Synthesis and Phase Identification of Lithium Gallium Oxide Compositions for Scintillator Applications

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Abstract

Investigation into new scintillation materials can be time consuming and costly; however, creating sintered pellets as a screening method can be a time- and cost-efficient alternative. In this study, pellets of three different cerium doped lithium gallium oxide compounds were synthesized. Compositions of $LiGaO_2$:Ce, Li_5GaO_4:Ce, and $LiGa_5O_8$:Ce were created from combining Li_2CO_3, Ga_2O_3 and CeO_2 at different stoichiometric ratios, assuming the CO_2 produced would burn off, and aiming to use 0.5% cerium by weight. These mixtures were made into pellets and sintered. The sintering temperatures of $LiGaO_2$ and $LiGa_5O_8$ used were based on the principle of being 2/3 the melting temperatures. The sintering temperatures used for $LiGaO_2$ and $LiGa_5O_8$ were 1100ºC and 987ºC, respectively. The sintering of Li_5GaO_4 was investigated at 1100ºC, 800ºC, and 500ºC. The only temperature tested that did not melt the Li_5GaO_4 pellets was 500ºC. X-ray diffraction and phase identification were used to find the given phase of each compound. The phase of $LiGaO_2$ has shown to be the right phase, while $LiGa_5O_8$ had an abundance of Ga_2O_3 and $LiGa_5O_8$, and Li_5GaO_4 showed an excess of $LiGaO_2$. Radioluminescence was used to determine the emission wavelength of these compounds, providing the importance of sintering pellets more than once with the $LiGa_5O_8$ data.

Introduction

Scintillators are materials used in various radiation detection applications, often in single crystal form, and doped with an activator, like cerium, to promote scintillation. Single crystal growth is expensive and time consuming, and sintering pellets has been shown to be a cost- and time-efficient screening method for material selection. The Li-Ga-O compounds were chosen because $LiGa_5O_8$:Cr has been reported to scintillate [1]. It along with two other compounds within the Li_2CO_3 and Ga_2O_3 phase diagram were investigated. In this case, cerium was used as a dopant to provide emission of visible light for radiation detection. The sintering temperature and scintillation performance of $LiGaO_2$, Li_5GaO_4, and $LiGa_5O_8$ were investigated using radioluminescence and x-ray diffraction.

Fig. 1: On the left is $LiGa_5O_8$ before sintering, and on the right is after sintering

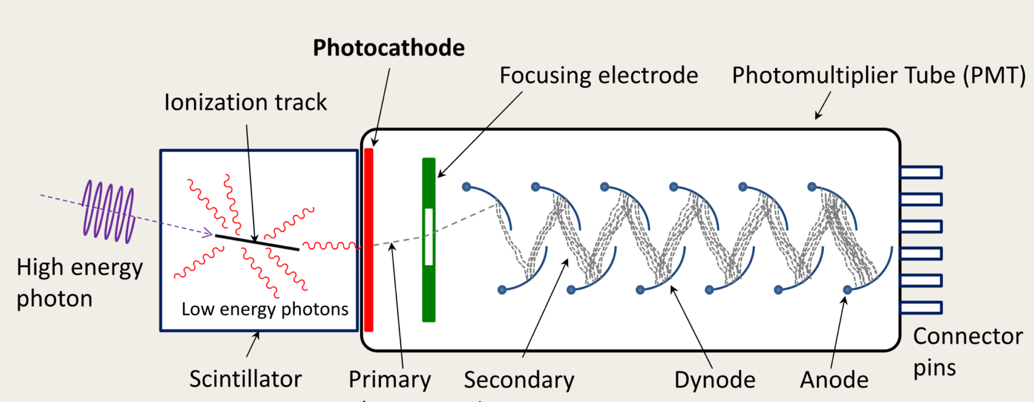


Fig. 2: The scintillation process diagram [2]

Experimental Methods

The raw powders of Li_2CO_3 and Ga_2O_3 were weighed stoichiometrically for each compound and mixed with a SPEX ball mill. The compounds were doped with Ce^{2+} at 0.5% by mass and pressed at 750 psi with a Carver pellet press. They were sintered for 10 hours in a Carbolite box furnace. The sintering temperatures were: $LiGaO_2$ at 1100ºC, Li_5GaO_8 at 987ºC, and Li_5GaO_4 at 500ºC, 800ºC, and 1100ºC. Sintering was repeated with half of the pellets of each compound and the density was calculated. Radioluminescence was used to determine emission wavelength, and x-ray diffraction was used with a Panalytical Empyrean Diffractometer and PDF-4+ database to find the phase.

Results

	% mass loss S1[1]	% mass loss S2	Density S1 in g/cc	Density S2 in g/cc	Theoretical density
$LiGaO_2$	18.3	21.7	2.87	2.50	4.20 [3]
$LiGa_5O_8$	2.48	29.4	3.01	3.37	2.89 [4]
Li_5GaO_4	7.34	22.6	1.56	1.75	2.91 [5]

[1]S1 and S2 stand for sintered once and sintered twice

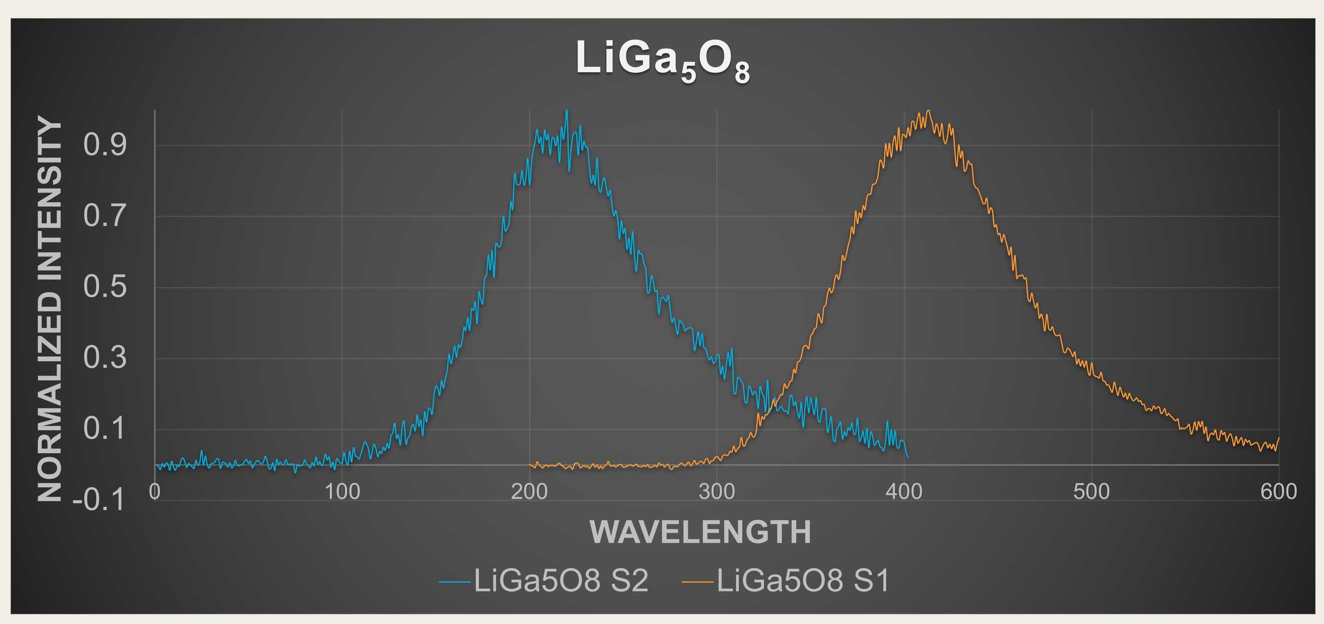


Fig. 3: Emission wavelength vs. normalized intensity of $LiGa_5O_8$ produced from radioluminescence. The blue line is the data from the sample sintered twice and the orange is sintered once. Multiple firings are necessary for this compound.

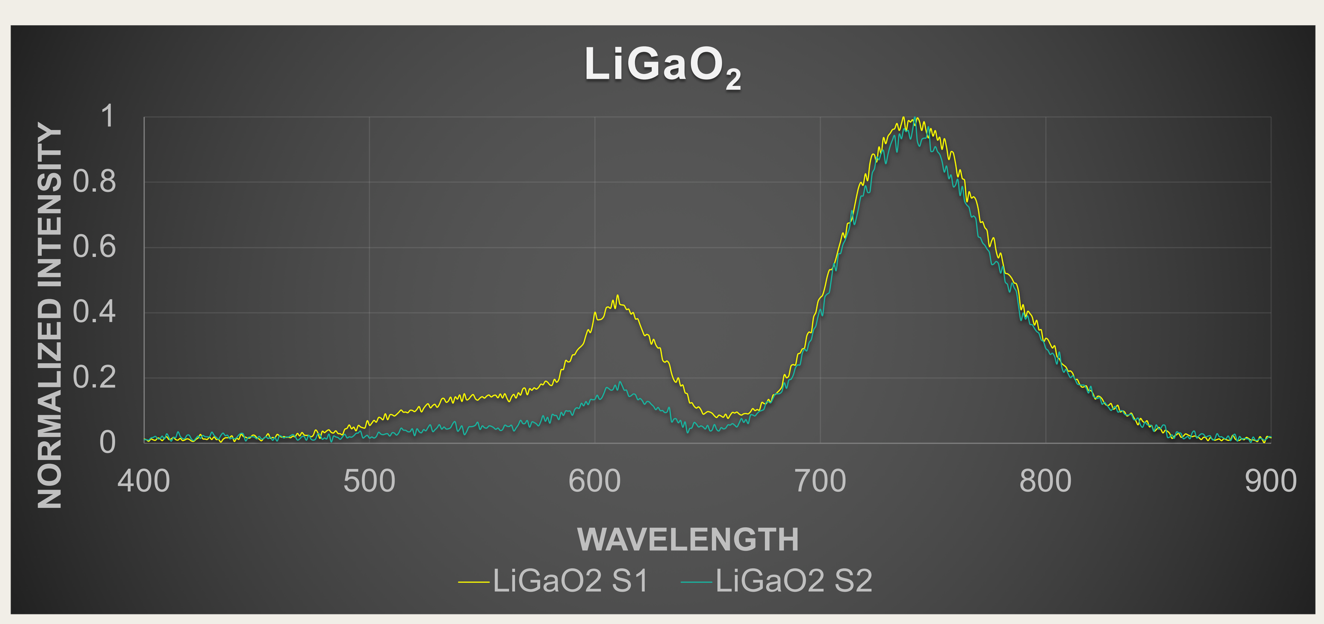


Fig. 4: Emission wavelength vs. normalized intensity of $LiGaO_2$ produced from radioluminescence. The yellow line indicates the data from the pellet sintered once and green is sintered twice. This compound forms a single phase more readily, as confirmed by XRD.

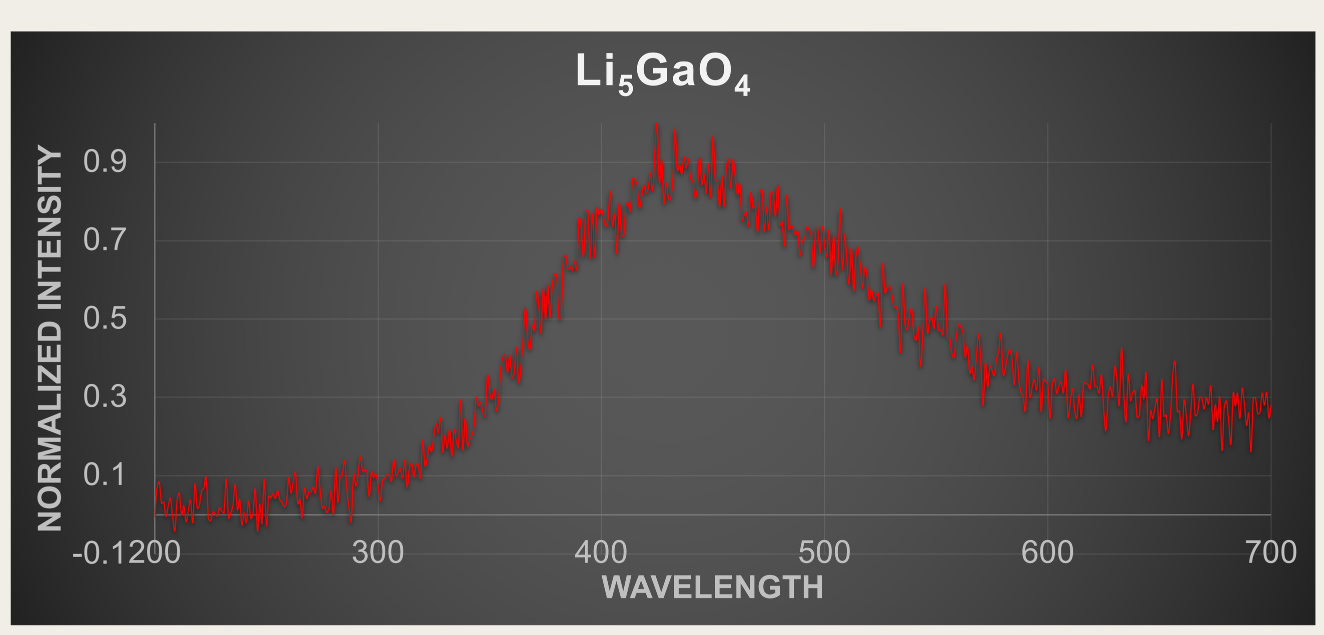
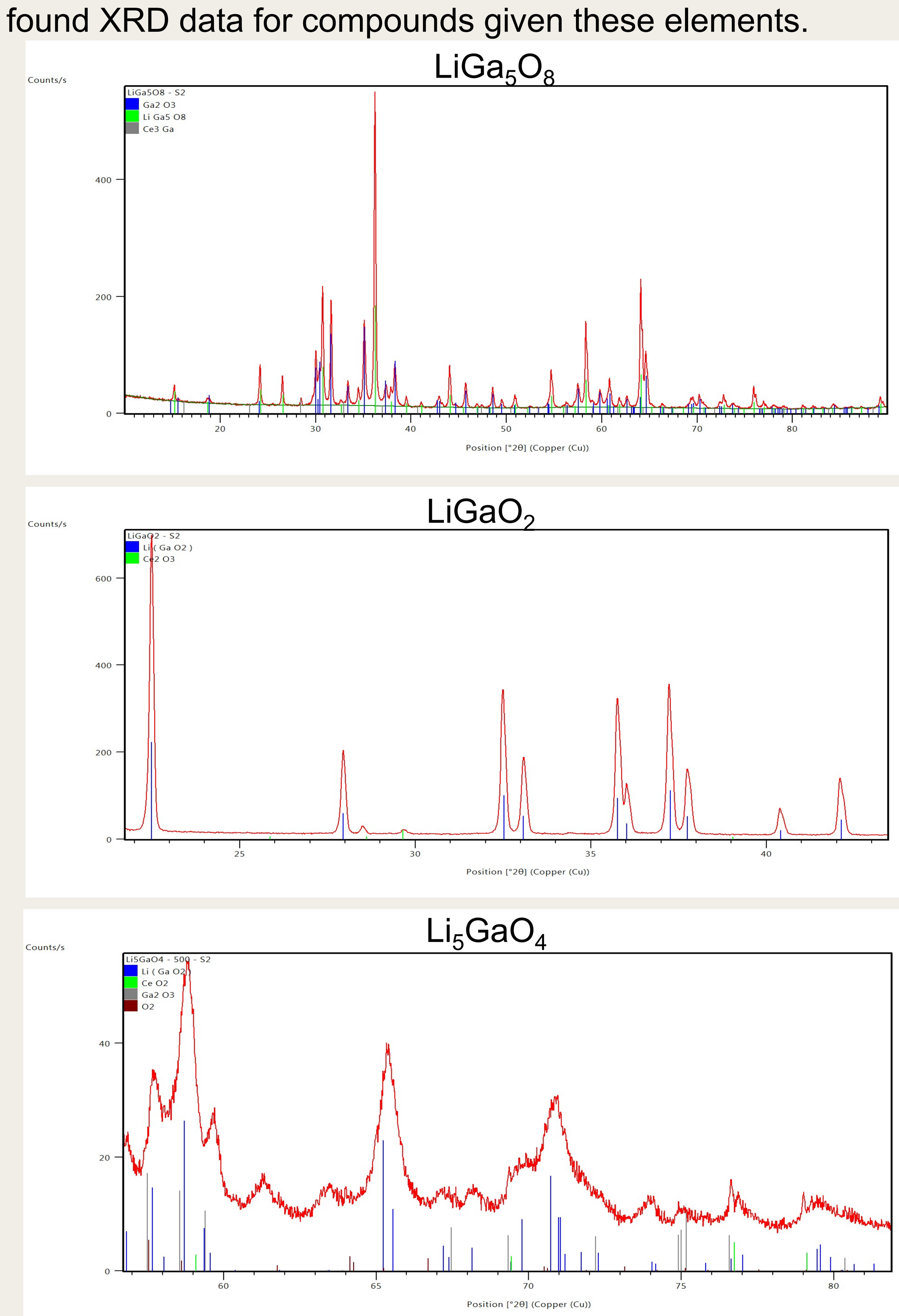


Fig. 5: Emission wavelength vs. normalized intensity of Li_5GaO_4 produced from radioluminescence. The data only represents the Li_5GaO_4 sintered once, because the data acquired from the pellet sintered twice was poor quality. This compound does not show a single phase, as confirmed by its XRD data.

X-Ray Diffraction

Fig. 5a-c: Phase Identification was found using a database that searched the given peaks and compared them to commonly found XRD data for compounds given these elements.



Discussion

With the RL and XRD results, $LiGaO_2$ displays the best sintering qualities out of the three compounds investigated, because it has a single phase. $LiGa_5O_8$ demonstrates the importance of sintering more than once, as it has two different emission wavelengths from the RL data and it contained Ga_2O_3 primarily, as shown in the XRD data. It is predicted that Li_5GaO_4 did not produce the correct phase because 500ºC was not a high enough sintering temperature. This is why the RL data did not show a strong emission wavelength and the phase was incorrect in the XRD data. Sintering temperature, 1100ºC melted the Li_5GaO_4 pellets, and 800ºC partially melted them.

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