объединенный
институт
ядерных
исследований
дубна

E7-94-346

Yu.S.Tsyganov, A.N.Polyakov

ON THE NATURE OF INCIDENT ANGLE DEPENDENCE OF RESIDUAL DEFECT IN SILICON SURFACE BARRIER DETECTOR

Submitted to «Nuclear Instruments and Methods»

1994

In the formation of the pulse height defect(PHD) in a silicon surface barrier detector (SSB), the residual defect is the component of PHD another than the nuclear stopping defect and the window one. At present there are two basic models explaining residual defect. The first one is more traditional, based on the phenomenon of non-equilibrium electron-hole recombination [1-4]. Recently, in [5,6] the residual defect was derived theoretically from the dielectric properties of the plasma column, although the contribution of recombination was not completely excluded. The residual defect was calculated using the length of the plasma column created by an incident charged particle and the depletion layer thickness of a SSB. This model contains one parameter (screening factor) which is determined experimentally. One of the arguments supporting this approach is the explanation of experimental data of the incident angle dependence of PHD for 133.9 MeV ^{58}Ni. Despite such a difference between the models very important conclusion follow from both ones, that there is no possibility to explain the angular dependence of the residual defect by the variation of the detector entrance window thickness.

From the viewpoint of application in computer simulation the formula for incident angle dependence of residual defect is required to calculate the spectra of spontaneous fission (SF) activity of the nuclei implanted into SSB. This is typical for the study of fusion-evaporation reactions at the facilities like the Dubna Gas Filled Recoil Separator [7].

To obtain the formula for the angular dependence of the residual defect we consider the plasma erosion process as described by Seibt et al.[8]. According to [2] we assume the surface channel to be the major recombination channel, hence the number of recombined electron-hole pairs is given by:

$$dN = s \times n(t) \times A(t) \times dt, \qquad (1)$$

where:

n(t) is the near surface concentration of non-equilibrium electron-hole pairs,

A(t) is the elapsed value of effective track area (see Fig.1),

s is the velocity of surface recombination.

The plasma column is assumed to have cylindrical configuration with homogeneous electron-hole density inside it, as in [2,6,8].
For tracks as 144.5 MeV Xe and 139.9 MeV Ni this assumption for our goal is true because the diffusion length $\sqrt{4DTp}$ has the same order of magnitude as the track length itself. Here D is the ambipollar diffusion constant in Si and Tp-plasma time according to Seibt. Thus, substituting N(t) by $No(1-\lambda(t))$ and taking into account A(t)=Ao/cosΘ, where No-the initial value of generated pairs and N(t) is that for the time t, Ao -top area of the plasma column and λ is the relative value of residual defect, n_l– linear electron-hole density, we obtain the equation for the value of λ in the form:

$$\Delta N = \frac{s}{\cos\Theta}\int_0^{Tp} n_l dt \qquad (2)$$

$$\lambda(Tp) = \frac{s}{\cos\Theta \times R}\int_0^{Tp}(1-\lambda(t))dt \qquad (3)$$

Considering Tp as a parameter after differentiating by this one we obtain equation for λ in the form

$$\frac{\partial\lambda}{\partial Tp} + \frac{s}{R\times\cos\Theta}\lambda(Tp) = \frac{s}{R\times\cos\Theta} \qquad (4)$$

with an evident solution :

$$\lambda(\Theta) = 1 - \exp\left(-\frac{\lambda o}{\cos\Theta}\right) \qquad (5)$$

The value of λo corresponds to zero incident angle.
Fig.2 demonstrates the agreement between the calculated dependence and measured one for ^{136}Xe [9]. The value of λ_0 =8.6% was measured in [9] with changing bias voltage. At vertical axis the difference between the residual defect for angle Θ ($\Delta_r(\Theta)$) and zero one ($\Delta_r(0)$) is presented. The same formula was applied to represent experimental data obtained by Kanno et al. for 139.9 MeV ^{58}Ni. We used a comparison at larger angle of 60 deg. (Fig3) and depletion layer thickness as independent variable as it was used in [5]. The values of window and nuclear stopping losses were taken from the tables presented at the same

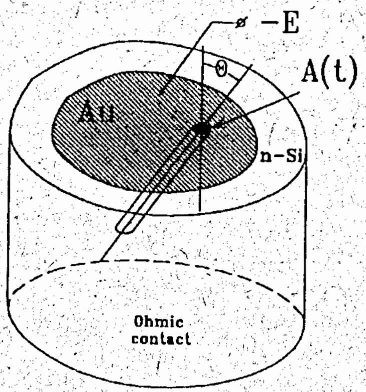

Fig.1

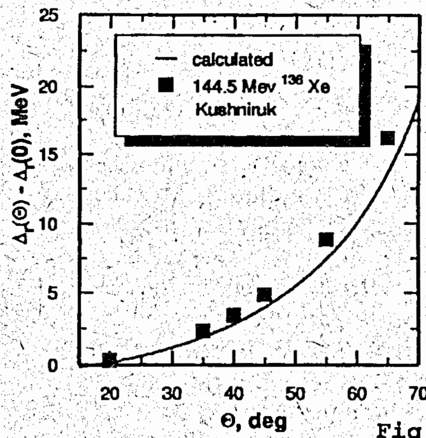

Fig.2

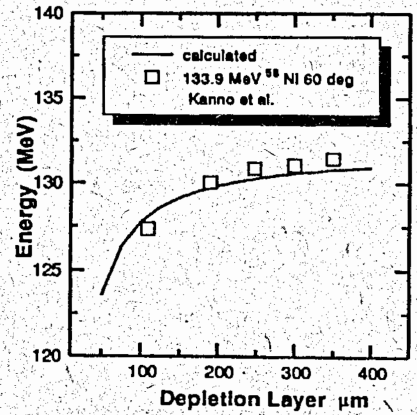

Fig.3

paper. To extract parameter λ_0 a fit according to formula (5) was done at angles from 0 deg. up to 60 deg. for one depletion layer thickness (110 μm). For our opinion a good agreement is evident.

After demonstration of these examples it is possible to draw two conclusions:

1. The recombination model in form of surface recombination provides an explanation for incident angle dependence of the residual defect.
2. An original formula was obtained which can be used for computer simulations of SF events spectra of nuclei implanted into SSB.

We would like to thank Drs. W.Kushniruk and I.Kanno for interesting discussion of this point.

REFERENCES

[1] E.Finch . Nucl. Inst.and Meth. , 142, (1977),539.
[2] W.Kushniruk. JINR P13-11933, Dubna , (1978).
[3] W.Kushniruk, Yu.Kharitonov and Yu.Tsyganov. JINR Report E7-91-75, Dubna, (1991),195.
[4].M.Ogihara, Y.Nagashima,W.Galster and T.Mikumo. Nucl. Instr. and Meth., A251 (1986),313.,
[5] I.Kanno et al. Nucl. Science and Technology, 28[6], (1991),582.
[6] I.Kanno et al. Nucl. Science and Technology, 29[7], (1992),690.
[7] Yu.Lazarev et al. JINR Report E3-93-57, Dubna (1993),203.
[8] W.Seibt, K.Sundstrom and P.Tove. Nucl.Instr and Meth. 113 (1973),317.
[9] W.Kushniruk and Yu.Kharitonov. JINR 13-9836, Dubna, (1976).

Received by Publishing Department
on August 29, 1994.