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Time-Resolved Luminescence Spectra of Dosimeter Glasses

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Time-resolved luminescence spectra were measured at 300 K in dosimeter glasses under N_2 laser excitation. Two emission bands were observed at 430 nm and 600 nm. The 430 nm band is due to the predose and decays rapidly. The 600 nm band is induced with gamma-ray irradiation and decays gradually. The decay time of the 600 nm band becomes longer with increase in the delay time.

KEYWORDS: dosimeter, radiophotoluminescence, time-resolved spectrum, decay time

When Ag-activated metaphosphate glass is irradiated by ionizing radiation, a dose-dependent radiophotoluminescence (RPL) is induced. The RPL is superimposed by parasitic luminescence not induced by ionizing radiation, which is called predose fluorescence. It has been reported that luminescence from dosimeter glass decays at least three different time constants: 1) short-term component of predose (delay time $t_d \leq$ 2 μs), 2) radiation-induced component (2 μs < $t_d \leq$ 20 μs) and 3) long-term component of predose (t_d > 20 μs).[1-4] The difference in decay times is used to separate the components of predose. The commercially available reader using a pulsed UV laser (N_2 laser) indicates a readout which is proportional to the radiation-induced dose and is practically independent of the short-term and long-term components of the predose.[5]

The decay times of luminescence described above have been measured at a fixed wavelength region centered at 600 nm. Wavelength dependence of the decay time has not been reported. In this paper, we report on the time-resolved luminescence spectra of dosimeter glasses and investigate the decay times at various wavelengths.

Li-Al-Ag-metaphosphate glass was used. Samples have a rectangular parallelepiped shape having dimensions of 8 x 8 x 4.7 mm^3 (Toshiba Glass FD-P8-3). Glasses were irradiated at 300 K by ^{60}Co gamma-rays.

Luminescence spectra of glasses were measured with the following apparatus at 300 K. The excitation source was a pulsed N_2 laser (NDC JS-1000L; λ = 337.1nm, pulse duration = 5ns, repetition rate = 4Hz). The laser beam was set at an angle of about 40^o off the normal incidence to the surface of a sample and was focused on a spot about 1 mm^2 in area by a quartz lens (focal length f = 150 mm). The peak intensity of the laser light on the sample was about 50kW/cm^2. Luminescence was observed at normal incidence in the backward direction and was focused on the entrance of optical fiber by a glass lens (f = 70mm). Luminescence was led to the entrance slit of a 27 cm monochromator (Jarrell-Ash Monospec 27). Luminescence spectra were measured with an optical multichannel analyzer (Princeton Instruments D/SIDA-700).

Figure 1 shows time-resolved luminescence spectra of the irradiated glass with a gamma dose of 1.8Gy and gate time t_g = 1 μs. Two emission bands were observed with peaks at about 430 nm and 600 nm. The 430 nm band decreases with increase in the delay time and disappears for $t_d \geqq$ 20ns. This result indicates that the decay time of the 430 nm band is very short. In order to estimate the decay time, time-resolved spectra were measured with t_g = 5 ns, which is the shortest gate time of the apparatus used in this experiment. Figure 2 shows the spectra with t_g = 5ns, t_d = 0, 5, 10, 15 and 20 ns. Decay time is estimated to be shorter than 3 ns.

Luminescence spectra of nonirradiated glass were also measured. The 430 nm band was observed, so that this band is due to predose. The luminescence intensity is about 1/2 of that for the irradiated glass with gamma dose of 1.8Gy. Time-resolved luminescence shows similar behavior to that for the irradiated glass shown in Fig. 2.

The 600 nm band decays gradually with increase in the delay time. Figure 3 (a) shows luminescence intensity at 600 nm as a function of the delay time with t_g = 1 μs. The decay time of the 600 nm band is 3 μs for t_d > 2.5 μs. This value is almost the same as the reported value.[1-4] Decay time for $t_d \leq$ 2.5 μs is shorter than 3 μs. We measured time-resolved luminescence spectra for $t_d \leqq$ 2.5 μs with shorter gate time. Figure 3(b) shows luminescence intensity at 600 nm as a function of the delay time with t_g = 50 ns. The luminescence decay time varies with the delay time. The decay time becomes longer with increase in the delay time: decay times are about 0.05 μs for t_d < 0.05 μs, 0.3 μs for 0.05 μs < $t_d \leq$ 0.3μs, 1.7 μs for 0.3 μs < $t_d \leq$ 2.5 μs and 3 μs for t_d > 2.5 μs.

The short-term component has been reported to be due to predose. In order to examine the origin of this component, transient characteristics of the 600 nm band were examined in glass with a gamma dose of 123 Gy, in which predose fluorescence may be negligible. The result is shown in Fig. 3(b). The short-term component is observed in the high-dose glass. This result indicates that the short-term component is not the component of predose but is a radiation-induced component. This is in disagreement with the reported results.[1-4] The disagreement is considered to be due to the difference in dose. In the low-dose sample, the 600 nm band is very weak, so that the tail of the 430 nm band may be observed at 600 nm. Thus, the short-term component is that of predose. In the high-dose sample, the tail of the 430 nm band may be weaker than the 600 nm band, so that the short-term component is the radiation-induced component.

The time constant of the rapid initial decay is shorter than the reported values: about 0.05 μs in the present experiment and about 0.3-0.7 μs in refs. 1-3. This discrepancy is probably due to the difference in the time resolution of the experimental apparatus.

In summary, time-resolved luminescence spectra were measured in Li-Al-Ag-metaphosphate glasses irradiated by ^{60}Co gamma-rays. The 430 nm band and the 600 nm band were observed. The 430 nm band is due to predose and the 600 nm band is induced with radiation. The decay time of the 430 nm band is shorter than 3 ns. The decay time of the 600 nm band depends on the delay time.

References

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Figure captions

Fig. 1. Time-resolved luminescence spectra of irradiated glass with a gamma dose of 1.8 Gy and gate time $t_g = 1\ \mu s$.

Fig. 2. Same as Fig. 1, with gate time $t_g = 5ns$.

Fig. 3. Luminescence intensity at 600 nm as a function of the delay time. (a) gate time $t_g = 1\ \mu s$, (b) $t_g = 50ns$. Intensities at $t_d = 0\ \mu s$ are normalized.

Fig. 1

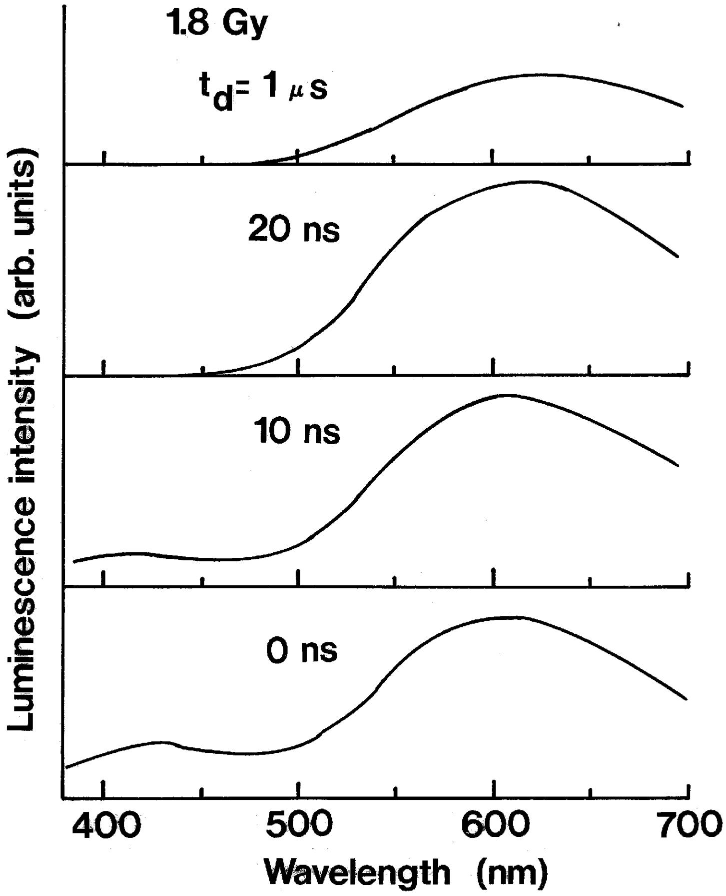

1.8 Gy
t_d= 1 μs
20 ns
10 ns
0 ns
Luminescence intensity (arb. units)
400
500
600
700
Wavelength (nm)

Fig. 2

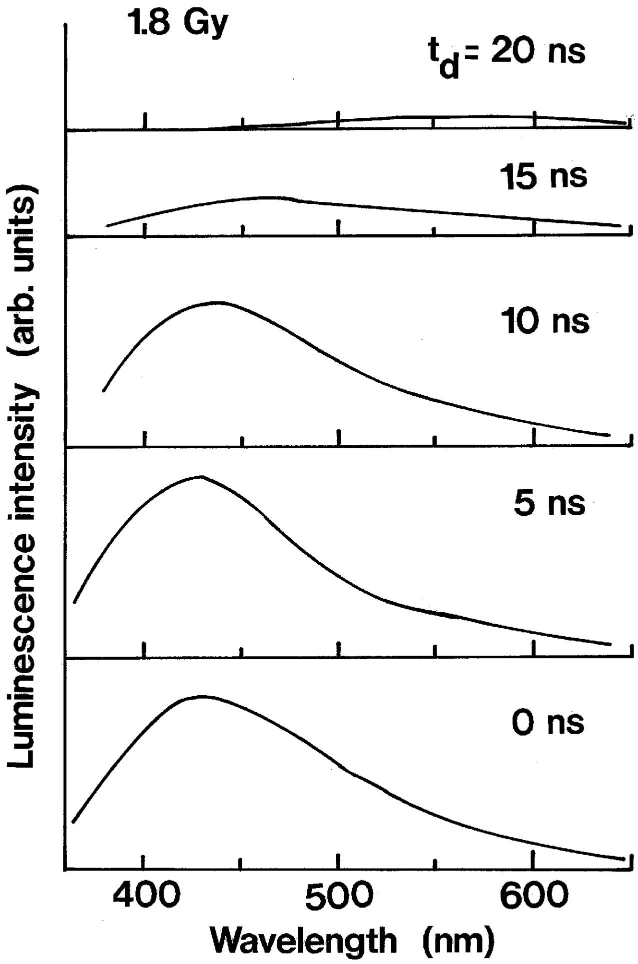
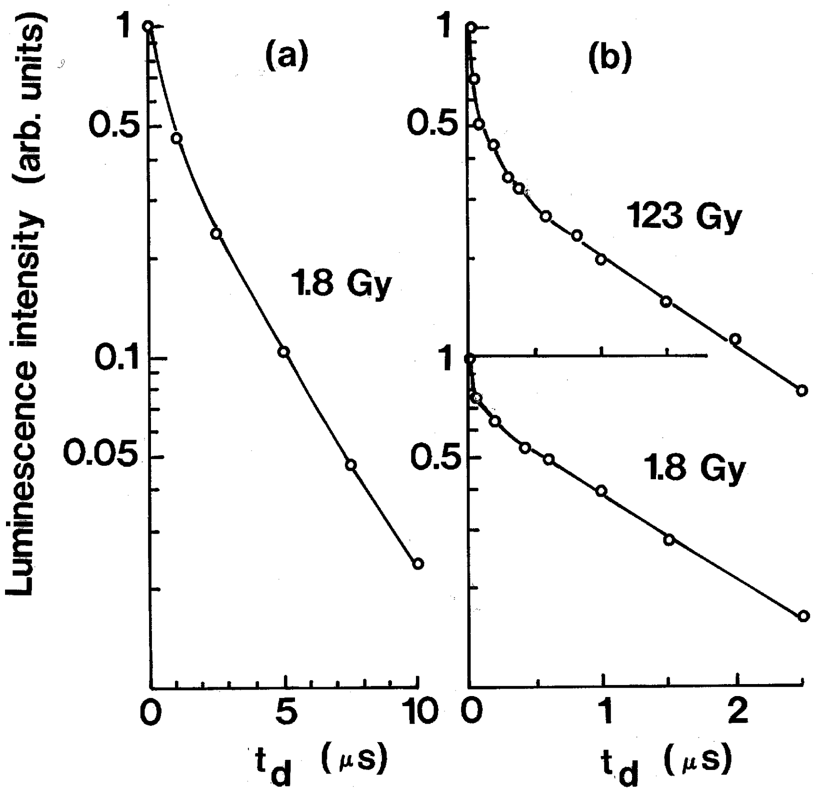

1.8 Gy
t_d= 20 ns
15 ns
10 ns
5 ns
0 ns
Luminescence intensity (arb. units)
400
500
600
Wavelength (nm)

Fig. 3



Luminescence intensity (arb. units)
1
0.5
0.1
0.05
(a)
1.8 Gy
0
5
10
t d (μs)
1
0.5
1
0.5
(b)
123 Gy
1.8 Gy
0
1
2
t d (μs)