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A new environmental dosimeter with imaging plates for the fast neutron monitoring

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Abstract

We describe a dosimeter incorporating BaFBr:Eu^{2+} imaging plates (IPs) for fast neutron ambient dose equivalent measurements. Its configuration and some of its characteristics will be described. While IPs are far more sensitive to radiation than photographic film or track detectors, they are nevertheless subject to fading and account must be taken of this phenomenon in order to arrive at a correct dose estimation. A procedure for making the fading correction will be presented.

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1. Introduction

Imaging plates (IPs) have begun to supplant photographic films as radiation detectors because of their sensitivity, dynamic range, ease of use and reutilizability [1]. The energy lost by energetic particles and electromagnetic radiation in an IP creates metastable states (latent image) in the BaFBr:Eu^{2+} phosphor that can be stimulated to decay, i.e. the detector can be ''read'' by scanning with a selective optical wavelength. This causes the emission of a photostimulated luminescence (PSL) whose distribution on the IP can be displayed on a monitor. Thus, the information furnished by an IP corresponds to that of an X-ray image on a photographic film or, in the present case, to the darkening of the emulsion of a film dosimeter. After being used, the IP can be erased by exposure to strong light and

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can be reused ad infinitum. These properties make possible the application of IPs to fast neutron ambient dosimetry for evaluating the ambient dose equivalent $H^*(10)$.

While possessing important advantages over other detectors, IPs are nonetheless subject to fading due to the spontaneous decay of their metastable states. For some applications, fading is not a serious problem. However, for an IP dosimeter, not taking fading into account will alter the interpretation of its reading. One approach that has been used for short or "instantaneous" irradiations is to make the readings after the same time delay following irradiation as that used for the calibration. When readings are made at different times after irradiation, the signal strength can be corrected to the same time delay by using a predetermined decay curve. Taniguchi et al. [2] combined both of these approaches by making many of their IP readings at a designated time (24 h) after X-ray irradiation, but they also used a decay correction to bring other readings to the same delay time. Whichever procedure is applied, one can arrive at an estimation of $H^*(10)$.

2. Experimental study

2.1. Imaging plates and reader

Fuji IPs [3] were used in conjunction with a DenOptix reader [3]. The IPs have dimensions of $31 \times 41 \times 0.36\,mm^3$ and consist of a 130 μm $BaFBr:Eu^{2+}$ layer with a hydrocarbon binder, a 10 μm polyethylene protective front layer and 215 μm of polyethylene used as a rigid backing. The thicknesses and stoichiometries were measured with a scanning electron microscope. Up to 29 IPs can be placed on the reader drum, which is scanned revolution by revolution from top to bottom using a laser beam (He–Ne, 633 nm) for the PSL (390 nm). The reading time is 2.25 min.

An image treatment software [4] gives its results as optical density in units of PSL/mm^2, representing the photostimulated signal and the corresponding uncertainty for the pixels in a given delimited zone.

2.2. Dosimeter configuration

Fig. 1 shows the configuration of the IP-based fast neutron dosimeter. As neutrons have to be detected indirectly, a polyethylene radiator is used to produce protons via (n, p) elastic scattering. With IPs sensitive to both β- and γ-rays, two 1 mm Pb layers attenuate γ-rays accompanying the neutron field and two 1 mm Al layers absorb β-rays resulting from n-capture in the Pb layers. IP_1 and IP_2 are assumed to receive the same radiations in the same quantities, except for recoil protons coming from the radiator. The signal from recoiling protons is given by the PSL density difference (Eq. (1)),

$$I_0 = I_{0,IP2} - I_{0,IP1}. \quad (1)$$

2.3. Radiator thickness

The MCNP (Monte Carlo n-particles) code [5] was used to calculate the number of (n, p) reactions occurring in the radiator. Then with the Monte Carlo program ProT [6] for proton tracking using range-energy values obtained with SRIM03 [7], the proton equilibrium thickness of the radiator, which is the thickness above which the number of emerging proton recoils becomes constant, was calculated (Fig. 2). For a neutron energy of 10 MeV, representing the maximum energy of Am–Be neutrons, this equilibrium is 1.2 mm. In Fig. 2 it is seen that this thickness represents the proton equilibrium thickness for all lower energies. For example, for 3.6 MeV neutrons, the thickness is 0.2 mm as has also been reported in [8]. Our

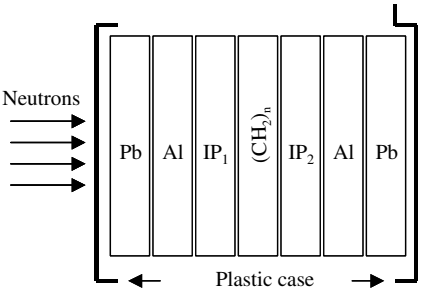

Fig. 1. Fast neutron dosimeter incorporating two $BaFBr:Eu^{2+}$ imaging plates, a polyethylene radiator and Pb and Al absorbers. The IP sensitive sides are oriented to the left.