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Detector of Thermal Neutrons Based on Synthesized New Composite Mediums $(Si)_I (LiF)_{II}(CsJ)_{III}(Ag)_{IV}$

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Abstract: The present paper is devoted to investigations in the field of development of new detectors of thermal neutrons. This research is based on the investigations of the phenomenon of birth, drift and multiplication of delta electrons originated due to interaction of thermal neutrons with the synthesized new composite mediums $(Si)_I(LiF)_{II}(CsJ)_{III}(Ag)_{IV}$ under the influence of external accelerating electric field. These investigations are continuation of the cycle of researches [1-5] in which the possibility of utilization of the above mentioned phenomena as operating bases of more effective detectors of elementary particles were explored. Experimental data of the conducted investigations and the results of comparative analysis with theoretical calculations are presented.

Keywords: thermal neutrons, delta electrons, multiplication, synthesis, porous medium, detector

1. Introduction

At the present time investigations to improve the methods of registration of thermal neutrons are conducting. However more important are investigations on development of essentially new methods of registration. In this respect major practical interest is represented by the phenomena of birth, drift and multiplication of delta electrons in porous mediums due to interaction with elementary particles under the influence of external electric field. Investigations of these phenomena have shown that under certain conditions it is possible to control the cross section of these phenomena. On the basis of these physical phenomena detectors of gamma quanta with fine temporary-spatial properties and high energy resolution were developed [1-5].

The efficiency of registration of neutrons mainly depends from three factors: probability of interaction of neutron with substance of the radiator, probability of exit of the formed fission products from substance of the radiator and efficiency of registration of these yields. Registration of fission products usually does not represent major work. Depending on energy of neutrons,

methods of their recording essentially differ. Till now there are no highly effective methods of registration of fast neutrons and consequently their registration occurs only after moderation of neutrons to thermal energies. In this field of energy, porous composite mediums reveal essentially new possibilities for highly effective registration.

For registration of thermal neutrons usually utilize either capture reactions, or fission reactions which with very high cross section occurs on some nucleus-radiators of neutrons. As a radiator the substances containing nucleus of helium (He), lithium (Li), boron (B) are most suitable and consequently response yields mainly are α - particles and protons. The thickness of radiator simultaneously should satisfy two requirements: to be potentially thick and to allow the formed charged particles exit substance of the radiator. In view of last requirement for each type of radiator, there is a critical thickness and magnification of thickness of the radiator at quantity major, than critical though increments probability of uptake of neutrons, but is not reflected in efficiency of registration. However, if the radiator is porous and an accelerating electric field is applied then the requirement for bounden exit of charged particles from substance of the porous radiator becomes inessential as effective drift of electrons of ionization can be achieved and secondary electronic emission will result. Thus depth of the exit of electrons is not restricted the porous radiator has no critical thickness.

Exothermic reactions (n, p) and (n, α) are most convenient for registration of slow neutrons by capture reactions, which occur with high cross section on some light nuclides:

$$n + {}^{3}He \rightarrow p + {}^{3}H + Q \approx 0.78MeV \tag{1}$$

$$n + {}^{6}Li \rightarrow {}^{4}He + {}^{3}H + Q \approx 4.78MeV \tag{2}$$

$$n + {}^{10}B \rightarrow {}^{4}He + {}^{7}Li + Q \approx 2.78MeV \tag{3}$$

where Q is the energy of reaction. Till energies of neutrons of ten KeV the cross section of these reactions σ is proportional $E_n^{-0.5}$, where E_n is kinetic energy of neutron. Energy of capturing Q is proportioned between the formed charged particles, which in inverse proportion to their masses. For example, in reaction (2) $E_{3H}/E_{4He} \sim M_{4He}/M_{3H}$. It must be mentioned, that even at very small energy of the neutron, the originated charged particles, possessing energy of reaction Q, form considerable ionization effect. So, in the same reaction (2) $E_{3H} \approx 2.7MeV, E_{4He} \approx 2MeV$. In this is consisting conveniences of exothermic reactions for registration of neutrons. Taking account above mentioned facts among alkaline- haloids only suitable are compounds containing atoms of $Li(LiF, LiCl, LiBr, LiI)$. Among these compounds good secondary electron emission properties have compound LiF.

On figure 1 dependence of absorption efficiency of thermal neutrons with energy $E_n = 0.025eV$ from the thickness of LiF and LiJ is given. With magnification of energy to $E_n = 10keV$ absorption efficiency falls as $1/\sqrt{E}$.

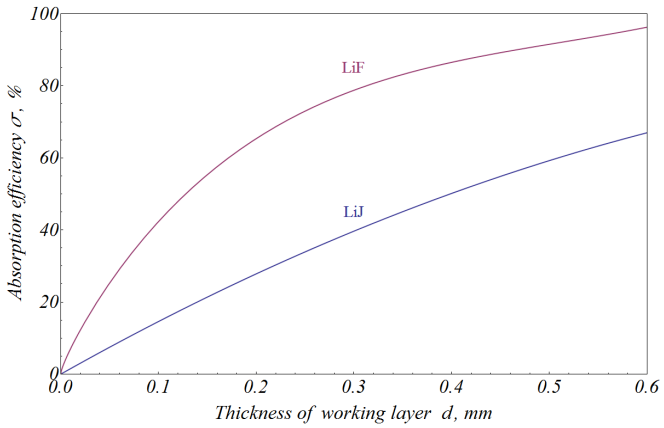

Fig. 1. Dependence of absorption efficiency of thermal neutrons on the thickness of operating porous layers *LiJ* and *LiF*

2. Experimental setup

For conducting the experimental investigation the laboratory sample of detectors of the thermal neutrons operating on the basis of the phenomenon of birth, drift and multiplication of secondary electrons in synthesized porous composite mediums $(Si)_I(LiF)_{II}(CsJ)_{III}(Ag)_{IV}$ has been developed. Providing certain requirements (pressure, velocity of rotation of substrate etc.) and utilizing of different methods of vacuum deposition composite mediums $(Si)_I(LiF)_{II}(CsJ)_{III}(Ag)_{IV}$ with relative density of $0.2\%-10\%$ and different percentage correspondence of chemical combinations have been synthesized.

In figure 2a the schematic view of the detector from a porous medium (2) placed in special vacuum chamber from stainless steel (5) with the vacuum tight window (1) from special material is given. By applying voltage on grid electrodes (4) and (3) the necessary accelerating electric field is created. Originated impulses which have proceeded from anodic wire electrodes, are registered by expressly developed electronic units.

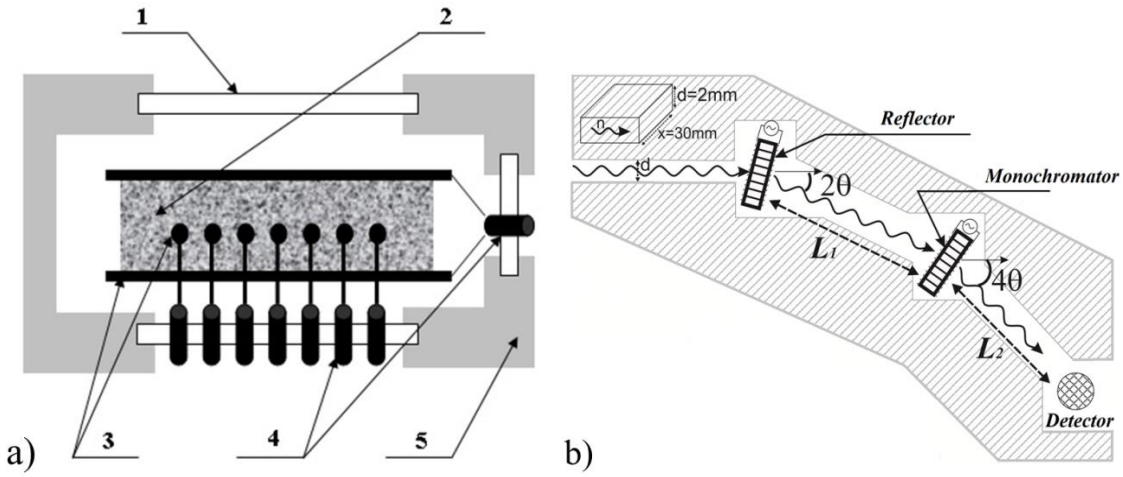

Fig. 2. a) Schematic view of the detector of thermal neutron and
b) schematic view of the experimental setup

On the construction, the developed registering systems can be compared to the proportional chamber with those odds that instead of gas as operating medium the synthesized medium serves. However on the performance characteristics and principles of operation they strongly differ that testifies to absolutely different processes occurring in gases and in multilayered composite mediums.

For carrying out the experimental researches a special experimental setup has been developed and created. The experimental setup schematic view is given in Figure 2b.

Utilization of new types of neutron monochromators gives the chance to determine with high accuracy the energy of thermal neutrons and to make calibration of the detector.

Passing through the system of collimation and monochromators, the neutron beam fell on the developed detector. By means of expressly developed electronic device the registered data are transmitted to accumulation and processing system.

3. Experimental results

To measure the efficiency of registration of neutrons, on either side of the cathodic electrodes of the detector, collateral to them, apart from them 5000μ the additional electrodes which are under a high voltage of the negative polarity in relation to the cathodic electrodes have been located. The space between additional and cathodic electrodes has been charged by substance of the radiator from LiF with relative density of 10%, and in the central part composite medium $(Si)_I (LiF)_{II} (CsJ)_{III} (Ag)_{IV}$ different relative density. At passage of neutrons through the detector perpendicularly to the cathodic electrodes the quantity of substance of the radiator taking into account relative density was $10^3 \mu$. Meanwhile $\approx 100\%$ efficiency of registration was provided. On figure 3 the detector count characteristic at registration of neutrons with energy $E_n = 0.025eV$ depending on the voltage U applied on radiator is given. Operating voltage corresponded to $100\% - $s' efficiency of registration of the secondary electrons injected from the radiator. From the Figure 3 it is visible that with magnification of accelerating electric field U the count rate of the detector is incremented and in the rage of the value $U = 4000V$ reaches plateau. Above $U = 4500V$ breakdowns occurred in the radiator.

The behavior of the curve in the range of values up to $U_p = 4000V$ is caused by magnification of number of secondary electrons n_e, injected from the radiator. When the median number of the injected electrons n_e reached quantities of registration with $100\% - $s' efficiency, its further growth is not reflected any more in efficiency of recording that leads to plateau occurrence on the curve. Due to fluctuation n_e, value $\bar{n}_e$ at which $100\% - $s' efficiency of registration is reached, is set by a relation: $\eta_e = 1 - e^{-\bar{n}_e}$ whence follows that $\bar{n}_e \approx 5$.

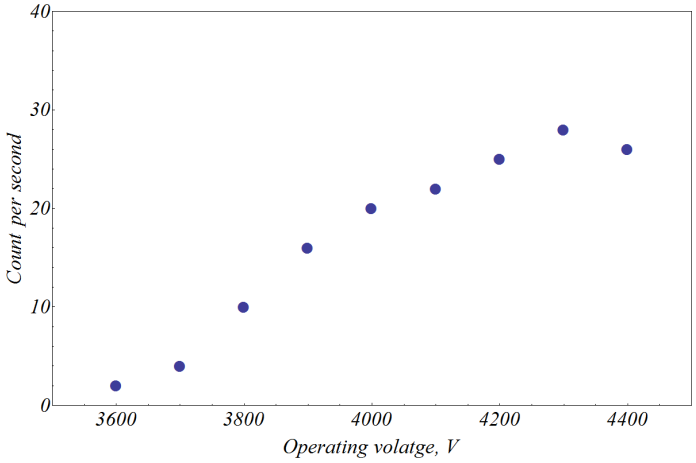

Fig. 3. The detector's count rate characteristic dependence on operating voltage

The plateau presence in count rate characteristics of the detector testifies about $\approx 100\%$-s' efficiency of registration of neutrons. It also proves to be true calculations of geometry of measuring and passport data of performances of the neutron source.

4. Conclusion

Preliminary experimental and theoretical investigations have shown that utilization phenomenon of birth, drift and multiplication of secondary electrons in the new porous mediums synthesized by us can yield jolt in sphere of development of neutron detectors as new generation which surpass all existing similar detectors in the all explored parameters. Necessity of conducted of the further investigations in this field are advisable and actual.

Conflict of Interest

There is no conflict of interest.

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