Diffusion model of low-energy secondary electrons in fullerite and other solids

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Low-energy secondary electrons can play an important role in forming the image in the fullerite based electron lithography [1], in cathodoluminescence [2] and in polymerization and modification of organic materials [3]. Therefore description of the behavior of the low-energy secondary electrons in solids is an actual task. This task has been solved here in the frame of the model of electrons generated in the layer with the thickness *h* and diffused everywhere. The following diffusion problem has been considered by integral transformation method:

$$\frac{\partial^2 U(x,t)}{\partial x^2}-\frac{1}{D}\frac{\partial U(x,t)}{\partial t}=-\frac{\alpha(x)}{D}\ ;\ \left.\frac{\partial U(x,t)}{\partial x}\right|_{x=0}=0,\ U\big|_{t=0}=0,\ 0\le x<\infty,\ t\ge 0\ ,$$

where $U(x,t)$ – the concentration of secondary electrons, D – the diffusion coefficient. Generation rate of secondary electrons $\alpha(x)=\begin{cases}\alpha_0=const,\ 0<x<h\\ 0,\ x>h\end{cases}$.

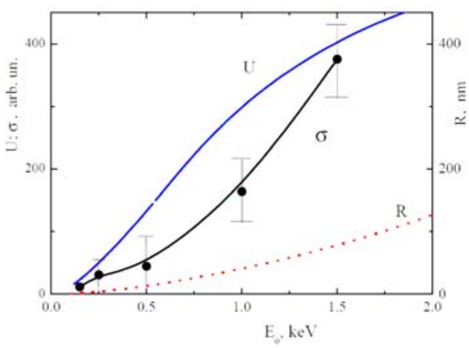
The solution may be represented in the analytical form:

$$U(x,t)=\frac{\alpha_0}{2}\cdot\begin{cases}2\cdot t-F(t,\beta_1)-F(t,\beta_2), x\le h\\ F(t,-\beta_1)-F(t,\beta_2), x\ge h\end{cases}\text{, where}$$

$$F(t,\beta)=(t+\beta^2)Erfc(\beta/2\sqrt{\tau})-\beta\frac{\sqrt{t}}{\sqrt{\pi}}\ell^{-\beta^2/4t}\ ,\ \beta_{1,2}=(h\pm x)\big/\sqrt{D}\ .$$

The important result is that the electron concentration $U(x,t)$ is proportional to the thickness *h* of the electron generation area which may be estimated as the electron projected range $h \sim R \sim E_o^{1.67}$ [2] of the primary electrons irradiating the surface with energy E_o. Thus the concentration of secondary electrons $U(x,t)$ proved to be a monotonously increasing function of the primary electron energy E_o.

This result was applied to the process of fullerite C_{60} polymerization used in electron-beam lithography. Fig. 1 shows the dependence $U(E_o)$ at $x=0$, $t=T$ for fullerite as well as the experimental energy dependence $\sigma(E_o)$ of the chemical bond generation rate in the process of fullerite polymerization induced by irradiating electrons. Fig. 1 shows that the monotonously increasing experimental energy dependence $\sigma(E_o)$ can be explained by the increasing concentration of secondary electrons in the frame of the model of an electron swarm diffusing to the surface from the bulk. The research was supported by the Russian Foundation for Basic Research (RFBR), Project № 10-07-00508-a.



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