ANGULAR RESPONSE OF POLYMER FILMS IRRADIATED WITH ACCELERATED ELECTRON BEAM

Galante, A. M. S.*; Campos, L. L.

Nuclear and Energy Research Institute – IPEN-CNEN/SP
Radiation Metrology Centre - Av. Prof. Lineu Prestes, 2242, Cidade Universitária, São Paulo, Brasil, 05508-000.

*sgalante@ipen.br

Abstract

Incident electrons on the material or on the patient are characterized by its different parameters of energy, incidence angle and particles average range in a specific medium. When radiation is applied in a large area, as in the skin diseases treatment in which the whole body must be irradiated, or in the industry which large and irregular volumes should be irradiated, obliquely incident particles must be considered, since, it may result in different doses from those obtained in irradiated material in normal direction exposure. Polymer films (3 mm thick) change its original color upon radiation exposure and therefore were used to determine angular response in irradiations with accelerated electron at IPEN. Optical densities were measured with a Shimadzu UV2101PC spectrophotometer.

Keywords: electron beam, oblique incident angle, polymer detector, spectrophotometric analysis

Introduction

There are many uses of radiation ionizing: in the industrial area it is used in product sterilization (medical instruments and food), polymers cross-linking, curing coatings, etc; in medicine for diagnosis and treatment of disease, such as cancer; in scientific research (it is used in biomedical research, metabolic studies, genetic engineering and environmental protection studies); in Archaeology ^{14}C is used to date artifacts containing plant or animal material; in criminal investigations it is used to examine evidence; museums rely on radioactive materials to verify authenticity of art objects and paintings **[1-4]**.

The main radiation sources used for these processes include ***gamma sources*** (high-energy photons emitted from an isotope source (Cobalt 60) producing ionization throughout a product; the gamma irradiation process does not create residuals or impart radioactivity in processed products) and ***electron accelerators*** (it is a device (linear or circular) that uses electrostatic or electromagnetic fields to increase the speed (energy) of electrically charged particles (molecular, atomic, or subatomic) or electrons, and to direct the charged particles to collide one with each other or with a target). The collision or interaction of the charged particles releases subatomic particles or produces various types of ionizing and non ionizing radiation. The

various types of accelerators differ in the way they produce the accelerated electric field and in how the field acts on the particles to be accelerated **[5-7]**.

In a radiation process, a product or material is intentionally irradiated to preserve, modify or improve its characteristics. This process is carried out by placing the product in the vicinity of a radiation source for a set time interval whereby the product is exposed to radiation released from the source.

The dose distribution determination for a given beam configuration is performed to optimize processes; it is necessary to ensure that the delivered dose is uniform throughout the irradiated volume. When radiation is applied in a large area, as in the skin diseases treatment in which the whole body must be irradiated, or in the industry which large and irregular volumes should be irradiated, obliquely incident particles must be considered, since, it may result in different doses from those obtained in irradiated material in normal direction exposure **[8-12]**.

The accurate measure of radiation dose (dosimetry) is extremely important in radiation processes. A material to be considered as a radiation dosimeter (a device, instrument or system that measures or evaluates, either directly or indirectly, the quantities of exposure, Kerma, absorbed dose or equivalent dose, or their time derivatives (rates), or related quantities of ionizing radiation) must possess at least one physical property that is a function of the measured dosimetric quantity and that can be used for radiation dosimetry with proper calibration **[13,14].**

The irradiation of polymeric materials with ionizing radiation (gamma rays, X rays, accelerated electrons, ion beams) leads to the formation of very reactive intermediates products. These intermediates products follow several reaction paths, which result in rearrangements and/or formation of new bonds. The ultimate effects of these reactions are the formation of oxidized products, grafts, main chains scission (degradation) or cross-linking **[15,16]**.

Polymer films present fast and inexpensive means for performing accurate quantitative radiation dosimetry, besides ruggedness, long shelf-life stability, ease handling, convenient analysis by spectrophotometry and are usually available in large reproducible batches.

Several polymers have been used as radiation dosimeter, such as, polymethylmethacrylate, polyvinylchloride, nylon, fluoropolymer, polycarbonate, cellulose triacetate. The main modification that occurs in polymers is the color change upon radiation, and, the received dose can be related with color change by the absorbance measures of the material before and after irradiation **[17-19]**.

In this work the obtained results of polymer detectors irradiated in an electron accelerator **[20]** with energies of 0.732 and 1.25 MeV, doses of 10 and 30 kGy and, in the normal direction

exposure (horizontal) and with angles of 30, 60 e 90^{o} were analyzed. The spectrophotometry based on the absorbance values change, comparing irradiated and non-irradiated detectors was chosen as analysis technique.

Experimental

Film pieces (3 x 1 cm^2) were cut from commercial sheets of *Polycarbonate* (PC), *Polymethylmetacrylate* (PMMA), *Cellulose Triacetate* (CTA), *Polyvinylchloride* (PVC) and *Fluoropolymer* (PF).

The polymeric films were irradiated in an electron accelerator (Dynamitron® Job 188, manufactured by RDI- Radiation Dynamics Inc.) with energies of 0.732 and 1.25 MeV and doses of 10 and 30 kGy. The samples were positioned at normal direction exposure (horizontal – parallel in relation to conveyor) (**Figure 1)** and with angles of 30, 60 e 90^{o}. A box with PC detectors positioned in different geometries and spread over the container volume was irradiated with dose of 30 kGy and energy of 0.732 MeV (**Figure 2**).

Optical densities of the films were measured with a Shimadzu UV2101PC spectrophotometer at maximum absorption band.

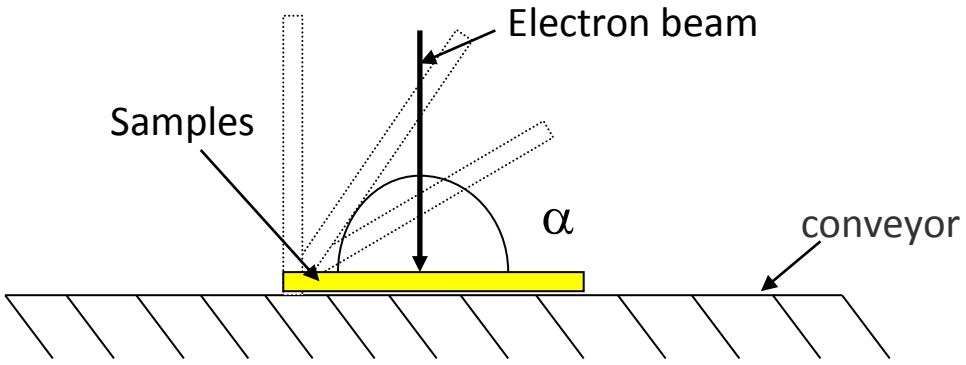

Figure 1. Schematic drawing of the samples positioning.

Legend: PC detector – position 90º

C detector – position 60º

PC detector – position 30º

PC detector – position 0º

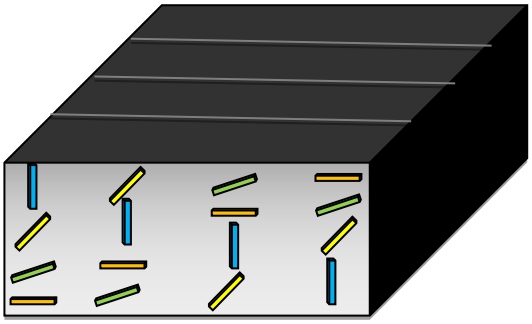

Figure 2. Schematic drawing of the container irradiated with PC detectors positioned at different angles.

Results and Discussion

Samples of different polymers positioned in different angles (0-90º) were irradiated and the spectrophotometric responses in function of electron beam incidence are shown in **Figure 3** (a); (b); (c); (d); (e) and (f) to **PC**; **PMMA**; **PVC**; **CTA**; **FEP** e **PFA** polymers, respectively.

All points were normalized to the values obtained using the following parameters: electron energy = 0.732 MeV / absorbed dose = 10 kGy / angle = 0º.

The results showed, as expected, when the electron beam incides in samples positioned with angle different from normal (0°) the dose received by the material decreases with the angle increase, since in normal incidence there is little dispersion around the medium. The PFA detector is not sufficiently sensitive to show the response variation, especially to energy of 1.25 MeV and dose of 30 kGy.

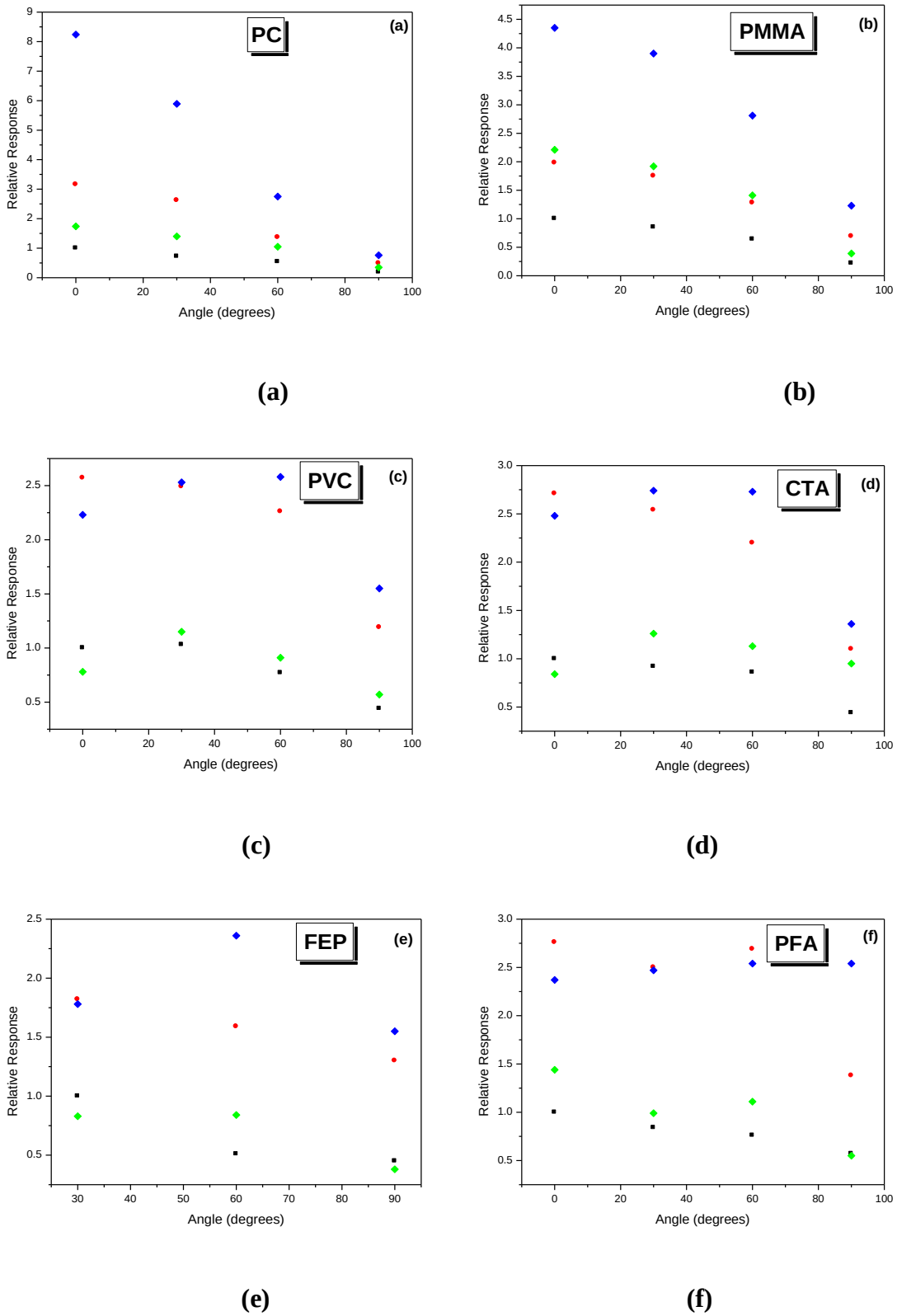

Figure 3: Relative Response of detectors (**a**) **PC** *(λ = 412 nm)*; (**b**) **PMMA** *(λ = 640 nm)*; (**c**) **PVC** *(λ = 395 nm)*; (**d**) **CTA** *(λ= 280 nm)*; (**e**) **FEP** *(λ = 250 nm)* e (**f**) **PFA** *(λ = 220 nm)* irradiated with accelerated electrons in different energy and angle - ▪ Energy= 0,732 MeV e Dose = 10 kGy; ● Energy = 0,732 MeV e Dose = 30 kGy; ◆ Energy = 1,250 MeV e Dose = 10 kGy e ◆ Energy = 1,250 MeV e Dose = 30 kGy.

The incident electron on the patient or material presents distribution both as a function of energy and in angle. A careful evaluation of the expected dose distribution must be made to adjust the irradiation parameters.

On the basis of irradiation simulation results of the box, could be observed that in the irradiated volume occurred a large change in the absorbed dose when the electron beam incides on the material surface positioned obliquely and there was a decrease in the dose penetration.

Detectors positioned in the container surface received dose of 83%, 43% and 15% respectively to angles of 30, 60 and 90^{o} of the dose obtained in the detector positioned in the normal exposure (0^{o}).

Electrons lose energy in collisions with the material in which they interact, and in irradiation with low energy electrons, lateral scattering occurs shortly after penetrating the medium, which leads to a high energy loss and abrupt dose decrease.

Detectors positioned at the bottom of the container received doses lower than 5% compared with the obtained dose in the normal position (0^{o}) due to the power attenuation in the medium and the surface-source distance, and, in detectors obliquely positioned the doses are close to zero (90^{o}).

The electron range depends on the electron initial energy and on the material density. To optimize dose distribution in the medium is necessary to choose convenient electron beam energy and restricting the material thickness, which must be lower than the electron range.

Conclusions

It can be concluded that incident electron beam in material obliquely positioned releases less energy in the medium, i.e., there is more energy dispersion, resulting that the received dose is lower. This change in the dose has important implications for industrial and medical radiation processes, in which it is essential that required dose, to promote the expected effect, is guaranteed.

This study is important due to the fact that materials and the human body present irregular surfaces that receive the radiation at different angles, as previously mentioned.

When it is not possible to guarantee that the irradiated surface is as close as possible of a flat shape, and irradiations with complicated geometries are necessary, simulations and planning systems are used, the doses are obtained in reference geometries with an adequate precision.

The results obtained have comprove that all tested detectors (with the exception of the PFA polymer) are effective in the mapping of received radiation dose distribution in electron beam irradiation in different configurations (angles).

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