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STUDY ON EFFECTIVE ATOMIC NUMBER AND EFFECTIVE
ELECTRON DENSITY OF
PbO-B₂O₃ GLASS SYSTEM

MISS KIERATI KIRDSIRI

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
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หัวข้อวิทยานิพนธ์	การศึกษาเลขอะตอมยังผลและความหนาแน่นอิเล็กทรอนิกส์ของระบบ แก้วเลดเบอร์เรต
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งานวิจัยนี้ได้ศึกษาการเตรียมแก้วในระบบ $(100-x)\text{B}_2\text{O}_3 : x\text{PbO}$ เมื่อ x มีค่าเท่ากับ 30, 40, 50, 60 และ 70 ร้อยละ โดยน้ำหนัก ด้วยวิธีการหลอมและทำให้เย็นตัวลงอย่างรวดเร็ว จากนั้นได้ศึกษาคุณสมบัติทางกายภาพ แสง และการป้องกันรังสีแกมมาที่พลังงาน 662 กิโลอิเล็กตรอน โวลต์ ผลที่ได้พบว่าค่าความหนาแน่นของแก้วมีค่าเพิ่มสูงขึ้นเมื่อเพิ่มความเข้มข้นของตะกั่วออกไซด์ ซึ่งมีสาเหตุมาจากการเติม PbO เข้าไปแทนที่ B_2O_3 ในโครงข่ายแก้ว ทำให้น้ำหนักโมเลกุลเฉลี่ยของไอออนออกไซด์ในแก้วสูงขึ้น สำหรับค่าปริมาตรเชิงโมลจะมีค่าลดลงเมื่อความเข้มข้นของ PbO มีค่าต่ำกว่า 40 ร้อยละ โดยน้ำหนัก เนื่องมาจากเกิดการลดลงของพันธะหรือระยะห่างระหว่างอะตอม แต่เมื่อความเข้มข้นของ PbO สูงกว่า 40 ร้อยละ โดยน้ำหนัก ค่าปริมาตรเชิงโมลจะมีค่าเพิ่มขึ้น เนื่องจาก PbO จะทำหน้าที่เป็นตัวปรับปรุงโครงสร้างแก้ว สำหรับการวัดสเปกตรัมการดูดกลืนแสงในช่วงความยาวคลื่น 190 - 1100 นาโนเมตร พบว่าช่องว่างพลังงานมีค่าลดลงเมื่อปริมาณของ PbO มีค่าสูงขึ้น จากเทคนิคดังกล่าวจะสามารถคำนวณค่าดัชนีหักเหของแก้วตัวอย่างได้ โดยเมื่อเพิ่มปริมาณของ PbO ค่าดัชนีหักเหจะมีค่าเพิ่มขึ้นซึ่งสอดคล้องกับค่าความหนาแน่น นอกจากนี้ได้ศึกษาสัมประสิทธิ์การลดทอนเชิงมวล อันตรายกิริยาของโฟตอน ภาคตัดขวางเชิงอะตอม รวมทั้งค่าเลขอะตอมยังผลและความหนาแน่นของอิเล็กตรอนยังผลที่พลังงาน 662 กิโลอิเล็กตรอน โวลต์ ผลที่ได้พบว่าค่าสัมประสิทธิ์การลดทอนเชิงมวลจากการทดลองมีค่าสอดคล้องกับค่าทางทฤษฎีที่คำนวณจากโปรแกรม WinXCom โดยเมื่อเพิ่มปริมาณของ PbO ค่าสัมประสิทธิ์การลดทอนเชิงมวล เลขอะตอมยังผล และความหนาแน่นอิเล็กตรอนยังผลจะมีค่าเพิ่มสูงขึ้น จากการศึกษาเปรียบเทียบคุณสมบัติทางการป้องกันรังสีกับ

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คอนกรีตที่ถูกใช้ในงานทั่วไป พบว่าแก้วที่เตรียมได้ในงานวิจัยมีคุณสมบัติที่ดีกว่า ซึ่งคุณสมบัติเหล่านี้ชี้ให้เห็นว่าแก้วในงานวิจัยมีศักยภาพที่เพียงพอที่จะถูกใช้เป็นวัสดุป้องกันรังสี

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Abstract

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In this research, glass with a composition of $(100-x)\text{B}_2\text{O}_3 : x\text{PbO}$ where x is 30, 40, 50, 60 and 70 wt% was prepared by a conventional melt-quenching technique. The physical, optical and radiation shielding properties at 662 keV gamma-rays of glass samples were investigated. The results showed that the density with increasing PbO concentration, indicating that replacing B₂O₃ with some amount of PbO in the glass network. Results in the increase of the average molecular weight of oxide ions in the glass due to the higher molecular weight of B₂O₃. The molar volume decreased when the concentration of PbO is less than 40 wt% due to the decrease in the bond length or the inter-atomic spacing between the atoms. However, when the concentration of PbO was more than 40 wt%, the molar volume increased due to the addition of PbO acting as a network modifier. The optical absorption spectra of the glasses were measured in the wavelength range of 300 - 1,100 nm. The fundamental absorption edge of the glasses was determined. Moreover, the optical energy gap obtained from Tauc's plot was decreased with increasing PbO content. The refractive index of samples calculated from the optical energy gap increased when the concentration of PbO increased, corresponding to the density. In addition, total mass attenuation coefficient, partial photon interactions, total atomic cross-section, effective atomic number and effective electron density were investigated at 662 keV gamma-rays. The experimental values of mass attenuation coefficients are in good agreement with the theoretical ones obtained from WinXCom program. It is noted that the total mass attenuation coefficient, effective atomic number and effective electron density increased with increasing PbO concentration. The radiation shielding property of the prepared glass samples is better than that of some conventional radiation shielding concrete. It can be concluded that the glass samples prepared in this work have the potential to replace ordinary concrete as an alternative choice of materials for radiation protection purpose.

Keywords: Borate Glass / Lead / Mass Attenuation Coefficient / Effective Atomic Number / Effective Electron Density / Radiation Shielding Materials

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LIST OF ABBREVIATIONS AND SYMBOLS

A	Absorbance
B	Band Tailing Parameter
B.E.	Binding Energy
BO	Bridging Oxygen Atom
c	Speed of Light
CN	Coordination Number
D	Optical Density
<i>d</i>	Thickness of Sample
<i>E</i>	Energy
E_g	Optical Band Gap
E_γ	Incident Photon Energy
$E_{\gamma'}$	Scattered Photon Energy
<i>h</i>	Planck Constant
I_0	Intensities of Incident Radiation
<i>I</i>	Intensities of Transmitted Radiation
kJ	kilojoules
m_i	Molecular Weight
MO	Molecular Orbital
M_T	Molecular Weight
MFP	Mean Free Path
<i>n</i>	Refractive Index
N_A	Avogadro's Number
NBOs	Non-Bridging Oxygens
N_e	Effective Electron Density
O_b	Bridging Oxygen Atom
p_γ	Momentum of Photon
R_0	Ionic Radii
R_{anion}	Radius of Cation
R_{cation}	Radius of Anion
R_M	Radius of Cation
R_X	Radius of Anion
<i>T</i>	Temperature
T_e	Kinetic Energy
T_g	Glass Transition Temperature
T_m	Melting Temperature
UV	Ultraviolet
v_i	Partial Molar Volume
VIS	Visible
V_M	Molar Volume
w_a	Weight of the Specimen in Air
w_b	Weight of the Specimen in Water
w_i	Weight Fraction
wt%	Weight Percent
<i>x</i>	Thickness
x_i	Mole Fraction or Weight Fraction

LIST OF ABBREVIATIONS AND SYMBOLS

Z	Atomic Number
Z_{eff}	Effective Atomic Number
α	Absorption Coefficient
α_T	Thermal Expansion Coefficient
α_o^{2-}	Electronic Oxide Polarizability
α_m	Molar Polarizability
ϵ_0	Absolute Permittivity of the Free Space
ϵ	Electric Permittivity of the Medium
ϵ_s	Relative dielectric constant
ρ	Density
λ	Wavelength
λ_{cutoff}	Cutoff Wavelength
A	Optical Basicity
$A(n_0)$	Refractive Index-Based Optical Basicity
A_{th}	Theoretical Optical Basicity
ν	Frequency
σ	Compton Coefficient
$\sigma_{t,a}$	Total Atomic Cross-Section
$\sigma_{t,el}$	Total Electric Cross-Section
τ	Photoelectric Coefficient
κ	Pair Production Coefficient
μ	Linear Attenuation Coefficient
μ_m	Mass Attenuation Coefficient
μ/ρ	Mass Attenuation Coefficient