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TICOR-BASED SCINTILLATION DETECTORS FOR DETECTION OF MIXED RADIATION

L.A.Litvinov[1], E.V.Krivonosov[1], V.B.Kolner[1], V.D.Ryzhikov[2], V.G.Volkov[2], V.V.Chernikov[2], V.A.Tarasov[3], O.V.Zelenskaya[3]

Department for optical crystals [1], STC RI [2], Department for Alkali Halide Crystals [3] of Concern "Institute for Single Crystals"

Розглянуто проблему реєстрації змішаного випромінювання теплових нейтронов та гамма-випромінювання за допомогою нового керамічного матеріалу на основі дрібнокристалічного довгохвильового сцинтилятора α - Al_2O_3:Ti (тікору) і фтористого літію. Приведено характеристики сцинтиляторів із фотоприймачами типу Si-PIN-ФД і фотоелектронними помножувачами на α-частках ^{239}Pu , електронах внутрішньої конверсії 207Bi і γ- квантах ^{241}Am і ^{137}Cs. Оцінюється ефективність реєстрації теплових нейтронів матеріалами на основі тікору і літію фтористого.

Рассмотрена проблема регистрации смешанного излучения теплового нейтрона и γ-излучения с помощью нового керамического материала на основе мелкокристаллического длинноволнового сцинтиллятора α-Al_2O_3:Ti (тикора) и фтористого лития.Приведены характеристики сцинтилляторов с фотоприемниками типа Si-PIN-PD и фотоэлектронными умножителями на α-частицах ^{239}Pu, электронах внутренней конверсии ^{207}Bi и γ-квантах ^{241}Am и ^{137}Cs. Оценивается эффективность регистрации тепловых нейтронов композиционными материалами на основе тикора и лития фтористого.

Detection of mixed radiation of thermal neutrons and gamma-rays have been realized using a new ceramic material based on small-crystalline long-wave scintillator α-Al_2O_3:Ti (Ticor) and lithium fluoride. Characteristics are presented for scintillators with Si-PIN-PD type photoreceivers and PMT under ^{239}Pu alpha-particles, ^{207}Bi internal conversion electrons, as well as ^{241}Am and ^{137}Cs gamma-quanta. Detection efficiency of thermal neutrons is estimated for composite materials based on Ticor and lithium fluoride.

INTRODUCTION

Titanum-doped aluminum oxide (Ticor) is an active medium for tunable solid-state lasers. Activator ion is Ti^{3+} with emission maximum at λ_{max}=750-780 nm. Intrinsic luminescence lifetime of Ti^{3+} remains constant to T=200 K and falls at T=300 K to the values of τ = 3.09 μs (80%). When the temperature is increased to T=500 K, the photoluminescence lifetime decreases almost by an order – to τ = 0.29 μs [1].

Ticor was tested as an active medium in screens for energy beams [2]. In our studies [3], no noticeable variation of light output linearity was observed for Ticor under irradiation by proton beams up to $2\cdot10^{14}$ cm^{-2}. The degree of pulse heating of the screens caused by the beam was 50-70ºC. X-ray luminescence studies have shown that Ticor single crystals with Ti^{3+} concentration (3-7)$\cdot10^{-18}$ cm^{-3} that had been subject to high-temperature treatment (2200 K) at the reduction potential in the annealing media ε = 20 – 150 kJ/mol can be considered as a highly efficient material [4].

EXPERIMENTAL PROCEDURES

Search for new methods of detection and identification of neutrons has always been one of the top priorities in studies of new scintillation materials.

One of such methods is the use of small-crystalline scintillators and substances including hydrogen nuclei, ^{6}Li and ^{10}B. PMT were most commonly used as photoreceivers, though a trend has appeared recently to broader use of long-wave scintillators of ZnSe(Te) and CdS(Te) type in combination with Si-PIN-PD photoreceivers [5].

Rather low atomic number and small thermal neutron capture cross-section suggest good prospects of using Ticor crystals in dispersed detectors for measurement of thermal neutron fluxes in mixed fields. In this paper, we report our studies of Ticor crystals and dispersed detectors on their base.

In Table 1, comparative characteristics are given for long-wave scintillators obtained in the Concern "Institute for Single Crystals".

Cristal	λ_{max}, nm	τ, μs	α, cm^{-1}	Z_{eff}	α, rel. un	T_{max}, K
ZnSe(Te)	600 - 620 630 - 640	2 –20 > 20	0,05 – 0,15	33	100	400-450
Al2O3: Ti^{3+}	790	3,0 – 5,0	0,002-0,05	12	16 - 20	560

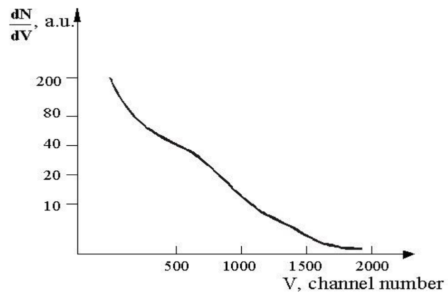
Here α is scintillation light absorption coefficient, S is relative light output, T_{max} is maximum working temperature.

The energy resolution of Ticor measured using Si-PIN-PD S-3590-01 (Hamamatsu, Japan) for ^{239}Pu alpha-particles of the energy E_α = 5.15 MeV is R_α = 11.6%, for ^{207}Bi internal conversion electrons (E_e = 0.976 MeV) $R_{e1/2}$ = 15% ($R_{e1/2}$ was measured using the right-hand half of the pulse amplitude distribution peak).

Alpha to beta ratio for Ticor is ~0.28-0.39, and afterglow is less than 0.1% after 10 ms.

By means of uniaxial hot compaction of the initial powders of magnesium, barium and lithium fluoride at temperatures below the melting point, as well as Ticor microcrystals, samples of transparent light-scattering ceramics were obtained, with dimensions of 15 mm x 3 mm and 40 mm x 3 mm.

Especially interesting was ceramics based on Ticor microcrystals and lithium fluoride. Fig.1 shows the pulse amplitude spectrum of such ceramics measured in a mixed field of thermal neutrons and gamma-quanta of a 239Pu-Be (α, nγ) source located in a polyethylene sphere of 150 mm diameter. For protection from low-energy gamma-quanta of ^{239}Pu, a 50 mm thick lead shield was used.



Pulse amplitude spectrum of ceramics based on Ticor microcrystals and lithium Auoride in the Thermal neutron field, measured using a R 1307 PMT ("Hamamatsu", Japan)

Sensitivity to thermal neutrons was determined by the thermal difference method. As a thermal shield, a 10 mm thick lithium fluoride crystal was used.

Detection efficiency of thermal neutrons determined in this way was $\varepsilon_{t.n} = 15\%$.

CONCLUSIONS

The results of our studies have shown that it is possible in principle to develop high-temperature scintillation detectors on the basis of lithium fluoride and small-crystalline Ticor.

The values of scintillation parameters and thermal neutrons detection efficiency obtained for the prepared ceramic materials suggest that such scintillation materials are promising for extreme conditions of high temperatures and powerful radiation fields, e.g., for detection and identification of neutrons from fuel-containing masses.

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