Strontium Aluminate Phosphorescent Materials: Bright Idea for in Vivo Dosimetry

X. TANG[1], E. Ehkler[1], D. Mathew[1]

1 Department of Radiation Oncology, University of Minnesota, Minneapolis, United States

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INTRODUCTION

The luminescence properties of the strontium aluminate materials have been extensively studied because of their high intensity and long persistence[1,2]. This research is part of a project to use phosphorescent materials as both a TL dosimeter and a real-time fluence detection tool via phosphorescence evaluation. Based on the linear relationship between the TLD reading of the Europium and Dysprosium doped Strontium Aluminate ($SrAl_2O_4$:Eu,Dy) and the delivered dose, this study proposes $SrAl_2O_4$:Eu,Dy as a low-cost, safe and reusable candidate for two-dimensional (2D) in vivo dosimetry. Furthermore, we are currently evaluating the real-time glow intensity of $SrAl_2O_4$:Eu,Dy during radiation and afterglow and its relation to the dose rate. Combined with an optical spectrometer or photodiode, $SrAl_2O_4$:Eu,Dy could serve as a 2D real-time fluence indicator for quality assurance verification of field matching with TLD capabilities as a dosimeter in the future.

AIM

This study aims at evaluating the use of the strontium aluminate phosphorescent powder as an in vivo TL dosimeter and real-time fluence monitor for electron beams. The goal would be to incorporate spatial and point dosimetry in a single dosimetry material.

METHOD

TL Dosimeter Part

- $SrAl_2O_4$:Eu,Dy powder was placed inside several identical light-tight cases and annealed
- After cooling, the powder filled cases were irradiated using an 18 MeV beam at 3.0 cm depth
- The samples were irradiated to five dose levels from 40 cGy to 650 cGy. Delivered doses was determined with optically stimulated luminescent dosimeters
- The irradiated $SrAl_2O_4$:Eu,Dy samples were read with a Harshaw TLD reader in a dark room one day after irradiation
- A linear temperature ramp from 20 degrees Celsius to 350 degrees Celsius with a high temperature hold for 60 seconds was used

Fluence Monitor Part

- $SrAl_2O_4$:Eu,Dy powder was placed in glass cuvettes, irradiated and immediately read out on an Exemplar Plus spectrometer to get the phosphorescent (glow) spectrum
- Two discs of identical dimensions were 3D-printed. One was printed from $SrAl_2O_4$:Eu,Dy powder mixed material and the other was printed from pure plastic
- The two discs were placed side by side in the electron beams. The real-time glow was observed both with the vault video camera as wall as visually when the electron beam is on

RESULTS

TL Dosimeter Part

Each dose group contains three cases of the $SrAl_2O_4$:Eu,Dy samples to account for uncertainty errors. Glow curves were acquired for all samples and the TLD reading signal was integrated across the temperature ramp (Figure 1).

The integration averaged among the three samples was used as the dose response of that group and was plotted against the delivered dose measured with OSL dosimeters (Figure 2). After irradiation, the results showed a strong linear relationship between the dose response of the $SrAl_2O_4$:Eu,Dy samples and the delivered dose from 40 cGy to 200 cGy for 18 MeV electron beams. The equation obtained from the linear regression model is as below:

$$R_{TLD}=1.07\ (\pm 0.182) \times D - 23.5\ (\pm 9.43),$$

(uncertainties are for 95% confidence interval), where R_{TLD} is the integrated TLD reading in nC, D is the delivered dose in cGy. The linear fit has an R-squared coefficient that equals 0.998.

Fluence Monitor Part

The powder phosphorescence spectrum was measured for the strontium aluminate sample with a peak at 520 nm (Figure 3), consistent with the $SrAl_2O_4$:Eu,Dy spectrum recorded in literature[3].

The disc printed with the $SrAl_2O_4$:Eu,Dy mixed material glowed in the dark when the electron beam was on while the one printed from plastic showed no sign of fluorescence. The glow area matched the treatment field contour. When adjusting the dose rate, the brightness of the glow changed accordingly. The glow could be observed both with the vault video camera as well as visually both during the treatment and after the treatment was completed

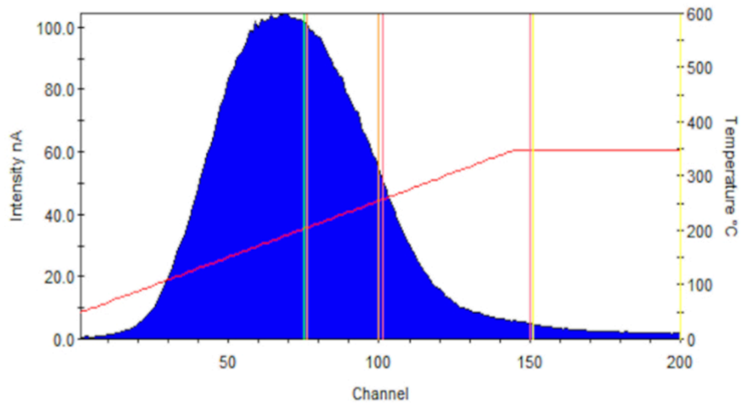

Figure 1. Glow curve of $SrAl_2O_4$:Eu,Dy for 18 MeV electron beam

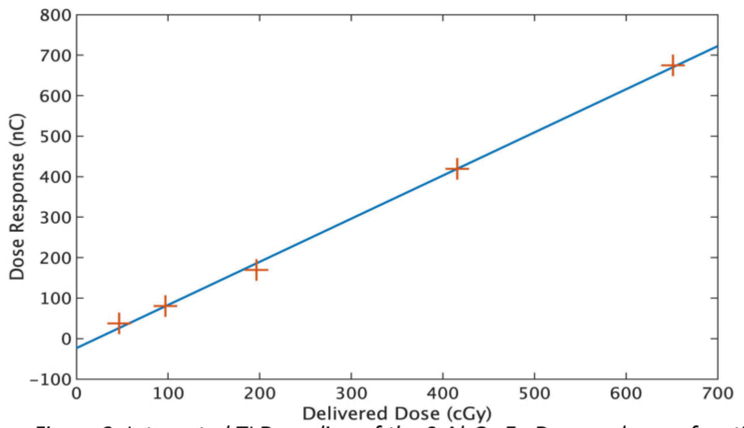

Figure 2. Integrated TLD reading of the $SrAl_2O_4$:Eu,Dy sample as a function of delivered dose for 18 MeV electron beam

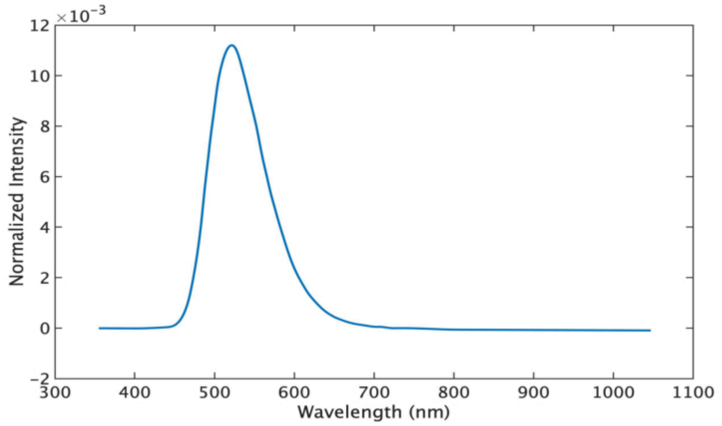

Figure 3. Emission spectrum of $SrAl_2O_4$:Eu,Dy after radiation

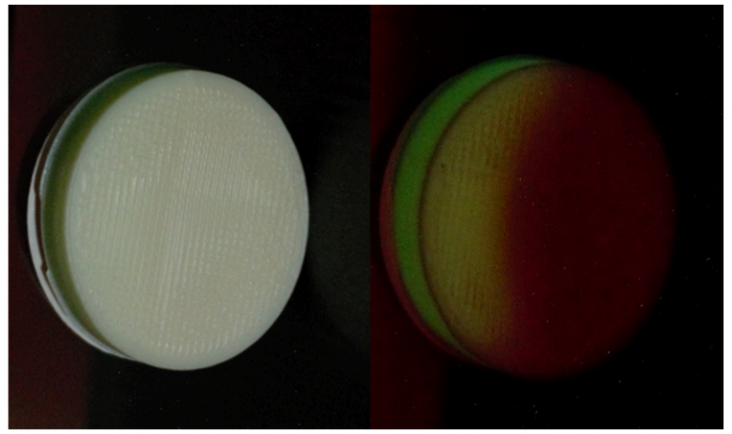

Figure 4. Disc 3D-printed without SrAl2O4:Eu,Dy (left) and printed from SrAl2O4:Eu,Dy mixed material (right) in 18 MeV electron beam

CONCLUSIONS

For the TL Dosimeter part, $SrAl_2O_4$:Eu,Dy is a potential TLD dosimeter for electron beams. A linear dose response was observed from 40 – 200 cGy; superlinearity was observed above 200 cGy. The equation describing the relationship between the TLD reading of the $SrAl_2O_4$:Eu,Dy sample and the delivered dose is provided.

For the Fluence monitor part, only the phantom 3D-printed from strontium aluminate mixed material shows luminescence under electron beams, the brightness of which is related to the dose rate. The persistent afterglow of $SrAl_2O_4$:Eu,Dy allows for visual inspection of the radiation field both during and immediately after radiation treatment.

FUTURE WORK

- Explore the dose response for different beam types, beam energies and dose rates. Determine the applicable range for the $SrAl_2O_4$:Eu,Dy powder as a TL Dosimeter
- Quantify the phosphorescence intensity of $SrAl_2O_4$:Eu,Dy sample as a function of the dose rate
- Obtain 2D real-time fluence map for $SrAl_2O_4$:Eu,Dy coated phantoms

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CONTACT INFORMATION

Xueyan Tang	tangx763@umn.edu
Eric Ehler PhD	ehler046@umn.edu
Damien Mathew PhD	math5574@umn.edu