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Colorimetric Characteristics of Glass Slides by Gamma Irradiation as a Dosimeter

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국문요약

산업적으로 이용이 가능한 유리판의 색상변화를 이용하여 감마선 조사의 선량측정에 응용하였다. 유리판을 1 kGy 간격으로 1 에서 15 kGy까지 감마선 조사하였다. 선량에 따른 색상 특성 즉, Hunter's color L, a 및 b값, chroma, hue 등을 조사하고 Peason법을 이용하여 상관계수를 구하였다. 유리판 색상의 변화는 비례적으로 나타났으며($P<0.05$), 특히 Hunter color 값을 3차원적 구조로 관찰한 결과 선량의존성을 나타내었다. 색상특성, 감마선 조사선량 및 저장기간 간에 높은 상관계수($P<0.01$)를 나타내었으며, 본 실험의 결과는 산업적으로 이용하기 용이한 유리판을 이용하여 색 특성만을 가지고 선량측정에 사용될 수 있는 가능성을 제시하였다.

Key words: gamma irradiation, glass, dosimeter, color values

Introduction

Radiation technology use is being increased in many industrial fields. Because of the trends, the dosimetric systems are required to be simple, easier, faster, and cheaper for measurement. There are many dosimetric studies by using glass (Akhavan, Sohrabpour, and Sharifzadeh, 2002; Do˘gn and Tu˘gul, 2001; Elalaily and Mahamed, 2002; Ereytag, 1971; Gripp, Häsing, Büker, and Ammon, 1994; Khan and Ali, 1995; Quezada and Caldas, 1999; Rodrigues and Caldas, 2002; Sławiński and Adawi, 2001; Suszynska and Macalik, 2001; Teixeira and Caldas, 2002). Most of the studies have measured only the optical density after irradiation. Measuring color values could be simpler, easier, and more useful for dosimetry because various and 3-dimentional data can be obtained by one measurement. In this study, the color values such as lightness, redness, yellowness (Hunter's color value), chroma, and hue of irradiated commercially available glass slides were investigated for use as irradiation indicators or dosimeters.

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Materials and Methods

The glass slides (Microscope Slides with ground edges, soda-lime glass, approx. 75 × 25 × 1.04 mm, Paul Marienfeld GmbH & Co. KG, Lauda-Königshofen, Germany) made of SiO_2 (72.8-73.0%), Na_2O (14.6-14.8%), K_2O (0.7-0.8%), CaO (5.8-6.0%), MgO (3.9-4.1%), Al_2O_3 (1.35-1.40%), Fe_2O_3 (0.045-0.047%) were irradiated in a cobalt-60 irradiator (point source, AECL, IR-79, Nordion International Co. Ltd., Ottawa, ON, Canada). The irradiation doses in this study were 1 to 15 kGy by 1 kGy intervals. The control and gamma-irradiated glasses were stored at room temperature for 4 weeks and used for 2 week-term experiments. The color values of the irradiated and non-irradiated glasses were measured by Spectrophotometer (CM-3500d, Minolta

Table 1. Changes in color values (Hunters L, a, b, chroma, hue) of glass slide by gamma irradiation during storage

Color values[1]	Storage (week)	Irradiation dose (kGy)															SEM[3]
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
L	0	98.86ax[2]	94.61by	92.76cz	91.38dz	89.60ez	88.16fz	86.91gz	86.04hz	84.94iz	83.98jz	83.36kz	83.24kz	82.35lz	81.60mz	81.29nz	80.94oz	0.047
	2	95.89az	94.30bz	93.10cy	92.16dy	90.99ey	90.07fy	89.27gy	88.72hy	88.02iy	87.37jy	86.99ky	86.92ky	86.31ly	85.90my	85.70ny	85.46oy	0.029
	4	96.85ay	95.43bx	94.29cx	93.44dx	92.38ex	91.54fx	90.81gx	90.31hx	89.69ix	89.09jx	88.76kx	88.68lx	88.16mx	87.77nx	87.59ox	87.37px	0.027
	SEM[4]	0.003	0.015	0.024	0.025	0.038	0.015	0.012	0.038	0.029	0.057	0.048	0.065	0.037	0.011	0.049	0.024	
A	0	-0.20oy	-0.15nx	-0.10mx	-0.03lx	0.06kx	0.16jx	0.24ix	0.30hx	0.40gx	0.50fx	0.56ex	0.57ex	0.65dx	0.71cx	0.75bx	0.79ax	0.007
	2	-0.35oz	-0.33ny	-0.31mz	-0.29lz	-0.25kz	-0.22jz	-0.18iz	-0.15hz	-0.11gz	-0.06fz	-0.05ez	-0.05ez	-0.02dz	0.00cz	0.02bz	0.04az	0.004
	4	-0.19ox	-0.16nx	-0.13my	-0.12ly	-0.08ky	-0.05jy	-0.02iy	0.01hy	0.03gy	0.06fy	0.08ey	0.08ey	0.12dy	0.14cy	0.15by	0.16ay	0.003
	SEM	0.002	0.003	0.005	0.004	0.004	0.005	0.003	0.003	0.005	0.004	0.008	0.008	0.004	0.008	0.005	0.004	
B	0	0.07ox	2.41nx	4.30mx	5.67lx	7.41kx	8.79jx	9.98ix	10.78hx	11.81gx	12.61fx	13.16ex	13.26ex	14.03dx	14.73cx	14.95bx	15.25ax	0.046
	2	-0.22oz	1.41nz	2.67my	3.61ly	4.77ky	5.67jy	6.45iy	6.99hy	7.65gy	8.23fy	8.61ey	8.68ey	9.24dy	9.67cy	9.85by	10.04ay	0.030
	4	0.06py	1.53oy	2.69ny	3.52my	4.59lz	5.39kz	6.12jz	6.60iz	7.20hz	7.76gz	8.06fz	8.15ez	8.62dz	9.01cz	9.18bz	9.36az	0.025
	SEM	0.002	0.008	0.034	0.031	0.048	0.021	0.022	0.038	0.028	0.042	0.043	0.064	0.027	0.014	0.054	0.020	
C	0	0.21oy[2]	2.42nx	4.31mx	5.67lx	7.41kx	8.79jx	9.98ix	10.78hx	11.82gx	12.62fx	13.17ex	13.28ex	14.04dx	14.75cx	14.97bx	15.26ax	0.046
	2	0.41ox	1.45nz	2.69my	3.62ly	4.77ky	5.67jy	6.46iy	6.99hy	7.66gy	8.23fy	8.61ey	8.68ey	9.24dy	9.67cy	9.85by	10.04ay	0.030
	4	0.20pz	1.54oy	2.69ny	3.52my	4.59lz	5.40kz	6.12jz	6.60iz	7.20hz	7.76gz	8.06fz	8.16ez	8.62dz	9.01cz	9.18bz	9.36az	0.025
	SEM[4]	0.002	0.009	0.033	0.031	0.048	0.021	0.021	0.039	0.027	0.042	0.043	0.063	0.027	0.013	0.054	0.019	
H	0	160.80az	93.52bz	91.28cz	90.37dz	89.57ez	88.98fz	88.62gz	88.39hz	88.05iz	87.73jz	87.55jkz	87.56jkz	87.34klz	87.24lmz	87.12lmz	87.02mz	0.079
	2	210.98ax	103.14bx	96.70cx	94.54dx	93.01ex	92.16fx	91.59gx	91.24hx	90.84ix	90.46jx	90.32jkx	90.32jkx	90.08klx	89.89lmx	89.89lmx	89.78mx	0.094
	4	162.15ay	96.04by	92.88cy	91.95dy	91.04ey	90.50fy	90.16gy	89.94ghy	89.73hiy	89.54iy	89.44ijy	89.45ijy	89.20jky	89.14ky	89.07ky	89.03ky	0.096
	SEM	0.313	0.140	0.048	0.040	0.028	0.039	0.014	0.020	0.028	0.026	0.029	0.027	0.023	0.041	0.017	0.016	

[1] Color values : L; lightness, a; redness, b; yellowness, C; chroma and H; hue.
[2] Different letters with same row (a-p) and column (x-z) mean significantly different ($p<0.05$).
[3] Standard error of the means (n=480).
[4] SEM: Standard error of the means (n=90).

Co. Ltd., Osaka, Japan). The measured color is represented by the Hunter's color value, L (lightness), a (redness), b (yellowness) values, and the chroma (C) and hue (H) values. All the measurements were done 10 times and replicated 3 times. The data was analyzed by ANOVA using SAS (Release 8.2, SAS Institute Inc., Cary, NC, USA) and differences among the mean values were processed by the Student-Newman-Keuls' multiple range tests. Mean values and the standard error of the means are reported and the significance was defined at $P<0.05$. Pearson's correlation coefficients among the experimental results for irradiation and storage were analyzed, and the significance was defined at $P<0.05$ and 0.01 levels, respectively.

Results and Discussion

Hunter's color (L, a, and b), chroma (C), and hue (H) values of gamma irradiated glass slides during defined storage periods are shown in Table 1. The Hunter's L (lightness) value was significantly decreased by irradiation. The L values at 10 and 11 kGy were not significantly different until 2 weeks. The value was gradually decreased in the control and increased in the gamma-irradiated samples during the storage periods, significantly. The Hunter's a and b values were significantly increased by irradiation. The coordinates from the Hunter's color values (L, a, and b) by gamma irradiation dose are shown in Fig. 1. The L, a, and b values represent a color coordinate three-dimensionally. Different coordinates were obtained with a irradiation dose dependant manner. Therefore, measuring color values of gamma irradiated commercial glass slides can be an easier, simpler, and more useful method for a dosimetric system.

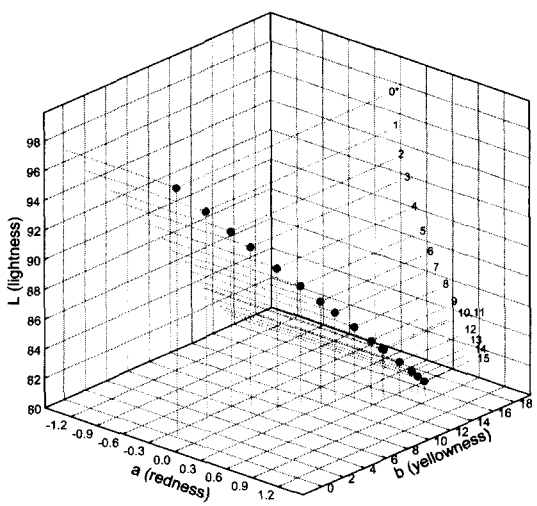

Fig. 1. Three-dimensional coordinates of Hunters color values (L, a, and b) by gamma irradiation (*: Gamma Irradiation dose; kGy).

Table 2. Pearsons correlation coefficients among irradiation, storage and color values of irradiated glass

Color Values[1)]	Irradiation	Storage
L	-0.86**	0.40**
a	0.65**	-0.45**
b	0.85**	-0.39**
C	0.85**	-0.39**
H	-0.48**	0.03

[1)]Color values : L (lightness), a (redness), b (yellowness), C (chroma), and H (hue).
**P<0.05

Conclusion

Colorimetric characteristics of commercially available micro glass slides were analyzed for use a dosimetry for gamma irradiation. The glass slides were irradiated at 1 to 15 kGy by 1 kGy intervals. The characteristics of color responses, Hunter's color values (L, a, and b), chroma, and hue, were obtained and the correlation coefficients were calculated by the Pearsons method. The color values showed linear changes ($P<0.05$). Especially, the Hunters color values could be plotted 3-dimensionally and the coordinates showed a linear feature in a dose dependent manner. High correlation coefficients ($P<0.01$) among the color values, irradiation doses, and storage periods were obtained. All the results indicate that the color values of the irradiated glass slides can be used as dosimetry parameters or indicators.

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