

SOME PHYSICAL PROPERTIES OF DOSIMETRIC MATERIALS USED IN INDUSTRIAL IRRADIATION PROCESSES

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ABSTRACT

Industrial processes using ionizing radiation have seen fast growing and enlargement of product types irradiation. Condensed materials as plastic films are used as routine dosimeters and must be known not only for its dosimetric properties but also for its main mechanical characteristics.

This paper considers different types of films, namely cellulose triacetate, nylon and cellulose diacetate containing radiosensible media, when exposed to ^{60}Co gamma rays. Emphasis on ambient light influence as well as tension-deformation behaviour is given, in order to determine care during laboratory manipulation and uses during product irradiation.

Quality control performances, based on dose distribution and product validation, generally follow international regulations. In a non homogeneous product, dosimetric materials must have a spatial distribution inside and outside boxes containing the product what can lead to contacts between both dosimeter and product. This contacts give rise to mechanical forces that can injury the films inutilizing them for dosimetric analysis.

Irradiations were performed with gammas and accelerated electrons. The films were irradiated with doses ranging from 0,1 Gy up to 300 kGy in order to simulate prescribed values ordered by the users.

INTRODUCTION

Dose mappings within the products are often performed with routine dosimeters as films made of plastic materials, that are used with or without electron equilibrium materials when exposed to gamma fields. When none electron equilibrium material is used, the contact between the dosimetric material and the product is direct. This situation gives rise to forces that can easily injury the dosimetric material in such a manner that its read out becomes altered.

In radiation processing planning it is very important to know relevant properties of the materials that will be employed in dose evaluation.

Several dyed or clear plastics are commercially available for dosimetry in industrial scale. Some of these materials are: cellulose triacetate, cellulose diacetate or radiochromic plastics. All these dose meters have different advantages such as linear response, large range dose rate response etc. However there are some other properties that should be known for manipulation conditions in laboratory and at the on line scale.

Among operational and technical items there are several considerations to be observed when routine dosimeters are selected. Ruggedness is one of the operational properties that means that the dosimetric material shall have resistance to damage during handling and use in routine processing environment⁽¹⁾. Light influence is an environmental condition that affect the technical properties of the dose meters and can disturb the manipulation conditions at both laboratory and at on line irradiation process.

Since the dosimetric materials that were considered in this work are plastic base, there are physical and functional tests specially for plastic materials evaluation as tensile and flexural properties, impact resistance, hardness, compressive strength and others.

This paper consist of partial evaluation of work that is under progress and considers the tensile properties⁽²⁾ as: tensile strength, ultimate elongation and extension at break. Ambient light influence was also considered for the materials since the laboratory and the irradiation installation works under fluorescent and mixed light lamps.

EXPERIMENTAL CONDITIONS

Dosimetric materials

Cellulose triacetate, CTA, is supplied by Fuji Photo Film Co. in the form of a tape with a width of 8 mm and thickness varying from 0.118 to 0.129 mm. Film composition is 84% of cellulose triacetate ($C_{12}H_{16}O_8$), 16% of triphenylphosphate ($C_{18}H_{15}PO_4$). Its response do not vary in the dose rate range from 200 Gy/h to 10 kGy/h. Absorbed dose response is linear from 10 to about 300 kGy.

Cellulose diacetate is supplied by ATC International Inc., code DY-4.2, in the form of a tape with a width of 8 mm and thickness varying from 0.116 to 0.120 mm. Absorbed dose response is linear from 10 to about 400 kGy and its yellow colour turns paler upon irradiation at high doses due to radiation-induced bleaching.

Other dyed acetate, supplied by GAF Chemicals Corp. with a commercial name Gafchromic DM-1260, was also tested. The film came in form of large tapes, about 5.1 inches width, and must be cut in strips with a wanted size. This film has a linear absorbed dose response from 0.01 up to 3 kGy and is independent of the dose rate in the range from 9×10^{-2} to 2,7 kGy/h as was observed in irradiations made with panoramic ^{60}Co source.

The aminotriphenyl methane dye derivate is supplied by Far West Technology Inc., code FWT - 60.20, and upon exposure to ultraviolet light and radiation becomes more and more intensive blue colour, depending on the exposure time and dose. Its response is linear for doses between 1×10^{-3} to 150 kGy.

The light influence was measured by optical absorption at wavelengths : CTA - 280 nm, DY - 450 nm , DM - 510 and 600 nm and FWT - 510 and 605 nm.

For tensile properties tests the specimens were prepared according to standards ⁽¹⁾. Excepting the DM film that was only tested for gamma radiation, all others were tested for both gamma and electron radiation. Gage marks were placed on specimens by using India ink.

Conditioning procedures and samples preparation

Before and after irradiation the samples were maintained at room temperature of $23 \pm 2^{\circ}\text{C}$ and $50 \pm 5\%$ relative humidity.

For light influence samples were cutted in strips form, 8 mm width and 50 mm long. For tensile experiments the specimens were moulded according to ASTM standards by using homemade film cutter that allow the specimens preparation by pressure.

Apparatus

Light influence was observed throught optical absorption growth by comparing the unexposed and exposed films. Optical absorption was measured with the Pharmacia Model Novaspec II spectrophotometer at specific wavelengths.

The films thicknesses were measured using a Peacock thickness gauge.

The irradiations were carried out by using a ⁶⁰Co panoramic source, a ⁶⁰Co Gamma-cell 220, and an electron accelerator RDI Model Dynamitron. Electron energy was fixed at 1500 keV and currents of 0.3 mA and 5.6 mA were used, in order to obtain different doses rates. Absorbed doses from 0.10 to 300 kGy were achieved for both radiation types.

The tensile properties were measured with an INSTRON testing machine Model 5567 in accordance with the ASTM D 638 - 82⁽¹⁾ standard. The speed of testing ranges from 25 mm/min to lowest speed that was selected as 0.5 mm/min in order to produce rupture between 30 and 300 seconds for those specimens that become rugged after electron irradiation.

RESULTS

Light influence

Film specimens were exposed continuously to ambient lighth during the working time at the laboratory during 47 hours. The experience show that the most influenced dosimetric material was FWT that is sensible to UV light. DM film is somewhat sensible and CTA as well as DY films are not sensible to ambient light during that exposition time . Figures 1 and 2 show the results obtained in this experiment.

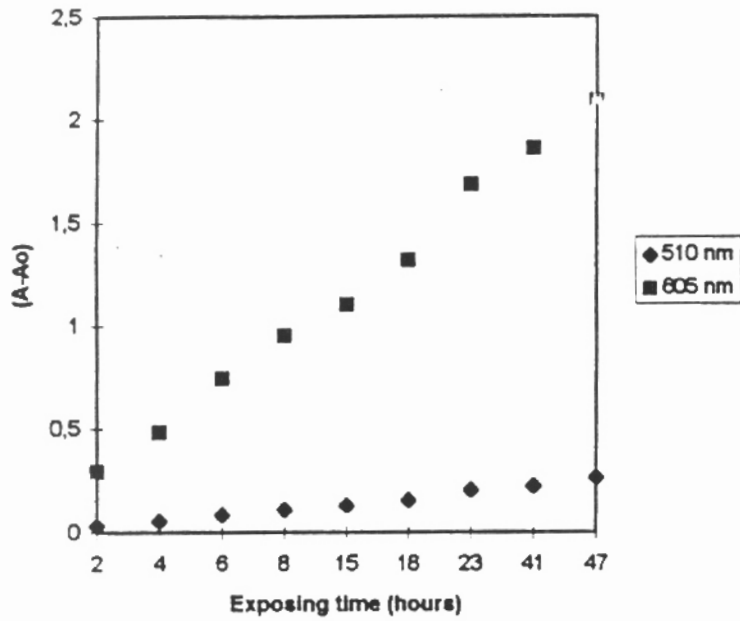


Figure 1 - Ambient light influence on FWT-60.20 dosimetric film .

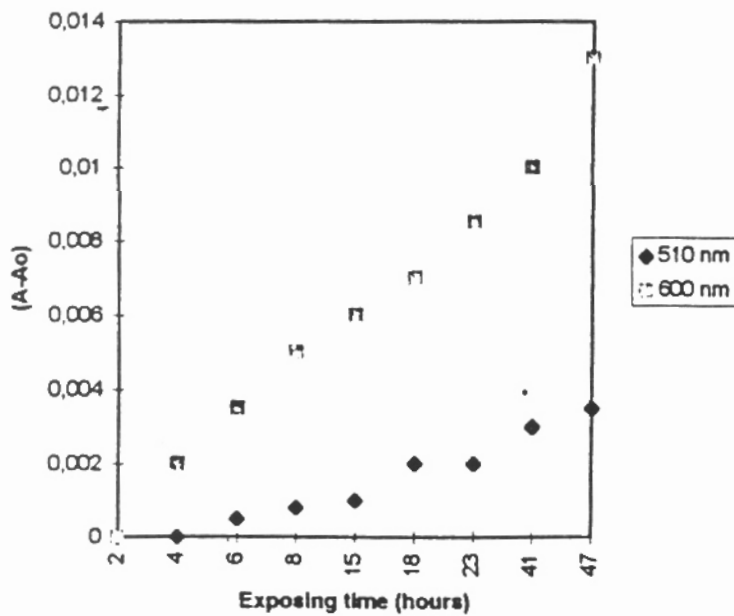


Figure 2 - Ambient light influence on DM-1260 dosimetric film.

Light influence in both FWT and DM films can be highly reduced or even annuled by shielding them with thin aluminium paper before undergoing irradiation. The manipulation at the laboratory can be admeliorate by using incandecent lamps or preferably leaving only a daylight illumination.

Tensile properties

Tables I,II, III and IV show the results obtained in tensile tests of the four analysed dosimetric films.

Table I - Tensile properties of the CTA film irradiated with ^{60}Co gamma rays and accelerated electrons with $E = 1500 \text{ keV}$.

Gamma absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	26.94	37.207	8.08
10	41.78	64.600	12.54
55.5	26.86	30.468	8.08
123.3	17.12	26.170	5.92
260	2.71	22.576	0.81
Electron absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	26.90	37.189	8.08
25	31.53	41.528	9.45
100	14.72	36.097	4.42
150	2.99	3.841	0.90

Table II - Tensile properties of the DM-1260 film irradiated with ^{60}Co gamma rays.

Gamma absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	84.05	143.871	28.21
0.15	93.11	155.462	27.93
1.50	88.43	136.274	26.5
2.50	80.76	87.475	24.23

Table III - Tensile properties of the DY-4.2 film irradiated with ^{60}Co gamma rays and accelerated electrons with $E=1500$ keV.

Gamma absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	38.15	43.786	11.44
9.6	39.17	48.928	11.75
34.8	33.52	44.485	10.06
100.8	31.11	34.353	9.33
260.3	9.00	20.810	2.70
Electron absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	38.15	43.786	11.44
25	42.23	59.527	12.67
50	42.13	57.339	12.64
100	35.56	44.305	9.77
150	25.37	42.493	7.61
200	10.39	30.762	3.12
300	1.91	21.219	0.57

Table IV - Tensile properties of the FWT film irradiated with ^{60}Co gamma rays and accelerated electrons with $E=1500$ keV.

Gamma absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	330.56	25.182	99.17
0.1	314.58	21.871	94.38
7	299.84	18.480	89.95
40	237.50	14.207	71.25
67	188.19	14.602	56.46
102.2	57.87	11.754	17.36
Electron absorbed dose (kGy)	Percent Elongation at Break (%)	Tensile Strength at Break (MPa)	Elongation at Break (mm)
0	330.56	25.182	99.17
1.07	454.77	37.801	136.43
2.40	459.72	25.439	137.92
25	369.47	26.222	110.84
100	325.69	17.058	97.71
150	281.94	19.035	84.58

The samples did not show any atypical strain patterns although those irradiated with electrons specially CTA films present a ruggedness after doses higher than 100 kGy. This is supposed to be due to an oxidative degradation when the molecular mass decrease with the dose⁽³⁾ and also due to a weak link between the carbon chains⁽⁴⁾.

On the other hand it is known that reticulation is a property that results on the linking between two or more polimeric chains when the material is irradiated at low doses before showing degradation. It can be seen that for low radiation doses the CTA, DY, DM and FWT film showed an increase of the tensile properties⁽⁵⁾.

Care must be taken to read out the optical absorption of those dose meters that undergo irradiation without electron equilibrium material when high doses are requested in gamma fields. Excepting FWT and DM films, CTA and DY become more rigid and weakly to manipulation procedures but shall not be discharged.

When electron irradiations are performed the nylon base material, FWT, is one of the most resistant up to its limiting doses of 150 kGy. Dy resists quite well up to 300 kGy and Cta shows ruggedness for doses higher than 150 kGy and high dose rates. When low dose rates are used in electron irradiation the behaviour of CTA films becomes admeliorated for very high doses ranging 300 kGy.

Experiences are continuing in this field since high doses are generally requested for research and development studies.

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