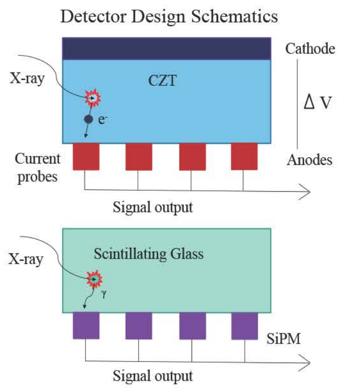
Eu^{3+} and Tb^{3+} Doped Gadolinium Borotungstate Glasses For X-ray Detectors

B. Smith, U. Akgun, Coe College Detector Research Group

Introduction

X-ray detectors are commonly used for imaging purposes in medical physics. This study focuses on producing scintillating glasses that can be used as an efficient and cost effective alternative to the current market material for X-ray detectors- which is cadmium zinc telluride (CZT), a semiconducting crystal. Scintillators are materials which will absorb energy and consequently emit photons in the visible range. For use in a medical detector the scintillating material must have a number of special properties:

- The density must be high enough to be a good absorber for x-rays
- The glass must have a high degree of optical transparency for emission wavelength
- The emission wavelength should match perfectly with the high quantum efficiency region of the photodetectors
- The energy output must rival CZT
- It must be able to perform with high precision at relatively standard pressures and temperatures over time



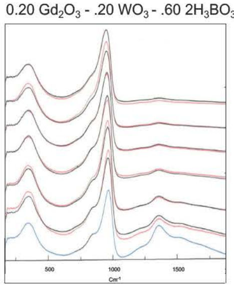
Glass Making Conditions

Glass samples composed of X Gd_2O_3 + Y WO_3 + (1-X-Y) $2H_3BO_3$ were formed. If X=.25 then Y=.25, .35, .45 and if X=.20 then Y=.20. For each glass composition, an additional 12 glass samples were created containing between 1-6% Eu^{3+} or Tb^{3+}. The amount of each reagent was varied to manipulate density and clarity while the amount of dopant was varied to maximize scintillation while avoiding self-quenching.

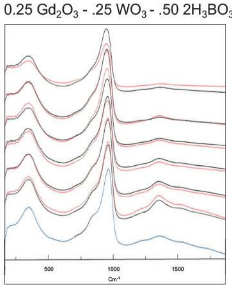
Reagents were measured into an alumina crucible in the desired ratios and were mixed by hand for at least five minutes. The crucible was then placed into a furnace that was preheated to 1200°C and was left for 30 minutes to allow for sufficient melting. The molten glass was poured onto a room temperature iron plate and formed readily.

Raman Spectra

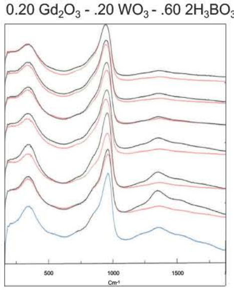
Glass 1
0.20 Gd_2O_3 - .20 WO_3 - .60 $2H_3BO_3$



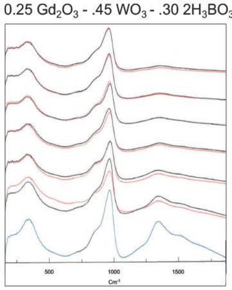
Glass 2
0.25 Gd_2O_3 - .25 WO_3 - .50 $2H_3BO_3$



Glass 3
0.20 Gd_2O_3 - .20 WO_3 - .60 $2H_3BO_3$



Glass 4
0.25 Gd_2O_3 - .45 WO_3 - .30 $2H_3BO_3$

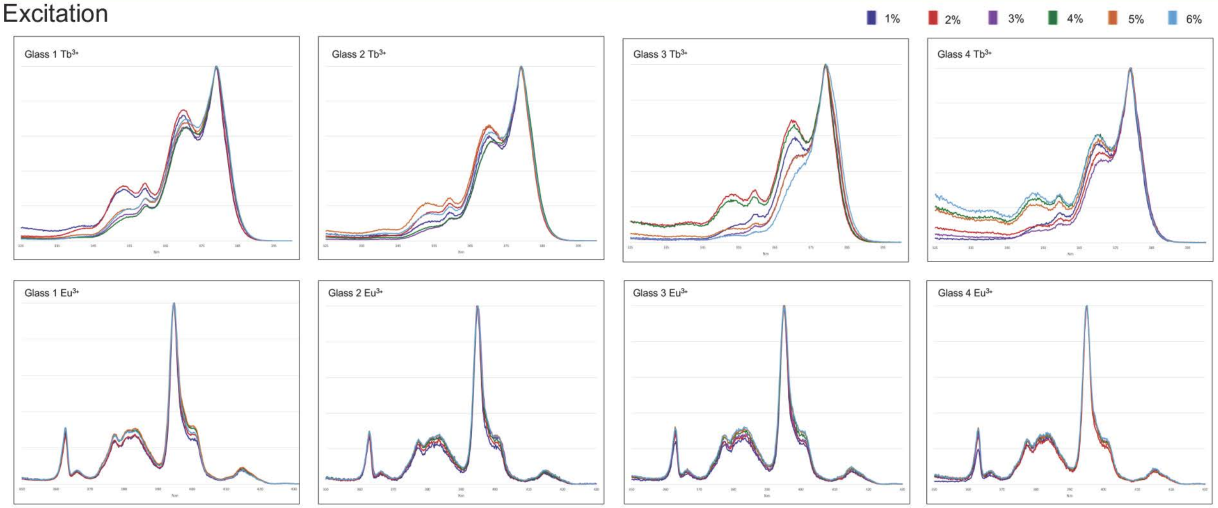


Raman spectra confirms that all materials are amorphous. Each base glass shows the same characteristic peaks with differences in the relative intensities. All glasses show the same basic behaviors as the dopant concentration increases:

- The peak occurring under 500 cm^{-1} and the peak occurring just below 1000 cm^{-1} shift slightly to the left.
- There is a clear decrease in the intensity of the peaks occurring near 1350 cm^{-1}; doping with Tb^{3+} shows a more gradual shift in this behavior than with Eu^{3+}.

This behavior indicates that the addition of Eu^{3+} and Tb^{3+} in the glass causes the preferential formation of tetrahedra (941) and Ln-O-Ln clusters (~300; where Ln=Gd, Eu, or Tb) in the glasses.

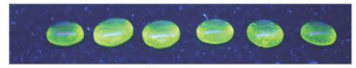
Excitation



Excitation scans were performed at the peak emission wavelengths for all glasses. The excitation data shows that no new bands form or disappear, however the ratio of intensity of each band within a glass changes. This is attributed to variations in local symmetries surrounding the scintillators within the glasses.

Emission

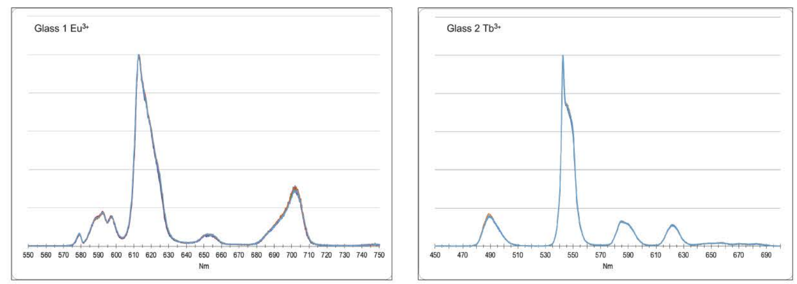
Glass 2 0-6% Tb^{3+}



Glass 2 0-6% Tb^{3+}

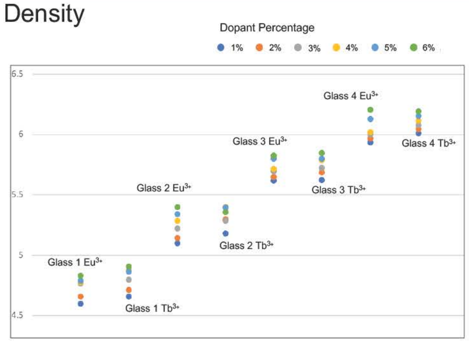
Glass 1 0-6% Eu^{3+}

The optimal concentration of scintillating ions in the glass to produce the brightest signal appears to be 3%.



Emission scans were performed at the samples' peak excitation wavelength. All glasses showed no change in emission spectra as dopant concentrations was increased. Both glasses emit within the high quantum efficiency range of commercial photodetectors.

Density



Density studies show that the densities of the glasses increase with the addition of rare-earths. Previous studies struggled to reach densities of 6.0 g/cm^3

Conclusion

Europium or Terbium doped gadolinium borotungstate glasses show very strong potential for use as a cheaper and more efficient alternative to CZT in x-ray detectors. The presence of scintillating ions within gadolinium borotungstate glasses have shown an obvious effect on the structure formed within the glasses. Additionally, as the dopant concentration in the glass increases, the density increases and a change is apparent in the raman spectra. Excitation data further suggests that the local environments surrounding the scintillators have an effect on the ratio of intensity of each emission band, and that there may exist a correlation between surrounding structure and excitation properties. Future studies will be conducted to determine the energy output of the glasses as well as the glass transition temperatures and further the stability of the glasses.

References and Acknowledgements

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