tau)][\alpha_{2V}+V_1(x,\tau)]\,d\tau \\ V_2(x,t)=\frac{\partial}{\partial x}\int_0^t D_V(x,T)\frac{\partial V_1(x,\tau)}{\partial x}d\tau+f_V(x)-\int_0^t k_{V,V}(x,T)\,[\alpha_{2V}+V_1(x,\tau)]^2 d\tau- \\ \qquad -\int_0^t k_{I,V}(x,T)\,[\alpha_{2I}+I_1(x,\tau)][\alpha_{2V}+V_1(x,\tau)]\,d\tau \end{cases} \tag{3e}$$

$$\begin{cases} \Phi_{2I}(x,t)=\frac{\partial}{\partial x}\int_0^t D_{\Phi_I}(x,T)\frac{\partial \Phi_{1I}(x,\tau)}{\partial x}d\tau+\int_0^t k_{I,I}(x,T)I^2(x,\tau)\,d\tau+ \\ \qquad +\int_0^t k_I(x,T)I(x,\tau)\,d\tau+f_{\Phi_I}(x) \\ \Phi_{2V}(x,t)=\frac{\partial}{\partial x}\int_0^t D_{\Phi_V}(x,T)\frac{\partial \Phi_{1V}(x,\tau)}{\partial x}d\tau+\int_0^t k_{V,V}(x,T)V^2(x,\tau)\,d\tau+ \\ \qquad +\int_0^t k_V(x,T)V(x,\tau)\,d\tau+f_{\Phi_V}(x) \end{cases} \tag{5e}$$

Average values of the second-order approximations of required approximations by using the following standard relation [10-12]

$$\alpha_{2\rho}=\frac{1}{\Theta L}\int_0^\Theta\int_0^L[\rho_2(x,t)-\rho_1(x,t)]\,d\,x\,d\,t \tag{8}$$

Substitution of the relations (1*e*), (3*e*), (5*e*) into relation (8) gives us possibility to obtain relations for required average values $\alpha_{2\rho}$

$\alpha_{2C}=0$, $\alpha_{2\Phi I}=0$, $\alpha_{2\Phi V}=0$, $$\alpha_{2V}=\sqrt{\frac{(b_3+E)^2}{4b_4^2}-4\left(F+\frac{\Theta a_3F+\Theta^2L\,b_1}{b_4}\right)}-\frac{b_3+E}{4b_4},$$

$$\alpha_{2I}=\frac{C_V-\alpha_{2V}^2S_{VV00}-\alpha_{2V}(2S_{VV01}+S_{IV10}+\Theta L)-S_{VV02}-S_{IV11}}{S_{IV01}+\alpha_{2V}S_{IV00}},$$

Where

$$b_4=\frac{1}{\Theta L}\left(S_{IV00}^2S_{VV00}-S_{VV00}^2S_{II00}\right),\; b_3=-\frac{S_{II00}S_{VV00}}{\Theta L}(2S_{VV01}+S_{IV10}+\Theta L)+\frac{S_{IV00}}{\Theta L}\times$$

$$\times S_{VV00}(S_{IV01}+2S_{II10}+S_{IV01}+\Theta L)+\frac{S_{IV00}^2}{\Theta L}(2S_{VV01}+S_{IV10}+\Theta L)-\frac{S_{IV00}^2S_{IV10}}{\Theta^3L^3},\; b_2=\frac{S_{II00}}{\Theta L}\times$$

$$\times S_{VV00}\left(S_{VV02}+S_{IV11}+C_V\right)-\left(S_{IV10}-2S_{VV01}+\Theta L\right)^2+\left(\Theta L+2S_{II10}+S_{IV01}\right)S_{IV01}\frac{S_{VV00}}{\Theta L}+$$

$$+\frac{S_{IV00}}{\Theta L}\left(S_{IV01}+2S_{II10}+2S_{IV01}+\Theta L\right)\left(2S_{VV01}+\Theta L+S_{IV10}\right)-\frac{S_{IV00}^2}{\Theta L}\left(C_V-S_{VV02}-S_{IV11}\right)+$$

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

$$\times\left(\Theta L+2S_{II10}+S_{IV01}\right)\left(2S_{VV01}+S_{IV10}+\Theta L\right)-S_{IV10}\frac{S_{IV01}^2}{\Theta L}-\frac{S_{IV00}}{\Theta L}\left(3S_{IV01}+2S_{II10}+\Theta L\right)\times$$

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

$$\times\left(C_V-S_{VV02}-S_{IV11}\right)\frac{S_{IV01}}{\Theta L}+2C_I S_{IV01}^2-\frac{S_{IV01}}{\Theta L}\left(C_V-S_{VV02}-S_{IV11}\right)\left(\Theta L+2S_{II10}+S_{IV01}\right),$$

$$C_I=\frac{\alpha_{1I}\alpha_{1V}S_{IV00}+\alpha_{1I}^2 S_{II00}-S_{II20}S_{II20}-S_{IV11}}{\Theta L},\quad C_V=\alpha_{1I}\alpha_{1V}S_{IV00}+\alpha_{1V}^2 S_{VV00}-S_{VV02}-S_{IV11},$$

$$E=\sqrt{8y+\Theta^2\frac{a_3^2}{a_4^2}-4\Theta\frac{a_2}{a_4}},\quad F=\frac{\Theta a_2}{6a_4}+\sqrt[3]{\sqrt{r^2+s^3}-r}-\sqrt[3]{\sqrt{r^2+s^3}+r},\quad r=\frac{\Theta^3 b_2}{24b_4^2}\times$$

$$\times\left(4b_0-\Theta L\frac{b_1 b_3}{b_4}\right)-\frac{\Theta^3 b_2^3}{54b_4^3}-\frac{b_0\Theta^3}{8b_4^2}\left(4b_2-\Theta\frac{b_3^2}{b_4}\right)-L^2\frac{\Theta^4 b_1^2}{8b_4^2},\quad s=\Theta^2\frac{4b_0 b_4-\Theta L b_1 b_3}{12b_4^2}-$$

$$-\Theta b_2/18b_4.$$

Framework this paper we determine concentration of dopant and radiation defects by using the second-order approximation framework method of averaging of function corrections. This approximation is usually enough good approximation to make qualitative analysis and to obtain some quantitative results. All obtained results have been checked by comparison with results of numerical simulations.

Discussion

In this section, we analyze dynamics of redistribution of dopant and radiation defects during their annealing. Typical distributions of concentration of dopant in the considered multilayer structures are shown in Fig. 2 for different values of the radiation dose. Fig. 3 shows typical distributions of charge carriers mobility for various values of the radiation dose. To calculate curves from Fig. 3 we take into account following empirical relation between the charge carriers mobility and dopant concentration: $\mu=\mu_0[C_0/C(x,t)]^{1/3}$ (see, for example,) [13], where $C_0=2\cdot10^{15}$ cm^{-3}, μ_0 is the mobility at low dopant concentrations. Fig. 3 shows, that increasing of the radiation dose to worse electrophysical properties of the irradiated material. At the same time, radiation exposure leads to decreasing of mismatch-induced stresses in multilayer structures [12].

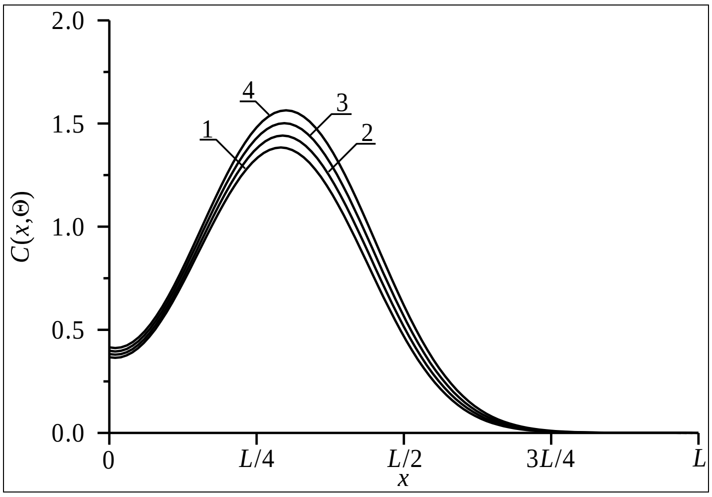

Fig 2: Typical distributions of dopant concentration at different values of the dose of implanted ions. Increasing of number of curve corresponds to increasing of value of dose of implanted ions.

Conclusion

Based on model, introduced framework the paper, we determine conditions to decrease radiation damage in the irradiated materials. Also we introduce an analytical approach to analyze mass transfer. The approach gives a possibility to take into account nonlinearity of the considered process, as well as changes in the considered parameters in space and simultaneously in time. It should be note that radiation exposure makes it possible to reduce mismatch-induced stresses in multilayer structures.

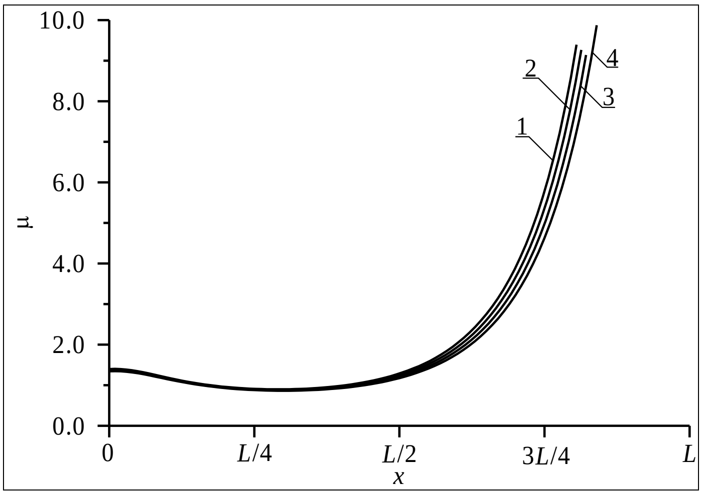

Fig 3: Typical distributions of charge carriers mobility at different values of the dose of implanted ions. Increasing of number of curve corresponds to increasing of value of dose of implanted ions.

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