12.10 A New Leuco Dye Dosifilm PVG

LIU Aiguo, CHEN Wenxiu and JIA Haishun
Department of Chemistry
Beijing Normal University
Beijing, 100875 CHINA

ABSTRACT

A leuco dye film dosimeter for dose measurement on Co-60 gamma radiation processing was developed. The matrix material polyvinyl butyral (PVB) with leuco malachite green (LMG) and additive halogenated compounds (RX) were manufactured as the PVG dosifilm. Its response (ΔA/L vs dose) at 627nm showed a linearity (correlation coefficient r> 0.999) in the dose range from 0.5 to 80 kGy. The calibration coefficient of temperature during irradiation was + 0.053/ ℃. The response increased slightly with the increasing of relative humidities (0-96.4%); and the the calibration coefficient was +0.006/Δr.h(%). From 54.9% to 96.4% the deviation was less than 4%.

The PVG dosifilm was stable before and after irradiation when it was stored in the dark at a given relative humidity. The deviation of response on PVG dosifilm kept in a brown desiccator was less than 4% after 40 days. It was suitable to serve as a routine dosimeter.

KEYWORDS

Polyvinyl butyral; Leuco malachite green; Halogenated organic compounds; Radiochromic film dosimeter; Radiation processing.

INTRODUCTION

Polyvinyl butyl (PVB) has been used as the matrix of dyed plastic film dosimeters(McLaughling et al., 1977; Miller et al., 1981, 1988), which based on one of several dye precursors of similar chemical structure, i.e, three benzene rings and a cyanide group surround a central carbon atom, such as hexa(hydroxyethyl) pararosaniline cyanide (HPR-CN) and pararosaniline cyanide (PR-CN). But these radiochromic dosimeters are sensitive to UV light and must be protected from fluorescent lights and sunlight (McLaughling et al.,1988,

Leuco malachite green (LMG) has been used for dosimetry purpose (Stolz et al., 1965; Dejchet et al., 1972,1973; Wang Yanqiao et al.,1985). LMG is less light sensitive compared with HPR-CN or PR-CN. This paper describes the initial investigations of films composed of PVB, LMG and halogenated organic compounds (RX). The effects of some factors such as temperature and relative humidities (r.h) during irradiation or storage on PVG dosifilm were introduced.

EXPERIMENTALS

Different compositions of LMG, RX and polymer base material have been tested. For the development of commercial routine dosimeters, a PVB film with LMG and RX was chosen. The requests for above materials were the solvents with less toxicity on mankind, PVB with high transparent and flexibility and the good compatibility among them.

Two components of dosimeter for different dose ranges were studied:

Components A (A #):	Components B (B #):
–2.5g of PVB	–2.5g of PVB
–0.0827g of RX	–1.5g of RX
–0.0826g of LMG	–0.0165g of LMG
–mixed solvent	–mixed solvent

Films were cast by pouring the above solutions on glass surfaces and till dry. Then the films were stripped off from the plates and stored in the dark. Finally dry films with thickness 70-100 μm were obtained, from which samples were cut into 1 × 1 cm^2 pieces and put in a brown glass desiccator. These pieces were named as PVG dosifilm.

Absorbance data were measured using HITACHI 200-20 UV spectrophotometer at given wavelengths.The dosifilm thickness was measured using an Elecont micrometer made by Mitutoyo, with a reproducibility of ±0.2 μm. Irradiations were carried out using a 5.55×10^{14} Bq ^{60}Co-γ irradiation facility at Beijing Normal University and the dosifilm was kept in electronic equilibrium during irradiation. Dose was measured by Fricke dosimeter. All the dose values are expressed in terms of dose in water.The absorbed dose rate was 16.2 kGy/h.

After irradiation all the samples were stored in a brown desiccator at room temperature.

RESULTS AND DISCUSSIONS

Absorption Spectrum and Dose Response

Upon irradiation the PVG dosifilm developed into green and showed two absorption maximum at 627 and 425 nm respectively. The absorbance change at 627 nm was more sensitive to dose than that at 425 nm(see Fig. 1). The dosifilm was irradiated within dose range from 0.25 to 90 kGy.

Three parallel samples of PVG dosifilm were irradiated at each given dose and the absorbance values were recorded 24hr after irradiation. The dose response plots were shown in Fig.2, 3.

The linearity of Δ A/L vs dose was in the range from 0.5 to 80 kGy with good reproducibility in same batches.

The dosifilm A # was used in the following tests. Its absorbance was measured at 627 nm. The stability of dosifilm PVG before and after irradiation during storage at various temperatures (T), relative humidities (r.h) and light conditions were listed. The response of dosifilm irradiated at various T and r.h was studied, too.

Stability After Irradiation

The radiation-induced color (absorbance at 627 nm) on dosifilm developed in the first 24 hours after irradiation, as shown in Fig. 4. The color development tendency depended on the total absorbed dose. The color faded slightly after 24 hours of storage. The radiation responses (Δ A/L, mm^{-1}) 42 days after irradiation decreased about 4% compared with that of 1 day after irradiation.

Light Stability During Storage

Exposed to sunlight, the color of unirradiated PVG dosifilm changed into green (absorbance at 627 nm increased) immediately. If it was exposed to ambient light (i.e, in room) for 48 hours, there was no change in color. After 16 days of exposure, the absorbance of PVG dosifilm increased from about 0.1 to 0.2. However the absorbance of dosifilms kept constant during storage in the dark. (Fig. 5)

Temperatures Effect Before Irradiation

All samples were stored in the dark in this experiment. Fig. 6 showed the change of absorbance vs temperatures. The dosifilm showed no change for two months at storage temperatures lower than 35 ℃. There was no change in the dosifilm stored at 40℃ for 5 days. But when the temperature was as high as 60℃, the absorbance increased about 20% after 24 hours of storage.

Relative Humidity Effect Before Irradiation

PVG dosifilm was not sensitive to relative humidity (r.h) before irradiation except for high r.h (>96.4%). (Fig. 7)

The deviation of absorbance of unirradiated dosifilm is less than ±4% stored a month at r.h <75.7%. The absorbance of samples stored at r.h 96.4% increased with time at the first two weeks (Δ A ≈ 0.1).

Temperature Effect During Irradiation

Six sets of dosifilm samples were irradiated by Co-60 γ with dose 16.9 kGy at temperatures (T) of 0, 15, 25, 35, 45 and 50℃, respectively. The relation of Δ A/L vs T was shown in Fig. 8.

The response upon irradiation increased with the increase of irradiation temperature and the approximate calibration coefficient is +0.053/℃ at the temperature range of 0-50 ℃.

Relative Humidity(r.h) Effect During Irradiation

Fig. 9 showed the relation of Δ A/L vs r.h. The response Δ A/L increased slightly with the increase of r.h during irradiation, and an approximate coefficient of +0.006/Δ r.h(%) can be used. All of the samples were irradiated 8.84 kGy.

CONCLUSIONS

A new PVG dosifilm has been developed. Its irradiation response (Δ A/L vs dose) showed a good linearity (correlation coefficient $r>0.999$) within dose range from 0.5 to 80 kGy. PVG dosifilm was low light sensitive and color stable before and after irradiation. The measured doses increased slightly with temperatures and relative humidities during irradiation, the calibration coefficients were introduced. It was suitable to serve as a routine dosifilm for radiation processing dosimetry purpose.

REFERENCES

Dejehet, F. G., F. G. Coget, D. J. Apers and P. C. Carpron. (1972). Radiolytic Oxidation of MG Leuco Base in Acetone solution. *Radiochem. Radioanal. Lett.*, 9(2), 93-103.

Dejehet, F. G., A. G. De Kimpe and D. J. Apers. (1973). Radiation-induced Oxidation of the Malachite Green Leucobase in Acetone Solution in the Presence of Calcium Chloride.*Radiochem. Radioanal. Lett.*, 15(3), 177-86.

McLaughlin, W. L., A. Miller, S. Fidan, K. Pejtersen and W. Batsberg Pedersen. (1977). Radiochromic Plastic Films for Accurate Measurement of Radiation Absorbed Doses and Dose Distributions. *Radiat. Phys. Chem.*, 10, 119-27.

McLaughlin, W. L., J. C. Humphreys, Dene Hocken and W. J. Chappas. (1988). Radiochromic Dosimetry for Validation and Commissioning of Industrial Radiation Processes. *Radiat. Phys. Chem.*, 31, 505-14.

Miller, A. and W. Batsberg Pedersen. (1981). Dose Distribution in Electron Irradiated Plastic Tubing. *Radiat. Phys. Chem.*, 18, 967.

Miller, A., W. Batsberg Pedersen and W. Karman. (1988). A New Radiochromic Thin-film Dosimeter System. *Radiat. Phys. Chem.*, 31(4-6), 491-6.

Stolz, W. and K. Prokert. (1965). Chemishe Dosimetric Ionisieren der Strahlungen mit den Leukoverbindungen eniger Triphenylmethanfarbstoffe in Polystyrol. *Kernenergie*, 8(7), 425-9.

Wang Yanqiao, Zhou Xiaomin, Tang Zangxiong and Zhang Gongming. (1985). CN 85,104,437.

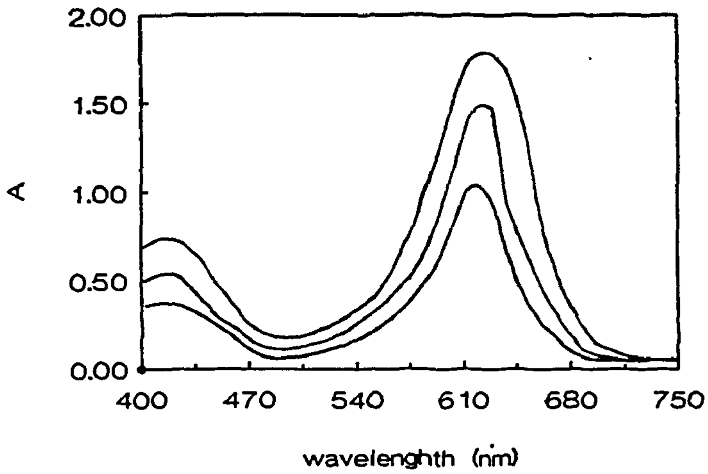

Fig.1 Absorption spectra of the PVG dosifilm, irradiated at a Co-60 source to absorbed doses as indicated.

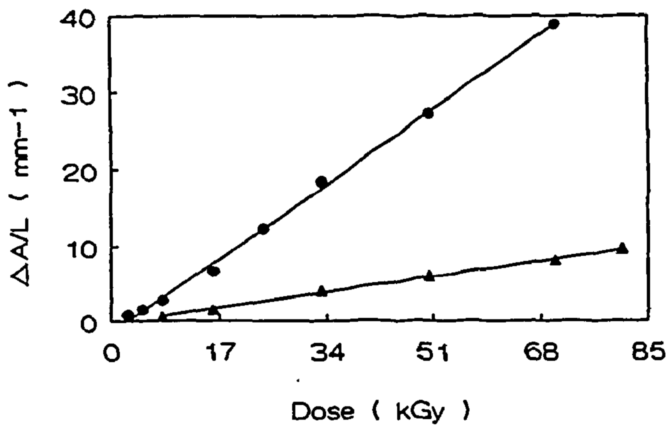

Fig.2 Response functions (ΔA/L, mm^{-1} vs dose, kGy) for A #PVG dosifilm at λ =627 nm (●) and 425 nm (▲).

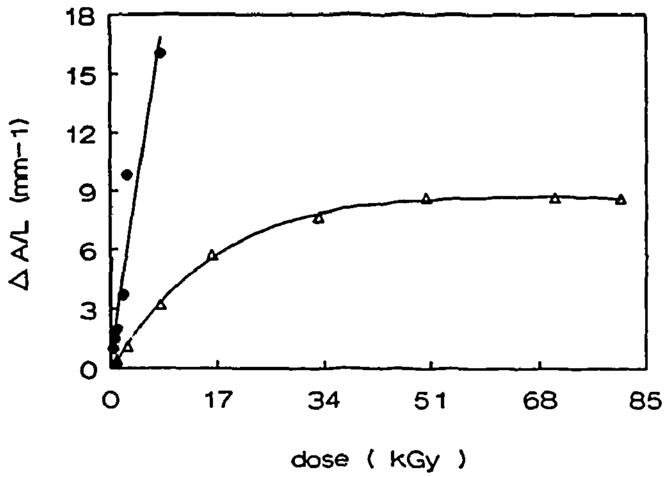

Fig.3 Response functions (ΔA/L, mm^{-1} vs dose, kGy) for B # PVG dosifilm at λ =627nm (●) and 425nm (Δ).

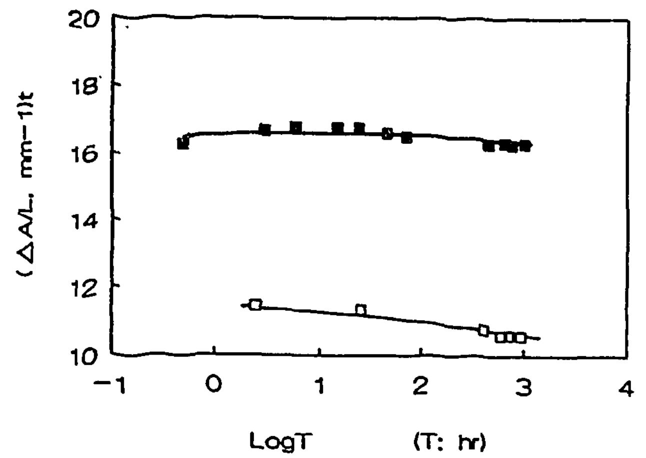

Fig.4 Stability of irradiated A # PVG dosifilm with absorbed dose 21.0 kGy (□) and 31.4 kGy (■).

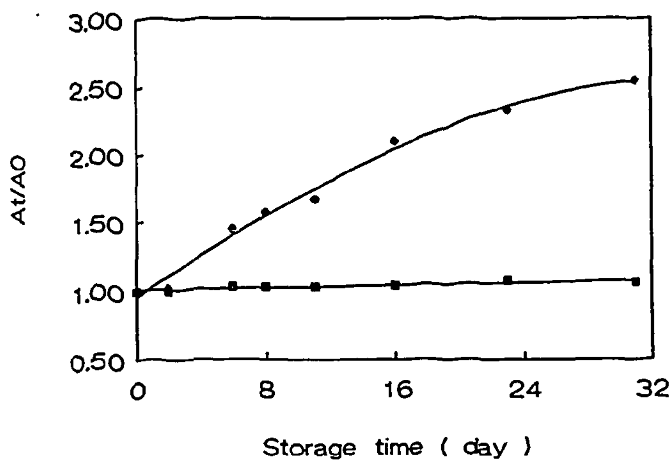

Fig.5 Changes in relative values of absorbance (A_t/A_0, A_t: exposure time t, A_0: exposure time 0) for A # PVG dosifilm exposed to ambient light (●) and stored in darkness (■).

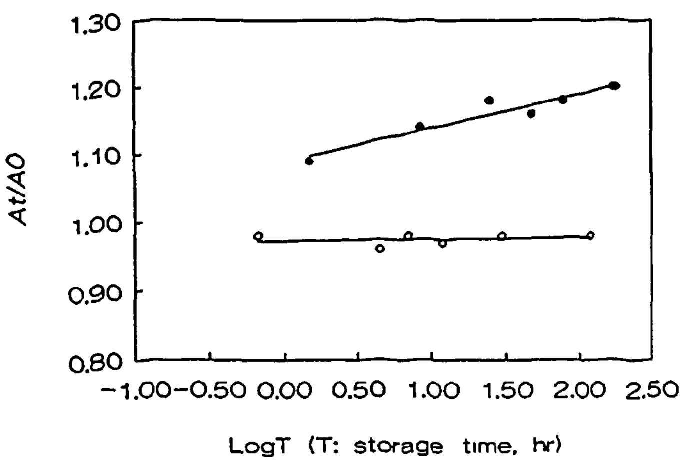

Fig.6 Changes in relative values of absorbance (A_t/A_0) for unirradiated A # PVG dosifilm stored in the dark at 40℃ (○) and 60 ℃ (●).

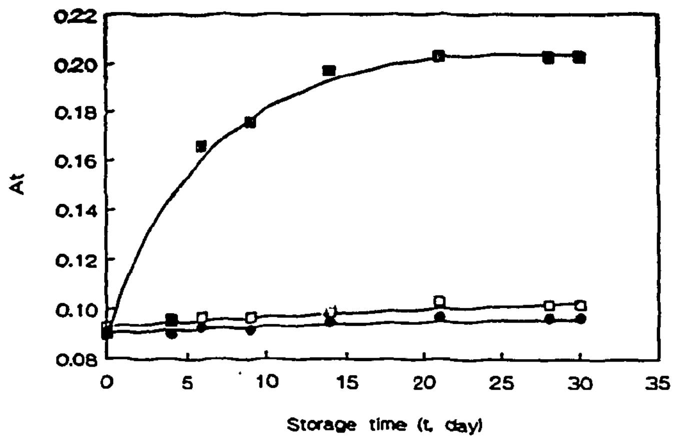

Fig.7 Changes in absorbance (A) for unirradiated A # PVG dosifilm stored in the dark at relative humidity (%) 54.9(●), 75.5 (□) and 96.4 (■).

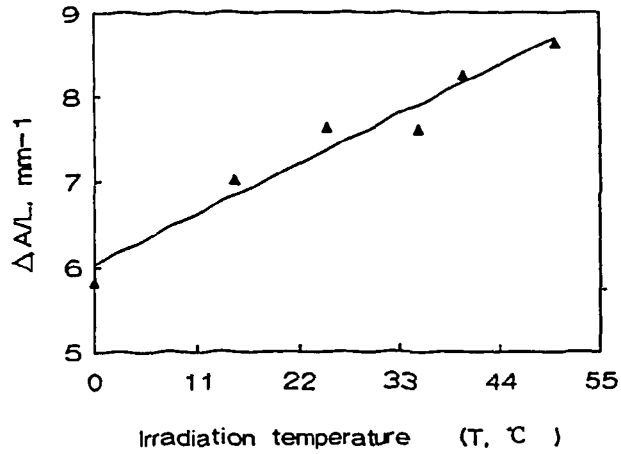

Fig.8 Changes in the response ($\Delta A/L$, mm^{-1}) for A # PVG dosifilm irradiated at different temperatures (T, ℃). (absorbed dose were 16.9 kGy)

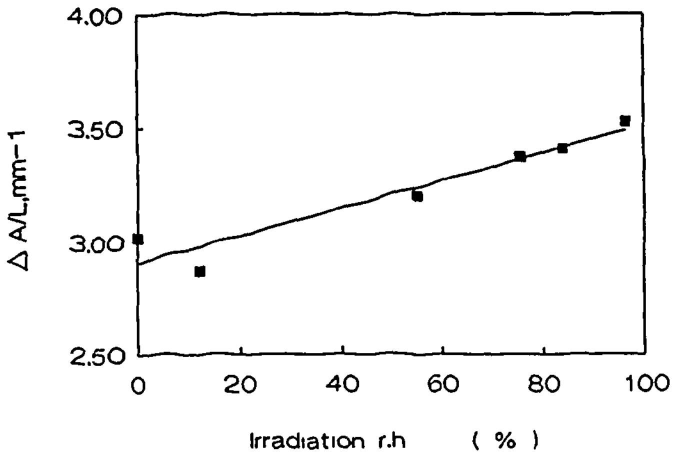

Fig.9 Changes in the response ($\Delta A/L$, mm^{-1}) for A # PVG dosifilm irradiated with 8 .84 kGy at different relative humidites (r.h).