PAIR/P.662/94

PREPARATION OF ALANINE/ESR DOSIMETER USING DIFFERENT BINDER OF POLYMER BLEND

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ABSTACT

PREPARATION OF ALANINE/ESR DOSIMETER USING DIFFERENT BINDER OF POLYMER BLEND. Different composition of polymer blend of low density polyethyllen (PE) and polystyrene (PS) have been studied to be used asa a binder for the preparation of Alanine/ESR dosimeter. The polymer binder and Alanine powder were blended in a laboplastomil Mixer at 140^{o}C and then it was pressed into a plastic film of 0.50 mm thickness. The film was cut into sample size of 250 mm x 2.5 mm and irradiated by gamma rays from a cobalt-60 source at different dose and dose rate. It was found that a blend of Alanine, PS and PE in composition of 60:30:10 is appropriate to prepare the Alanine/ESR dosimeter.

ABSTRAK

PEMBUATAN DOSIMETER ALANIN/ESR MENGGUNAKAN BERBAGAI BAHAN CAMPURAN POLIMER PENGIKAT. Berbagai komposisi campuran polimer polietilen dan polistiren telah dipelajari untuk digunakan sebagai bahan pengikat bagi pembuatan dosimeter Alanine/ESR. Bahan pengikat tersebut dicampur dengan bahan alanin dalam alat pencampur Labo plastomil pada temperatur 140^{o}C, dipres menjadi film dengan ketebalan 0,50 mm, dipotong menjadi ukuran sampel 250 mm x 2,5 mm dan diiradiasi dengan sinar r pada berbagai dosis. Didapatkan bahwa campuran alanin, PS dan PE dengan komposisi 60 : 30 : 10 adalah baik bagi pembuatan dosimeter Alanain/ESR.

KEYWORDS

Alanine/ESR dosimeter, polymer blend, gamma rays irradiation, absorbed dose, polystyrene, pollyethylene, alanine powder.

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*) Presented at the International Meeting Radiation Processing (IMRAP-9), Turkey, 12-16 September 1994.

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INTRODUCTION

Several laboratories have successfully developed Alanine/ESR dosimeter (Bradshaw et al., 1962, Regulla et al.,1982, Kojima et al.,1986, Janovsky et al.,1988, Bartolotta et al.,1990). The dosimeter has also been commercially produced under a trade name "AMINOGRAY" (Kojima et al., 1992).Following approval by IAEA (Nam, 1988) the use of Alanine/ESR dosimeter for calibration and routine monitoring of radiation processing was become important. Recently, radiation processing by using gamma rays irradiation has begun to be used commercially in Indonesia, mainly for the sterilization of medical devices and pharmaceutical products. In order to establish a Good Radiation Practice (GRP) and in the framework of the role of National Atomic Energy Agency to promote the application of high-energy radiation in industrial line, it is necessary to develop.

Alanine/ESR dosimeter which is easy to handle, capable of mass production and it can be applied for interlaboratory dosimeter comparisons. It has been previously reported (Sutjipto et al.,1993) about the use of paraffin for binding Alanine powder into a dosimeter rod. In the present report, the preparation of Alanine/ESR dosimeter has been done by mixing the Alanine powder with a blend of polystyrene and polyethylene.

MATERIALS AND METHODS

Materials. DL-Alanine powder (Merck for biochemistry Art.963, Germany), polystyrene (PS) granule (trade name; MALEN E, Poland) and low density polyethylene (LDPE) granule (trade name AUSTREX, Australia) were used as supplied.

Preparation of dosimeter. PS granule was blended with PE granule in a Laboplastomil (Toyoseiki) mixer at 140°C. The Alanine powder was then added gradually to the molten polymer blend until a homogeneous mixture was obtained. The quantity ratio of alanine and the polymers were 60/30/10 by weight percent. Three different compositions of Alanine/PS/PE mixtures namely 60/30/10, 60/20/20, and 60/10/30 were prepared. The obtained homogeneous

mixture was molded into film sheets of 0.50 mm thickness by using a hot press machine (140°C) followed by cooling into room temperature using a cold press machine. The resulting film sheet appear clean and smooth. It was then cut into a sample size (film strip) of 2.5 mm width and 250 mm length by using a cutter. The weight of film strip was in the range of 0.04 to 0.05 gram.

Irradiation. The dosimeter film strip was placed in a plastic vial with a cap. The plastic vial having a wall thickness of 4 mm which is specially designed to establish electron equilibrium during the Co-60 gamma rays irradiation.

The irradiation was done at room temperature by using a 10 kCi Co-60 gamma rays irradiator of "Gamma Chamber 4000 A" and at elevated temperature by a 60 kCi Co-60 gamma rays panoramic batch irradiator (IRPASENA). The dose rate at the irradiation position was calibrated by Fricke dosimeter and it was 6.25 kGy/h for a Gamma Chamber 4000 A and 10.42 kGy/h for IRPASENA. The irradiation dose in the range of 0.5 to 50 kGy was done according to the necessary dose applicable for the sterilization of medical devices and pharmaceutical products.

ESR Measurement. After irradiation, the film strip was taken out from the plastic vial and placed in quartz tube for Electron Spin Resonance (ESR) measurement. The ESR measurement were performed at room temperature (25°C) and humidity ± 60% by using ESR spectrometer JES-REIX, X-band, Japan Electron Optic Laboratory Co. Ltd. (JEOL). The spectrometer was operated at a frequency of 9.4 GHz and optimized constant microwave power level of 1 mA.

The magnetic field setting was 335 mT, scan range 30 mT, the magnetic field modulation amplitude was 1.25 x 0.1 mT, the sweep width was 1x10 mT, the sweep line and time constant were 10 sec and 0.03 sec, respectively. The receiver gain (G) was always adjusted to obtain an optimum ESR signals. The ESR spectra were recorded by using a personal computer and the peak area of the ESR spectra was also calculated.

The ESR response was then determined based on the value of peak area (A) divided by the weight of film strip sample (W) and corrected by the value of the receiver gain (G). The ESR response is expressed in a arbitary unit

according to the following equation,

$$\text{ESR response} = \frac{A}{W \times G} \quad \text{(arbitrary unit)} \qquad (1)$$

RESULTS AND DISCUSSION

Mechanical properties. An adequate mechanical properties of Alanine/ESR dosimeter is needed if it is aimed to be used for interlaboratory dosimeter. In addition, the dosimeter should be easy to handle as well as mass productions. The use of polymeric material as a binder of alanine powder seems to be appropriate in such purpose (Kojima et.al.1986, Janovski et al.,1988). In a prelimanary study, we have known that the preparation of Alanine/ESR dosimeter by mixing of 40 weight percent polystyrene and 60 weight percent alanine powder results an Alanine/ESR dosimeter film having a weak mechanical properties and also brittle. This is different, when the dosimeter was prepared in the form of rod such as reported by Kojima et al., 1986. To avoid the brittleness and to improve the mechanical properties, attempted has been made by mixing the alanine powder with a blend of polystyrene and polyethylene. Table 1 shows the tensile strength of alanine /ESR dosimeter films that were prepared in our laboratory.

As can be seen in Table 1, the tensile strength of alanine/ESR dosimeter was found to be good enough and less brittle than that dosimeter film prepared by polystyrene alone as binder. Such improvement of the mechanical properties make the alanine/ESR dosimeter that was prepared by the polymer blend is appropriate to be used for interlaboratory comparison.

Dose-response. The peak area of the ESR spectrum which is proportional to the concentration of the radiation-generated stable free radicals was applied to determining absorbed dose. Alternatively, the peak height of the ESR spectrum can also be used for absorbed dose determination instead of the peak area measurement. Fig.1 shows a typical ESR spectrum that was recorded from an irradiated film strip of alanine/ESR dosimeter.

Based on the peak area of the spectrum, the ESR response was calculated for each irradiation dose and a calibration curve was made. Fig.2 shows the calibration curves obtained from the iradiation of 3 (three) composition of alanine/ESR dosimeter. As can be seen in Fig.2, the ESR response increases as the dose increases and each curve follows a polynomial equation. By using a simple mathematical formula, the absorbed dose can be easily calculated. For example, in the case of alanine/ESR dosimeter with a composition Alanine/PS/PE of 60/30/10, the calibration curve has a polynomial equation of $y = 0.0369 + 0.4651\ X - 0.0021\ X^2$. If the value of y (ESR response) is subtituted to the equation, then the value of x (absorbed dose) can be calculated as follows,

$$Y = 0.0369 + 0.4651\ X - 0,0021\ X^2 \qquad (2)$$

re-arranged to be,

$$0.0021\ X^2 - 0.4651\ X + Y - 0.0369 = 0 \qquad (3)$$

or,

$$\underset{(a)}{0.0021\ X^2} - \underset{(b)}{0.4651\ X} + \underset{(c)}{(\ Y - 0.0369\ )} = 0 \qquad (4)$$

$$X_{1,2} = \frac{-\ b \pm \sqrt{\ b^2 - 4\ ac}}{2a} \qquad (5)$$

The positive value of X was then used to express the absorbed dose value. By using the above mentioned formula, the deviation of less then 2% was found for all dose mesurement range (5 to 50 kGy).

Effect of temperature. The effect of elevated temperature during irradiation on the response was observed at temperature range from 0°C to 60°C. The results are shown in Fig.3. As can be seen in Fig.3, the ESR response did not changed significantly with temperature in the range from 0°C to 60°C. This character is the same as the results of other author (Regulla et.al. 1981).

CONCLUSION

Alanine/ESR dosimeter has been prepared by using a polymer blend of polystyrene and polyethylene for binding of alanine powder. The quantity ratios of the alanine in the polymer blend (Alanine/PS/PE) were 60/30/10; 60/20/20 and 60/10/30.

The three compositions gave a good ESR response and applicable for measuring absorbed dose in the range of 5 to 50 kGy. The composition of 60/30/10 was found to be the best. It will be selected to be a composition for mass production.

ACKNOWLEDGMENTS

The authors wish to thank Dr.Mehta, for his valuable comment, Mr. Tri Hardono for his assistance with Co-60 gamma rays irradiation and Mr. Yahya for typing the manuscript. The work is supported in part by the International Atomic Energy Agency (IAEA), Vienna under a Research Contract No. 6688/R1/RAS.

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Table 1. The tensile strength (kg/cm²) of alanine/ESR dosimeter film prepared by different composition polymer blend

Polymer blend composition (the ratio of Alanine/PS/PE)	Tensile strength (kg/cm²)
60/30/10	27.35
60/20/20	26.02
60/10/30	28.39

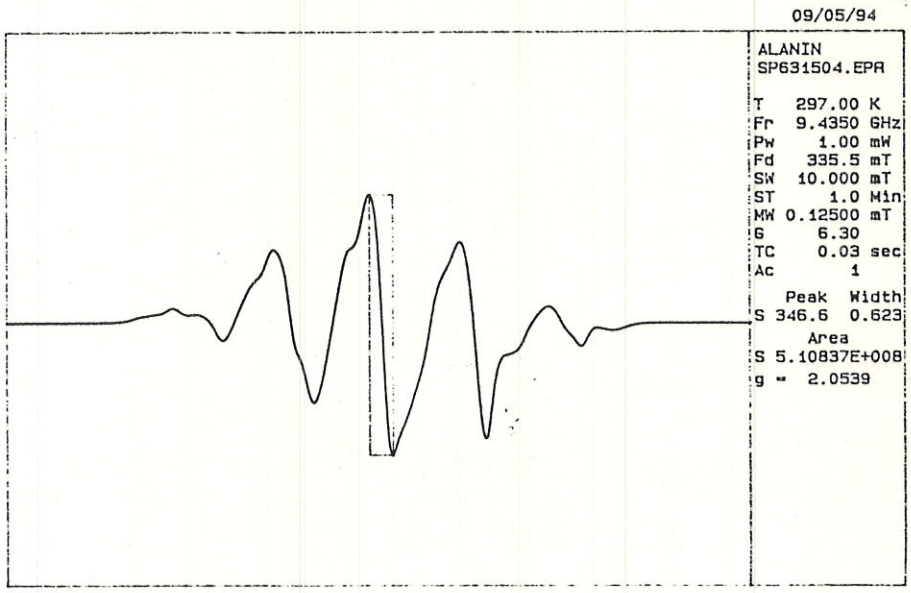

Fig.1. ESR spectrum of Alanine/ESR dosimeter that was prepared by using polymer blend of PS and PE as a binder for alanine powder. The dosimeter was irradiated by gamma rays from Co-60 source at 50 kGy 50 kGy

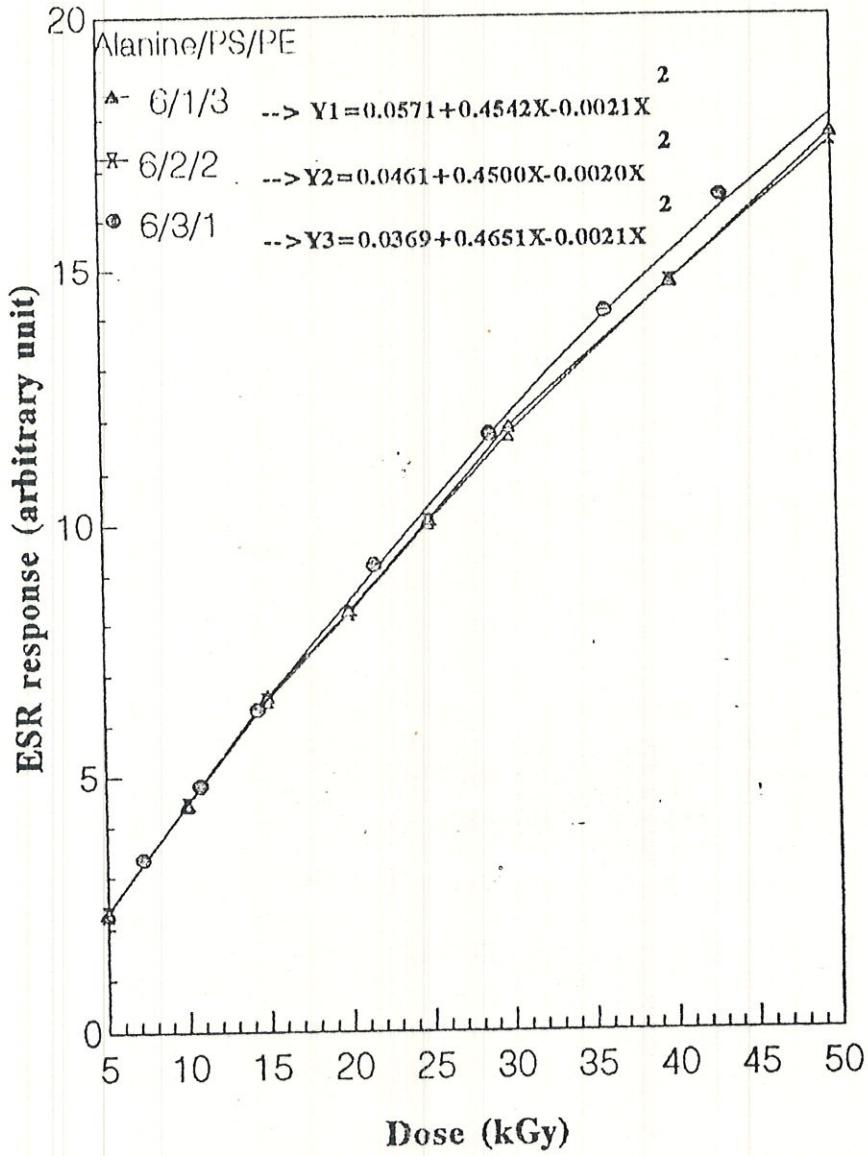

Figure. 2 Calibration curve of Alanine / ESR dosimeter. Polysterene and Polyethylene blend in different composition were used as a binder for the alanine powder to prepare the dosimeter.

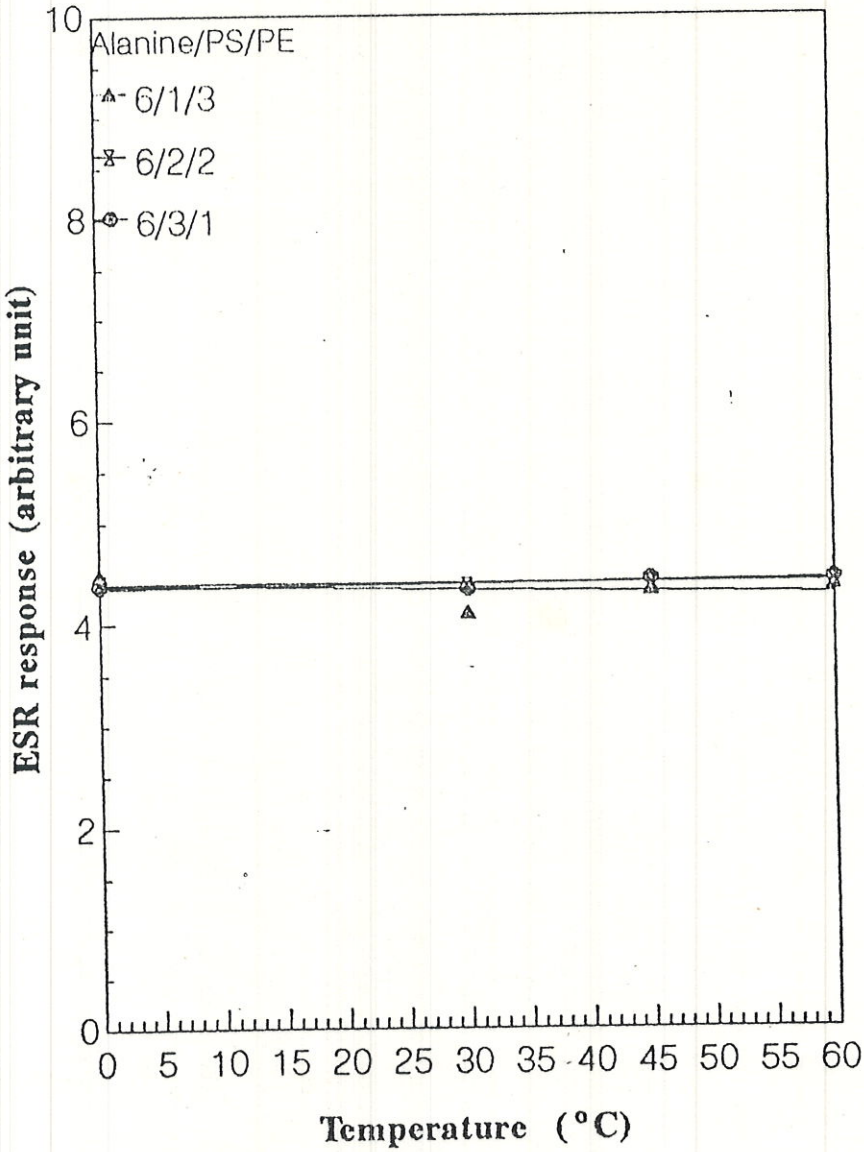

Figure 3. Effect of temperature on Irradiation of Alanine / ESR dosimeter. A blend of polysterene and polyethylene in different composition is used as a binder for alanine powder to prepared the dosimeter.