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The potentiality of sunlight observed in CsI(Tl) crystal

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Abstract

The effect of sunlight on Φ 2.54 × 2.54 cm^2 CsI(Tl) crystal of Tl concentration 500 ppm has been studied. Long period of sunlight exposure can induce new defects and reduce the transparency of the crystal. The optical absorption spectra in the infrared region are mostly affected rather than in the visible region. After the exposure of sunlight the rate of optical bleaching and optical darkening effect on CsI(Tl) crystal is almost same.

Introduction

Radiation hardness studies of Caesium Iodide has generally focused on Thallium doped CsI crystals due to their widespread use in particle detectors[1-5]. Radiation hardness of CsI crystals leads to high quality detectors designed for high energy and nuclear physics experiments. All crystal scintillators are affected by radiation when exposed to over prolonged periods to high fluxes of radiation. The damage effects are often observed to be dose rate dependent and will vary greatly with the type of radiation involved in the exposure. The radiation induced absorption bands caused by colour centre formation is the common phenomenon. Absorption bands appear at visible and infrared wavelengths when CsI(Tl) crystals are irradiated, and those in the scintillation wavelength region reduces the scintillation light output[6-10]. These absorption bands are generally due to energy levels in the band gap of the crystal, arising from irregularities in the lattice, caused either by chemical impurities or structural defects[11]. The absorption bands reduce crystal light's attenuation length (LAL), and hence the light output. The radiation also causes phosphorescence (after glow), which leads to an increase of readout noise. Additional effect may include a reduced intrinsic scintillation light yield (damage of scintillation mechanism), which would lead to a reduced light output and a deformation of the light response uniformity[12]. The damage may recover under room temperature, which leads to the dose rate dependence[13].

Experimental Procedure :

A cylindrical CsI(Tl) crystal of diameter 2.54 cm , length 2.54 cm grown by Hilger analytical, Kent, England using the Kyropoulos technique[H14] was used to study the effect of sunlight on it.

The Tl concentration of the sample was measured using atomic absorption spectroscopy and found to be 500 ppm. The crystal was irradiated by sunlight for cumulative period of time and at each and every step of time the absorption spectra was observed with the help of UV-1650 PC spectrophotometer. The measurements were repeated after cumulative exposure to sunlight.

Optical absorption measurement :

The crystal was washed by distilled water and wiped out with tissue paper to make it suitable for optical transmission measurement. Optical absorption spectra of the crystal were measured with spectrophotometer for different sunlight doses. For the measurement of absorption spectra the wavelength range was chosen to be 300 nm-1000 nm. Fig. 1 shows the absorption spectra of CsI(Tl) crystal before exposure of sunlight. we see that at wavelength 440 nm there is a small change in absorbance. This shows presence of small defect centre in the sample during growth time. Fig. 2 illustrates the absorbance spectra of the test sample of CsI(Tl) crystal for cumulative doses of (a) 0 hr (b) 2 hr (c) 5 hr (d) 10 hr (e) 20 hr (f) 50 hr (g) 100 hr sunlight. All the results are normalized to the value of sunlight exposures. At the first two stages of exposure i.e. after 2 hr and after 3 hr (cumulative 5 hr) the absorption coefficient of the sample has decreased very rapidly. For 2 hr exposure the decreasing rate is 47.4% and for 5 hr exposure the decreasing rate is 69.3% from the value before the exposure of sunlight. At these two cases optical bleaching has occurred. The transparency of the crystal has increased by a greater amount. At the 4th step of sunlight exposure for 5 hr (cumulative time 10 hr) the transparency of the crystal again decreases. The total absorption coefficient decreases by only 1.75% from the value before sunlight exposure. The defect that was created during growth time is now totally abolished. The observed graph is now smooth and steady. This is due to the fact that long time exposure of sunlight reduces the growth defect but there is decrease in transparency. The heat absorbed in the crystal help to rearrange the defects of the crystal structure. At the 5th step of sunlight exposure *i.e.* 10 hr (cumulative time 20 hr) the transparency of the crystal has increased by a great amount. The total decrease of absorption coefficient is 71.05% from that without sunlight but the defect that was created at the growth time reappears. At the 6th step of sunlight exposure of 30 hr (cumulative time 50 hr) the absorbance increased a very little and new defects at wavelength 633 nm along with growth time defect also appear. At the final dose of sunlight radiation for 50 hr (cumulative time 100 hr) the total absorption coefficient has increased a greater amount though it did not reach the value before sunlight exposure. Excess of heating makes the crystal less transparent and induce new defects. This is due to the optical darkening effect.

Fig. 3 shows dose or time vs. absorbance graph for different wavelengths. In the short wavelength region *i.e.* between 400 nm – 700 nm the rate of change of absorbance is small but at longer wavelength region 800 nm -1000 nm the change of optical absorption coefficient is large. This is true only for small doses *i.e.* small period for sunlight exposure. But for long period of exposure the behaviour is same for all range of wavelengths. The rate of change of optical absorption coefficient is small over the wavelength. This means for higher dose of sunlight exposure optical darkening process in the crystal occur very slowly in the visible and infrared region.

After 100 hr absorbance the sample was removed from outside and kept in a desiccator. Then again absorbance spectra of the test sample were observed for the following stages: (1) after 1 day (2) after 2 days (3) after 5 days and (4) after 10 days.

At the first two steps after 100 hr sunlight exposure *i.e.* after 1 day and then 2 days there is almost no change in absorption spectra but a little increase in transparency in the crystal. But after 3 days (cumulative time 5 days) the transparency of the crystal has increased 7.5% from the absorbance value of 100 hr exposure of sunlight. During this period of time optical bleaching has occurred in the crystal. Next 5 days (cumulative time 10 days) transparency of the crystal has decreased a large amount. The absorbance value increased by 14.5% in 5 days and 5.8% from the absorbance value of 100 hr sunlight exposure but could not reach the value of absorbance before sunlight (fig. 5). At this step optical darkening of the crystal has occurred.

After the sunlight irradiation over 10 days the first half of time was spent for bleaching the crystal and next half of time was for optical darkening i.e. rate of optical bleaching and optical darkening is almost same.

Fig. 6 shows time vs. absorbance graph after 100 hr irradiation with sunlight at different wavelength. Graph shows variation of absorbance with time for different wavelength. At higher wavelength region (800 nm – 1000 nm) the values of absorbance is closer than in

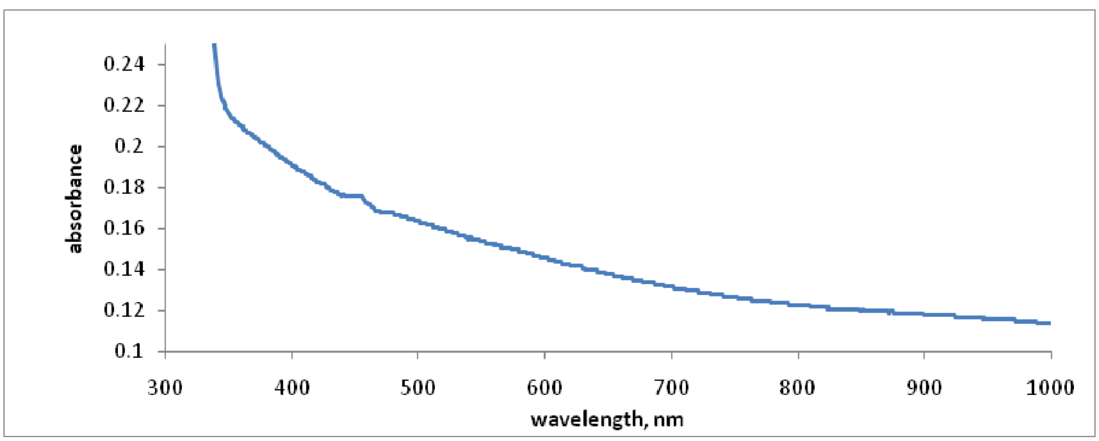

Fig. 1. Absorbance vs. wavelength for the CsI(Tl) crystal before sunlight exposure

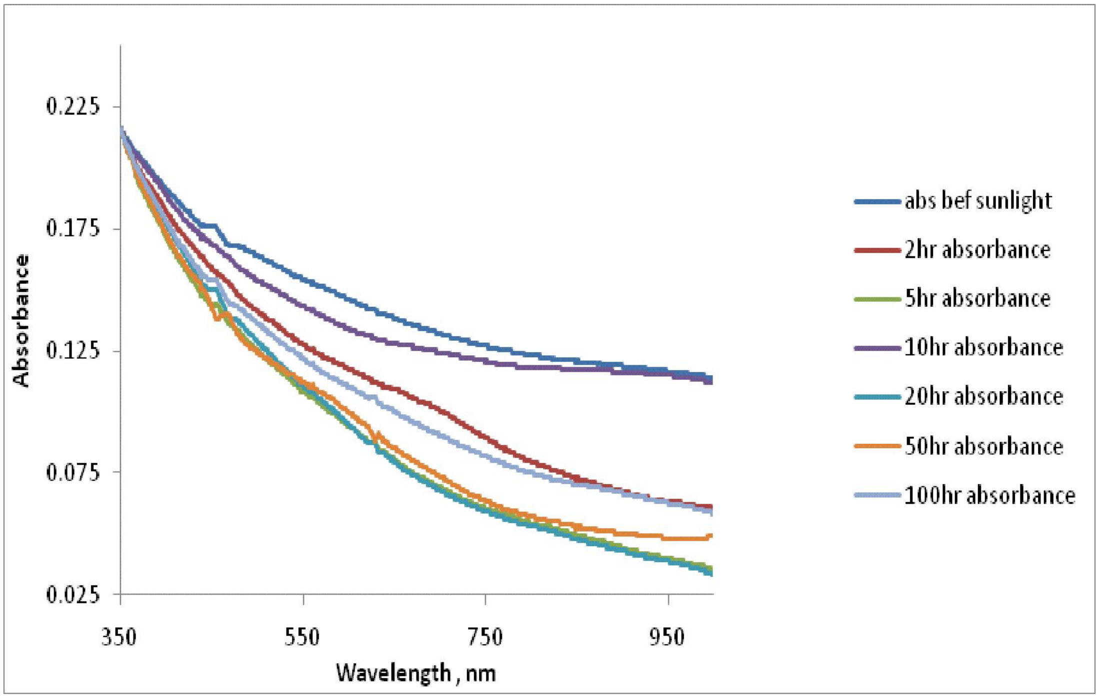

Fig. 2. The optical absorption spectra for the following integrated sunlight doses: (1) 0 hr (2) 2 hr (3) 5 hr (4) 10 hr (5) 20 hr (6) 50 hr (7) 100 hr.

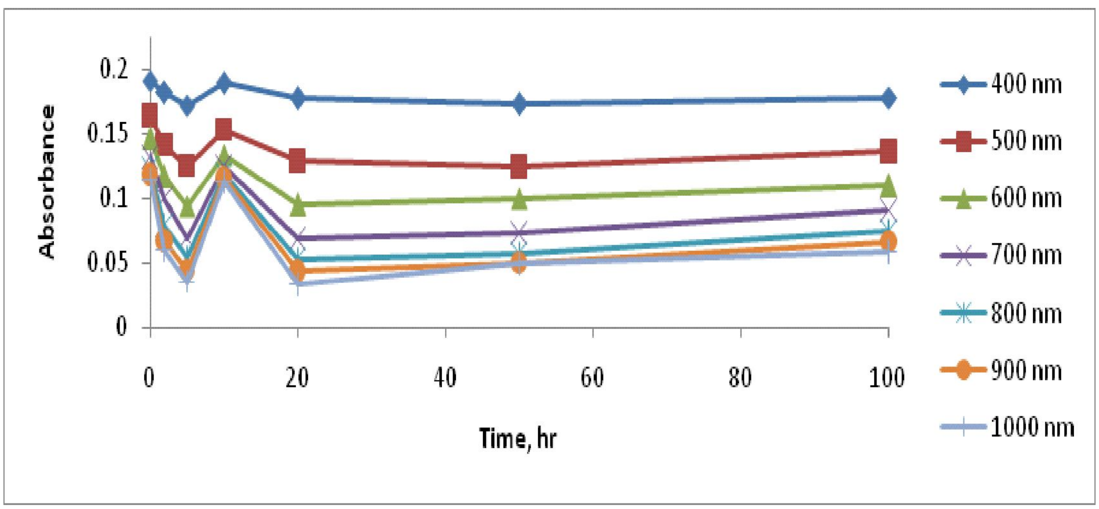

Fig. 3. The variation of optical density of CsI(Tl) crystal at various wavelengths for cumulative dose of sunlight

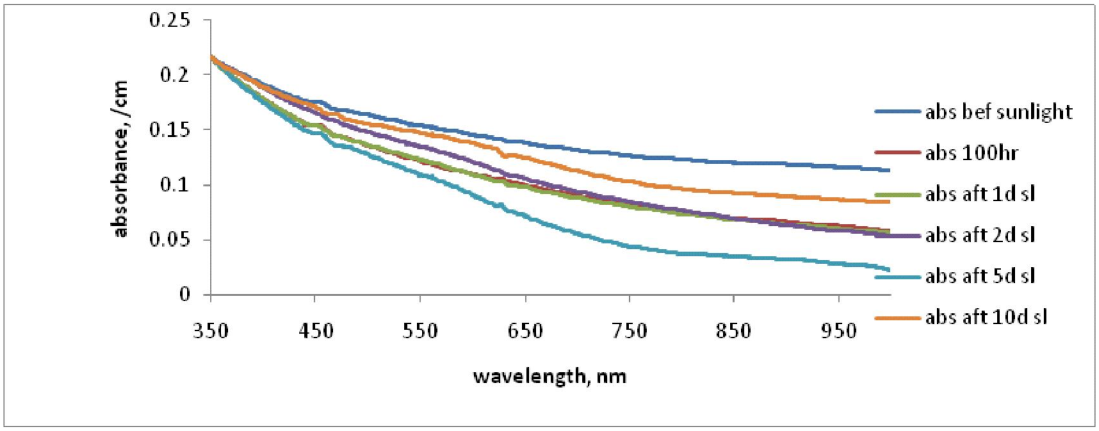

Fig. 4. The optical absorption spectra of CsI(Tl) crystal as a function of wavelength after 100 hr absorbance of sunlight at different period of time.

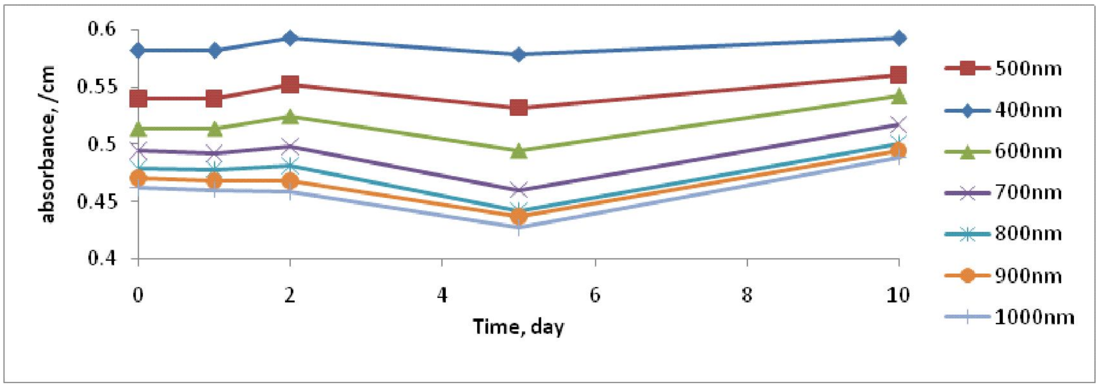

Fig. 5. The optical absorption spectra of CsI(Tl) crystal as a function of wavelength before sunlight expose, 100 hr sunlight expose and after the effect of sunlight expose.

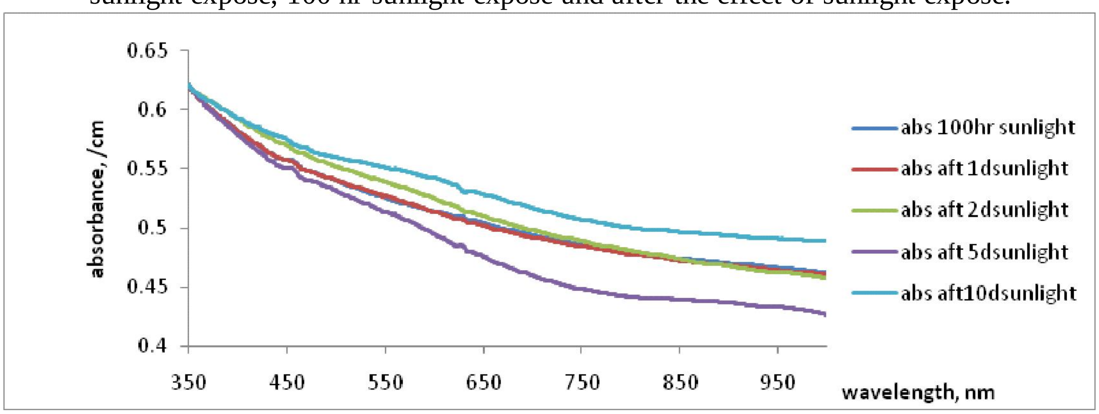

Fig. 6. The change of absorption coefficient of CsI(Tl) crystal as a function of time after 100hr expose of sunlight for different wavelength.

the short wavelength region i.e. for the same dose of sunlight radiation absorbance is greater and varies in values at the visible region whereas at infrared region the absorbance is smaller and variation of absorbance value is also smaller. The optical bleaching and darkening rate is slightly greater at infrared region visible region.

Conclusion

From the above discussion we can conclude that :

(1) For a very long period of sunlight exposure CsI(Tl) crystal may be damaged and new defect is induced along with the growth time defect.

(2) At the initial stages of exposure we cannot measure scintillation light output due to high level of noise resulting from fast change of optical bleaching and darkening.

(3) The light output is affected mostly in the infrared region.

(4) For certain dose of sunlight the absorbance value change closely at infrared region and the absorbance value change spatially at visible region.

(5) After sunlight exposure overall transparency of the crystal has increased.

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