X-RAY LUMINESCENCE PROPERTIES OF THIN ORGANIC FILMS

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The results of studies on the soft X-ray sensitivity of thin organic Lengmuir-Blodgett (LB) films are presented. A linear behavior of the relationship between the integral luminescence (Δλ=380-400nm) and the dose rate of X-ray irradiation in the range of 10^{-6}-10^{-5} A/kg at the energy of 5 keV has been established. It is shown that the specific X-ray luminescence of the 0.5 μm LB film exceeds that one of the single-crystal CsJ(Tl) scintillator of 1mm in thickness by two orders of magnitude. It is supposed that these films can be used for measurement of the plasma temperature.
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1. INTRODUCTION

The registration and the dosimetry of soft X-ray radiation (< 10keV) are problems of current interest in laboratory plasma diagnostics, X-ray astronomy, biology and medicine. With the advent of new luminescence materials, the scintillation method of detecting soft X-rays has obtained further development. Of special practical interest are thin (~1μm) organic LB films [1]. Owing to the compact packing up of luminescence molecule centers in monolayers, to the varying value of the effective atomic number Z_{eff} in activating additions and to the small thickness, LB films can appear more efficient in the region of soft X-rays as compared to traditional three-dimensional single-crystal scintillators.

The purpose of this work is producing LB films and studying their luminescence properties under X-ray irradiation.

2. EXPERIMENTAL PROCEDURE OF PRODUCING LB FILMS AND STUDYING THEIR PHOTOLUMINESCENCE PROPERTIES

LB films were manufactured by transfer onto the hard substrate (onto the glass or directly onto the input window of a photomultiplier) of 1000 polycomponent monolayers being formed at the water subphase surface. Monolayers were obtained from the solutions of styrene copolymer in ethyl acetate with maleic anhydride (STM), the first luminescence additive (L-1) and the second one (L-2). The ratio of components in the solution is 50: 45 : 5 molar percents, respectively.

During the ionizing irradiation with UV-rays (λ_{ex}= 300nm) there are arising the exited states of the STM and, partially, L-1, owing to a series of radiation processes. Since the quantity of L-1 molecules in the film is great, the probability of their direct interaction with radiation is high.

Subsequently a nonradiative transfer of the excitation energy from the matrix (STM) on L-1, and from L-1 on L-2 is observed. The luminophores were selected so that the absorption spectrum of the acceptors L-2 was in the maximum overlapping with the spectrum of L-1 donor luminescence. The source of UV radiation was a Deuterium-Xenon lamp. The luminescence spectrum measured with the use of the spectrometer SDL-2 (LOMO RUSSIA) is given in Fig. 1. The figure shows that when the film is excited by the light with a wavelength of 300 nm, that corresponds to the maximum of L-1 absorption spectra, and by the light with λ=350nm into the L-2 absorption maximum, the luminescence of L-2molecules is observed. It points on the effective excitation energy transfer from L-1 to L-2. During excitation into the matrix (STM) λ=250nm we have observed the same spectrum with a maximum on 424μm contoured by L-2.

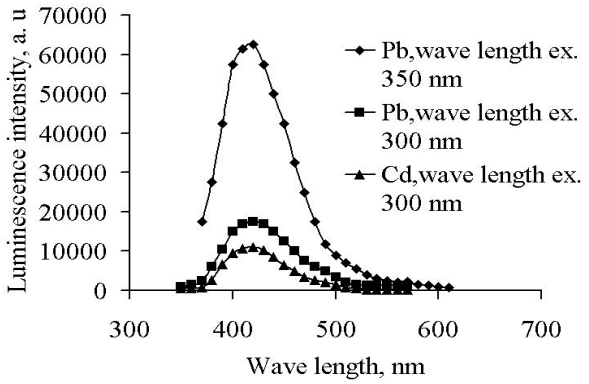

Fig.1 Luminescence spectra of LB films with additions of 2% Cd^{2+} and 1.5 % Pb^{2+}

Thus, in the films being investigated the effective cascade energy transfer from the excited elementary components of the copolymer (STM) to molecules of the luminescent addition (L-1) and from them to the secondary luminescent addition (L-2) with subsequent emitting decontamination takes place.

3. X-RAY LUMINESCENCE OF LB FILMS

During X-ray excitation of LB films a similar scheme of cascade transfer of excitation energy is quite probable. The pilot experiments indicated that the intensity of X-ray luminescence is near to the case of photoluminescence. To increase the film sensitivity to X-rays we have increased Z_{eff} of the film by blending heavy metals. In this case the water subphase for forming the films represents a water solution of salts $CdCl_2$ and $PbCl_2$. Ions Cd^{2+} and Pb^{2+} make an addition reaction with copolimer molecules which are distributed in the solution. The concentration of these ions in monolayers was 2.0 and 1.5 at. %, respectively.

The X-ray apparatus with a tube having a copper anticathode served as a source of X-rays. The anode

voltage was selected below the value of characteristic copper emanation. Thus, the samples were irradiated by the bremsstrahlung continuum with a critical value of 8 keV and below. LB films were installed directly on the input multiplier window, which was placed in front of the tube output window at the distance of 8mm. The peak spectral sensitivity of our multiplier was near to the maximum photoluminescence. The multiplier was operating in the current regime. The signal from the anode load (80kΩ) was supplied to the oscillograph.

In practice the most important characteristic of the scintillator is the fluorescence intensity. We have investigated the relative luminescence intensities depending on the X-irradiation dose and the effect of activating additives on the anode current of the X-ray tube. Its anode voltage was constant and equal to 5 keV. The dose rate was measured by LiF dosimeter (DTG-4).

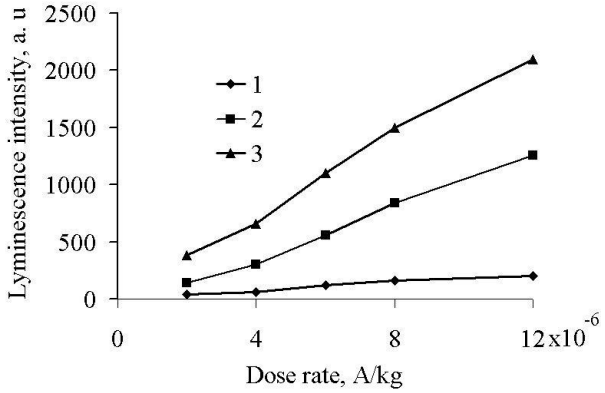

Fig.2. Radioluminescence intensities as a function of dose rate for LB films without additives (1) with a content of 2 % Cd (2) and 1.5 % Pb (3). Boundary energy of X-rays is 5 keV

As is obvious from Fig.2 the luminescence intensity increases linearly with X-ray tube intensity increasing. The luminescence of the film with 2 % is five times higher and that of the film with 1.5 % Pb is ten times higher in comparison with a clean film. We have compared the X-ray luminescence intensity of LB film samples (0.5 μm) with that of the single crystal CsJ(Tl) (1mm) under X-ray irradiation at energy of 5 keV. The measurements show that the specific radioluminescence dL/dx [2] of the LB/film exceeds by two orders of magnitude that of CsJ(Tl), which we have took as a standard. The cause of such a high specific luminescence is probably conditioned with the LB film feature**,** i.e. structure combination of high concentration of fluorescent centers and high degree of their ordering in monolayers. This makes it possible to reduce losses during excitation energy transfer between fluorescence centers.

4.CONCLUSION

Thus, the experimental data obtained allow us to conclude that LB films can be used in measuring the soft X-ray radiation with the use of a scintillator. The specific radioluminescence of LB films significantly exceeds that of traditional single-crystal ones. The increase of the film sensitivity with addition of a heavy metal activator is especially promising.

The concentration optimization of this activators, chemical composition and geometrical form of LB films will be the subjects of our further investigations. But already now it is possible to believe that the proposed films can be used as a detector of soft X-ray radiation in devices for heating and confinement of high temperature plasma.

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РЕНТГЕНОЛЮМІНЕСЦЕНТНІ ВЛАСТИВОСТІ ТОНКИХ ОРГАНІЧНИХ ПЛІВОК

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В роботі наведені результати експериментальних досліджень рентгенолюмінесценції тонких органічних плівок, одержаних з допомогою техніки Ленгмюра – Блоджетт (ЛБ). Зразки ЛБ плівок, що складалися з 1000 моношарів полімеру, люмінесцентних додатків *Cd* та *Pb* загальною товщиною 0,5мкм опромінювались рентгенівськими квантами. Джерелом випромінювання була рентгенівська трубка при напрузі *2…8кВ* і струмові *2…12мА*. При опроміненні діапазон зміни струму відповідав інтервалу потужностей доз від $2\cdot10^{-6}$ до 10^{-5}А/кг (1– 44мР/с). Встановлено лінійний характер залежності інтенсивності люмінесценції від потужності дози. Введення в структуру плівки іонів *Cd* і *Pb* підвищує світловихід у 5 і 10 разів відносно плівки без додатків. Показано, що питома люмінесценція ЛБ плівок у дослідженому інтервалі енергій рентгенівських квантів приблизно на два порядки вища в порівнянні з відомим монокристалічним сцинтиллятором *CsJ(Tl)*, прийнятим нами за еталон.

РЕНТГЕНОЛЮМИНЕСЦЕНТНЫЕ СВОЙСТВА ТОНКИХ ОРГАНИЧЕСКИХ ПЛЕНОК

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В работе приведены результаты экспериментальных исследований рентгенолюминесценции тонких органических пленок, полученных с помощью техники Ленгмюра- Блонджет (ЛБ). Образцы ЛБ пленок, состоящие из 1000 монослоев полимера, люминесцентных добавок и ионов *Cd* и *Pb* общей толщиной 0,5мкм облучались рентгеновскими квантами. Источником излучения служила рентгеновская трубка, работающая при напряжении *2-8кВ* и токе *2-12мА*. При облучении диапазон изменения тока трубки соответствовал интервалу мощностей доз $2\cdot10^{-6}$ …10^{-5}А/кг (1– 44мР/с). Установлен линейный характер зависимости интенсивности люминесценции от мощности дозы. Введение в структуру пленки ионов *Cd* и *Pb* повышает световыход в 5 и 10 раз соответственно. Показано, что

удельная люминесценция ЛБ пленок в исследованном диапазоне энергий рентгеновских квантов примерно на два порядка выше по сравнению с известным монокристаллическим сцинтилятором *CsJ(Tl)*, принятый нами за эталон.