Low Dose Measurement of 150 ns Pulsed X-Ray Source with Silver Doped $Li_2B_4O_7$ Single Crystals

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Introduction

Flash X-rays (FXR) systems are used to produce hard X-rays by intense electron beam pulses. The Flash X-ray System rated for 225kV, 6kA,140J has been developed by 'Accelerator and Pulse Power Division', BARC. The system consists of 15 stages Marx Generator generating pulse of duration 150ns and rise time of 50ns using indigenously developed Folded Pulse Forming Line. For generation of X-Rays, FXR tube of Industrial pinch diode having tungsten anode at high voltage and Stainless steel annular cathode at ground potential, connected with dynamic pumping vacuum system for gun chamber has been used. The FXR is useful in a wide range of applications like radiography of high Z materials, investigation of nontransparent high speed transient phenomena etc. [1]. It is a powerful system and has applications in national security and other research activities. As this system generate high energy X-rays with very high flux, it is important to measure the radiation dose during each experiment.

Themoluminescent dosimeters (TLD) are generally used for radiation dose measurements. As the X-ray pulse-width is extremely small (100 ns) the dose measurements are required to be carried out using an efficient TLD phosphor. The Ag doped lithium tetraborate ($Li_2B_4O_7$) or LTB:Ag is a tissue equivalent material with good thermo-luminescence (TL) properties [2]. Recently we have shown that, LTB:Ag single crystal can detect very low doses of about 0.3 mR with a linear dose response up to 10000 R [3]. This material is also found suitable for the optically stimulated luminescence (OSL) based dosimetry and neutron dosimetry [4]. The use of LTB:Ag single crystal for dose measurement of FXR is reported in this work.

Experimental

Commercially available LTB polycrystalline powder (99.998 % pure) and Ag_2O (1.0 wt %) (99.9% pure) were taken as a starting charge for the growth of single crystals of Ag doped LTB. The growth was carried out by the Czochralski method in air ambient using an automatic diameter control crystal puller having an induction heated furnace. After the growth, sample of size 6 x 6 × 0.6 mm^3 were cut and polished from the crystal ingot for the measurement. The TL glow curves were recorded at a constant heating rate (1K/s) using a programmable home-built TL reader with a 110-360 nm response solar blind photomultiplier tube. The solar blind photomultiplier tube was found suitable for the emission at 270 nm from the LTB:Ag [3]. The other advantage of the solar blind PMT is reduction of background noise and improvement in the S/N ratio. Dose calibrations were carried out by recording the TL signal after irradiation of a few samples using a calibrated ^{60}Co gamma source in the dose range from 0.2 mR to 10 R. For dose measurements at FXR, the calibrated samples of LTB:Ag were first annealed at 300°C for half an hour and subsequently wrapped in aluminum foil and kept at different distance from FXR source window as shown in Fig.1 and exposed to 5 number of X-ray pulses (250 keV X-Ray and pulse duration 150ns generated from the FXR system). Thereafter, the TL was recorded for the samples kept at different position. Two samples were kept at each position to find the average dose.

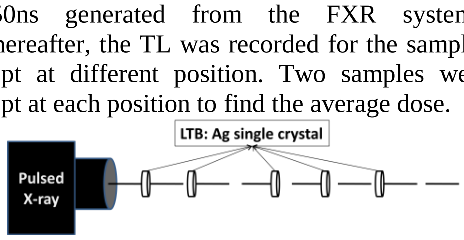

Fig. 1 Schematic of dose measurement set up

Results and discussion

The TL glow curves of LTB:Ag single crystals exposed to different doses in the range from 0.2 mR to 10 R were recorded. The glow curve consists of a well resolved glow peak at around 160°C, as shown in Fig.2 [3]. The height of the TL peak increases as dose increases. The intensity of for each glow curve is integrated and plotted as a function of dose and shown in Fig.3.

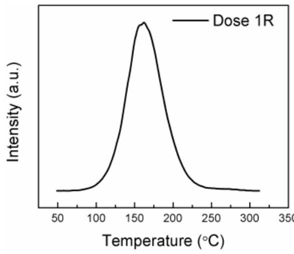

Fig.2. TL glow curve of LTB:Ag

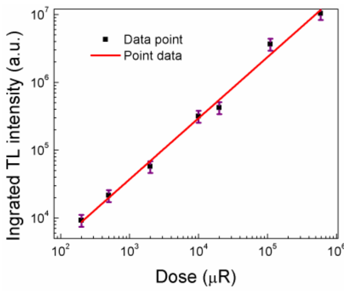

Fig.3. TL dose response of LTB:Ag

We can observe from Fig.3, that the LTB:Ag shows a linear behavior in a dose range from 0.2 mR to 10 R. This is one of the basic properties required for a TLD material for measurement of an unknown dose. The TL glow curve for samples exposed to 5 number of X-ray pulses from the FXR kept at different distances from the source were recorded and the TL intensity of each sample was integrated and corresponding counts were compared with the calibration plot (Fig.2.) to determine the unknown dose. The measured doses at different distances are plotted and shown in Fig.4.

From Fig.4 it is observed that the dose is around 120 mR at a distance of 7 cm from the source and the dose decreases with the distance and falls down to 1 mR at a distance of 110 cm.

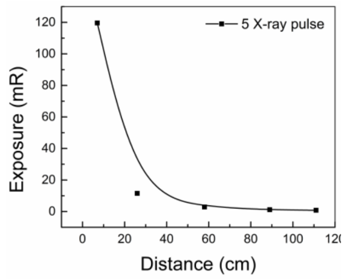

Fig.4. Measured doses for 5 X-ray pulses for the FXR at different distances from the source window.

For a point X-ray source, the dose Vs distance should follow the inverse square law. This was confirmed by plotting the dose as a function of $1/D^2$ as shown in Fig.5. The measured dose was found to match with that estimated using a commercial TLD ($CaSo_4$:Dy) [5].

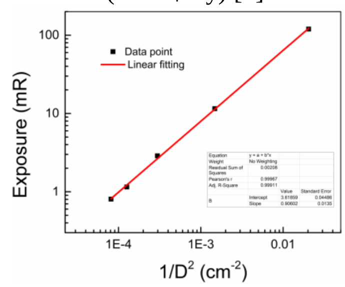

Fig.5. Estimated exposure of FXR with $1/D^2$

Conclusion

The LTB:Ag single crystal is found to have a linear response over a wide range of doses, which makes it useful for dose measurements. The dose estimation for the pulse X-ray source of the FXR has been carried out successfully using this material.

Acknowledgement

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