PECULIARITIES OF FLUORESCENCE OF THIN ORGANIC FILMS IN THE FIELD OF SOFT X-RAY RADIATION

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The paper presents the results of experimental study on the X-ray fluorescence of new organic films manufactured on the base of polystyrene with activating dopes of P-Terphenyl 1.0%, 1.4-Di-(2-(5-Phenyloxazolyl))-Benzene (POPOP) 0.02% and compounds containing Sn atoms. The fluorescent films, 18 and 20 μm thick, containing Sn 8% by mass are manufactured and their properties are studied. Measurements were carried out at the special vacuum installation with a low-voltage electron beam. The braking X-ray radiation was excited on the tungsten target in the energy range from 0.25 to 2.5 keV and the beam current of 0.1 mA. It is shown that the given fluorescence material reveals the sensitivity to the X-ray continuum up to the energy of 250 eV without applying a low-noise amplifying device. In this case the specific fluorescence is significantly higher than the respective value for CsI(Tl) single crystal that we have taken as a standard. Addition of Sn ions in the film structure leads to the increase of the film sensitivity at the low-energy edge of the energy range being studied. There is a discussion about possible application of above-mentioned films in the accelerator technique, plasma physics, X-ray microscopy and other fields where the recording of soft X-ray radiation is required.

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INTRODUCTION

At present, for detection of X-ray and gamma-ray radiation one uses detectors based on Si, CdZnTe, traditional NaI(Tl), CsI(Tl) crystals etc. The main application of these detectors is the elementary X-ray fluorescence analysis in the energy range of 10keV [1]. In investigation of parameters of quick-changing processes related to obtaining high densities of energy there arises a necessity to use the spectrometry of soft (E≈1keV) X-radiation [2]. In the presence of a mixed flow of neutrons, accelerated electrons and ions, superhigh-frequency radiation and hard gamma-ray background one should determine the X-radiation soft component contribution into the total balance of radiation energy. The available detectors are low-sensitive to this component.

In this case thin-film scintillators may be more preferable. In the low-energy region the relative sensitivity of the film can be increased due to the effect of the finite path of an ionizing particle in the film material.

The present paper, being a continuation of [3] gives the results of measuring the light yield from thin organic films excited at a long-wave edge of the X-ray range within 1KeV.

EXPERIMENTAL SETUP

The films of 20 μm thickness made on the base of polystyrene with activating dopes n-Terphenyl 1.0%, 1.4-Di-(2-(5-Phenyloxazolyl))-Benzene (POPOP) 0.02% were used as a scintillation material. To study the material sensitivity to the low-energy X-radiation (LEXR) one can introduce into the film structure the compounds containing Sn atoms. In the case of film excitation with ultraviolet quanta, the emission maximum corresponds to the wave length of 340 nm, as a result of conversion into the visible region of an optical spectrum.

Investigations of the film light yield under LEXR action were carried out at the setup comprising: vacuum chamber, electron gun, focusing-deflecting system, and detector unit. Vacuum in the chamber, not worse than $1.3 \cdot 10^{-3}$Pa·(10^{-5}·Torr), was provided by the cryogenic pump. The layout of the setup is shown in Fig.1.

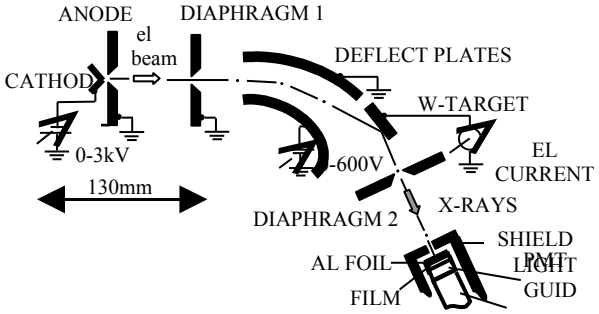

Fig.1 Diagram of experimental setup

An electron beam with a current intensity up to 100 μA was supplied from the electron gun provided with a W filament cathode and a hollow anode. A negative accelerating potential in the form of an one-half-period sinusoid was applied to the cathode of the electron gun with a repetition rate of 50Hz. In the space behind the anode a beam was collimated by diaphragm 1 and transmitted through the sectoral condenser. The presence of deflecting plates made it possible to decrease the electron spread by particle velocities, as well as to decrease the parasitic background light of the photomultiplier tube (PMT) caused by the filament.

The braking X-radiation was excited by the electron beam at the W target and directed by diaphragm 2 onto the film sample. A scintillation unit composed of a film, a plastic light guide and a PMT was placed into the steel screen. For recording the luminescence a PMT-60 was

selected. Its spectral sensitivity is well mated with the emission spectrum of the sample under investigation. As in the above-described experiments the problem of measuring the time characteristic of the scintillation flash has not been posed, the PMT was operating in the integral mode with a load in the anode circuit of 100 kΩ . A signal from the loading resistor was applied to the high-resistance input of the oscillograph.

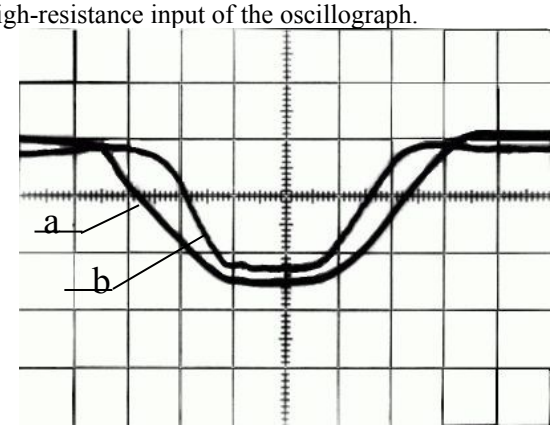

Fig.2. Oscillograms of beam voltage (a) and PMT current (b), a-250 V/div; b-0,5 μA/div; t-1,5 ms/div

The oscillograms of the accelerating voltage from the electron gun and of the PMT current are presented in Fig.2. From these oscillograms one can judge about a qualitative dependence of the sample glowing intensity on the electron beam energy that characterizes the braking X-radiation energy. It is seen that the X-ray luminescence takes place already at energy of about 300 eV.

MEASUREMENT RESULTS

The purpose of above-described measurements was determining of a minimum X-radiation energy at which it is possible to measure reliably the scintillator light yield without applying low-noise amplifying electronic equipment and cooling the PMT and the scintillator itself up to the liquid nitrogen temperature.

In the course of investigations the PMT photocurrent amplitude was measured by changing the anode voltage of the electron gun, i.e. X-ray production voltage. The beam current was maintained by constant adjustment of the filament heating value.

During measurements we have studied samples of films without Sn addition, with 8% addition of Sn atoms, as well as, standard plates from CsI(Tl) single crystal of 1mm thickness. The results obtained are presented in the plot of Fig.3.

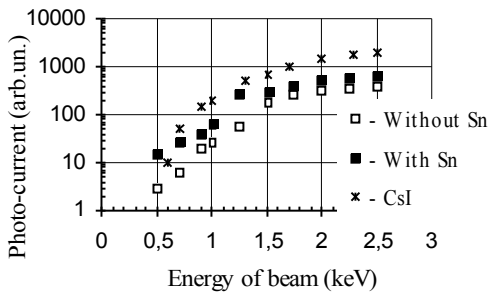

Fig.3. Light intensity as a function of beam energy

It is seen from the plot that in the range of energies from 0.5 to 1.5 keV an exponential increase of the luminous intensity is observed. Ranging from 1.5 keV the increase slows down and after 2 keV it tends to saturation. The decrease of the light yield in the range from 1.5 to 2.5 keV can b e explained by the influence of the finite film thickness: at energy of 2.5 keV the high-energy part of the braking X-radiation continuum passes throughout the film without interaction with the luminescence centers.

In the case with addition of a heavy dope - Sn atoms into the material structure, a gain of the light yield is observed. So, at 500 eV it increases by a factor of four, and .at 2 keV the increase is 30%. This result can be explained by the influence of an effective atomic number of the scintillator material on the excitation energy transfer between the fluorescent centers.

Comparison of luminescence signal amplitudes in the film and the CsI(Tl) crystal of 1 mm thickness in terms of the specific luminescence shows the gain of the film light yield by an order of magnitude.

To determine the absolute sensitivity of the detector under investigation (scintillator-photomultiplier PMT-60 assembly), a thermoluminescence dosimeter DTG-4 was placed into the measurement point.

In Fig.3 plotted are the values of the exposure dose power. Thus, at an energy, e.g. 1 keV the detector sensitivity is 1.0(A·kg·s)/C.

CONCLUSIONS

The film offered can be used as a scintillator in detectors of vacuum X-radiation.

The sensitivity of the detector comprising the film of 20 μm thickness and the photomultiplier (PMT-60) at an 1 keV energy is 1.0(A·kg·s)/C or (4·A·s)/mR.

The film sensitivity can be increased by increasing the effective atomic number by introduction of Sn atoms into the film composition.

A simple source of soft vacuum X-radiation of long-term operation working in the range of energies from 0.25 to 2.5 keV (λ=50...5 Å) and exposure dose powers from 10^{-6} to 10^{-4}C/(kg·s) is developed. The above-described developments can find use in a wide field of practical applications such as: fluorescence analysis, X-ray nondestructive medicine, X-ray source monitoring etc., where a long-wave X-radiation is used as an instrument for active diagnostics.

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ОСОБЕННОСТИ ФЛУОРЕСЦЕНЦИИ ТОНКИХ ОРГАНИЧЕСКИХ ПЛЕНОК В ПОЛЕ МЯГКОГО РЕНТГЕНОВСКОГО ИЗЛУЧЕНИЯ

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Приведены результаты экспериментального исследования рентгенофлуоресценции новых органических пленок, изготовленных на основе полистирола с активирующими добавками P-Terphenyl 1.0%, 1.4-Di-(2-(5-Phenyloxazolyl))-Benzene (POPOP) 0.02% и соединениями, включающими атомы Sn. Были изготовлены и исследованы флуоресцентные свойства пленок толщинами 18 и 20 мкм, содержащие Sn 8% по массе. Измерения проводились на специальной вакуумной установке с низковольтным электронным пучком. Тормозное рентгеновское излучение возбуждалось на вольфрамовой мишени в интервале энергий 0.25...2.5 кэВ при токе в пучке 0.1 мА. Показано, что данный флуоресцентный материал обнаруживает чувствительность к рентгеновскому континууму вплоть до энергий 250 эВ без применения низкошумящей усилительной аппаратуры. Удельная флуоресценция при этом существенно превышает соответствующую величину для монокристалла CsI(Tl), принятого нами за эталон. Добавка в структуру пленки ионов Sn приводит к увеличению чувствительности пленки на низкоэнергетичном краю исследованного диапазона энергии. Обсуждаются возможные применения предлагаемых пленок в ускорительной технике, физике плазмы, рентгеновской микроскопии и других областях, где требуется регистрация мягкого рентгеновского излучения.

ОСОБЛИВОСТІ ФЛУОРЕСЦЕНЦІЇ ТОНКИХ ОРГАНІЧНИХ ПЛІВОК У ПОЛІ М'ЯКОГО РЕНТГЕНІВСЬКОГО ВИПРОМІНЮВАННЯ

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Наведено результати експериментального дослідження рентгенофлуоресценції нових органічних плівок, виготовлених на основі полістиролу з активуючими домішками P-Terpheny l.0%, 1.4-Di-(2-(5-Phenyloxazolyl))-Benzene (POPOP) 0.02% та сполуками з атомами Sn. Були виготовлені та досліджені флуоресцентні властивості плівок товщиною 18 і 20 мкм з вмістом Sn 8% по масі. Вимірювання проводилися на спеціальній вакуумній установці з низьковольтовим електронним пучком. Гальмівне рентгенівське випромінювання збуджувалося на вольфрамовій мішені в інтервалі енергій 0,25...2,5 кеВ при струмові у пучку 0,1 мА. Показано, що даний флуоресцентний матеріал виявляє чутливість до рентгенівського континууму аж до енергій 250 еВ без застосування низькошумової підсилювальної апаратури. Питома флуоресценція при цьому суттєво вища за відповідну величину для монокристала CsI(Tl), що взятий був нами за еталон. Додання до структури плівки іонів Sn призводить до підвищення чутливості на низькоенергетичному краю дослідженого діапазону енергій. Обговорюються можливості використання запропонованих плівок у прискорювальній техніці, фізиці плазми, рентгенівській мікроскопії та інших областях, де потрібно реєструвати і вимірювати м’яке рентгенівське випромінювання.