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EXPERIMENTAL AND THEORETICAL DETERMINATION OF THE FAST NEUTRON SENSITIVITY OF DIFFERENT RADIATOR TL DETECTOR COMBINATIONS

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1. INTRODUCTION

So far some authors have tried to enlarge the low neutron sensitivity of TL detectors by using hydrogen containing radiators (e.g., /1-5/). It could be shown that very thin TL detectors combined with hydrogen containing radiators are especially convenient /6/. In /7-10/ a procedure was presented for the calculation of the neutron sensitivity of TL detectors. In it a special consideration was given to combinations of detectors and radiators with a high hydrogen content.

For checking the general validity of the calculation method measurements of the neutron sensitivity are required for different radiator-TL-detector combinations (different luminophors and detector thicknesses). In the given paper these investigations were carried out for planar radiator-detector arrangements under free-air conditions, because the influence of hydrogen containing radiators is more dominant in this case.

2. EXPERIMENTAL AND METHODS

The radiator-detector combinations investigated have been arranged in such a manner that a detector disc is covered by a radiator disc and that neutrons at first have to pass the radiator. As radiator for all irradiations polyethylene discs with a thickness of 2.5 mm were used. Investigations were made for the following detectors:

1. $CaSO_4$: Dy (prepared according to the method of Yamashita et al. /11/ ; thickness of the TL layer 40 μm).

2. CaF_2: Mn (luminophor S 28 of VEB Leuchtstoffwerke Bad Liebenstein, DDR; thickness of the TL layer 40 μm) and

3. hot pressed ^{7}LiF chips (TLD 700 of M/S Harshaw Chemicals Ltd. Ohio, USA; dimensions 3.18 x 3.18 x 0.89 mm^3).

The thin detectors (1. and 2.) were produced by spraying the luminophor onto an aluminium disc (300 μm thick, diameter 7.5 mm) wetted with a temperature stable glue. The irradiated detectors were evaluated with a TL reader NHZ-203 /12/.

The TL light is detected by a low noise EMI 9844 B type photomultiplier tube. As detector reading the integrated light current between the temperatures T_1 and T_2 was used. T_1 for all three luminophors was 100°C, T_2 for $CaSO_4$: Dy and ^{7}LiF was 280°C; and for CaF_2: Mn, 320°C, respectively. The heating rate was 4 Ks^{-1}

in all cases. The neutron sensitivity m(E) is defined as the ratio

$$m(E) = \frac{M(E)}{\Phi} \qquad (1)$$

with M(E) as the detector reading caused by neutrons of the energy E and Φ as the neutron fluence.

Since in experimental determination of the neutron sensitivity there is not only neutron but also gamma radiation one has to eliminate the influence of these gammas. Therefore the gamma component in the different radiation fields was determined by a relative neutron insensitive TL detector (CaF_2:Mn - PTFE; quantities referring to this detector are marked with*). Then for the detector readings of the radiator-detector combination and of this CaF_2: Mn - PTFE there follow the equations

$$M = m'_\gamma D_\gamma + m(E)\Phi \qquad (2)$$

and

$$M^* = m'^*_\gamma \frac{(\mu_E/\rho)^*}{(\mu_E/\rho)} D_\gamma + m(E)^* \Phi . \qquad (3)$$

Here μ_E/ρ is the mass energy absorption coefficient; m'^*_γ, the gamma sensitivity of the detectors related on the absorbed gamma dose, and D_γ is the absorbed dose of gamma radiation measured with the radiator-detector combination. By solving the equation system (2) and (3) one gets the neutron sensitivity m(E), $m(E)^*$ is calculated /13,14/. Possible incorrectness has nearly no influence on m(E) because of the term $m(E)^* \cdot \Phi$ in eq.(3) is only a small correction.

The experimental determination of the neutron sensitivity was carried out at three radiation sources:

1. (d, D) generator of Technical University Dresden (E = 3.2 MeV),
2. cyclotron U-120 of ZfK Rossendorf (mean energy of fast neutrons $\bar{E}$ = 5.7 MeV /15/) and
3. (d, T) generator of Technical University Dresden (E = 14.7 MeV).

Fluences were measured with the aid of semiconductor , monitors, ionization chambers and solid state nuclear track detectors, respectively. During the irradiation all radiator-detector combinations were encapsulated in PTFE holders.

Since in the radiation fields investigated the gamma energies were > 200 keV for the gamma sensitivities, the values for ^{60}Co gamma radiation could be used.

3. THEORETICAL DETERMINATION OF THE NEUTRON SENSITIVITY

According to the calculation procedure given in /7/ the neutron sensitivity is divided into two independent components (valid for free-air conditions)

$$m(E) = m_D(E) + m_R(E), \qquad (4)$$

$m_D(E)$ is the sensitivity component caused by the interaction of neutrons with the luminophor atoms and $m_R(E)$ is the component caused by secondary particles (mainly recoil protons) which come out from the radiators. As is shown in /7/ the calculation is independent of the evaluation equipment implased /7/ by using the equation

$$m(E) = m'_\gamma \cdot [f_D(E) + f_R(E)]. \qquad (5)$$

The component $f_D(E)$ for the corresponding luminophors was taken from /13,14,16/. The component $f_R(E)$ was calculated with the computer programme TLY/82 /17/. Compared with /7/ there is a better accuracy by using more precise values for the stopping power based on new stopping cross sections and ranges for the recoil protons (computer programme STOPOW/83 /18/) on the basis of ZIEGLER's and AHLEN's treatments /19,20/.

4. RESULTS AND DISCUSSION

The calculated and experimentally determined neutron sensitivities of the three radiator-detector combinations under investigation are given in the table. There is good agreement between calculation and experiment. The experimental error contains the error of the detector reading (about 3%), the error of the gamma sensitivity (about 5%) and the error of the fluence determination (about 10%). From the results obtained it can be concluded that the calculation procedure gives precise neutron sensitivities in the energy range from 1 to 15 MeV both for thick and for thin TL detectors in combination with hydrogen containing radiators.

The computer programme TLY/82 allows the calculation of sensitivities of detectors combined with hydrogen containing radiators in slab geometry. For more complicated geometries the Monte-Carlo programmes are necessary /21/.

Table

The calculated and experimentally determined neutron sensitivities of various radiator-detector combinations

Detector	m_γ in dig·Gy^{-1}	E_n in MeV	$f_R(E)$ in	$f_D(E)$ in	$m(E)_{cal}$ in dig/cm^{-2}	$m(E)_{exp}$ in dig/cm^{-2}
$CaSO_4$:Dy	39000±2200	3,2	1.30 -11	9.15 -13	5.42 -7	(5.48±0.78) -7
		5,7	2.46 -11	3.45 -12	1.09 -6	(1.07±0.13) -6
		14,7	3.94 -11	7.70 -12	1.84 -6	(1.92±0.25) -6
CaF_2:Mn	35700±1800	3,2	1.01 -11	6.14 -13	3.83 -7	(3.71±0.57) -7
		5,7	2.09 -11	3.13 -12	8.59 -7	(8.95±1.12) -7
		14,7	3.61 -11	6.71 -12	1.53 -6	(1.67±0.28) -6
^7LiF	54800±1600	3,2	0.61 -12	1.13 -12	9.53 -8	(8.95±1.45) -8
		5,7	2.45 -12	2.13 -12	2.51 -7	(2.63±0.44) -7
		14,7	1.34 -11	4.10 -12	9.59 -7	(10.05±1.53) -7

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Экспериментальное и теоретическое определение чувствительности к быстрым нейтронам различных комбинаций ТЛД с радиаторами

В предыдущей статье приведен способ вычисления чувствительности к нейтронам комбинаций радиатор-ТЛ-детектор. Для проверки общей справедливости метода вычислений требуется эксперимент. Результаты для $CaSO_4$:Dy, CaF_2:Mn и ^{7}LiF в комбинации с радиаторами из полиэтилена находятся в хорошем согласии с вычисленными величинами.

Работа выполнена в Отделе радиационной безопасности и радиационных исследований ОИЯИ.

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Experimental and Theoretical Determination of the Fast Neutron Sensitivity of Different Radiator TL Detector Combinations

In the previous paper the calculation procedure of the neutron sensitivity of radiator-TL-detector combinations was given. For checking the general validity of the calculation method measurements are required. The results for $CaSO_4$:Dy, CaF_2:Mn and ^{7}LiF combined with polyethylene radiators are in good agreement with the calculated values.

The investigation has been performed at the Department of Radiation Safety and Radiation Researches, JINR.

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