THERMOLUMINESCENCE RESPONSE OF NANO GOLD DOPED LITHIUM BORATE GLASS SUBJECTED TO PHOTON IRRADIATION

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I dedicate this work

To my dear parents

Father. Khudhair Obeyes Khudhair and great Mother. Azhar Hamed Mousa

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

For their love, understanding and support through my endeavours

To my beloved brother and sisters

Whose presence fills my life with joy and success

Never forget to dedicate my full appreciation for my

beloved country that is dear to my heart in every step forward in my life

(Iraq)

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ABSTRACT

This study investigated thermoluminescence (TL) properties of undoped and gold nano-particle doped lithium borate glass subjected to Co-60 gamma irradiation. The TL properties of both glasses were studied and compared in terms of TL glow curves, linearity, sensitivity and reproducibility. A number of samples based on $xLi_2CO_3 + (100 - x) H_3BO_3$, where $10 \leq x \leq 25$ mol%, have been prepared using melt - quenching technique. The crystalline phases of undoped and doped glasses were identified by X-ray diffraction (XRD) analysis. The results of XRD patterns indicated that the glass samples were amorphous. The best TL-response of undoped lithium borate glass was identified with a composition of 85% H_3BO_3 + 15% Li_2CO_3 and this glass composition was doped with 0.1 mol% gold nano-particle. The samples were exposed to Co-60 gamma radiation with doses ranging from 10 Gy to 60 Gy. The glow curves were analyzed to determine various characterizations of TLD's. The result clearly shows the superiority of gold nano-particle doped lithium borate glass in terms of TL response and sensitivity to produce luminescence compared to undoped lithium borate glass. Gold nano-particle doped glass provides sensitivity of about 22 times compared to the undoped glass. The doped glass has reproducibility about 3.6% after 2 cycles of exposure. The effective atomic numbers, Z_{eff} of undoped and gold nano-particle doped glass were calculated as 7.1 and 59.03, respectively.

ABSTRAK

Kajian ini menyiasat ciri-ciri termopendar cahaya kaca litium borat yang tidak didop dan didopkan dengan zarah nano emas terahadap penyinaran gama dari Co-60. Ciri-ciri termopendar cahaya bagi kedua-dua kaca telah dikaji dan dibandingkan dari segi ciri-ciri lengkung berbara, kelinearan, kepekaan dan kebolehgunaan semula. Beberapa sampel kaca berdasarkan x Li_2CO_3 + (100–x) H_3BO_3 dengan $10 \leq x \leq 25$ mol % telah disediakan menggunakan teknik pelindapan lebur. Fasa hablur bagi kaca yang tidak didopkan dan didopkan dikenalpasti dengan menggunakan analisis belauan sinar-X. Hasil corak belauan sinar-X yang dihasilkan menunjukkan bahawa sampel kaca tersebut adalah amorfus. Sambutan termopendar cahaya terbaik bagi kaca litium borat yang tidak didopkan telah dikenal pasti dengan komposisi 85% H_3BO_3 + 15% Li_2CO_3 dan komposisi kaca ini telah didopkan dengan 0.1 mol% zarah nano emas. Sampel-sampel tersebut didedahkan kepada kepada sinar gamma dari Co-60 dengan dos berjulat antara 10 Gy hingga 60 Gy. Lengkung berbara telah dianalisis bagi menentukan berbagai ciri termopendar cahaya. Hasilnya menunjukkan dengan jelas kelebihan kaca litium borat yang didopkan dengan zarah-nano emas dari segi sambutan dan kepekaan bagi menghasilkan termopendar cahaya berbanding dengan kaca litium yang tidak didopkan. Kaca yang didopkan dengan zarah nano emas menghasilkan kepekaan kira-kira 22 kali berbanding dengan kaca yang tidak didopkan. Kaca yang didopkan mempunyai kebolehgunaan semula kira-kira 3.6% bagi 2 kali kitaran dedahan. Nombor atom berkesan, Z_{eff} bagi kaca yang tidak didopkan dan didop masing-masing adalah 7.1 and 59.03.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MU	-	Monitor Unit
PMT	-	Photomultiplier
TL	-	Thermoluminescence
TLD	-	Thermoluminescence Dosimeter
XRD	-	X-Ray Diffraction

LIST OF SYMBOLS

a_n	-	Weight fraction contribution
Au	-	Gold
A_w	-	Atomic weight
D	-	Absorbed dose
Gy	-	Gray
H_3BO_3	-	Acid Boric
K	-	Boltzmann's constant
Li_2CO_3	-	Lithium Carbonate
m	-	Mass
MeV	-	Mega Electron Volt
N_2	-	Nitrogen
N_A	-	Avogadro's number
nC	-	NanoCoulomb
N_e	-	Number of electrons per gram
pC	-	picoCoulomb
T	-	Temperature
t	-	Time
w_i	-	Fraction weight of that element
Z	-	Atomic number of the atom
Z_{eff}	-	The effective atomic number

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

It has been more than 400 years since Robert Boyle accidentally discovered the thermoluminescence (TL) in diamonds. All through the years, it has motivated interest and curiosity among scientists and numerous studies have been carried out on this phenomenon. Thermoluminescence has been defined in many different explanations, but in the simplest and modern form, thermoluminescence can be defined as the emission of light from a semiconductor or an insulator when it is heated, due to the previous absorbed energy and the stored energy will be released in the form of radiation (Furetta, 2003; Furetta *et al.*, 2006). Thermoluminescence now has various applications such as radiation dosimetry, age determination and geological researches.

The type of dosimetry material chosen depends on a number of characteristics. The material must have good sensitivity and linearity between dose and TL response, low fading rate, is inexpensive to manufacture, good stability through multiple readout cycles and have a near-tissue equivalent of effective atomic number (Z_{eff}). The latter is important because materials with effective number of higher or lower than human tissue will misjudge the contributions of high energy photons. The search for the best material in terms of these characteristics has led to the discovery and testing of a number of various glasses compounds.

In today's evolving world, minerals are becoming more and more important for many industrial applications including radiation dosimetry. On the other hand, not many researches have been conducted for these compounds on its thermoluminescence properties. Thus, in this work, it is aimed to investigate the thermoluminescence properties of lithium borate glass subjected to gamma radiation. At the end of the study, the results of various properties of the glass such as glow curve, linearity, sensitivity and reproducibility are presented.

Borates glass is one of the most interesting materials, having been known and have been used since the earliest recorded history, first for precious metal working and later in ceramic industries. Boron and its compounds have large applications from glass to fibres, flame-retardants to nuclear applications, leading us to the idea that many new applications may be found in the future. In addition to those, due to the developments in the field of radiation protection dosimetry nowadays, attention is directed toward the application of borate glass as a new thermoluminescence material. The borate glasses are relatively chemically stable compounds and show no serious problems to be doped with impurities such as rare earths, copper and manganese ions. Such materials show high sensitivity, linearity and good fading properties (Garrett, 1998).

There are several natural and synthetic borates that have been used in different applications in industries. Natural borates are generally cleaned from their impurities in processing plants and are further treated to more qualified end products such as boric acid, anhydrous boric acid, anhydrous borax, borax pentahydrate, borax decahydrate and sodium perborate in re-crystallizer units. Inconsistency of borate crystal chemistry (Yu *et al.*, 2002) allows researchers to synthesize numerous borate structures usable in high technology areas.

Lithium borate is one of the suitable materials to be used in radiation dosimetry, especially radiation therapy and clinical applications since these materials have nearly tissue equivalent of its effective atomic number (Z_{eff}=7.3) and easy handling. In addition, doped lithium borate crystals have potential as new materials for neutron detection, due to the presence of Li and B, which have large neutron capture cross-section (Krogh-Moe, 1968). Thus, efficient neutron capture is expected with high-energy deposits in the material (Van Eijk, 1997). Lithium triborate, LiB_3O_5, is one of the most known lithium borate compounds. This compound is the promising material for personal dosimetry, being chemically inert to body fluids, non-toxic and tissue equivalent.

1.2 Statement of the Problem

Dosimetric materials should have some properties like near tissue equivalence, high sensitivity, excellent stability, simple glow curve structure (that is ideally a single glow peak at about 200 °C), nontoxic and simple annealing procedure. There are several dosimetric materials that have been used and many new compounds have been investigated by many researchers, but none of them has all the above stated properties (Kortov, 2007; Salah *et al.*, 2007). Generally, lithium tetraborate, one of borate compounds is used in dosimetric application, but it does not meet all the dosimetric properties requirements. Therefore, there is a need to conduct studies related to borate compounds. The literature review indicates that thermoluminescence properties and appropriate recombination processes in doped or undoped $Li_2B_3O_5$ are not fully studied. Therefore, more investigation is needed to study the thermoluminescent characteristics of the lithium borate compounds.

1.3 Research Objectives

This study focused on the following objectives:

1. To prepare the undoped and Au-doped lithium borate glasses.
2. To investigate the fundamental thermoluminescence properties of undoped and Au-doped lithium borate glass subjected to Co-60 gamma ray.
3. To determine the effective atomic number for Au-doped lithium borate glass.

1.4 Scope of Study

Lithium borate glass was prepared by melt-quenching technique at high temperature in different compositions. Lithium borate glass was then doped with gold nanoparticles with a concentration of 0.1 wt.%. The prepared glass samples were characterized by X-Ray Diffraction (XRD). The doped and undoped lithium borate glasses were exposed to ^{60}Co Gamma ray with different doses ranging from 10 Gy to 60 Gy. Dosimetric properties of the irradiated glass samples were investigated by thermoluminescence (TL) technique. This work was carried out at Physics Department, Faculty Science, Universiti Teknologi Malaysia to prepare and to introduce a new TL material for radiation measurements.

1.5 Significance of the Study

The current study has been conducted to search for a new borate compound to be used as thermoluminescence dosimetry (TLD) by understanding the thermoluminescence characteristics of Au-doped lithium borate glass.

1.6 Organization of the Dissertation

This thesis consists of five chapters. The following is a brief summary of the content of each chapter.

Chapter 1 describes the introduction and background of the study, problem statement, objectives, scope and significance of the study.

Chapter 2 describes the primary theory of glass provision. The attractive dimensions for host, modifier, and activators are also represented. In addition, the thermoluminescence occurrence is discussed in line with the thermoluminescence dosimetry scheme.

C**hapter 3** describes the glass creation procedures that could help in studying the information on its physical features. The XRD technique was implemented to characterize the material.

Chapter 4 describes the results obtained in this work as stated in the objective of the research.

Finally, chapter 5 concludes the results and discussions. The recommendation and suggestions about the future works are also provided.

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