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The international calibration procedure for B3 film dosimetry system to ensure the quality irradiated products by 10 MeV electron beam accelerators at VINAGAMMA

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Abstract: We performed an in-plant calibration of dosimetry system by electron beam (EB) irradiating the B3 film dosimeters at VINAGAMMA, and inter-compared with the alanine dosimetry, which were supplied and analyzed by Risø High Dose Reference Laboratory (HDRL) as the reference standard. The results revealed that the relative deviation between the values of absorbed doses obtained with our dosimeter and the transfer standards dosimeter measured by HDRL was within the acceptable limitation (about ± 3.0 % in the target range of 2.0-10.0 kGy). And post-irradiation stability of B3 film dosimeters was still maintained after 180 days storage. It is suggested that the B3 film dosimetry could be used in routine radiation processing at VINAGAMMA with the investigated dose range for quality assurance of the irradiated products, specially are foods and foodstuffs processed under the 10 MeV EB accelerator at VINAGAMMA.

Keywords: *B3 dosimeter, in-plant calibration, alanine reference dosimeter, electron beam radiation.*

I. INTRODUCTION

Calibration and measurement of radiation doses are one of the most important steps in the good irradiation practices to ensure the quality of irradiation process [1,2].

B3 dosimeter is a radiochromic film consisted of polyvinyl butyral (PVB) resin mixed with the radiochromic dye (pararosaniline) are increasingly used as a routine dosimeter to measure the absorbed doses in irradiation on practices for both gamma and EB facilities due to its small in size and simple requirements for its dose-mearsuring equipment. Briefly, absorbed dose is determined based on the color change when the film was exposed to ionizing radiation. This dosimeter was stable and has been applied to measure the absorbed doses in the range of 1 – 140 kGy. On the other hand, energy absorption of B3 film from EB irradiation is similar to water, the B3 dosimeter becomes an excellent candidate for measuring the doses at material/material and air/material interfaces [3,4,5].

With the increasing of irradiation facility (gamma or electron beams) for multi-purpose irradiation processing, many dosimeters and dosimetry systems have been developed for measuring absorbed dose. And the calibration becomes an essential and important procedure to control the quality of irradiation process. This paper reported an in-plant calibration for B3 film dosimeters which used for EB irradiation at VINAGAMMA, intercompared with alanine dosimeter from Risø High Dose

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Reference Laboratory (HDRL, Danmark) as reference standard dosimetry.

II. EXPERIMENTAL

Materials and equipment

• Routine dosimeter system: B3 film (GEX Corp., USA; Product: B3000; Batch: CB; Average thickness: 0.0177mm)

• Reference standard dosimeters: Alanine pellets, 4 pellets per dosimeter (Risø High Dose Reference Laboratory)

• Electron beam facility: UERL-10-15S2, 10 MeV, 15 kW, supplied by CORAD Ltd., Co., Russia;

• Genesys 20 spectrophotometer, GEX Corp., USA

• EB calibration phantom (Risø High Dose Reference Laboratory).

Irradiation of dosimeters and calibration of the dosimetry

The routine (B3 film) and reference transfer standard (alanine pellets) dosimeters are placed into an EB phantom and simultaneously irradiated by a 10MeV UERL-10-15S2 linac accelerator at 5 points of doses from 2 to 10 kGy as shown in Fig.1a [1,2,6].

In-plant calibration of the B3 film dosimeters was performed by irradiating them together with reference standard dosimeters to minimize the contribution of influence quantities, to the overall uncertainty and to ensure the same irradiation conditions for both reference and routine dosimeters during the production run.

EB irradiations were carried out under the 10MeV accelerator (UERL-10-15S2 linac, CORAD Ltd., Russia) equipped by a conveyor system with beam scanning width of 60 cm and average pulse current of 0.25A. The conveyor speed, scanning frequency, sync frequency of accelerator were controlled to ensure the uniformity of absorbed dose. The phantom was placed parallel on the conveyor, perpendicular to electron beams and irradiation, as shown in Fig.1b.

Four of B3 film dosimeters and four alanine pellets were used for each dose point. For each dose point, start and maximum temperature were recorded during the irradiation. The calibration irradiations were carried out by placing one pack of alanine reference standard dosimeters (containing four pellets) and four B3 film dosimeters (in one sachet) into polystyrene phantom supplied by HDRL of Risø National Laboratory. The phantom was put into carton tray, normally used to carry the product boxes, as shown in Fig.2a and 2b, and irradiated at doses of 2.0; 3.5; 5.0; 7.5; 10 kGy, respectively

After irradiation, the alanine dosimeters were sent back to Risø High Dose Reference Laboratory, Danmark for analysis. The absorbed doses obtained. The absorbed doses with the B3 dosimeters were also measured by using Genesys 20 spectrophotometer at the wavelength of 552 nm (ISO/ASTM 51310 and Guidelines for the measuring GEX dosimeters 100-258 D) [7,8].

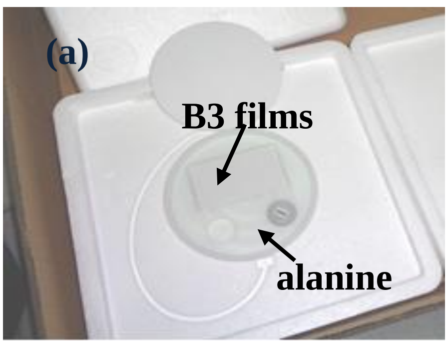

Fig.1. A phantom used for irradiation of alanine pellets and B3 dosimeters (a) and irradiation of the phantom by 10 MeV EB, VINAGAMMA (b).

Measurement uncertainty and calibration curve

Components of uncertainty were identified by statistical method using the Excel software. The combined uncertainty of an absorbance value and an absorbed dose of the dosimeter system were evaluated within ± 5 % at a 95 % for confidence level [9].

Finally, the calibration curve was plotted as function of R=f (Dose),

Where

R = Response = Ai/T, with

Ai = irradiated absorbance and

T = Thickness of B3 film

Dose = Alanine reference standard dose (kGy).

III. RESULTS AND DISCUSSION

Intercomparison calibration of B3 film dosimetry

As shown in Figure 2, color of the B3 films was changed from white to pink after irradiation with a 10 MeV electron beams. These changes were also confirmed by UV spectra. These spectrum show a major absorption peak at the wavelength around 550 - 552 nm, which was increased in proportion to the electron affluence. Because of the broad peak of the B3 film, measurement at any fixed wavelength between 550 – 555 nm is considered acceptable, as recommended by GEX [1,2,3].

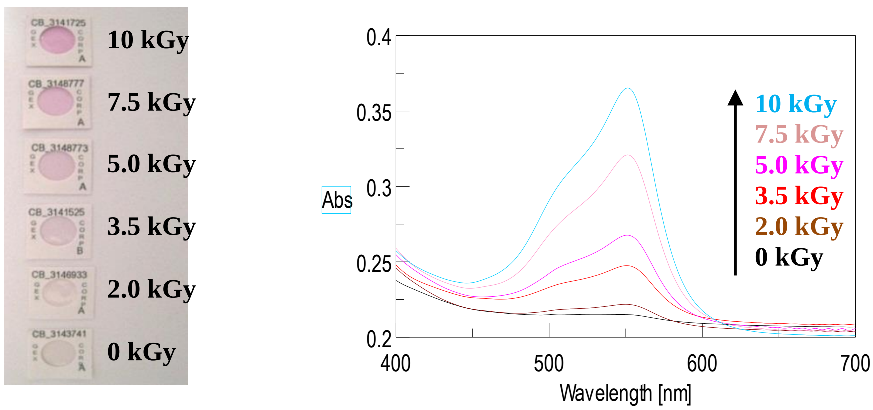

Fig.2. Photo (Left) and absorption spectra (Right) of B3 films irradiated from 0 to 10 kGy.

Table I. Dose intercomparison using B3 film and HDRL alanine reference standard dosimeters irradiated by 10 MeV EB at VINAGAMMA

No.	Target dose, kGy	B3 film measured dose, kGy	Code of alanine dosimeters	Alanine measured dose*, kGy	Ratio B3 film/Alanine	CV**
1	2.0	2.37	1043	2.44	0.970	**- 3.0 %**
2	3.5	3.82	1048	3.92	0.974	
3	5.0	5.39	1049	5.66	0.952	
4	7.5	7.87	1050	8.15	0.966	
5	10.0	11.05	1047	11.22	0.987	
Overall mean					0.970	

**Reference dosimeter certificate no: 16C-32, reported by HDRL of Risø National Laboratory*

***CV: coefficients of variation. Irradiation date: 14 May 2016.*

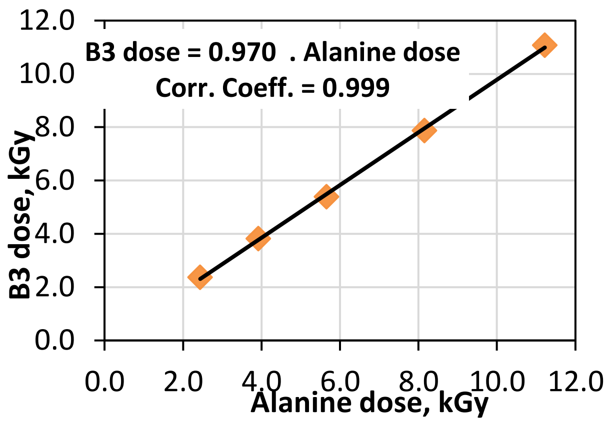

Fig.3. Comparison of doses measured by B3 film and HDRL alanine reference standard dosimeters irradiated at VINAGAMMA EB facility.

As one can see from Table.I and Fig.3, the relative deviation of absorbed dose values quoted by VINAGAMMA to dose values estimated at HDRL are in good agreement of within about ± 3.0 % at the absorbed dose range of 2.44-11.22 kGy [1,3]. The dose–response between the alanine and B3 film dosimeters were studied for the dose range between 2 and 10 kGy when exposed to electron beams. The dependence of the response on doses given in the 10 MeV EB accelerators is described in Fig.4. The linear regression coefficient is better than 0.9999. No statistically significant difference was observed between the two sets of data in the absorbed dose range of 2.44-.22 kGy.

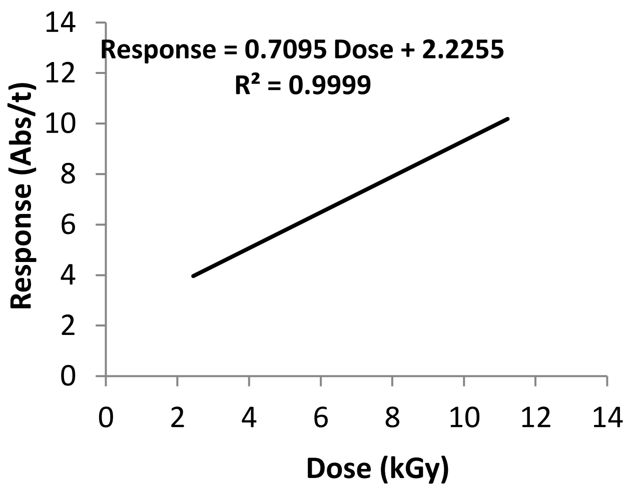

Fig. 4. Calibration curve of the B3 film dosimeter irradiated together with alanine reference standard dosimeter at VINAGAMMA EB facility.

Post irradiation stability of B3 film dosimeters

To test the post-irradiation stability of the B3 dosimeters, dosimetry packages, containing five B3 film dosimeters were irradiated during the production run. The stability of the B3 film dosimeters (irradiated to 5 kGy) was studied by measuring it 5 times in 180 days storage. The absorbed dose results measured by the B3 dosimeters in the different storage time were shown in Fig.5. The standard deviation of these 5 results was found to be 2.52 % at 95 % confidence level. It indicated that the post-irradiation stability of B3 film dosimeters was still maintained after 180 days storage.

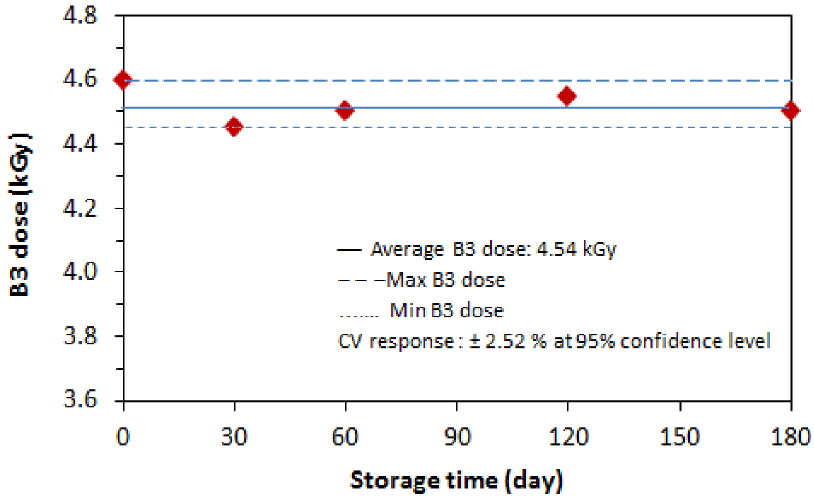

Fig.5. Stability of the B3 film dosimeters stored in dark at room temperature during storage time.

IV. CONLUSIONS

In the dose range of 2.44 -11.22 kGy, the B3 film dosimeter was applicable in practice of EB radiation processing, which has been calibrated with alanine reference standard dosimeter by HDRL of Risø National Laboratory at an acceptable deviation. The absorbed dose measured with B3 film dosimeter was in good agreement with that measured by alanine reference standard dosimeter within ± 3.0 % (in the acceptable limitation). The overall uncertainty was 2.52 % at 95 % confidence level at an absorbed dose of 4.54 kGy on 10 MeV, 15 kW electron beam accelerators. The results of this work indicated that the B3 dosimeter can be utilized as a routine dosimeter system for quality assurance of goods by electron beams at VINAGAMMA. However, to ensure the quality of irradiated products, the calibration process should be performed periodically.

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