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Optical sensitivity of the Agfa "personal monitoring" Film to X and gamma rays under FD-III-D badge filters

F. MIHAI, T. VISAN[a], A. STOCHIOIU, S. BERCEA, F. SCARLAT[b]
Horia Hulubei National Institute of Physics and Nuclear Engineering – Bucharest, POB MG-6, code: 077125, Romania
[a]Politehnica University of Bucharest, Chemical Department, 313 Splaiul Independentei, RO 060042, Bucharest, Romania
[b]National Institute of Laser, Plasma and Radiation Physics, Bucharest POB MG 36, code 077125, Romania

In Romania, the national regulations impose the use of the film dosemeter as principal means for personal radiation protection monitoring. One of the parameters of the incident photon radiation which has an important influence on the dosemeter response is the photon energy. In this paper the conclusions of the studies concerning the dependence of the dosemeter response on the photon energy are presented. For this study, the "personal monitoring" Agfa Gevaert, class B, index 3, films were used together with a FD-III-B badge, since this dosemeter is in current use in Romania. The dose equivalent measuring Chalcogenide Letters Vol. 5, No. 4, April 2008, p. 58 - range is between 0.1 mSv and 1 Sv and the energy range of the photons is between 20 keV and 9 MeV. For studying the influence of the photon energy on the film response, these films were irradiated at the same value of the dose equivalent, Hp(10) = 1 mSv, for several values of the photon energy. The paper also presents the conditions for the film processing and the results concerning the dependence of the optical density on the photon energy. The activities which involve the use of ionizing radiation cover a large area from the biomedical applications to the industrial applications, including nuclear power plants.

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1. Introduction

The use of the ionizing radiation in a large area of applications involves a complete characterization of the dosemeters for personal monitoring, according the specific requirements of the national and international regulations [1, 2]. All these applications use photon radiation in a large range of energy. For photon energies lower then 0.3 - 0.5 MeV, the optical density depends both on the photon energy and the dose; in this case, it is necessary to use adequate procedures, so that the measured values of the absorbed dose be as close as possible to the real values.

Usually, in conventional and interventional radiology fields from low X-ray energies (mammography) to maximum100 keV energy are used. The response of the personal dosemeters depends mostly on radiation energy in this range. It is advisable that dosemeter testing to be performed under conditions which are close to working conditions. However, in practice, it is frequently performed to: 1250 keV (S-Co), used in radiotherapy department then radiology or industry; at 662 keV (S-Cs), well acceptable in personal monitoring; and rarely at 60keV (S-Am).

For this reason, it is important to study the behavior of the dosemeter that are currently used, taking into account the photon energies. Many dosemeters used for skin dose measurements in radiology show an importance dependence on energy [3]. A growing number of papers present different type of dosemetric films that are very promising for tracking the maximum skin dose (MSD) in complicate procedures [3,4]. In this paper we are characterizing the photodosemeter system: Agfa "personal monitoring" film with FD-III-B type badge, used in Romania for occupational exposure from medical, industry, research, radiopharmaceutical fields.

2. Experimental part

Description of the photo-dosemeter used in the experimental work: the plastic made badge, has an "open window" on its front side allows the radiation to reach the film directly, as well as, five metallic filters, made of different materials and of different thicknesses (Table 1).

According to Romanian standard [1] the dosemeters used for the present study are class "B" according to the detectable photon radiation energy range. Agfa "personal monitoring" package consist of a double-coated, low speed, high contrast film (D2) and double-coated, very sensitive, high contrast film (D10). This film combination is specially created to allow measurements in a range of dose equivalent from 0.1mSv to 1 Sv.

Table 1. The characteristics of the photo-dosemeter filters.

Material	Length (mm)	Width (mm)	Thickness (mm)
Plastic	15	10	0.3
Al	10	10	1
Cu	13	10	0.1
Cu	13	10	0.5
Pb	15	15	0.4
Cu	15	10	1

For the evaluation of the photodosemeter response to radiation of various energies, X and gamma rays with the following energies were used: -X rays of 29 keV, 60 keV, 65keV, 83.2 keV, 120 keV, 143 keV produced by a THX-250 X-ray machinery; and gamma rays of 662 keV (S-Cs), 1250 keV (S-Co) [5]. In order to obtain a high accuracy, the average values and the standard deviations were calculated on five dosemeters irradiated at each value of the dose equivalent, Hp (10), for every energy.

The irradiation was performed with the photo-dosemeters placed on a "PMMA Water" phantom, according to [2], in 'reference condition'. For gamma rays of 662 keV (S-Cs) and 1250 keV (S-Co) gamma rays, the photo-dosemeters were irradiated in a panoramic geometry. The optical density was measured with a GRETAG D 200II densitometer with an uncertainty ±0.01 or ±0.04 depend on effective range.

3. Results and discussions

The first step was to establish the homogeneity of the Agfa film batch employed in this experiment by optical density – base fog - measures. The base optic density was of 0.37 $\pm$0.5% for the high sensitivity film (D10) and 0.14 $\pm$ 0.01% for the low sensitivity film (D2). The films exposed to the photon radiation were chemically processed in the same conditions of temperature and concentration (pH) of the developer. Temperature in the developing bath was kept constant at 20 ^{0}C ($\pm$ 1 ^{0}C); the pH had the value in the range of 10 – 10.5, for to reduce the Ag^+ from AgBr to metallic Ag.

In order to characterize the response of the FD-III-B dosemeter (the response of a Agfa film) to the photon radiation of different energies, the parameters which influence the dose equivalent assessment, mainly for the high sensitivity film D10, have been studied: i)the optical density for the different energies at the same value of the dose equivalent ; ii)the ratio of the optical densities for two filters, for the same value of the dose equivalent (at a constant photon energy); iii)the dose equivalent for a given value of the optical density (a value of 2 was chosen for optical density); iv)the relative sensitivity of the film: the ratio of the dose produced by the radiation of the highest energy (gamma – rays from S-Co) to the doses corresponding to the other energies for a given optical density.

The films have been irradiated at 1mSv and 10 mSv dose equivalent for different values of energy. The optical density on the (D10) and (D2) films in each field corresponding to each badge filter was measured. The standard deviation for the optical density has been calculated for each filter, energy and those two types of Agfa film, and the values between 0.69% and 4.13% for D10, respectively, 3.23% to 3.94% for D2, has been obtained.

The dependence of the D10 film optical density on the radiation energy is given in Fg.1 In the range of low energies the dose equivalent of 1 mSv produces important variations of the optical density in the fields corresponding to the different filters of the dosemeter. For the plastic filter, the optical density varies between 4.81 (60 keV) and 2.43 (143 keV). The dependence of the response of the FD-III-B dosemeter on the radiation energy is significantly attenuated with the Pb filter; in the energy range 60 keV – 143 keV, a constant response was obtained (1.625 ± 3.84%). A special behavior was observed for 29 keV, due to the dominant interaction process in the emulsion film (the photoelectric effect) and to the penetrated material. For the energy range 660 keV – 1250 keV, the variation of the optical density under the filters is smallest: the average variation is ± 20.3% for 660 keV and 5.27% for 1250 keV.

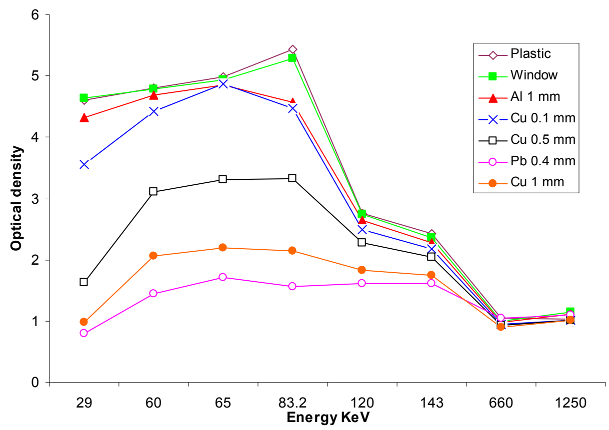

Fig.1. D10 Agfa film - FD-III-B type badge response on different energies at 1mSv dose.

In case D2 film at 10 mSv we can see the optical density vs energy dependence is most diminished, under Pb filter. Variation of the optical density is 0.282 ± 0.04324 in energy range (60keV – 143keV) and 0.244 ± 0.062 from 29 keV to 1250 keV. Fig. 2

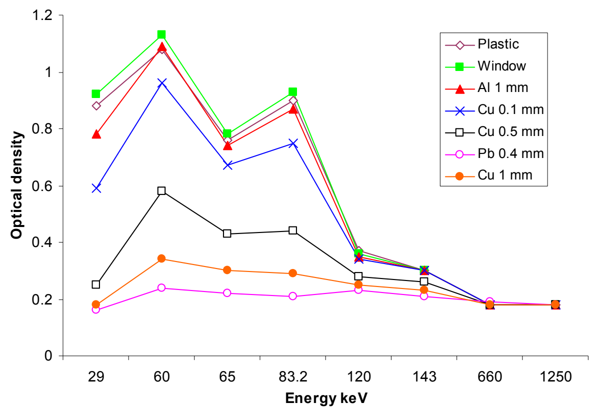

Fig. 2. D 2 Agfa film - FD-III-B type badge response on ionizing radiation energies at 10 mSv dose.

In table 2 gives dose equivalent assessment on each sensitometer curve corresponding to each filter, based on the average value of the optical densities on the film. A better estimation of the dose equivalent can be obtained by combining the optical densities film under the FD-III-B dosemeter filters and assessment of the dose equivalent on the plastic filter sensitometer curve at 1250 keV.

In order to obtain the relative sensitivity of the film, the dose equivalent was estimated for a value of 2 of the optical density, for each filter of the dosemeter. The results of this estimation are given in Table 3. Although, the optical density under plastic filter depends significantly on energy, the doses measured at a 2 optical density on each of corresponding energy curves are very closes - high OD deviations induce small doses variations.

Table 2. The dose equivalent assessment by the optical density mean values measured on the D10 film.

Energy (keV)	Dose equivalent – D10 film (mSv)							Hp(10) (mSv) conventional true value	Optical density mean value and ± standard deviation
	Plastic	Window	Al 1 mm	Cu 0.1 mm	Cu 0.5 mm	Pb 0.4 mm	Cu 1 mm		
662	1.05	1.13	1.2	1.3	1.3	1.07	1.3	1	1.07 ± 20.3%
1250	1.05	0.85	0.95	1.2	1.15	0.95	1.08	1	1.06 ± 5.27%

Table 3. Relative sensitivity of FD-III-B dosemeter, Agfa D10 film.

Energy (keV)	Optical density	Sensitivity						
		Plastic	Window	Al 1mm	Cu 0.1 mm	Cu 0.5 mm	Pb 0.4 mm	Cu 1 mm
29	2	17.89	18.42	12.06	11.42	2.8	0.22	0.64
60		18.88	19.44	15.9	17.39	10.5	1.61	3.78
65		18.88	19.43	15.89	17.39	12	1.75	3.78
82.3		18.27	18.42	15.9	16.66	10.5	1.72	4
120		5.57	5.83	5.0	4.44	5.6	1.75	3.25
143		5.48	4.66	3.88	4.08	4.66	1.75	2.57
662		0.98	1	0.93	1	0.97	1.03	0.78
1250		1	1	1	1	1	1	1

As it can be seen, the Pb filter produces a considerable diminution of the photo-dosemeter response to X rays. The maximum relative sensitivity to 60 keV has the value of 18.88 for the plastic filter, 3.78 for the 1 mm Cu filter and 1.61 for the 0.4 mm Pb filter. The relative sensitivity of the film is the least dependent on the radiation energy, under the 0.4 mm Pb filter. The X-OMAT-V film, with a long tradition in radiotherapy monitoring, shows an increase in sensitivity by a factor 20 at 70 kVp (approximately 60keV) compared with 1250 keV (S-Co) [6] and EDR2 film, recently introduced in interventional cardiology does not show a significant variation in the sensitivity between 60 and 110 kVp [7].

4. Conclusions

As shown by the experimental data it is important to establish the nature of the filter where the value of Hp(10) can be most accurately estimated, especially when the radiation energy is unknown. For the normal incidence of the radiation, the response of the FD-III-B with Agfa film dosemeter is almost independent of the photon energy in the range 662 keV – 1250 keV and increases significantly in the range of low energy, 29 keV – 143 keV. In the upper range of energy, the value of Hp(10) can be evaluated using any filter of the dosemeter – the variation of the optical density from one filter being insignificant.

For the X-rays, taking into account the fact that the metal filters produce a significant diminution of the response of the photo-dosemeter the dose equivalent has to be measured under the plastic filter, where has approximately the same value for the same optical density on the energy range 29keV – 82,3keV; it also stops the beta rays.

The evaluation of the equivalent dose for the photon radiation of unknown energy has to be done under the Pb filter, which significantly reduces the dependence of the photo-dosemeter response on the photon energy. Tacking into account the results from literature obtained on different dosemetric films it is interesting to investigate these with FB-III-B type badge manufactured in Romania.

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*Corresponding author: f.mihai@nipne.ro