Hanaa Mohammed

بسم اللّه الرحمن الرحيم

مركز الشبكات وتكنولوجيا المعلومات

قسم التوثيق الإلكتروني

Safaa Mahmoud

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم باللّه العظيم أن المادة التي تم توثيقها وتسجيلها

علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات

Physics Department
Faculty of Science
Ain Shams University

Investigation Of Radiation Dosimetric Properties Of Natural Minerals

A Thesis Submitted in partial fulfillment of the requirements for the degree of

Master of Science in physics

By

Mohamed Sabry Zakaria Ahmed

Physics Department

Faculty of Science, Ain Shams University

Egypt

Supervisors

Prof. Dr. Nabil Ali El-Faramawy
Professor of Nuclear and radiation physics
Physics Department, Ain Shams University

Dr. Ahmed Gad Abd El Wahed
Associate Professor in Geology
Geology Department, Ain Shams University

Dr. Huda Abdulstar Alazab
Teacher of physics
Nuclear and Radiological Regularity Authority

2021

Physics Department
Faculty of Science
Ain Shams University

Name: Mohamed Sabry Zakaria Ahmed
Title: Investigation Of Radiation Dosimetric Properties Of Natural Minerals
Degree: Master of Science in Physics

Thesis Supervisors:

Prof. Dr. Nabil Ali El-Farmawy
Professor of Nuclear and radiation Physics
Physics Department, Faculty of Science Ain Shams University

Dr. Ahmed Gad Abd El wahed
Associate professor of geology
Geology Department, Faculty of Science Ain Shams University

Dr. Huda Abd El star El Azab
Teacher of physics
Nuclear and Radiological Regulatory Authority

2021

Physics Department
Faculty of Science
Ain Shams University

Name: Mohamed Sabry Zakaria Ahmed
Title: Investigation Of Radiation Dosimetric Properties Of Natural Minerals
Degree: Master of Science in Physics

Thesis Supervisors:

Prof. Dr. Nabil Ali El-Farmawy

Professor of Nuclear and radiation Physics
Physics Department, Faculty of Science Ain Shams University

Dr. Ahmed Gad Abd El wahed

Associate professor of geology
Geology Department, Faculty of Science Ain Shams University

Dr. Huda Abd El star El Azab

Teacher of physics
Nuclear and Radiological Regulatory Authority

Examining Committee

1. Prof. Dr. Nabil Ali El-Farmawy Professor of Nuclear and radiation Physics – Physics department – Faculty of Science – Ain shams University

2. Prof. Dr. Azza Abd El-Raouf Abd El-Qader Professor of Physics – Faculty of Science – Al-Azhar University

3. Prof. Dr. Hanan Mohamed Ahmed Professor in the department of Radiation Protection – Atomic Energy Agency

Approval Stamp **Date of Approval**

/ / 2021 **/ / 2021**

Approval of Faculty Council **Approval of University Council**

/ / 2021 **/ / 2021**

ACKNOWLEDGEMENTS

First, I thank **Allah** the most **Beneficent,** and the most **Merciful,** for giving me the ability to work on this thesis and learning new things. And I ask for his support in my future scientific career.

And I want to express my deepest gratitude and my warmest thanks to my distinguished supervisor ***Prof. Dr. Nabil EL-Faramawy*** for his valuable guidance that made the success of the experiments and analysis was possible.

Also, I thank ***Dr. Ahmed Gad Abd El-wahed*** and ***Dr. Huda abd El star El Azab*** for their guidance and help they provided during my research period.

Many thanks to family, friends, lab mates, and faculty colleagues for the support they gave me during my research work.

Contents

List of Figures	v
List of Tables	x
Summary	1
CHAPTER 1: THEORETICAL ASPECTS	
1.1. Luminescence	4
1.1.1. Types of luminescence	7
1.1.1.1. Photoluminescence	7
1.1.1.2. Cathodoluminescence	8
1.1.1.3. Radioluminescence	8
1.1.1.4. Electroluminescence	9
1.1.1.5. Chemiluminescence	9
1.1.1.6. Bioluminescence	10
1.1.1.7. Triboluminescence	10
1.2. Thermoluminescence	11
1.3. Defect states in TL	13
1.3.1. Defects that trap electrons	14
1.3.2. Defects that trap holes	15
1.3.3. Defect generation by irradiation	16
1.3.4. Traps and recombination centers	19
1.4. Recombination processes	20
1.5. Thermoluminescence models	21
1.5.1. The OTOR model	22
1.5.1.1. First-Order kinetics model (FO)	25
1.5.1.2. Second-Order kinetics model (SO)	26

1.5.1.3. General-Order kinetics model (GO)	27
1.5.2. Mixed Order kinetics model (MO)	28
1.6. TL glow curve analysis	32
1.6.1. Empirical methods	32
1.6.2. Initial rise method (IR)	33
1.6.3. Various heating rates method	34
1.6.4. Isothermal decay method	35
1.6.5. Peak shape method (PS)	37
1.6.6. Curve Fitting method	40
1.7. Types of TL materials	41
1.7.1. Artificial TL materials	41
1.7.2. Natural TL materials	41
1.8. Calcite	42
1.8.1. Physical properties	43
1.8.2. Structure	45
1.9. General characteristics of TLD materials	47
1.9.1. Linearity	47
1.9.2. Fading	49
1.9.3. Annealing procedure	49
1.9.4. stability and reproducibility	50
1.9.5. sensitivity	50
1.9.6. sensitization	51
1.10. Applications of TLD materials	51
1.10.1. Personal dosimetry	51
1.10.2. Environmental Dosimetry	52
1.10.3. Clinical Dosimetry	52
1.10.4. High dose	53
1.10.5. Retrospective Dosimetry	53

1.11. advantages of TLD	54
CHAPTER 2: LITERATURE REVIEW	
2.1. TL properties of natural minerals	57
2.2. TL properties from natural mineral calcite	62
CHAPTER 3: MATERIALS AND METHODS	
3.1. Sample preparation	76
3.2. Annealing procedure	79
3.3. Sample characterization	80
3.4. Sample irradiation	81
3.5. TLD measurements	82
CHAPTER 4: RESULTS AND DISCUSSION	
4.1. Thermoluminescence properties of natural Egyptian Calcite	85
4.1.1. X-ray results	85
4.1.2. X-ray fluorescence (XRF) results	88
4.1.3. TL glow curve analysis	89
4.1.3.1. Tm – Tstop method	89
4.1.3.2. Computerized glow curve deconvolution (CGCD) method	91
4.1.3.3. Peak shape method results	95
4.1.4. Linearity	98
4.1.5. Sensitivity	101
4.1.6. Minimum detectable dose (MDD)	103
4.1.7. Fading	104
4.2. Thermoluminescence study of β-irradiated natural calcite	107

4.2.1. X-ray results	107
4.2.2. Atomic absorption spectroscopy results	109
4.2.3. TL studies	110
4.2.3.1. Glow curve structure	110
4.2.3.2. Kinetic analysis	112
4.2.3.2.1. Tm – Tstop, and initial rise (IR) methods	112
4.2.3.2.2. Glow curve deconvolution results	115
4.2.3.2.3. Peak shape method results	117
4.2.3.2.4. Various heating rates (VHR) method	119
4.2.3.3. Linearity	123
4.2.3.4. Sensitivity	127
4.2.3.5. Repeatability	128
4.2.3.6. Minimum detectable dose (MDD)	130
4.2.3.7. Fading	130
Conclusions	134
References	137
Appendices	146
الملخص العربي	I

List of Figures

Figure No.	Title	Page No.
Figure (1.1)	Sub-classification of the luminescence phenomenon into fluorescence and phosphorescence.	**5**
Figure (1.2)	Energy diagrams illustrate the mechanism of (a) fluorescence process and (b) phosphorescence process.	**7**
Figure (1.3)	Illustrates the induced processes in the material due to irradiation. Process (a) in which the electron may be trapped in the defect state, (b) in which the electron may recombine radiatively or non-radiatively with a hole in the valence band, (c) in which the electron may recombine radiatively with a hole in the hole center.	**12**
Figure (1.4)	Illustrates the induced processes due to heating. Process (a) in which the electron may be re-trapped in the defect state, (b) in which the electron may recombine radiatively or non-radiatively with a hole in the valence band, (c) in which the electron may recombine radiatively with a hole in the hole center.	**12**
Figure (1.5)	Energy band model showing the simple OTOR model: (a) production of electron-hole pair (b) trapping of electron and hole (c) thermal release of the electron (d) electron-hole recombination. Level T represents a trap, level R represents a recombination center, and Ef is the fermi level	**21**
Figure (1.6)	MO glow peaks simulated with the following parameters: E = 1 eV, s'= 10^{-5} cm^3 s^{-1}, C = 10^{16} cm^{-3}, N = 10^{18} cm^{-3} and β = 1 Ks^{-1}. Glow curves 1 – 8	**31**

	correspond to n_0/N = 9, 4, 3, 1, 0.25, 0.1 and 0.001, respectively. Also, correspond to α = 0.9, 0.8, 0.75, 0.5, 0.2, 0.091, 0.0099 and 0.000999, respectively. For glow peaks 5 – 8, the intensities are multiplied by factors shown above each peak, respectively.	
Figure (1.7)	The approximation of the glow peak as two right-angled triangles of the same height.	**38**
Figure (1.8)	white and colorless calcite.	**44**
Figure (1.9)	Different colors of the calcite mineral.	**44**
Figure (1.10)	the crystal structure of the natural mineral calcite	**47**
Figure (1.11)	Linearity behavior.	**48**
Figure (3.1)	Location of the white calcite samples.	**77**
Figure (3.2)	Location of the brownish calcite samples.	**78**
Figure (3.3)	White calcite samples turned into powder and discs.	**79**
Figure (3.4)	Electrical furnace (type 6-525, Ney Co., USA).	**80**
Figure (3.5)	Harshaw model 4500 TLD reader.	**82**
Figure (3.6)	Lexsyg Smart TL/OSL luminescent reader.	**83**
Figure (4.1)	(a) The XRD pattern of the investigated sample, (b) matching between the XRD pattern of the investigated sample, and of ICDD card no. 01-081-2027	**87**
Figure (4.2)	Plot of the first maximum temperature (Tm) of the remaining glow curve versus each stopping temperature (Tstop) following Tm – Tstop procedure.	**90**
Figure (4.3)	(a) The deconvolution analysis of the TL glow curve of the investigated sample irradiated with 500 Gy of gamma rays. (b) The residue of the fitted curve.	**94**
Figure (4.4)	Dose response behavior of: a) the glow curves recorded from the calcite sample after irradiation with gamma-rays in the range 0.25 Gy – 25 Gy. b) in	**99**

	the range 50 Gy – 2 kGy.	
Figure (4.5)	Dose response behavior of each individual TL glow peak composing these glow curves.	**99**
Figure (4.6)	TL sensitivity behavior of the investigated calcite sample for doses ranging from 250 mGy up to 2 kGy.	**102**
Figure (4.7)	Fading behavior of: a) the glow curves recorded from the calcite sample after storage periods namely, 0, 1, 2, and 5 days, b) 12, 15, 20, 29, and 42 days.	**106**
Figure (4.8)	Fading behavior of the TL glow peaks composing these glow curves over the same storage periods.	**106**
Figure (4.9)	The XRD pattern of the calcite sample compared to the ICDD card No. 010-081-2027.	**108**
Figure (4.10)	The glow curves of the investigated calcite sample after irradiation with beta particles of doses (a) 1.1 – 55 Gy (b) 110 – 330 Gy.	**112**
Figure (4.11)	A plot of: (a) The Tm against Tstop following the Tm – Tstop procedure (b) The activation energy (E) calculated using Arrehnius plots against Tstop.	**114**
Figure (4.12)	(a) The glow curve of the calcite sample deconvoluted to 6 peaks after irradiation with 110 Gy of beta particles (b) the residue of the fitted curve.	**116**
Figure (4.13)	Glow curves of the investigated calcite sample at different heating rates namely, 1, 2, 3, 5, and 8 K/s.	**120**
Figure (4.14)	A plot between Ln [Im(b − 1) * ((Tm2)/β) ^ b] and 1/Tm for each glow peak at different heating rates stated.	**121**
Figure (4.15)	(a) the linearity behavior of the investigated calcite sample employing the whole glow curve area over the specified range of doses (1.1 – 330 Gy). (b) the linearity index f(D) against the applied dose. (c) the	**125**

	linearity behavior of each separated peak within the dose ranges from 5.5 up to 330 Gy.	
Figure (4.16)	The sensitivity behavior of the investigated sample with changing the applied dose from 1.1 up to 330 Gy.	**128**
Figure (4.17)	The repeatability behavior of each glow peak with 6 readouts times.	**129**
Figure (4.18)	The fading behavior of the calcite sample with changing the storage time.	**132**

List of Tables

Table No.	Title	Page No.
Table (1.1)	Types of defect centers	**18**
Table (1.2)	Physical and optical properties of the natural mineral calcite.	**45**
Table (1.3)	crystallographic properties of natural mineral calcite.	**46**
Table (4.1)	Analysis of the XRD pattern of the investigated calcite sample.	**86**
Table (4.2)	Chemical composition of the investigated calcite sample employing X-ray fluorescence method.	**88**
Table (4.3)	Kinetic parameters and traps lifetimes of the investigated calcite sample obtained using CGCD method for doses from 5 Gy up to 2 kGy of gamma rays.	**95**
Table (4.4)	Kinetic and geometrical parameters of the investigated calcite sample, irradiated with 500 Gy of gamma rays, obtained using peak shape method.	**97**
Table (4.5)	Comparison of the kinetic parameters obtained using CGCD and PS method for doses from 5 Gy up to 2 kGy of gamma rays.	**97**
Table (4.6)	Linearity behavior of each glow peak.	**100**
Table (4.7)	Fitting parameters of the fading behavior of peaks 1 and 2 fitted to empirical one exponential decay function.	**107**
Table (4.8)	Fitting parameters of the fading behavior of the peaks 3 – 6 fitted to langevin function.	**107**
Table (4.9)	shows the diffraction angles, interplanar spacing(d), and miller indices (hkl) obtained from the XRD	**109**