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# The Absorption and Luminescence of Glasses During Electron Irradiation*

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## ABSTRACT

Absorption spectrum, growth and decay curves, and luminescence emission measurements have been made on NBS 710 and 711, and AO-"C" glass during and after 1.5 MeV electron irradiation.



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As an initial step in a program to investigate radiation effects in materials for fiber optic, CTR and laser fusion applications, the optical absorption and luminescence spectra of several glasses have been measured during continuous electron bombardment. The measurements were made with a recently completed computer controlled double beam recording digital spectrometer. A sequential chopping arrangement provides simultaneous measurement of absorption and luminescence spectra; separate 256 point spectra are recorded once every 40 seconds in either the 200-400 nm or 400-800 nm range. The absorption spectra are fully corrected for sample and window emission, airglow, etc.

The glasses studied are representative of three general types: soda-lime-silica (NBS710), lead-silica (NBS711) and high-index lanthanide (American Optical C). Qualitatively similar results are obtained for each material. As shown in Fig. 1, for NBS710 glass, the irradiation induced absorption typically covers the region from the ultraviolet "edge" to the spectrophotometer limit at 800 nm. The figure indicates that at least two absorption bands are present, and possibly an "edge" shift toward lower energy. Similar results were obtained with NBS711 and American Optical C glasses, although the band energies differ.

Plots of the absorption coefficient ($\alpha$) vs. time (t) at photon energies near the band maxima, show that the coloring curves are accurately represented by an expression of the form:

$$\alpha(t) = \alpha_L(t) + \sum_{i=1}^{n} A_i[1-\exp(-a_i t)] \qquad (1)$$

where $\alpha(t)$ is evaluated at a particular photon energy and $\alpha_L$, $A_i$ and $a_i$ are constants. The applicability of (1) is demonstrated in Fig. 2, showing the fit to the data points for NBS710 glass at 4 eV.

In all glasses studied the absorption begins to decrease immediately when the irradiation is terminated. The decreasing absorption is accurately described by the relation:

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$$\alpha(t) = \sum_{i=1}^{n} \alpha_i \exp[-d_i(t-t')] \quad t>t' \qquad (2)$$

i.e. a sum of decaying exponentials with amplitude $\alpha_i$ and decay constant $d_i$, the irradiation being terminated at time t'. Fig. 3 demonstrates that this equation describes accurately the measured decay at 4 eV in NBS710 glass.

In contrast to our experience with alkali halides, pronounced radioluminescence was not observed from the glass samples during electron bombardment. At best, only marginal luminescence was detected. The strong radiation induced absorption produced at all wavelengths will markedly attenuate, by self-absorption, any luminescence emitted within the sample.

Several conclusions are indicated by the results obtained to date: First, the definite similarities in the absorption spectra and coloring and decay curves for the three different glasses suggest that the coloring characteristics may be largely controlled by a common constituent. Second, the coloring and decay are describable by equations (1) and (2), which have been found to apply, with one exception, to all materials studied previously during irradiation in this laboratory. Third, the pronounced decay of the absorption following irradiation indicates that the most meaningful radiation damage information is obtained only if measurements are made during irradiation. Fourth, the decay occurring after irradiation provides strong evidence that centers are both created and destroyed during irradiation. Lastly, although only a few glasses have been examined, these results indicate that equipment for measuring absorption and luminescence during irradiation can provide a large fraction of the information required to determine operating characteristics of optical materials which must function both during and after exposure to radiation.

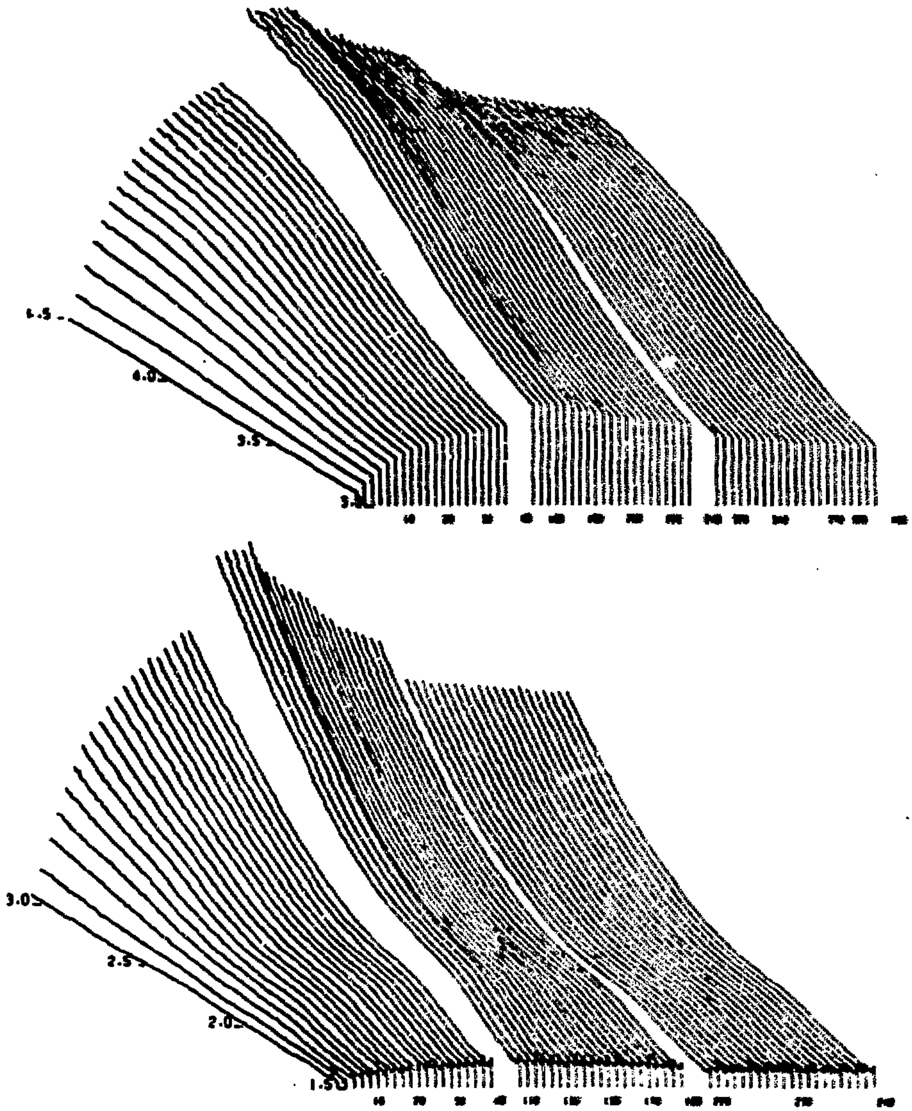


**Fig. 1** Radiation induced absorption spectra of NBS710 glass in the ultraviolet (upper plot) and visible (lower plot) ranges. The measurements were made both during and after 1.5 MeV electron irradiation at room temperature. The absorption (vertical) scale units for the upper plot are four times those for the lower plot. The horizontal scales are photon energy and "scan number"; time between scans is 40 sec. or longer. A large number of scans have been omitted. This data is subsequently used to construct absorption spectra, growth curves at specific photon energies and other analysis "aids".

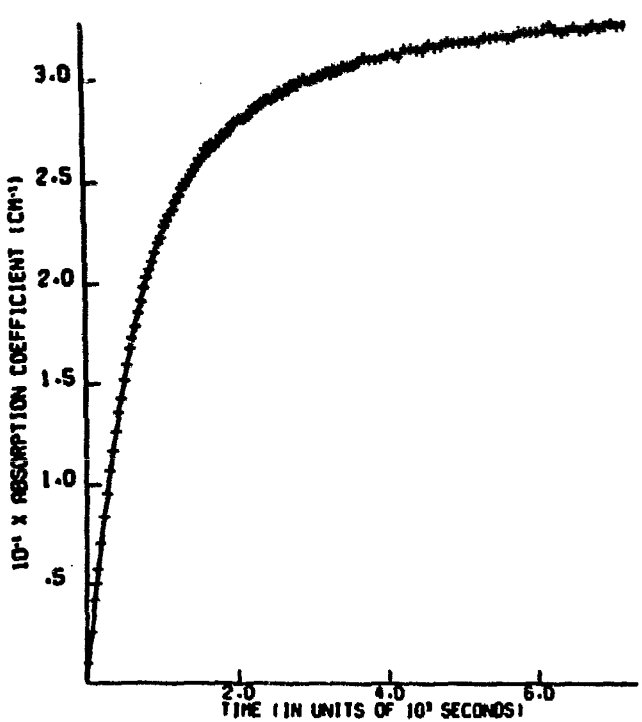


Fig. 2 The absorption of NBS710 glass at 3.99 eV, recorded during irradiation, at room temperature, with 1.5 MeV electrons. The beam current is approx. 50 na/cm$^2$ (5 x 10$^3$rad/sec). The solid line through the data was computed from Eq.(1) in the text, using one linear and two exponential components and constants determined by a computerized least squares procedure.

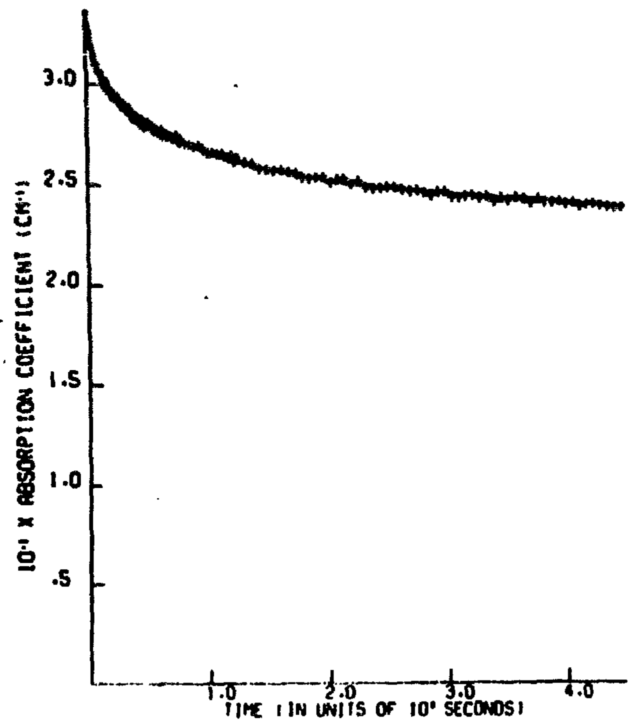


Fig. 3 The decay of the radiation induced absorption at 3.99 eV in NBS710 glass recorded, without interrupting the measurements, after the electron bombardment was terminated. The solid line through the data was computed from Eq.(2) in the text, using three decay components and constants determined with a computerized least squares procedure.