

OPTICAL AND PHYSICAL PROPERTIES OF EUROPIUM DOPED LITHIUM
POTASSIUM BORATE GLASS

MAJDI MOHAMMAD ALAYAN MAQABLEH

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Science (Physics)

Faculty of Science
Department of Physics
Universiti Teknologi Malaysia

OCTOBER 2013

I dedicate this work

To my dear parents

Whose love, kindness, patience and prayer have brought me this
far

To my siblings

To my wife

For their endless laughs and tears

To my nieces and nephews

Whose presence fills my life with joy

To my friends

For their love, understanding and support through my endeavour

ACKNOWLEDGEMENT

First and foremost, my unlimited and sincere appreciation goes to the Lord of the seven heavens and earth ALLAH (SWT) for His endless mercies, blessings and guidance through from birth till now and forever. Alhamdulillah Robi Alamin.

My sincere appreciation also goes to my supervisor the person of DR SuhairulHashim for his continued guidance, support and encouragement to ensure this work is a success. My earnest appreciation also goes to all my friends and well wishers that contributed to the success of this study and the knowledge acquired in cause. To you all I say thank you.

I shall forever be grateful to my parent, my siblings, their families and my wife for their belief in me even when I did not and for their unending support, spiritually and emotionally. To them I am highly indebted and words alone cannot describe my gratitude. I pray ALLAH (SWT) make you reap the fruit of your labour on me, Jazakum Allahu Khyran.

ABSTRACT

Borate glass is widely used in many scientific studies. By using melt-quenching technique five samples of lithium potassium borate (LKB) doped with different concentration of europium oxide (Eu_2O_3) were prepared. To investigate the influence of dopant on the optical and physical characteristics of the glass, X-ray Diffraction and photoluminescence analyses were performed. The amorphous nature was confirmed by X-ray diffraction. The physical parameters of the glass which was doped by different oxidation state have been analyzed. These parameters involved are density, molar volume, ion concentration, inter-nuclear distance and Polaron radius. The exchange in the concentration of Eu^{+3} indicated the influence of Eu as a dopant on the photoluminescence emission of LKB glasses. The photoluminescence emission spectrum of LKB: Eu^{+3} were due to the transition of Eu^{3+} from $^5\text{D}_0$ - $^7\text{F}_r$ ($r = 1, 2, 3$ and 4). The luminescence studies showed four peaks (590 nm, 613 nm, 650 nm, and 698 nm) for all samples excluding the pure sample. The glow curve exhibits single peak at 164 °C. We establish that the proposed TL dosimeter at 0.5 mol% of Eu^{3+} has been observed to be 20 times less sensitive than TLD-100.

ABSTRAK

Kaca borat banyak digunakan dalam kajian saintifik. Dengan menggunakan teknik sepuh-lindap, 5 sampel litium potassium borat yang dengan europium oksida (Eu_2O_3) yang mempunyai kepekatan yang berbeza disediakan. Bagi mengkaji kesan dopan terhadap ciri-ciri optikal dan fizikal bagi kaca, analisis pembelauan sinar-X dan fotoluminesens telah dilakukan. Sifat amorfus bahan telah dibuktikan dengan pembelauan sinar-X. Parameter fizikal bagi kaca yang didop dengan aras pengoksidaan berbeza dianalisis. Parameter yang terlibat adalah ketumpatan, isipadu molar, kepekatan ion, jarak antara nukleus dan jejari Polaron. Perubahan kepekatan Eu^{3+} menunjukkan kesan Eu sebagai dopan dalam pancaran fotoluminesens kaca LKB. Pancaran spektra luminesens disebabkan peralihan Eu^{3+} dari $^5\text{D}_0$ - $^7\text{F}_r$ ($r=1, 2, 3$ dan 4). Kajian luminesens menunjukkan 4 puncak (590 nm, 613 nm, 650 nm dan 698 nm) untuk semua sampel kecuali sampel tulen. Satu lengkung berbara menunjukkan puncak tunggal pada 164°C . Dosimeter TL yang dicadangkan ini menunjukkan kepekaan 20 kali lebih rendah berbanding TLD-100 pada kepekatan 0.5 mol % Eu^{3+} .

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF SYMBOLS	xii
	LIST OF ABBREVIATIONS	xiii
	LIST OF APPENDICES	xiv
1	INTRODUCTION	
	1.1 Overview	1
	1.2 Back ground of the problem	3
	1.3 Problem Statement	3
	1.4 Objectives	4
	1.4 Scope of the research	4
	1.5 Significance of Study	5
	1.6 Organization of the dissertation	5
2	LITERATURE REVIEW	
	2.1 Introduction	7
	2.2 Definition of Glass	7
	2.2.1 Glass formation	8
	2.2.2 Techniques of glass preparation	10

2.3	Borates Glasses	10
2.4	Lithium carbonate	11
2.5	Potassium Carbonate	11
2.6	Europium Oxide	12
2.7	X-Ray Diffraction	12
2.8	UV-Vis-NIR Spectrophotometer	15
2.9	Luminescence	16
2.9.1	Photoluminescence (PL)	16
2.9.2	Thermoluminescence (TL)	18
2.10	Fundamental Radiation Dosimetry	20
2.10.1	Thermoluminescence Dosimeter Systems	20
2.10.2	The physics of TL	21
2.11	Characterization of Thermoluminescence Materials	23
2.11.1	Glow Curve	23
2.11.2	Sensitivity	25
2.12	Summery of the previous research	25

3 EXPERIMENTAL PROCEDURES

3.1	Introduction	30
3.2	Sample Preparation	31
3.3	X-ray Diffraction (XRD) Analysis	33
3.4	UV-Vis-NIR Measurement	33
3.5	Photoluminescence Measurement	34
3.6	Physical Parameters	35
3.6.1	Density and molar volume	35
3.6.2	Ion Concentration	36
3.6.3	Reflection measurement	37
3.6.4	Oscillator strengths	37
3.7	Exposure to Radiation	38
3.7.1	Equipment at Sultan IsmailHospital	38
3.7.2	Photons	38
3.7.3	Sensitivity	39

4	RESULTS AND DISCUSSION	
4.1	Introduction	40
4.2	Glass Preparation	41
4.3	X-Ray Diffraction Analysis	41
4.4	UV-Vis-Absorption Spectra	42
4.5	Energy Band Gap	43
4.6	Photoluminescence spectra of LKB:Eu ⁺³	45
4.7	Physical Parameters	47
4.6	TL Glow Curve	49
5	CONCLUSION AND FUTURE WORKS	
5.1	Conclusion	52
5.2	Future works	53
	REFERENCES	55
	APPENDIX	60

LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 2.1	Isotopic constituents of Harshaw TLD-100, 600 and 700	22
Table 3.1	The concentration of all raw material employed in current study	31
Table 4.1	Energy band gap forLKB doped with different concentration of Eu^{+3}	44
Table 4.2	Physical parameters for LKB doped with different concentration of Eu^{+3}	47
Table 4.3	The variation betweenoscillator strengths and the transition levels	48

LIST OF FIGURES

FIGURE NO	TITLE	PAGE
Fig. 2.1	The structure of crystal and glass	8
Fig. 2.2	SiO ₄ tetrahedron linkage in crystallized and amorphous SiO ₂	9
Fig. 2.3	Bragg's law for the periodic arrangement of atoms	13
Fig. 2.4	XRD pattern obtained for SrAl ₂ B ₂ O ₇ polycrystalline	14
Fig. 2.5	XRD Spectrum obtained for pure and doped LKB: x-TiO ₂	15
Fig. 2.6	Excitation and recombination mechanisms in photoluminescence	17
Fig. 2.7	A simple model of energy absorption in a TL material	18
Fig. 2.8	A typical thermogram (glow curve) of LiF:Mg,Ti measured with a TLD reader	24
Fig. 3.1	The LKB:Eu ³⁺ glass after preparation	32
Fig. 3.2	Flow chart of sample preparation	32
Fig. 3.3	UV-Vis-NIR spectrophotometer	34
Fig. 3.4	Photoluminescence spectrum	35
Fig. 4.1	The X-ray Diffraction (XRD) pattern of materials in Table 3.1	42
Fig. 4.2	Optical absorption spectra of LKB doped with Eu ³⁺ ions glasses.	43
Fig. 4.3	Urbach plot of LKB doped with different concentration of Eu ³⁺	44
Fig. 4.4	PL spectrum of LKB doped with Eu ³⁺	45
Fig. 4.5	PL excitation and emission spectrum of LKB doped with different concentration of Eu ³⁺ at 380 nm excitation.	46
Fig. 4.6	Variation of refractive index for Eu ₂ O ₃ in different concentration	48
Fig. 4.7	TL glow curve of LKB:Eu ³⁺ exposed to 1 Gy dose	49
Fig. 4.8	TL chine curves of sample 2 exposed to various dose (1 & 2Gy)	50

LIST OF SYMPOLS

λ	Wavelength
n	Integer, Refractive index
d	Distance between atomic layers in a crystal
θ	Incedant plan wave
P	Probability of escaping from the trap
E	Energy
s	constant
k	Boltzman constant
ρ	Density
a	Weight of glass sample in the air
b	Weight of glass sample in the toluene
V_m	The molar volume
M	Molecular wiehgt
N	Ion concentration
r_p	Polaron radius
r_i	Inter-nuclear distance
E_g	Energy gap
f_{exp}	Oscillator strengths
ϵ	Molar absorption coefficient
$\Delta\nu$	The width of the band at half the peak intensity

LIST OF ABBREVIATIONS

TLD	Thermoluminescence dosimeters
TL	Thermoluminescence
PMT	Photomultiplier
ESR	Electron spin resonance
STE	Self-trapped exciton
DFT	Density functional theory
LINAC	Linear accelerator
RF	Radio frequency
PMMA	Polymethylmethacrylate
MU	Monitor Unit
SSD	Source to surface distance
ICRP	International Commission on Radiological Protection
SEM	Scanning electron microscope
NDT	Non-destructive

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
	Calculation of glass composition	

CHAPTER 1

INTRODUCTION

1.1 Overview

The solids are subdivided into two groups depending on their network structure. The crystalline solids have reticular structure and atoms arranged in three dimensional periodic. The other kind of solids is amorphous (non-crystalline) which have no reticular structure and atoms packing fairly random. The common examples of amorphous are plastic and glass.

The energy required to arrange atoms in irregular packing is larger than that of regular packing, so nature favours the crystalline state and most of the solids in the universe exist in this case. Nearly all material can form glass by changing a network structure form from regular to irregular packing by heating the material to its melting temperature then reduce the temperature sufficiently fast to ensure atoms don't have enough time to rearrange themselves, this is called random network theory (Turnbull, 1969). There are many types of glass that are known recently such metallic glass, halide glass, magnetic glass, commercial glass, oxyhalide glass, and oxide glass.

There are many techniques which can be used for producing glass. The most prevalent method called melt quenching technique which is based on melting a metal oxide then increase the viscosity very quickly, so the crystal growth could not occur.

The most important point in this technique is the ratio between melting and cooling temperature different from material to another.

Some minerals such as fluorite emit a transient glow when temperature increases in darkness, this phenomenon called thermoluminescence. In addition, this phenomenon becomes one of most important research topics especially in the dosimetry field (Oberhoffer *et al.*, 1981).

Denial and his-workers in the 1940s, were used this phenomena in order to measure the amount of radiation exposure and they concluded (LiF) was the most appropriate compound for evaluating ionizing radiation exposure (McKinlay, 1981).

Currently, there are extensive studies on a borate glass subject in industries to develop technological products based on thermoluminescence properties due to its lower cost compared to other compositions. It also owns high sensitivity and easy to prepare (Jiang *et al.*, 2009).

Recently there are many studies about thermoluminescence for borate glass to be used in dosimeter in several fields such as industry and medical fields. Moreover, preliminary studies have shown the possibility of TL characteristic exploitation such as TLD.

Amendments in borate glass composition are going to be executed in our work by adding other oxide alkali on this composite to get the proposed network formed. Such network will be achieved by changing the structure of glass borate. The goal of this modified structure is for reinforcing the glass properties and consequently release some of undesirable properties like unstable alone, easily crystallized and got hygroscopic properties (Hussin *et al.*, 2009).

1.2 Background of the problem

Recently, different radiation source became important in various industrial and medical applications. In order to work in a safe environment and avoid or reduce radiation risk especially for who work in this environment and exposed to rays continually, for this point measure quantity of radiation become a requirement. For this purpose, badge was created from several materials that have got special properties carried out by radiation worker specialists. It is known as a film dosimeter and is calibrated by determine radiation dose, the first one was produced is Eggerd and Luft (1929).

The thermoluminescence dosimetry (TLD) becomes widespread in measurement radiation dose, due to its high sensitivity with small size. (Mayles *et al*, 2007). Most previous studies of thermoluminescence focused on developing and investigate optical fibre in the commercial uses as TLD material. Comparatively there are a few thermoluminescence researches on the glass being reported.

In radiation detector not all material can be used, it's depending on the thermoluminescence properties. The properties of borate glass such as effective atomic number ($Z_{\text{eff}}= 7.42$), chemical stability, capability to accept transition metal ions, and the attractive nonlinear optical properties encouraged researchers to study the possibility to use it as a TLD (Rao, 2002).

1.3 Problem statement

The researchers are using the borate system especially binary borate referring to its attractive properties. Unfortunately, lithium potassium borate is studied by a small number of researchers. Furthermore, they are narrowed specific features and doping with rare earth is not much studied. The current study aims to investigate the structure characteristic and optical properties of the undoped and doped lithium

potassium borate glass as well as the effect of concentration europium ion on luminescence properties.

1.4 Objectives

This study embarks on the following goals:

- i) To study the optical properties of lithium potassium borate doped with europium.
- ii) To identify the physical properties of the new prepared glass.
- iii) To determine the thermoluminescence glow curve and sensitivity of lithium potassium borate doped and un-doped samples.

1.5 Scope of the research

The current study subdivided into some scopes in order to achieve the stated objectives as follow:

- i) Preparation of glass samples from lithium potassium borate doped with europium by using melt quenching technique.
- ii) Use x-ray diffraction to identify the amorphous phase of the prepared glass samples.
- iii) To investigate the absorption properties of the obtained glass by using UV-vis spectroscopy.

- iv) Determination of excitation and emission spectra of the samples by using Photoluminescence Spectroscopy.
- v) Evaluation some of physical parameters for doping and un-doping lithium potassium borate glass
- vi) Investigate the thermoluminescence characteristics for the samples by exposing to photon radiation source.

1.6 Significant of the study

The current study has been done to promote the understanding of the luminescence and thermoluminescence characteristics of the glass. Furthermore, doping samples by Eu^{3+} may develop as a new material.

1.7 Organization of the dissertation

Chapter 1, borate glass system studied by many researchers, overview about the results are carried out in this chapter to establish a fundamental knowledge for present research. Lithium potassium borate glass doped with europium is proposed to become new thermoluminescence material. Three main objectives are listed in this chapter to be accomplished.

Chapter 2 describes briefly the basic theory of glass preparation. The attractive properties for host, modifier, and activators are briefly presented. Furthermore, this explains the thermoluminescence phenomena and presented the thermoluminescence dosimetry system.

In chapter 3, the glass preparation process and the methodology used to investigate the optical and physical properties are described in details. The techniques that being used for the characterization are PL, UV, XRD, ion concentration, and molar volume.

Chapter 4, the results of the current study were presented in this chapter. PL, UV, and thermoluminescence were carried out and discussed. The amorphous phase was confirmed by XRD.

Finally chapter 5 presents the concluding remarks and suggests some recommendation for future study.

REFERENCES

- Alajerami, Y. S. M., Hashim, S., Ramli, A. T., Saleh, M. A., & Kadni, T. (2013). Thermoluminescence properties of $\text{Li}_2\text{CO}_3\text{-K}_2\text{CO}_3\text{-H}_3\text{BO}_3$ glass system co-doped with CuO and MgO. *Radiation Protection Dosimetry*, 155(1), 1-10.
- Alajerami, Y. S. M., Hashim, S., Ramli, A. T., Saleh, M. A., Kadir, A. B. B. A., & Saripan, M. I. (2013). Dosimetric Characteristics of a LKB: Cu, Mg Solid Thermoluminescence Detector. *Chinese Physics Letters*, 30(1), 017801.
- Alajerami, Y. S. M., Hashim, S., Ramli, A. T., Saleh, M. A., Saripan, M. I., Alzimami, K., & Min Ung, N. (2013). Thermoluminescence responses of photon-and electron-irradiated lithium potassium borate co-doped with Cu+ Mg or Ti+ Mg. *Applied Radiation and Isotopes*, 78, 21-25.
- Alajerami, Y. S., Hashim, S., Hassan, W. M. S. W., & Ramli, A. T. (2012). The effect of CuO and MgO impurities on the optical properties of lithium potassium borate glass. *Physica B: Condensed Matter*, 407(13), 2390-2397.
- Annalakshmi, O., Jose, M. T., & Amarendra, G. (2011). Dosimetric characteristics of manganese doped lithium tetraborate—An improved TL phosphor. *Radiation Measurements*, 46(8), 669-675.
- Azeem, P.A., Kalidasan, M., Rama K. G., & Reddy R.R. (2009). Spectral analysis of $\text{Eu}^{3+}:\text{B}_2\text{O}_3\text{-Al}_2\text{O}_3\text{-MF}_2$ (M = Zn, Ca, Pb) glasses. *Journal of Alloys and Compounds*. 474, 536–540.
- Aznar, M., Polf, J., Akselrod, M., Andersen, C., Back, S., Boetter-Jensen, L., Mattsson, S., McKeever, S., & Medin J. (2002). Real-time optical fibre dosimetry in radiotherapy. <http://www.aapm.org/meetings/02AM/pdf/7626-20413.pdf>.

- Streetman, B. G. (1995), *Solid State Electronic Devices*, Texas, Published by Prentice Hall.
- Barthelmy, D. Zabuyelite Mineral Data. Mineralogy Database. <http://webmineral.com/data/Zabuyelite.shtml#.UmjjWXBkNTg>, Retrieved 2010 02 07.
- Dwivedi, B. P., & Khanna B. N. (1995). Cation dependence of raman scattering in alkali borate glasses. *J. Phys. Chem. Solids*. 56, 39-49.
- El-Adawy, A., Khaled, N. E., El-Sersy, A. R., Hussein, A., & Donya, H. (2010). TL dosimetric properties of $\text{Li}_2\text{O}-\text{B}_2\text{O}_3$ glasses for gamma dosimetry. *Applied Radiation and Isotopes*, 68(6), 1132-1136.
- Espinosa, G., Golzarri, J. I., Bogard, J., & Garcia-Macedo, J. (2006). Commercial optical fibre as TLD material. *Radiation Protection Dosimetry*, 119(1-4), 197-200.
- Furetta, C. (2003). *Handbook of thermoluminescence*. New York, World Scientific.
- Gedam, S. C. Thermoluminescence (TL) in Eu doped $\text{Na}_3\text{SO}_4\text{F}$ Fluoride Phosphor. *Research Journal of Material Sciences*, 1(1), 2-5.
- Glennie, G. D. (2003). *A Comparison of TLD: LiF:Mg,Ti and LiF:Mg,Cu,P, for Measurement of Radiation Therapy Doses*. Doctor of Philosophy. University of Virginia.
- Harold, E. J. & John, R. L., (1983). *The Physics of Radiology, fourth edn*, Springfield, Charles C Thomas.
- Hussin, R., Hamdan, S., Fazliana, D.N., Abdul Halim., & Shawal Husin M. (2009). The Origin of Emission in Strontium Magnesium Pyrophosphate doped with Dy_2O_3 . *Materials Chemistry and Physics*. 121, 37-41.
- Jiang, L.H., Zhang, Y.L., Li, C.Y., Hao J.Q., & Su Q. (2009). Synthesis, photoluminescence, thermoluminescence and dosimetry properties of novel phosphor $\text{KSr}_4(\text{BO}_3)_3:\text{Ce}$. *Journal of Alloys and Compounds*, 482(1), 313-316.

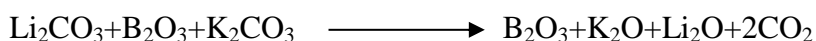
- Kelemen, A., Mesterhazy, D., Ignatovych, M., & Holovey, V. (2012). Thermoluminescence characterization of newly developed Cu-doped lithium tetraborate materials. *Radiation Physics and Chemistry*, 81(9), 1533-1535.
- Kortov, V (2007). Materials for thermoluminescent dosimetry: Current status and future trends. *Radiation Measurements*. 42, 576 – 581.
- Leonard, J., Lygo, B. and Procter, G. (1998). *Advanced Practical Organic Chemistry*, Salford, Stanley Thomas Publishers Ltd.
- Lin, C.K., Yu, M. Pang M.L. & Lin J. (2007). Photoluminescent properties of sol-gel derived (La,Gd) Mg B₅O₁₀:Ce³⁺/Tb³⁺ nanocrystalline thin films. *Optical Materials*. 28, 13–918.
- Maniu, D., Iliescu, T., Ardelean, I., Cinta-Pinzaru, S., Tarcea, N., & Kiefer, W. (2003). Raman study on B₂O₃–CaO glasses. *Journal of molecular structure*, 651, 485-488.
- Mayles, P., Nahum, A. & Rosenwald, J. C. (2007). *Handbook of Radiotherapy Physic Theory and Practice*. France. London, Taylor & Francis.
- McKeever, S. W., Moscovitch, M., & Townsend, P. D. (1995). *Thermoluminescence dosimetry materials: properties and uses* (Vol. 1870965191). Ashford, Nuclear Technology Publishing.
- McKinlay, A.F. (1981). *Thermoluminescence Dosimetry. Medical Physics Handbooks 5*, Bristol, Adam Hilger Ltd.
- Meera, B.N., Sood, A.K. Chandrabhas, N. & Ramakrishna J. (1990). Raman study of lead borate glasses. *Journal of Non-Crystalline Solids*, 126, 224-230.
- Michels, J.J., Huskens J. & Reinhoudt, D.N. (2002), Noncovalent Binding of Sensitizers for Lanthanide(III) Luminescence in an EDTA-bis(-cyclodextrin) Ligand. *J. Amer. Chem. Soc.*, 124, 2056-2064.
- Nagpure, I. M., Saha, S., & Dhoble, S. J. (2009). Photoluminescence and thermoluminescence characterization of Eu³⁺ and Dy³⁺ activated Ca₃ (PO₄)₂ phosphor. *Journal of Luminescence*, 129(9), 898-905.

- Oberhoffer, M. & Schermann, A. (1981). *Applied thermoluminescence dosimetry*. Bristol, Adam Hilger Ltd.
- Podgorsak, E.B. (2005). *Radiation oncology physics: A handbook for teacher and students*. Vienna: International Atomic Energy Agency.
- Proki, M. (2002). Dosimetric characteristics of Li₂B₄O₇: Cu, Ag, P solid TL detectors. *Radiation Protection Dosimetry*, 100(1-4), 265-268.
- Puppalar, S. P., & Dhoble, S. J. (2013). Development of high sensitive LiNaSO₄:Cu, Mg phosphor for TLdosimetry. *Journal of Luminescence*, 137, 245-251.
- Puppalar, S. P., Dhoble, S. J., Lochab, S. P., & Kumar, A. (2012). Luminescence characteristics of Eu and Ti doped LiNaF₂ phosphor. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 285, 6-10.
- Rao, G. V., & Veeraiyah, N. (2002). Study on dielectric relaxation and various other physical properties of Li₂O-CaF₂-B₂O₃: MnO glass system. *Physics and Chemistry of Glasses-European Journal of Glass Science and Technology Part B*, 43(4), 205-211.
- Reddy, R. R., Nazeer Ahammed, Y., Abdul Azeem, P., Rama Gopal, K., Rao, T. V. R., Buddhudu, S., & Sooraj Hussain, N. (2003). Absorption and emission spectral studies of Sm³⁺ and Dy³⁺ doped alkali fluoroborate glasses. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 77(2), 149-163.
- Ren, Z., Yang, C. T. H. and Feng, S. (2007). A novel green emitting phosphor SrAl₂B₂O₇:Tb³⁺. *Materials Letters*. 61, 1654–1657.
- Sahar, M. R. (1998). *Sains Kaca*. Penerbit Universiti Teknologi Malaysia, Skudai.
- Shelby, J. E., & Ruller J. (1987). Properties of barium gallium germanate glasses. *Phys. Chem. Glasses* 28, 262.

- Som, S., Choubey, A., & Sharma, S. K. (2012). Luminescence studies of rare earth doped yttrium gadolinium mixed oxide phosphor. *Physica B: Condensed Matter*, 407(17), 3515-3519.
- Syed Naeem Ahmed (2007). *Physics and Engineering of Radiation Detection*. New York, Academic Press.
- Tiwari, B., Rawat, N. S., Desai, D. G., Singh, S. G., Tyagi, M., Ratna, P. & Kulkarni, M. S. (2010). Thermoluminescence studies on Cu-doped $\text{Li}_2\text{B}_4\text{O}_7$ single crystals. *Journal of Luminescence*, 130(11), 2076-2083.
- Turnbull, D. (1969). Under what conditions can a glass be formed?. *Contemporary Physics*, 10(5), 473-488.
- Venkatramu, V., Babu, P. & Jayasankar, C.K. (2005). Fluorescence properties of Eu^{3+} ions doped borate and fluoroborate glasses containing lithium, zinc and lead. *Spectrochimica Acta Part A*. 63, 276-281.
- Wietelmann, U. Bauer, R. G. (2005) "*Lithium and Lithium Compounds*" in Ullmann's Encyclopedia of Industrial Chemistry, Weinheim, Wiley-VCH.
- Xiong, Z., Tang, Q., Xiong, X., Luo, D., & Ding, P. (2011). The roles of Ag, in and P in the thermoluminescence emission of $\text{Li}_2\text{B}_4\text{O}_7$ phosphors. *Radiation Measurements*, 46(3), 323-328.
- Yacobi, B.G. & Holt D.B. (1990), *Cathodoluminescence Microscopy of Inorganic Solids*. New York, Plenum Press.
- Yang, X., Ning, G., Li, X., & Lin, Y. (2007). Synthesis and luminescence properties of a novel Eu^{3+} doped $\gamma\text{-LiAlO}_2$ phosphor. *Materials Letters*, 61(25), 4694-4696.

APPENDIX

CALCULATION OF GLASS COMPOSITION



The quantity needed to prepare glasses sample is calculated as below:

$$\text{Molar mass of Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$$

$$\text{Molar mass of Li}_2\text{O} = 29.8800 \text{ g/mol}$$

$$\text{Molar mass of B}_2\text{O}_3 = 69.6202 \text{ g/mol}$$

$$\text{Molar mass of K}_2\text{O} = 94.20 \text{ g/mol}$$

$$\text{Molar mass of K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$$

$$\begin{aligned} \text{Weight system, W}_{\text{sys}} &= (0.7 \times 69.6202) + (0.1 \times 94.20) + (0.2 \times 29.8800) \\ &= 48.7341 + 9.420 + 5.976 \\ &= 64.1301 \text{ g/mol} \end{aligned}$$

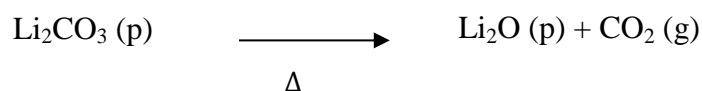
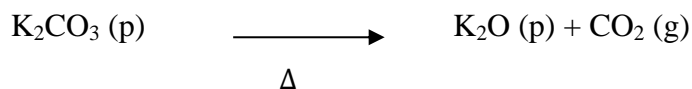
$$\text{Total mass} = 15\text{g}$$

$$\text{For B}_2\text{O}_3, \text{ Mass} = \frac{48.7341}{64.1301} \times 15\text{g} = 11.3989 \text{ g}$$

$$\text{For K}_2\text{O, Mass} = \frac{9.420}{64.1301} \times 15\text{g} = 2.2033 \text{ g}$$

$$\text{For Li}_2\text{O, Mass} = \frac{5.976}{64.1301} \times 15\text{g} = 1.3984 \text{ g}$$

In this project, potassium oxide and lithium oxide are made by heating K_2CO_3 and Li_2CO_3 to above 825°C and liberate a molecule of carbon dioxide (CO_2); leaving potassium oxide.



To get the mass for K_2CO_3 and Li_2CO_3 ,

$$\frac{100}{\frac{\text{Molar mass of Li}_2\text{O}}{\text{Molar mass of Li}_2\text{CO}_3} \times 100\%} \times \frac{100}{\text{Grade Purity of Li}_2\text{CO}_3} \quad \text{Eq.1}$$

$$\frac{100}{\frac{\text{Molar mass of K}_2\text{O}}{\text{Molar mass of K}_2\text{CO}_3} \times 100\%} \times \frac{100}{\text{Grade Purity of K}_2\text{CO}_3} \quad \text{Eq.2}$$

$$\text{Li}_2\text{CO}_3 = \text{Mass of Li}_2\text{O} \times \text{Eq.1}$$

$$\text{K}_2\text{CO}_3 = \text{Mass of K}_2\text{O} \times \text{Eq.2}$$

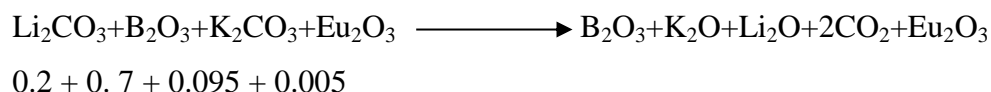
Molar mass of $\text{Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$

$$\text{Hence, the mass Li}_2\text{CO}_3 = 1.3984 \times \frac{100}{40.4379} \times \frac{100}{99} = 3.4930 \text{ g}$$

Molar mass of $\text{K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$

$$\text{Hence, the mass K}_2\text{CO}_3 = 2.2033 \times \frac{100}{68.1593} \times \frac{100}{99} = 3.2652 \text{ g}$$

Doped 0.3



The quantity needed to prepare glasses sample is calculated as below:

Molar mass of Li_2CO_3	= 73.8910 g/mol
Molar mass of Li_2O	= 29.8800 g/mol
Molar mass of B_2O_3	= 69.6202 g/mol
Molar mass of K_2O	= 94.2000 g/mol
Molar mass of K_2CO_3	= 138.2055 g/mol
Molar mass of Eu_2O_3	= 351.926 g/mol
Weight system, W_{sys}	= $(0.7 \times 69.6202) + (0.097 \times 94.20) + (0.2 \times 29.8800)$ $+ (0.003 \times 351.926)$ $= 48.7341 + 9.1374 + 5.976 + 1.0558$ $= 64.9033$ g/mol
Total mass	= 15g

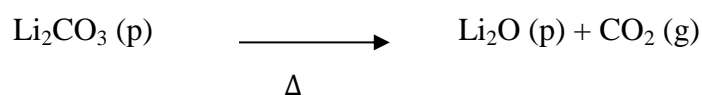
$$\text{For } \text{B}_2\text{O}_3, \text{ Mass} = \frac{48.7341}{64.9033} \times 15\text{g} = 11.2630 \text{ g}$$

$$\text{For } \text{K}_2\text{O}, \text{ Mass} = \frac{9.1374}{64.9033} \times 15\text{g} = 2.1118 \text{ g}$$

$$\text{For } \text{Li}_2\text{O}, \text{ Mass} = \frac{5.976}{64.9033} \times 15\text{g} = 1.3811 \text{ g}$$

$$\text{For } \text{Eu}_2\text{O}_3, \text{ Mass} = \frac{1.0558}{64.9033} \times 15\text{g} = 0.2440 \text{ g}$$

In this project, potassium oxide and lithium oxide are made by heating K_2CO_3 and Li_2CO_3 to above 825°C and liberate a molecule of carbon dioxide (CO_2); leaving potassium oxide.



To get the mass for K_2CO_3 and Li_2CO_3 ,

$$Li_2CO_3 = \text{Mass of } Li_2O \times \text{Eq. 1}$$

$$K_2CO_3 = \text{Mass of } K_2O \times \text{Eq. 2}$$

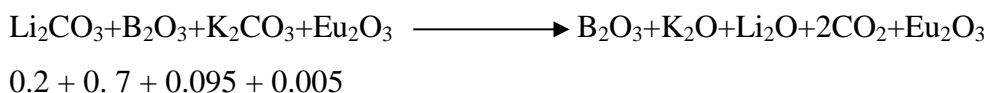
$$\text{Molar mass of } Li_2CO_3 = 73.8910 \text{ g/mol}$$

$$\text{Hence, the mass } Li_2CO_3 = 1.3811 \times \frac{100}{40.4379} \times \frac{100}{99} = 3.4498 \text{ g}$$

$$\text{Molar mass of } K_2CO_3 = 138.2055 \text{ g/mol}$$

$$\text{Hence, the mass } K_2CO_3 = 2.1118 \times \frac{100}{68.1593} \times \frac{100}{99} = 3.1296 \text{ g}$$

Doped 0.5



The quantity needed to prepare glasses sample is calculated as below:

$$\text{Molar mass of } Li_2CO_3 = 73.8910 \text{ g/mol}$$

$$\text{Molar mass of } Li_2O = 29.8800 \text{ g/mol}$$

$$\text{Molar mass of } B_2O_3 = 69.6202 \text{ g/mol}$$

$$\text{Molar mass of } K_2O = 94.20 \text{ g/mol}$$

$$\text{Molar mass of } K_2CO_3 = 138.2055 \text{ g/mol}$$

$$\text{Molar mass of } Eu_2O_3 = 351.926 \text{ g/mol}$$

$$\begin{aligned} \text{Weight system, } W_{\text{sys}} &= (0.7 \times 69.6202) + (0.095 \times 94.20) + (0.2 \times 29.8800) \\ &\quad + (0.005 \times 351.926) \\ &= 48.7341 + 8.9490 + 5.976 + 1.7596 \\ &= 65.4187 \text{ g/mol} \end{aligned}$$

$$\text{Total mass} = 15 \text{ g}$$

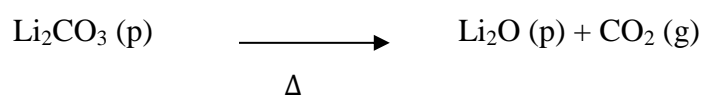
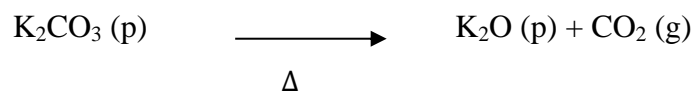
$$\text{For B}_2\text{O}_3, \text{ Mass} = \frac{48.7341}{65.4187} \times 15\text{g} = 11.1743 \text{ g}$$

$$\text{For k}_2\text{O, Mass} = \frac{9.1374}{64.9033} \times 15\text{g} = 2.0519 \text{ g}$$

$$\text{For Li}_2\text{O, Mass} = \frac{5.976}{64.9033} \times 15\text{g} = 1.3703 \text{ g}$$

$$\text{For Eu}_2\text{O}_3, \text{ Mass} = \frac{1.0558}{64.9033} \times 15\text{g} = 0.4035 \text{ g}$$

In this project, potassium oxide and lithium oxide are made by heating K_2CO_3 and Li_2CO_3 to above 825°C and liberate a molecule of carbon dioxide (CO_2); leaving potassium oxide.



To get the mass for K_2CO_3 and Li_2CO_3 ,

$$\text{Li}_2\text{CO}_3 = \text{Mass of Li}_2\text{O} \times \text{Eq. 1}$$

$$\text{K}_2\text{CO}_3 = \text{Mass of K}_2\text{O} \times \text{Eq. 1}$$

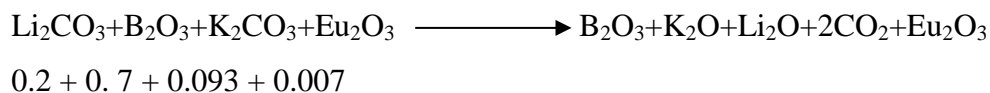
$$\text{Molar mass of Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$$

$$\text{Hence, the mass Li}_2\text{CO}_3 = 1.3703 \times \frac{100}{40.4379} \times \frac{100}{99} = 3.4224 \text{ g}$$

$$\text{Molar mass of K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$$

$$\text{Hence, the mass K}_2\text{CO}_3 = 2.0519 \times \frac{100}{68.1593} \times \frac{100}{99} = 3.0408 \text{ g}$$

Doped 0.7



The quantity needed to prepare glasses sample is calculated as below:

$$\text{Molar mass of Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$$

$$\text{Molar mass of Li}_2\text{O} = 29.8800 \text{ g/mol}$$

$$\text{Molar mass of B}_2\text{O}_3 = 69.6202 \text{ g/mol}$$

$$\text{Molar mass of K}_2\text{O} = 94.20 \text{ g/mol}$$

$$\text{Molar mass of K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$$

$$\text{Molar mass of Eu}_2\text{O}_3 = 351.926 \text{ g/mol}$$

$$\begin{aligned} \text{Weight system, W}_{\text{sys}} &= (0.7 \times 69.6202) + (0.095 \times 94.20) + (0.2 \times 29.8800) \\ &\quad + (0.007 \times 351.926) \\ &= 48.7341 + 8.7606 + 5.976 + 2.4635 \\ &= 65.9342 \text{ g/mol} \end{aligned}$$

$$\text{Total mass} = 15 \text{ g}$$

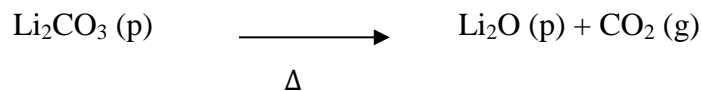
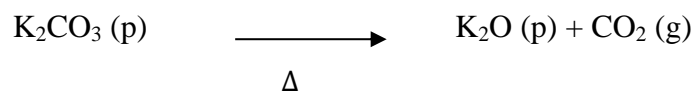
$$\text{For B}_2\text{O}_3, \text{ Mass} = \frac{48.7341}{65.9342} \times 15 \text{ g} = 11.0869 \text{ g}$$

$$\text{For k}_2\text{O, Mass} = \frac{8.7606}{65.9342} \times 15 \text{ g} = 1.9930 \text{ g}$$

$$\text{For Li}_2\text{O, Mass} = \frac{5.976}{65.9342} \times 15 \text{ g} = 1.3595 \text{ g}$$

$$\text{For Eu}_2\text{O}_3, \text{ Mass} = \frac{2.4635}{65.9342} \times 15 \text{ g} = 0.5604 \text{ g}$$

In this project, potassium oxide and lithium oxide are made by heating K_2CO_3 and Li_2CO_3 to above 825°C and liberate a molecule of carbon dioxide (CO_2); leaving potassium oxide.



To get the mass for K_2CO_3 and Li_2CO_3 ,

$$\text{Li}_2\text{CO}_3 = \text{Mass of Li}_2\text{O} \times \text{Eq. 1}$$

$$\text{K}_2\text{CO}_3 = \text{Mass of K}_2\text{O} \times \text{Eq. 2}$$

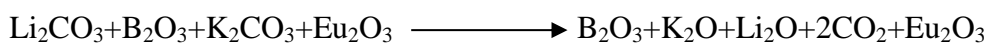
$$\text{Molar mass of Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$$

$$\text{Hence, the mass Li}_2\text{CO}_3 = 1.3595 \times \frac{100}{40.4379} \times \frac{100}{99} = 3.3960 \text{ g}$$

$$\text{Molar mass of K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$$

$$\text{Hence, the mass K}_2\text{CO}_3 = 1.993 \times \frac{100}{68.1593} \times \frac{100}{99} = 2.9535 \text{ g}$$

Doped 1.0



$$0.2 + 0.7 + 0.09 + 0.01$$

The quantity needed to prepare glasses sample is calculated as below:

$$\text{Molar mass of Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$$

$$\text{Molar mass of Li}_2\text{O} = 29.8800 \text{ g/mol}$$

$$\text{Molar mass of B}_2\text{O}_3 = 69.6202 \text{ g/mol}$$

$$\text{Molar mass of K}_2\text{O} = 94.20 \text{ g/mol}$$

$$\text{Molar mass of K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$$

$$\text{Molar mass of Eu}_2\text{O}_3 = 351.926 \text{ g/mol}$$

$$\begin{aligned}
 \text{Weight system, } W_{\text{sys}} &= (0.7 \times 69.6202) + (0.090 \times 94.20) + (0.2 \times 29.8800) \\
 &+ (0.010 \times 351.926) \\
 &= 48.7341 + 8.4780 + 5.976 + 3.5192 \\
 &= 66.7073 \text{ g/mol} \\
 \text{Total mass} &= 15\text{g}
 \end{aligned}$$

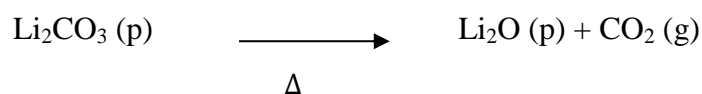
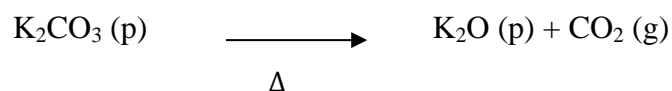
$$\text{For } \text{B}_2\text{O}_3, \text{ Mass} = \frac{48.7341}{66.7073} \times 15\text{g} = 10.9584 \text{ g}$$

$$\text{For } \text{k}_2\text{O}, \text{ Mass} = \frac{9.1374}{66.7073} \times 15\text{g} = 1.9063 \text{ g}$$

$$\text{For } \text{Li}_2\text{O}, \text{ Mass} = \frac{5.976}{66.7073} \times 15\text{g} = 1.3437 \text{ g}$$

$$\text{For } \text{Eu}_2\text{O}_3, \text{ Mass} = \frac{1.0558}{66.7073} \times 15\text{g} = 0.7913 \text{ g}$$

In this project, potassium oxide and lithium oxide are made by heating K_2CO_3 and Li_2CO_3 to above $825 \text{ }^\circ\text{C}$ and liberate a molecule of carbon dioxide (CO_2); leaving potassium oxide.



To get the mass for K_2CO_3 and Li_2CO_3 ,

$$\text{Li}_2\text{CO}_3 = \text{Mass of Li}_2\text{O} \times \text{Eq. 1}$$

$$\text{K}_2\text{CO}_3 = \text{Mass of K}_2\text{O} \times \text{Eq. 2}$$

$$\text{Molar mass of Li}_2\text{CO}_3 = 73.8910 \text{ g/mol}$$

$$\text{Hence, the mass Li}_2\text{CO}_3 = 1.3437 \times \frac{100}{40.4379} \times \frac{100}{99} = 3.3564 \text{ g}$$

Molar mass of $\text{K}_2\text{CO}_3 = 138.2055 \text{ g/mol}$

$$\text{Hence, the mass K}_2\text{CO}_3 = 1.9063 \times \frac{100}{68.1593} \times \frac{100}{99} = 2.8250 \text{ g}$$