ON THE OPPORTUNITY OF β-RADIATION DETECTION BY SI DETECTORS IN THE CHERNOBYL FAILURE AREA

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It is demonstrated that a double silicon detector operating in the coincidence mode [1,2] can be used in radiation-monitoring instruments for registering β-radiation at high γ-background conditions, e.g., in Chernobyl.

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1. INTRODUCTION

In the Chernobyl accident zone there often arises the problem of registering β-particles under conditions of a high γ-background. The ^{90}Sr and ^{137}Cs contamination levels of the 30 km zone around the Chernobyl NPP vary from 1 to 500 Ci/km^2 and from 5 to 1000 Ci/km^2, respectively [3]. The epicentrum of radioactive effect of the Chernobyl accident on the environment is the industrial site of the Chernobyl NPP, and particularly, the environs of the “Shelter” object. This is due to the following two sources: a) an active buried layer up to 2 meters in thickness, that contains about 10^7 Bq/g ^{137}Cs and ^{90}Sr, and b) the “Shelter” object with an enormous concentration of radionuclides [4].

It is known that the gamma-radiation intensity at the industrial site around the “Shelter” object makes 0.02 to 5 R/h, while in the central reactor hall and the rooms of the “Shelter” object it attains several thousands R/h [5]. The measurement of beta-radiation at such severe conditions due to the presence of a powerful gamma background is not a simple task. Standard dosimeters-radiometers manufactured by Ukrainian plants (“Tetra” Ltd. in Zheltye Vody, Scientific Production Organization “AtomKompleksPrylad in Kiev, NVPP “Sparring-Vist Center” in L’vov) are not designed for operation at these conditions.

The issue of detecting and localizing the radiation sources still remains open, since up to now the radioecological hazard of the “Shelter” object exists. This hazard increases with time as the probability of interior structure failure of the object increases. As a consequence, this would lead to the radioactive dust release, activity washing-out and entry into the environment.

2. CALCULATION RESULTS

Calculations have been made for the use of the duplex detector to be operated in the coincidence regime in the Chernobyl accident zone. The task assigned has been to create a new electron radiation counter-dosimeter, which can, unlike the existing radiometers, not only indicate the presence of background and its value, but also determine both the location and activity of the β-radiation source.

According to the experimental data, 300 μm thick silicon detectors and the spectrometry electronics being developed at the NSC KIPT are capable of registering more than 10^5 particles per second. Two such detectors operating in the coincidence mode make it possible to tune away from the γ-background [1] and to register β-particles directly from the source. Moreover, such an assembly may play the role of an electronic collimator in order to localize the β-radiation area. If the coincidence mode is turned off and the signal (properly calibrated) is picked up only from one detector, then a version of the usual dosimeter can be obtained.

In other words, the mentioned dosimeter-localizer in its simplest form consists of a double silicon detector operating in the coincidence regime, and the corresponding control system (CS). The special feature of the dosimeter-localizer is its spectrometric mode of operation, i.e., each particle is measured with a high energy resolution.

The double silicon detector operating in the coincidence regime was investigated with the use of the ^{90}Sr-^{90}Y source. The decay chain of the ^{90}Sr-^{90}Y source looks as follows:

$$^{90}\mathrm{Sr} \xrightarrow{T_{1/2}=27.7\ \text{лет}} {}^{90}\mathrm{Y}+\beta^-;\ {}^{90}\mathrm{Y} \xrightarrow{T_{1/2}=64\ \text{час}} {}^{90}\mathrm{Zr}+\beta^-.$$

The electron energy spectrum [6] is presented in Fig.1.

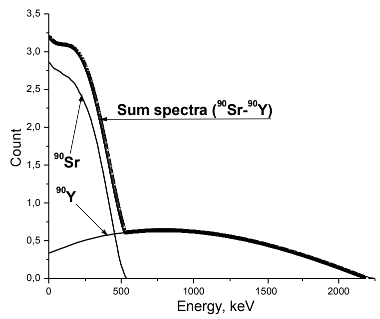

Fig.1. Electron energy spectrum from the ^{90}Sr-^{90}Y source

The main physical parameters of silicon PIN detectors, that have been developed by the present time at the NSC KIPT and can be used at creation of the mentioned dosimeter-localizer, are given in the Table.

The software package GEANT was used to compute the path of electrons from the ^{90}Sr-^{90}Y source in air. A total of 10^5 events were investigated (Fig.2).

The calculations on detection of β-radiation by two Si detectors with size of 5×5 mm and thickness of 300 μm working in a coincidence mode and located at the distance of 5 cm from each other are carried out. It is shown that at the distance up to 2 meters using of such construction is rational. Coincidences are 209 and 56 for distances to the source 1 and 2 m.

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Main physical parameters of silicon PIN detectors

Silicon type		n
Detector thickness, μm		300
Dead layer thickness of the detector, μm		0.05…0.15
Active area size (of single element), mm^2		4…100
Specific resistance, kΩ·cm		3-5
Depletion voltage, V		~ 50
Total capacitance at depletion voltage, (1 kHz), pF	4 mm^2 active area 25 mm^2 active area	~ 2 ~ 10
The number and type of protection ring		1, p^+
Radiation constant K_τ, cm^2/s	14 MeV neutrons 20 MeV electrons	$1.5 \cdot 10^{-6}$ $4.1 \cdot 10^{-8}$
Energy resolution (60 keV, 25°C), keV	4 mm^2 active area 25 mm^2 active area	1.5 2.1
Registration efficiency	122 keV 60 keV	$1 \cdot 10^{-3}$ $4.6 \cdot 10^{-3}$

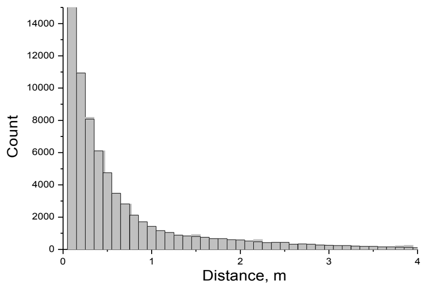

Fig.2. The path of electrons from the ^{90}Sr-^{90}Y source in air

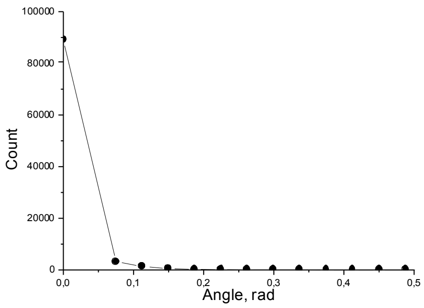

Fig.3. Angular distribution of electrons at a distance 1 m

The incidence of electrons on the detector area in the solid angle $2.5 \cdot 10^{-5}$ sr was simulated. The number of events was put to be 10^5, this approximately corresponding to the radiation of the source of 1 Ci ($3.7 \cdot 10^{10}$ Bq) intensity for the given solid angle. In practice, these figures may be somewhat greater, because the electron scattered by air from any other solid angle may fall on the detector and be registered. However, the probability of this event is low, as it can be seen from Fig.3.

In conclusion we note that the application of our dosimeter is advisable at a small distance, thus all the assembly must be fixed on a rod lest the operator approach the source. As it is obvious from Fig.2, electrons do not practically pass a distance more than 4 m.

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О ВОЗМОЖНОСТИ РЕГИСТРАЦИИ β-ИЗЛУЧЕНИЯ SI-ДЕТЕКТОРАМИ В ЗОНЕ ЧЕРНОБЫЛЬСКОЙ АВАРИИ

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Показана возможность применения сдвоенного кремниевого детектора в режиме совпадений в дозиметрических средствах измерительной техники с целью регистрации β-излучения в условиях высокого γ-фона.

ПРО МОЖЛИВІСТЬ РЕЄСТРАЦІЇ β-ВИПРОМІНЮВАННЯ SI-ДЕТЕКТОРАМИ В ЗОНІ ЧОРНОБИЛЬСЬКОЇ АВАРІЇ

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Показана можливість застосування здвоєного кремнієвого детектора в режимі співпадання в дозиметричних засобах вимірювальної техніки з метою реєстрації β-випромінювання в умовах високого γ-фону.