STUDY OF THE EFFECT OF THE FILTRATION ON THE FILM BADGE SENSITIVITY BY USING THE ROENTGEN TUBE TYPE PANTAK HF-320

Nahida J. H. Al-Mashhadani
Applied Science Department, University of Technology.

Abstract

This work is carried out at The NOFER Institute laboratories of Occupational Medicine, Lodz Poland. The aim of this research is to study of the filtration effect on the personal film badge XO film type (Foton –Warszawa, Poland) sensitivity by using the roentgen tube type Pantak HF-320 and the water slab phantom as recommended by NCRP. By changing the radiation energy at fixed dose, the film sensitivity will change according to the mean energy. It is found that the maximum sensitivity for the film approaches the energy of 33 keV. Construction of a film holder (badge), which contains the filters, four pairs of filters (0.05 mm Cu, 0. 5 mm Cu, 1. 5 mm Cu and 1.0 mm Pb), moreover, there is an open window in the badge. The holder filters will overcome the sensitivity changing of the film, so it must be used. It is found that, there is decreasing in optical density according to the increasing of Cu-filter thickness, the optical density of the Pb is the lowest in the (24-248keV) range. There is increasing in optical density (film sensitivity) by changing the radiation energy at fixed dose up to 33keV, which record the maximum sensitivity of the film. Anon–linear correlation has been found between the optical density and the radiation dose, this curve, called–calibration curve. The typical background of the film has been found below 0.1 mSv, thus the lowest measurable dose was calculated to be 0.1 mSv. It is found that the optical density increases with the absorbed dose, which is attributed to the photo degradation of the films, may induce localized states in the energy gap causing increasing in optical absorption up to (33keV). For the high energy, the optical density decreases, which attributed to the photo degradation of the films may cause some cracks at the film surface. The optical analysis of the film surface in the sites shielded by the filters and in the open window allows calculating three components of the radiation spectrum of energy weak, medium and hard. The method described by Dresler method is to determine calibration function. This method in film badge calibration is more accurate than that used which uses gamma source (Ra-226) as a calibration source in our country, because of using x-ray source of different energy is taking into account the exposing radiation of different energy of the worker in radiation field, its effect on the film sensitivity, and the personal dosimeter.

Introduction

The objective of dosimetry is to provide an accurate estimation of maximum and minimum irradiation dose [1]. The film dosimeter is one of the two types of devices which are commonly used for personal dosimetry .The principal role of dosimetry is in establishing the required minimum dose also ensuring that correct dose is delivered to the worker in radiation field. Selection of suitable dosimetry range depends on several considerations, including dose range of interest, ease of measurement, the expertise available, environmental factors that can be important at the location of use, cost and uncertainty that is consistent with the process. The radiation protection against the gamma and X radiation, the other apparatus used for this purpose is the thermoluminescnt dosimeter [2-5]. The NOFER Institute of Occupational Medicine, Lodz .Poland provides radiation protection service for all Polish workers occupationally exposed to X-rays [6], so as in our country. To this end the film dosimetery is implemented. The advantage of this method is a low cost of dose measurement and the possibility of multiple readout of the exposed film. The negative characteristics are the fact that the sensitivity of the film`s emulsion depends on the dose, radiation energy, and the angle of radiation beam. These films are manufactured by the XO film type (Foton–Warszawa, Poland) [6-9]. The film is composed of (Cellulose acetate (CA)), coated with thin layer of (Emulsion). The emulsion is sensitive material, which is composed of microscopic silver halide crystals. These crystals diffuse in gel material. The ordinary emulsion of (1-25µm) is coated with gel material of (0.5 µm) thickness [9.10]. The photographic emulsion is sensitive to the energy of the radiation beam. The maximum sensitivity for the XO film type (Foton–Warszawa, Poland) approaches the energy of 33 keV. The film holder contains the filters, four pairs of filters is used 0.05 mm Cu, 0.5 mm Cu, 1.5 mm Cu and 1.0 mm Pb, moreover, there is an open window in the badge [6].

Experimental Part

2-1 The calibration procedure

The calibration unit consists of a roentgen tube type Pantak HF -320 and on the water slab phantom as recommended by NCRP [11] Fig.(1). The film dosimeters were calibrated to personal dose equivalent $H_{P(10)}$.This value is recommended by ICRU as an stimulations of the effective dose (the commission such as collective committed effective dose equivalent) for dose limitation [12].The $H_{P(10)}$ dose (the individual dose equivalent $H_{p(d)}$ is comparable to the effective dose HE in the wide range of the radiation beam energy. The calibration of the film was carried out using ISO narrow spectrum described in ISO [13].

The calibration was prepared using following parameters;

- Mean energies [keV]: 24 .33. 48. 65, 83 100.118 .163 .205.248
- Doses H (10) [mSv] : 0.05 ,0.1,0.2 ,1.5 .10, 20, 50.

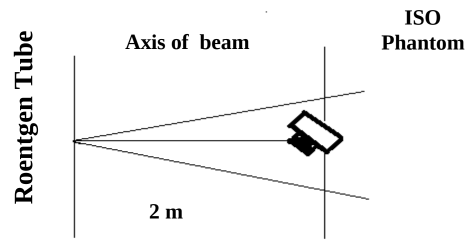

Fig.(1): A diagram of the calibration unit.

2-2 Photographic Imaging Procedure

-**Developing** : It is chemical process to convert silver ions in exposed grains to silver atoms to form the latent image, which caused darken in the emulsion. This process carried out by putting the films in the developing solution, and took five minutes Fig.(2). Wash the films in water of (20 °C) temperature.

-**Fixing:** In this process the unconverted silver grains would be removed to obtain fixed and clear image. This process takes fives minutes.

-**Washing:** This process carried out to remove the processing solutions before and after the fixing process. It takes thirty minutes. **-Drying:** Left the films to dry at room temperature without exposed it to the heat.

2-3 Optical density measurement:

The optical density is the logarithm of the ratio of the incident intensity on the medium to the transferred intensity from the medium. The measurement is carried out by using the densitometer [9].

Results and Discussion

As a result of interaction of the high energy ionizing radiation with silver grains, the silver atoms would be formed. During the developing process, the latent image would be formed as reduction center for unexposed silver halide crystal. The radiological photographic process contained of developing process, which is chemical reduction of silver ions to silver atoms to form the latent image, and fixing process during which the silver grains would be removed. The emulsion would be soiled, and the fixed image would be formed. The reaction of radiation with film material caused changes in optical properties of the film. If the incident intensity of the radiation is I_0, and the transferred intensity is I, the optical density will be: (optical density=log I_0/ I)[9].By changing the radiation energy at fixed dose, the film sensitivity will change according to the mean energy. Figs (2-4) show decreasing in optical density with mean energy. The soft energy interacts with the film material and causes darkness in the film more than the high energy. This is attributed to the soft energy interacts with film material, whereas the high energy radiation penetrates the film. For this reason, it is very important to use the film badge (holder).The holder filters will overcome the sensitivity changing of the film [9, 14, 15]. Figs.(2-4)show the relationship between the optical density and the mean energy for the filters (0.05 mm Cu , 0. 5 mm Cu , 1. 5 mm Cu and 1.0 mm Pb) or three doses (1, 10, 20 mSv), there is decreasing in optical density according to increasing of Cu-filter thickness, the optical density of the Pb is the lowest in the rang of (24-248keV). There is increasing in optical density by changing the radiation energy at fixed dose up to 33keV, the film sensitivity will change according to the mean energy. It is found decreasing in optical density with mean energy, and the maximum sensitivity for the XO film type approaches the energy of (33keV) for the open window region. It is found that the optical density increases with the absorbed dose, which is attributed to the photo degradation of the films, may induce localized states in the energy gap causing increasing in optical absorption up to (33keV). For the high energy, the optical density decreases, which attributed to the photo degradation of the films may cause some cracks at the film surface [14-15].

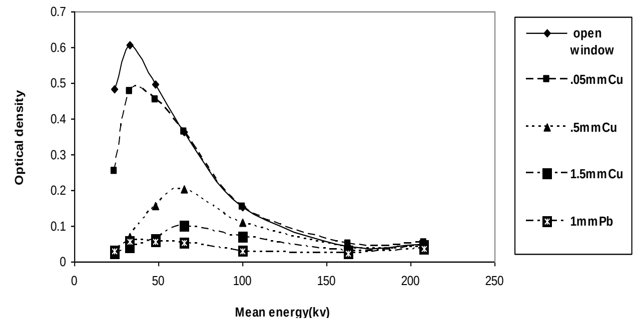

Fig.(2) : The optical density as a function of the mean energy, dose Hp 10 (1 m Sv).

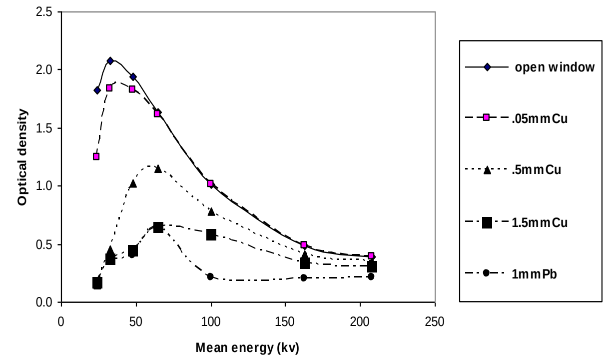

Fig.(3) : The optical density as a function of the mean energy, dose Hp 10 (10 m Sv).

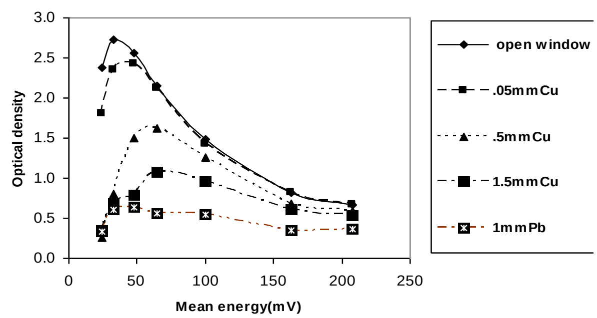

Fig.(4) : The optical density as a function of the mean energy, dose Hp 10 (20 m Sv).

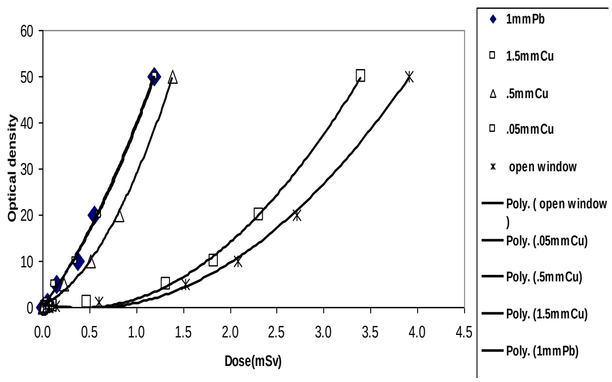

Fig. (5): Correlation between $H_{p(10)}$ dose and the optical density.

Table (1)
The measures doses under the three filters regions and the open window

D (Dose)	Equation
D0	**D(Open window) = 4.2437g²-4.0947g+ 0.7242**
D1	**D(0.05mm-cu) = 5.583 g²-4.5392g+ 0.6907**
D2	**D(.5mm) = 18.736 g² + 9.515g + 0.3455**
D3	**D(1.5mm-cu) = 13.242 g²+25.635g+ 0.097**
D4	**D(1mm-pb) = 12.166 g²+27.792g-0.196**

Anon–linear correlation has been found between the optical density and the radiation dose. This curve, called –calibration curve, is presented in (Fig.5). The typical background of the film has been found below 0.1 mSv, thus the lowest measurable dose was calculated to be 0.1 mSv. The non–linear correlation described above (Fig.5) pertain to the same energy of radiation. A special method (should be applied to determine the ratio between the optical density caused by the radiation energy, this requires a construction of a film holder (badge), which contains the filters .Four pairs of filters are used 0.05, 0. 5 mm, 1.5mm Cu and 1.0 mm Pb. Moreover, there is an open window in the badge to determine the personal dose. The optical analysis of the film surface in the sites shielded by the filters and in the open window allows calculating three components of the radiation spectrum of energy weak, medium and hard. The method described by Dresler method is to determine calibration function [14-17].

$$D_0 = D_M = f(g_0 - g_t) \quad \text{......................(1)}$$

Where Dm is the dose measured for the radiation energy at the highest film sensitivity (33keV), g_0 is the optical density of the film measured below the open window; g_t is the optical density of the background. Next, three h_1 functions should be determined

$$h = h_1\left[\frac{D_{l-1}}{D_1}\right] \quad \text{..(2)}$$

Where; l=1..3, D_l stands for so called phantom dose calculated from Eq .(1) and measured under appropriate filter (l=0)indicates the open window). The (h) quantity is defined by the formula;

$$h = \left[\frac{D_{OM}}{D_0}\right] \qquad (3)$$

Where; D0M is the true value of the dose and D_0 was described above. The least square method is useful to calculate the d_{00}, d_{01}, and d_{02} .

$$d_{oo} = D_o$$

$$d_{01} = \exp\left[\frac{10\ln D_1 - \ln D_2}{9}\right] \quad \text{.......................(4)}$$

$$d_{02} = \exp\left[\frac{3\ln D_2 - \ln D_3}{2}\right]$$

$$H_{P(10)} = h_3 d_{02} + h_2(d_{01} - d_{o2}) + h_1(d_{00} - d_{01}) \quad \text{....................................(5)}$$

The total dose $\{H_{p(10)}\}$ registered on the film can be calculated from the formula ;

The values h_1, h_2, h_3 equal h values obtained Eq .2

The lead filter is used only for very hard radiation (above 1MeV); hence not for X-radiation. The optical analysis of the film surface in the sites shielded by the filters and in the open window allows calculating three components of the radiation spectrum of energy weak, medium and hard. The method was described above by Dresler [18].

Conclusion

- The reaction of radiation with film material caused changes in optical properties of the film. By changing the radiation energy at fixed dose, the film sensitivity will change according to the mean energy, so using this calibration unit(x-ray with deferent energy)is better than that use in our country, which uses gamma source (Ra-226) as a calibration source in our country.
- Decreasing in optical density with mean energy, which is attributed to the photo degradation of the films .It may cause some cracks at the film surface and change the optical absorption of the film involved.
- The maximum sensitivity for the XO film type, which approaches the energy of (33keV) for the open window region.
- It is found that the optical density increases with absorbed dose.
- The film badge filters overcomes the changing in film sensitivity, so it must be used.
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الخلاصة

كونها تأخذ بالحسبان أشعاع التعرض المختلف الطاقة بالنسبة للعاملين في حقل الاشعاع, وتأثيره على حساسية الفلم ومن ثم قياس الجرع الشخصية.

أجري البحث في معهد نوفر في بولندا. ان الهدف من البحث هو دراسة تأثير الترشيح على حساسية فلم قياس مستوى التعرض الشخصي نوع XO film type (Foton–Warszawa, Poland) بأستخدام أنبوبة الآشعة السينية نوع Pantak HF-320 وفانتوم حسب ماهو مقرر من اللجنة الوطنية للوقاية من الاشعاع NCRP وجد انه بتغيير طاقة الاشعاع عند جرع ثابتة ستتغير حساسية الفلم وفقا لمتوسط الطاقة, وان اقصى حساسية للفلم مدار البحث تقترب من الطاقة 33 keV.تحتوي حاملة الافلام على اربعة ازواج من المرشحات (0.05 mm Cu, 0.5 mm Cu, 1.5 mm Cu and 1.0 mm Pb), أضافة الى منطقة الشباك. تعمل المرشحات على توحيد حساسية الفلم, لذا استخدمت.وجد ان هناك نقصان في الكثافة الضوئية بزيادة سمك الفلتر Cu وان اقل كثافة ضوئية هي عند منطقة فلتر Pb باستخدام متوسط الطاقة ضمن المدى (24-248keV). وجد انه بزيادة متوسط الطاقة تزداد الكثافة الضوئية (حساسية الفلم) حتى يقترب متوسط الطاقة منkeV 33 حيث تسجل اقصى حساسية للفلم. أظهرت النتائج وجود علاقة لاخطية بين الكثافة الضوئية والجرعةالاشعاعية, وتسمى هذه المنحنيات بمنحنيات المعايرة. وجد ان الخلفية الاشعاعية النموذجية للفلم دون 0.1 mSv, والتي تمثل اقل جرعة قابلة للقياس ويمكن أحتسابها. وجد زيادة في الكثافة الضوئية مع الجرعة الممتصة, وقد اعزي ذلك الى عملية التفكك الضوئى وامكانية أحداث مصائد (مواقع ثابتة) داخل فجوة الطاقة وذلك لحد متوسط الطاقة 33keV. وبالنسبة للطاقات الاعلى منها وجد تناقص في الكثافة الضوئية مع الجرعة الممتصة ويرجع ذلك الى احتمالية حدوث تشقق بتأثير التفكك الضوئي في سطح العينة.أن التحليل الطيفي لسطح العينة(الفلم) ففي المواقع المدعومة بالمرشحات ومنطقة الشباك تسمح بحساب ثلاث مركبات لطيف الاشعاع (منطقة الاشعاع الضعيف, منطقة الاشعاع المتوسط, منطقة الاشعاع القوي), ويتم تحديد دوال المعايرة باستخدام طريقة درسلر. (Dresler method). تعتبر هذه الطريقة أكثر دقة من معايرة أفلام قياس مستوى التعرض الشخصي المستخدمة في بلدنا