



*Ain Shams University
Faculty of Education
Physics Department*

Positron Annihilation Study in Metals and Alloys

THESIS

*Submitted in partial fulfillment
Of the requirement for the Master degree of
Teacher Preparation in Science (Physics)*

*To
Physics Department
Faculty of Education
Ain Shams University*

*By
Samy El-Gamal Mohammed El-Gamal
B.Sc. and Education, Gen. Diploma and Spec. Diploma
Of Teacher Preparation in physics*

2005

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

{وَقُلْ رَبِّي زَكَوِي عَلَمًا}

صَدَقَ اللَّهُ الْعَظِيمُ



Ain Shams University
Faculty of Education
Physics Department

Student Name: *Samy El-Gamal Mohammed El-Gamal*

Title of the thesis: *"Positron Annihilation Study in Metals and Alloys"*

Submitted to: *Physics Department, Faculty of Education,
Ain Shams University.*

Supervisors:

- 1-Prof. Dr. Hosni Ahmed Ismail**
- 2- Prof. Dr. Ashry Hassan Ashry**
- 3- Prof. Dr. Esam El-Sayed Abdel-Hady**

Acknowledgement

Acknowledgement

I wish to express my deep gratitude to *Prof. Dr. Atef Rizk*, head of physics department, faculty of education, Ain Shams University for his assistance and encouragement.

The author wishes to express his sincere appreciation to *Prof. Dr. H. Ismail*, physics department, faculty of education, Ain Shams University for suggesting this work, for his supervision and advice during the course of this work.

I am deeply indebted to *Prof. Dr. A. Ashry*, physics department, faculty of education, Ain Shams University for his help, fruitful discussions and his persistent interest.

I wish also to express my deep gratitude to *Prof. Dr. Esam E. Abdel-Hady*, physics department, faculty of science, El-Minia University, for his valuable help, guidance and support, continuous encouragement and supervision throughout this work.

I would like to thank *Dr. S. M. Soliman* physics department, faculty of education, Ain Shams University for her fruitful discussions.

I would like to express my thanks to all members of the nuclear physics lab., faculty of science, El-Minia University for their support during this work.



Contents

Contents

	Page no
List of figures	(I)
List of tables	(IV)
Abstract	(VI)

CHAPTER 1:

Introduction and Theoretical Background

1.1 Introduction.....	(1)
1.2 Theoretical Background.....	(6)
1.2.1 Basic concepts of positron annihilation spectroscopy.....	(6)
1.2.2 Trapping Model	(10)
1.2.3 Interaction of positrons with precipitates.....	(15)

CHAPTER 2:

Experimental Techniques and Methods

2.1. Materials and heat treatment.....	(21)
2.2. Positron source.....	(22)
2.3. Instrumental methods and data analysis	(25)
2.3.1. Experimental set-up of DBAR.....	(25)
2.3.2. Data analysis of DBAR spectra.....	(28)
2.3.3. Experimental set up of PAL.	(31)
2.3.4. Data analysis of PAL spectra.....	(35)
2.3.5 Time calibration..	(36)
2.3.6 The time resolution.	(37)
2.4. The Vickers microhardness measurements.....	(38)
2.5. X-ray diffraction measurements	(40)

CHAPTER 3:

Results and Discussions

3.1. Commercially pure Al (1100)	(49)
3.2. Al-Mn-Mg (3004) alloy.....	(51)
3.3. Al-Mg-Si (6201) alloy.....	(53)
3.4. Correlation between the positron annihilation parameters and Vickers microhardness.....	(55)
3.5. Determination of the activation energy.....	(56)
3.6. Determination of the grain size.....	(60)
3.7. Positron annihilation parameters derived from chemical composition.....	(62)
 Conclusion	 (67)
Summary	(69)
References	(73)
Arabic Summary	

List of Figures

List of Figures

Page
no.

- Figure (1-1):** *The positron experiment* 7
- Figure (1-2):** *Vector diagram of the momentum conservation in the 2γ -annihilation process. The momentum of the annihilating pair is denoted by p . Subscripts L and T refer to longitudinal and transverse components, respectively.* 9
- Figure (1-3):** *Annihilation mechanism of positrons in free and defect states* 13
- Figure (1-4):** *Electron (a) and positron (b) potentials and energy levels near a metal surface. Δ is the dipole potential at the surface. $U_{xc}(n_o)$ is the exchange correlation potential in the interstitial region, and ϕ_- , ϕ_+ denote the electron and positron work functions, respectively. μ_- and μ_+ are the electron and positron chemical potentials, respectively. Arrows pointing upwards and downwards denote positive and negative quantities, respectively.* 17
- Figure (1-5):** *Electron (a) and positron (b) potentials and energy levels near a junction of two metals. The vertical scale corresponds to an Al-Zn junction.* 19
- Figure (2-1):** *Decay scheme of ^{22}Na .* 24
- Figure (2-2):** *The source-sample sandwich* 25

Figure (2-3): *The experimental set up of DBAR technique* 27

Figure (2-4): *The Doppler broadening of the 511 keV gamma line for commercially pure Al alloy at RT.* 29

Figure (2-5): *Positron Annihilation Lifetime spectrometer.* 32

Figure (2-6): *The system time calibration by the two sources method.* 37

Figure (2-7): *The prompt resolution curve with ^{60}Co* 38

Figure (2-8): *X-ray diffraction pattern of Al (1100) at RT* 41

Figure (2-9): *X-ray diffraction pattern of Al(1100) after annealing at 500 °C* 41

Figure (3-1): 44

a) The long-lifetime component τ_2 as a function of annealing temperature for Al (1100) alloy.

b) The intensity of the long- lifetime component I_2 as a function of annealing temperature for Al (1100) alloy.

Figure (3-2):

a) The long-lifetime component τ_2 as a function of annealing temperature for Al (3004) alloy. 45

b) The intensity of the long- lifetime component I_2 as a function of annealing temperature for Al (3004) alloy.

Figure (3-3):

- a) *The long-lifetime component τ_2 as a function of annealing temperature for Al (6201) alloy.* 46
- b) *The intensity of the long- lifetime component I_2 as a function of annealing temperature for Al (6201) alloy.*

Figure (3-4): n_e as a function of annealing temperature for Al (1100), Al (3004) and Al (6201) alloys. 48

Figure (3-5):

- a) *The normalized line shape parameter S_{nor} as a function of annealing temperature for Al (1100) alloy.* 50
- b) *The positron mean lifetime τ_m as a function of annealing temperature for Al (1100) alloy.*
- c) *The microhardness (Hv) as a function of annealing temperature for Al (1100) alloy.*

Figure (3-6):

- a) *The normalized line shape parameter S_{nor} as a function of annealing temperature for Al (3004) alloy.* 52
- b) *The positron mean lifetime τ_m as a function of annealing temperature for Al (3004) alloy.*
- c) *The microhardness (Hv) as a function of annealing temperature for Al (3004) alloy.*

Figure (3-7):

- a) *The normalized line shape parameter S_{nor} as a function of annealing temperature for Al (6201) alloy.* 54
- b) *The positron mean lifetime τ_m as a function of annealing temperature for Al (6201) alloy.*
- c) *The microhardness (Hv) as a function of annealing temperature for Al (6201) alloy.*

Figure (3-8): *The dependence of τ_m on the hardness for the three industrial Al alloys.* 57

Figure (3-9): *The Arrhenius plots between the positrons trapping rate K_d and $1/T$ for the three samples. The slope is equal to E_a/K .* 58

Figure (3-10): *$\ln H$ as a function of $1/T$. The slope is equal to $E_a/3K$* 59

Figure (3-11): *l as a function of annealing temperature for the three Al samples.* 61

List of Tables

List of Tables

**Page
no.**

Table (1-1): <i>Calculated positron affinities A_+ (eV)</i>	20
Table (2-1): <i>The chemical analysis of the alloys (wt %)</i>	21
Table (2-2): <i>The positron sources</i>	23
Table (2-3): <i>The lattice parameter values for the three Al alloys at RT and after annealing at 500 °C</i>	42
Table (3-1): <i>The activation energies of defect migration for Al (1100), Al (3004) and Al (6201) alloys</i>	59
Table (3-2): <i>The difference in positron affinity ΔA_+ between the host (Al) and the precipitate of each element, and the critical radii r_c of the precipitates for which positron trapping is occurred.</i>	62
Table (3-3): <i>The Wigner-Sietz radii of atoms (in a_0) used in the calculations</i>	63
Table (3-4): <i>The minimum number of atoms in a precipitate of critical size (n_c)</i>	63
Table (3-5): <i>Number of impurity atoms in Al (1100) alloy (n_1), Al (3004) alloy (n_2) and Al (6201) alloy (n_3), respectively.</i>	64