KAKATIYA GOVERNMENT COLLEGE

HANUMAKONDA

Name	:	Dr. Kethireddy Narendar
Designation	:	Assistant professor of Physics
Year of Award of PhD.	:	2014
Name of the University	:	Kakatiya University
Year of entering into Govt. Service	:	1996

S. No.	Details of copies of Certificates	Remarks
1	Copy of Ph.D Certificate	Enclosed
2	Press note	Enclosed
3	Research work dates of seminars and Pre-Ph.D Date of joining in this college	Letter Enclosed
4	Details of Ph.D Admission-part time or full time	Part time
5	Copies of RDC Approval letters of Ph.D	Letter enclosed
6	Name of guide/supervisors with mobile number, email id	Prof. N. Gopi Krishna nallacheruvugopi@yahoo.com
7	Copies of guide allotment letter	Letter enclosed
8	No. of increments sanctioned for Ph.D.	3
9	Published Research article-copies.	18
10	Original Ph.D Thesis.- Book.	available at office

PRINCIPAL
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Hanamkonda.

Signature

2/4/2?

Name & Designation Dr. K. Narendar

Sl. No. [redacted]

2353

159264

Kakatiya University

Faculty of Science

This is to certify that *K. Narendar* son/~~daughter~~ of *K. Srinivas Reddy* having pursued a course of study prescribed by this University and having passed the requisite examination by thesis, has been admitted to the degree of

Doctor of Philosophy

in Physics

The title of the thesis is:

THERMOPHYSICAL PROPERTIES OF WROUGHT ALUMINUM ALLOYS BY GAMMA RAY ATTENUATION TECHNIQUE

The candidate has been declared qualified for the award of the Degree of Ph.D. on 22/01/2014.

Given under the seal of the University

Warangal, A.P., India

Date : *12 May 2014*

Vice - Chancellor

EXAMINATION BRANCH
Kakatiya University
WARANGAL - 506 009 (A.P.)

No.1653/Ph.D./E1/KU/2014 Date: 22-01-2014

PRESS NOTE

Mr. **K. Narendar,** Research Scholar in Physics, Kakatiya University, Warangal, who has presented a thesis for the Degree of Ph.D. in **Physics** entitled **"THERMOPHYSICAL PROPERTIES OF WROUGHT ALUMINUM ALLOYS BY GAMMA RAY ATTENUATION TECHNIQUE"** has been declared qualified for the Degree of **Doctor of Philosophy** (Ph.D.) of the Kakatiya University.

"By Order"

CONTROLLER OF EXAMINATIONS

Copy forwarded for information to:

1. The Registrar, Kakatiya University, Warangal.
2. The Secretary, University Grants Commission, New Delhi-110 002.
3. The Editor, University News, A.I.U., 16 Kotla Marg, New Delhi-110 002.
4. The Dean, Faculty of Science, Kakatiya University, Warangal.
5. The Coordinating Officer, U.G.C. Unit, Kakatiya University, Warangal.
6. The Principal, University College, Kakatiya University, Warangal.
7. The Chairperson, Board of Studies in Physics, Kakatiya University, Warangal.
8. The Head, Department of Physics, Kakatiya University, Warangal.
9. The E X A M I N E R.
10. **Prof. N. Gopi Krishna**(Supervisor), Dept. of Physics, Kakatiya University,Warangal.
11. The Nodal Officer, Kakatiya University, Warangal.
12. The Member-in-Charge, University Library, Kakatiya University, Warangal.
13. The Deputy Registrar (Admn.), Kakatiya University, Warangal.
14. The Public Relations Officer, Kakatiya University, Warangal.
15. The Secretary to Vice-Chancellor, Kakatiya University, Warangal.
16. The Documentation Section (E5), Examination Branch, Kakatiya University, Warangal.
17. The Person concerned (Mr. **K. Narendar,** S/o. **K. Srinivas Reddy**)

$$$

(2353)

*Vak**

KAKATIYA UNIVERSITY
WARANGAL - 506 009.

Prof. N. Gopi Krishna
Dept. of Physics
KU, Warangal

To
The Dean
Faculty of Sciences
KU, Warangal.

Sir,

I am willing to supervise the research work for the Ph.D degree of Sri K. Narender.

Thanking you,

Yours sincerely

Gopikrishna
7/6/09

Dr. N. Gopi Krishna
Professor and Head

Department of Physics
Kakatiya University
Warangal – 506 009
A.P., India

Phone 0091-870-2461428 (O) mobile :9849942805 nallacheruvu_gopi@yahoo.com

Date: 17-08-2013

CERTIFICATE

This is to certify that **Mr. K. Narender** who is a part time research scholar of this department, as partial fulfilment of Ph.D. programme has given ***two seminar talks*** as the details given below.

Seminar talk	Title of the talk	Date
1	**Thermal expansion and density measurement of molten and solid materials at high temperature by gamma attenuation method.**	15-04-2011
2	**Thermophysical properties of wrought aluminum alloys by gamma ray attenuation technique**	17-08-2013

17/8/2013

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OFFICE OF THE DEAN

Faculty of Science

Kakatiya University : : Warangal – 506 009 (A.P.), India

Prof. S.S.V.N. Sarma
Dean

Phone : (O) 0870 – 2439988

No. 170 /DFS/KU/2009

10th August, 2009

ORDERS

Sub: FACULTY OF SCIENCE – Ph.D. Admissions in the faculty of Science for the year 2008- 2009 – Orders – Issued

* * *

On the recommendations of the Admission Committee and with the approval of the Vice-Chancellor, Kakatiya University, Warangal, the following candidates have been provisionally selected for the admission into Ph.D. Programme for the year 2008 – 2009 in the Department of **Physics** as mentioned below.

Sl. No.	Name of the Candidate	Name of the Supervisor	Topic of Research	Remarks
1.	K. Narender	Prof. N. Gopi Krishna	Thermal expansion and density measurements of molten and solid materials at high temperature by the gamma attenuation technique	Part-time
2.	A. Madhusudhan Rao	Prof. N. Gopi Krishna	Density and thermal expansion measurements on alloys by gamma densitometry	Part-time
3.	D. Madhuri	Prof. A.S. Nageshwara Rao	Study of gamma ray interactions in building materials	Regular
4.	P. Surender	Prof. Khaja Althaf Hussain	Preparation and study of physical properties of alkalihalide mixed crystals with NaCl and CuCl structure	Part-time
5.	A. Rajendra Prasad	Prof. A.S. Nageshwara Rao	The study of elemental analysis of herbal medicinal plants using EDXRF	Part-time
6.	J. Adam	Prof. Khaja Althaf Hussain	Study of physical properties of mixed crystals	Part-time
7.	L. Haritha	Dr. G. Gangadhar Reddy	A theoretical study on the magnetic properties of narrow energy band systems	Regular
8.	M. Kalpana Devi	Prof. K. Suresh Babu	Fourier optics – Apodisation studies	Part-time

S. S. V. N. Sarma

DEAN

9.	B. Raju	Prof. Khaja Althaf Hussain	Crystal Growth and Physical properties of some Lysine derivaties	Part-time
10.	A. Saritha	Prof. Khaja Althaf Hussain	Crystal Growth and Physical properties of some L-Threonine derivatives	Part-time

The above selected candidates are required to submit the following certificates in original to the Principal, University College, KU for verification and finalization of admissions into the Ph.D. Programme:

1. All the original certificates from SSC to PG
2. Transfer Certificate
3. No Objection Certificate from the Employer (in case of employees)
4. Migration Certificate (for candidates who possess PG from other than Kakatiya University)
5. Admission fee of **Rs. 100/-** and Tuition fee of **Rs. 1000/-** for University students (**Rs. 10,000/-** for KITS students) may be paid in "A" challan and Non University fee of **Rs. 200/-** may be paid in "D" challan at SBH, KU Branch, Warangal as per the norms of the University.
6. In case of Ph. D. admission into affiliated Colleges (including KITS) admission fee as prescribed may be paid in "A" challan at SBH, KU Branch, Warangal. These candidates should pay the prescribed non-university fee through Demand Draft drawn in favour of the Registrar Income Account, KU payable at SBH, KU Branch. The tuition fee may be paid at the college concerned.

After getting verification of the above they have to submit their joining report duly endorsed by the **Research Supervisor, Head of the Department, Chairperson, Board of Studies and the Dean, Faculty of Science** to the Principal of the College where the Department exists, under intimation to the undersigned on or after 17-08-2009 and before 29-08-2009 failing which the provisional selection for admission given through these orders automatically stands cancelled.

The above admissions are subject to the following conditions:

1. They have to complete the programme within a minimum period of 2/3 years and maximum of 4/5 years from the date of registration for full time/part time scholars, respectively.
2. They have to pay the tuition fee every year as per the norms and submit the renewal application form along with the Challan in the office of the Principal
3. They should give a minimum of two (2) Seminars during their programme.
   I Seminar – within one year from the date of registration and
   II Seminar – during the II year or before the submission of the thesis

DEAN

4. They should publish at least one paper in a reputed/recognized journal, before submission of thesis.

5. They should submit half yearly reports of the Research work through the Supervisor and Head of the Department to the undersigned with a copy marked to the office of the Principal

6. The candidates other than M. Phil holders should pass Pre-Ph. D. examination within two successive examinations from the date of registration.

7. The candidates registered for the Ph. D. programme on full time (Regular) basis shall be available in the Department throughout the programme and the Head of the Department shall maintain their attendance in the Department. They should not take up any employment during the tenure of their Ph. D. program.

8. The candidates in service outside Warangal are required to put in at least one year of attendance in the department.

9. They shall be governed by the existing rules and regulations of the programme

10. Any deviations in observing the above rules by the candidates entail cancellation of their admission.

11. **The candidate has to fill the attached Bio-data form and submit the same in the Dean's office**

DEAN

To

The persons concerned

Copy to:-

1. The Principal, University College, KU.
2. The Head, Department of Physics, KU.
3. The Chairperson, Board of Studies in Physics, KU.
4. The Supervisor concerned.
5. The Controller of Examinations, KU.
6. The Member-in-Charge, University Library, KU.
7. The Joint Registrar, Academic Branch, KU.
8. The Secretary to Vice-Chancellor, KU.
9. The P.A. to Registrar, KU
10. The SF

DEAN

Warangal,

Date: 22-08-2009.

To

The Principal

University College

Kakatiya University

Warangal
ate: 22-08-2009

Sir,

Sub: Joining Report-Ph.D(part-time)-Department of Physics-Reg.

In response to Letter No.170/DFS/KU/2009 Dated 10-08-2009 from Office of the DEAN Faculty of Science, Kakatiya University-Warangal, I, K. NARENDER , hereby submit my joining report into Ph.D programme(Part-time) for the year 2008-2009 in Physics under Supervision of Prof. N.GopiKrishna, Dept. of Physics Kakatiya University,Warangal.

Signature of Student

(K. NARENDER)

Research Supervisor

Head of the Department

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WARANGAL-506 009 A.P.

Chairperson, Board of Studies

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GJC Co-Edn Hanamkonda

PROCEEDINGS OF THE REGIONAL JOINT DIRECTOR OF INTERMEDIATE EDUCATION WARANGAL

Rc. No.911 /C1/2008

Dated:- 13-03-2008

Sub:- APIES:- Permission is accorded to the Junior Lecturers working in Govt. Junior College's in zone to do Ph. D /M. Phil (On part time basis)- Orders- Issued.

Ref:- 1) Lr. Rc. No. Spl/E1/2008 Dt. 11-01-08 of the Principal, GJC Fort Warangal Warangal Dist.
2) Lr. Rc. No. Nil, Dt.13-02-2007 & 04-03-08 of the Principal, GJC Girls Waddepally Warangal Dist.
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Permission is hereby accorded to the following Junior Lecturers working in Govt. Junior Colleges in Zone V to do M. Phil/Ph.D (On part time basis) the name of the Universities showed against their name subject to the following conditions

Sl. No.	Name of the JL & Place of working	Subject	Name of the University in which Ph.D./ M. Phil to do
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2	N.Ashok Rao JL Maths GJC (G) Waddepally	M. Phil.	Periyar University Kerla
3	P. Divakar JL Physics GJC (G) Waddepally	Ph.D.	Periyar University Kerla
4	V. Mamatha JL Hindi GJC (G) Waddepally	Ph.D.	Venkateshwar University
5	Smt. B. Sunitha JL Chemistry GJC (G) Waddepally	M. Phil	SDLCE KUC Warangal
6	R.Madhavai JL in Zoology GJC (G) Waddepally	M. Phil.	SDLCE KUC Warangal
7	B.Veeraiah JL Botany GJC(B) Narsampet	M. Phil	Vinayak Mission Selam
8	T. Srinivasulu JL Commerce GJC(B) Narsampet	M. Phil	Vinayak Mission Selam
9	V.Sesha Chary JL Maths GJC Parkal	M. Phil	Periyar University Kerla
10	Ch. Sharath Kumar JL Physics GJC(B) Jagtiyal	M. Phil	Vinayak Mission Selam
11	V.Kiran Kumar JL Physics GJC Mustabad	M. Phil/ Ph. D	Vinayak Mission Selam
12	S. Sridher JL in Botany GJC Co-Edn Hanamkonda	M. Phil/ Ph.D	Vinayak Mission Selam
13	D.Sudhakar Reddy JL Physics GJC Co-Edn Hanamkonda	M. Phil/ Ph.D	Periyar University Kerla
14	K. Narender JL Physics GJC Co-Edn Hanamkonda	Ph.D	KUC Warangal

Contd. P. No.2..

1) That there should not be any financial commitment to the Government
2) That his research work should not be in any way detrimental to his to Duties.
3) That he should not accept any financial Assistance from any source .
4) That he should under take the Research work at his own cost.
5) That he should under take the Research work only after he is selected for the course.
6) That this permission shall not be made a ground for either transfer or retention in future.

G.BALAKISHAN
REGIONAL JOINT DIRECTOR.

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The individual concerned (through Principal)
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// t. c. f. b. o. //

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KAKATIYA UNIVERSITY
WARANGAL - 506 009

No. 1420

Date 28-01-2011

MEMORANDUM OF MARKS

Pre-Ph.D. Physics Examination, ~~Annual~~ Dec,2010 - 2~~00~~

Roll No. 100001501

Name K. Narendar

Son / ~~Daughter~~ of K. Srinivas Reddy

PAPERS	MAXIMUM MARKS	MARKS SECURED	RESULT
Paper-I. General physics	100	061	Pass
Paper-II. Solid state physics	100	067	Pass
Grand Total	200	128	

Aggregate in words One hundred and Twenty eight only

Result Passed

Clerk-in-Charge　　Superintendent　　Controller of Examinations

0788

Kakatiya University

Provisional Certificate

This is to certify that K. Narendar

Son / Daughter of K. Srinivas Reddy

has been declared qualified for the award of the Ph.D. Degree in Physics of this University in Jan. 2014

Topic of Thesis :

" Thermophysical Properties of Wrought Aluminum Alloys by Gamma Ray Attenuation Technique "

Warangal - 506 009.

Date : 28 JAN 2014

Registrar

Thermochimica Acta 569 (2013) 90–96

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journal homepage: www.elsevier.com/locate/tca

Thermo physical properties of wrought aluminum alloys 6061, 2219 and 2014 by gamma ray attenuation method

K. Narender[a], A.S. Madhusudhan Rao[b], K. Gopal Kishan Rao[c], N. Gopi Krishna[a,*]

[a] Department of Physics, Kakatiya University, Warangal 506009, India
[b] Varadha Reddy College of Engineering, Warangal 506009, India
[c] CIC, Kakatiya University, Warangal 506009, India

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ABSTRACT

The temperature dependence of linear attenuation coefficient, density and thermal expansion of 6061, 2219 and 2014 aluminum alloys have been studied by gamma ray attenuation technique in the temperature range 298–773 K. The gamma ray attenuation studies have been carried out using a gamma ray densitometer fabricated in our laboratory. The linear attenuation coefficients (μ_l) for the alloys as a function of temperature and the coefficients of temperature dependence of density have been reported. The variation of density and thermal expansion of these alloys have been represented by linear equations. Volume thermal expansion coefficients have been reported.

1. Introduction

Aluminum is very important and extremely useful engineering material with very good physical properties. Although pure aluminum has low strength, it can be alloyed to gain high strengths,so that it finds many applications in modern technology. The knowledge of temperature dependence of density and thermal expansion is very important for understanding their physical properties like thermal conductivity, specific heats, diffusion coefficients, thermo elastic constants and their applications in various fields. Thermo physical properties can be investigated through a variety of techniques like dilatometric method, pycnometric method, electromagnetic levitation method, method of maximal pressure in gas bubble, high temperature electrostatic levitation, method of sessile drop, method of hydrostatic weighing and gamma ray attenuation method. The gamma radiation attenuation technique for the determination of thermo physical properties in the condensed state offers several advantages over other methods at high temperatures. This is because the gamma ray is not in any kind of thermal contact with the material and hence the thermal losses are also reduced and this condition eliminates sample and probe compatibility problem. Using this technique Drotning [1] measured thermal expansion of isotropic solid materials at high temperatures. He studied thermal expansion of Aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state [2,3]. A number of other techniques have been used to measure the temperature dependence of density of metals [4–7], and alloys [8–15] at high temperatures. Recently the behavior of thermal expansion of carbon fiber reinforced 6061 aluminum alloy has been reported [16] and mechanical properties of alloy 2219 have also been reported [17]. It is desirable to study the thermophysical properties of new materials at high temperatures for their practical applications. No reports on temperature variation of thermophysical properties of 6061, 2219 and 2014 aluminum alloys were found and hence in the present communication, we report the results of systematic study on the density and thermal expansion of these alloys in the temperature range 298–773 K determined using gamma ray attenuation technique.

2. Experimental

In order to carry out this work, we have fabricated a gamma ray densitometer based on the design proposed by Drotning [1] and a programmable temperature controlled furnace (PTC) which can reach up to a temperature of 1300 K in our laboratory. Cross-sectional view of gamma ray densitometer is shown in Fig. 1. The gamma radiation detector used in our study is a sodium iodide-thallium activated detector. The 0.0762 m diameter and 0.0762 m thick crystal is integrally coupled to a 0.0762 m diameter photo multiplier tube (PMT). The PMT has a 14 pin base and can

* Corresponding author. Tel.: +91 9849942805.
E-mail addresses: kethireddyn@yahoo.com (K. Narender), ngopikrishna13@yahoo.com (N.G. Krishna).

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International Journal of Scientific & Engineering Research, Volume 5, Issue 3, March-2014
ISSN 2229-5518

γ-Ray Attenuation Studies on NaI

A.S. Madhusudhan Rao[1], K. Narender[2]

Abstract—Temperature dependent γ- ray attenuation studies have been carried out by a γ- ray densitometer fabricated in our laboratory. The linear attenuation coefficients (μ_l) of NaI as a function of temperature in the range 300K-900K have been determined using different energies of γ-beam viz., Am (0.0595MeV), CO(1.173MeV & 1.332MeV). The coefficient of temperature dependence of density has been reported. The variation of density and thermal expansion of NaI in the temperature range have been studied and compared with the results available in the literature. The temperature dependence of linear attenuation coefficient, density and thermal expansion has been represented by second degree polynomials. Volumetric thermal expansion coefficient as a function of temperature has been reported by γ-ray attenuation studies for the first time.

Index Terms—Linear attenuation coefficient, density, thermal expansion.

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1 INTRODUCTION

THE study of temperature dependence of fundamental thermophysical properties such as density and thermal expansion of solids is very important for understanding temperature variation of other properties like elastic constants, refractive indices, dielectric constants, thermal conductivity, diffusion coefficients and other heat transfer dimensionless numbers. Thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material in high temperature applications in science and technology. Number of methods have evolved for the determination of density and thermal expansion of solids at high temperature Thermal expansion studies on alkali halides have been reported by several workers using X-ray diffraction [1-3], dilatometry [4, 5], Fabrey - Perot interference method [6] and by other theoretical models [7-14]. Using γ-ray attenuation technique W.D. Drotning [15] measured thermal expansion of isotropic solid materials at high temperatures. He studied thermal expansion of Aluminum at high temperatures and such studies have been extended by him to study the thermal expansion of other materials such as metals and glasses in the condensed state [16]. Authors employed γ-radiation attenuation technique for the determination of thermo physical properties of alkali halides by using γ-beam of energy Cs (0.66MeV) [17]. The γ- radiation attenuation technique for the determination of thermo physical properties in the condensed state offers several advantages over other methods at high temperatures. This is possible because the γ-ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and in addition eliminates sample and probe compatibility problem.

Present work focuses the studies on temperature dependence of γ-ray attenuation, density and thermal expansion of Na in the temperature range 300K-900K using different energies of γ- beam viz., Am (0.0595MeV), CO (1.173MeV & 1.332MeV) for the first time. We also compare with the data available in literature in the temperature range 300K-900K. The present study has been carried out using a γ-ray densitometer fabricated in our laboratory which includes a programmable temperature controlled furnace (PTC).

2 THEORY

The technique of γ-ray attenuation method is based on the fundamental equation

$$I = I_0 \exp[-\mu \rho l] \quad (1)$$

where I_0, the intensity of γ- ray before passing through the sample, I, the intensity of γ- ray after passing through the sample, μ, the mass attenuation coefficient of the sample, ρ, the density of the sample and l, the thickness of the sample. It is clear from Equation (1) that any change in the temperature of the solid is accompanied by change in it's density causing a change in the measured intensity. The density and thermal expansion of the materials studied in the present work have been determined following the method suggested by Drotning [15]. The relation between coefficient of volumetric thermal expansion (α_ρ) and coefficient of linear thermal expansion (α_l) is given by

$$\alpha_\rho \equiv -3\,\alpha_l(1 - 2\,\alpha_l\Delta T) \quad (2)$$

where α_ρ and α_l are mean values over a temperature interval $\Delta T = T_2 - T_1$ such that $\alpha_l = (l_2 - l_1) / (\Delta T)l_1$ and

$$\alpha_\rho = (\rho_2 - \rho_1) / (\Delta T)\rho_1$$

where $\rho_1 = \rho(T_1)$, $l_1 = l(T_1)$, etc.

Rewriting Equation (2) as

$$(\Delta T)^2 \alpha_l\, \alpha_\rho = z - (\Delta T)\,\alpha_l - (\Delta T)\,\alpha_\rho \quad (3)$$

where z is defined by

$$z = \ln\{[I(T_1)I_0(T_2) / I(T_2)I_0(T_1)] / (\mu\, \rho_1\, l_1)\}$$
$$= (\rho_2 l_2 / \rho_1 l_1) - 1 \quad (4)$$

Substituting for α_ρ from Equation (2) gives

$$-3\,(\Delta T)^2 \alpha_l^2 (1 - 2\,\alpha_l\, \Delta T) = z - (\Delta T)\,\alpha_l + 3(\Delta T)\,\alpha_l(1 - 2\alpha_l\Delta T).$$

- A.S. Madhusudhan Rao, Department of Physics, Varadha Reddy College of Engineering, Warangal, Andhra Pradesh, India-506001, PH-9849352562 E-mail: madhusmmsrtgs@yahoo.co.in
- K. Narender Department of Physics, Kakatiya University, Warangal, Andhra Pradesh, India-506001. PH-9393662344 E-mail: kethireddynarender@gmail.com

AIP Conference Proceedings

Density and thermal expansion of 7010 and 7017 wrought aluminum alloys by gamma ray attenuation technique

K. Gopal Kishan Rao, K. Narender, A. S. Madhusudhan Rao, and N. Gopi Krishna

Citation: AIP Conf. Proc. 1512, 490 (2013); doi: 10.1063/1.4791125
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ISSN 2229-5518

Temperature dependent density and thermal expansion of 5088 wrought aluminum alloy by Gamma Ray Attenuation Technique

K. Narender, A.S. Madhusudhan Rao[a], Ch. Snehalatha Reddy[b]
Department of Physics, Kakatiya University, Warangal-506009, India
[a]Varadha Reddy College of Engg. Warangal-506009, India
[b]Government Degree College, Peddapally, Karimanagar- India

Abstract— The density and thermal expansion of wrought aluminum alloy 5088 has been measured from 300K - 850K by measuring attenuation of gamma beam of different energies viz, Cs(661.16 KeV), Am (59.54 KeV) Co (1173 KeV& 1332 KeV). The temperature dependence of linear attenuation coefficient (□) of gamma photons of different energies in the temperature range 300 – 850 K for the alloy has been reported. The gamma ray attenuation studies have been carried out by using a gamma ray densitometer. the variation of density and thermal expansion of the alloy has been represented by linear equations. The coefficients of temperature dependence of density, volume thermal expansion and mass attenuation coefficients have been reported for the alloy.

Index Terms— □-ray attenuation, linear attenuation coefficient, density, thermal expansion.

1 Introduction

THIS document Density and thermal expansion are the basic parameters in discussing nature and behavior of metals and alloys. Density values are necessary to the process of computer simulation, the calculation of other physical properties and extracting quantitative structural information from diffraction spectra. The knowledge of temperature dependence of their density and thermal expansion is very important for understanding their physical properties like thermal conductivity, specific heats, diffusion coefficients, thermo elastic constants and their applications in various fields.Thermo physical properties can be investigated through a variety of techniques. which have evolved for the determination of density and thermal expansion of solids at high temperature. Some of the techniques are Archimedean method, pycnometry, dilatometry, electromagnetic levitation, Method of maximal pressure in a gas bubble, method of sessile drop, hydrostatic weighing, high temperature electrostatic levitation and gamma ray densitometry. Thermal expansion studies on isotropic solids have been reported by several workers using X-ray diffraction [1-3], dilatometry [4,5], Fabrey-Perot interference method [6] and by other theoretical models [7-13]. The gamma radiation attenuation technique for the determination of thermo physical properties in the condensed state offers several advantages over other methods at high temperatures. This is possible because the gamma ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and this condition eliminates sample and probe compatibility problem. Using this technique Drotning [14] measured thermal expansion of isotropic solid materials at high temperatures. He studied thermal expansion of Aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state [15 16]. A number of other techniques have been used to measure the temperature dependence of density of metals [17-20], alloys [21-28] at high temperatures. Recently the behavior of thermal expansion of carbon fiber reinforced 6061 aluminum alloy has been reported [29] and mechanical properties of alloy 2219 have also been reported [30]. The thermal expansion of ZrW2O8 Polyimide hybrid films was determined [31]. In this communication we report the density and thermal expansion of aluminum alloy 5088 in the temperature range 300 K to 850 K determined from gamma ray attenuation technique, as wrought aluminum alloys have wide range of applications in science and engineering.

2 Experimental

The gamma ray densitometer and a programmable temperature controlled furnace (PTC) was designed and fabricated following the design proposed by Drotning [14]. The furnace can reach up to 1300K.To detect the penetrating gamma radiation a sodium iodide – thallium activated detector was used. The 7.62X10-2m diameter and 7.62X10-2m thick crystal is integrally coupled to a 7.62X10-2m diameter photo multiplier tube (PMT). The PMT has a 14 pin base and can be mounted on two types of PMT preamplifier units. The one used in our study is a coaxial in-line pre-amplifier. The detector has a energy resolution of 8.5% for 137Cs. The alloy studied in the present work was prepared by ingot metallurgy route. The alloy was melted in the air, in the induction furnace and cast iron moulds were used to obtain ingot. The ingot was subsequently homogenized at about 813 K and hot rolled to obtain 12mm - 15mm thick plates.

The chemical composition of 5088 alloy is given in Table 1. The X-ray diffraction (XRD) pattern of the alloy is shown in Fig.1. The XRD pattern confirms that the alloy is in the fcc phase. The alloy sample was machined into a cuboid with all

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Determination of effective atomic numbers and mass attenuation coefficients of wrought aluminium alloys 2014 and 2219 with multi energetic photons

[1]Dr.K.Narender, [2]Dr.Ch.Snehalatha Reddy,
[1]Department of Physics, Government Degree college Narsampet, Warangal-506009, India
[2]Govt.Degree College Peddapally Karimnagar, India

Abstract: *The total mass attenuation coefficients (μ_m) for wrought aluminum alloys 2014 and 2219 were measured at 59.5, 661.16, 1173, 1332keV photon energies. The samples were exposed to ^{137}Cs, ^{60}Co and ^{241}Am radioactive point sources using narrow beam transmission arrangement. The gamma-rays were counted by a NaI(Tl) detector with resolution of 8% of photon energy. Total atomic cross-sections (□) and electronic cross-sections (□$_e$), effective atomic number (Z_{eff}) ,effective electron density (N_e) and photon mean free path(λ) have been determined using the values of μ_m for 2014,and 2219 aluminum alloys. The experimental values have been compared with theoretical values estimated from mixture rule and XCOM and the agreement is found to be good.*

Keywords: *mass attenuation coefficient, effective atomic number, effective electron number, total atomic, electronic cross sections*

1. INTRODUCTION:

In view of the extensive use of the radioactive sources in medicine, agriculture, industry etc., the study of photon atom interaction in different materials has gained importance in recent years. Since these interactions involve various compounds with different compositions, the effective atomic number of a material composed of several elements cannot be expressed by a single number. The (Z_{eff}) becomes an energy dependent parameter due to the different partial photon interaction processes with matter for which the various atomic numbers in the material have to be weighted differently. The effective atomic number (Z_{eff}) for the total and partial gamma ray interactions in alloys are equally important. In all materials, the absorption and scattering of gamma-rays are related to value of Z_{eff} of materials and the energy of photons. There is energy transfer from photon to matter in these interactions. Although the dependence on the photon energy is dominant in interaction with low energies, it can be negligible at high energies. A number of investigations on effective atomic number for total and partial photon interactions have been reported in the literature. Theoretical [1-10] and experimental [11-25] studies have been reported in a wide range of energies from a few keV up to several GeV. There was a study on few compounds in which the effective atomic number has been determined using the ratio of elastic-to-inelastic scattering [26, 27]. While the extensive and accurate data sets are available for elements [3-7] Similar studies have been carried out on various types of mixtures like alloys compounds and other composite materials including biological tissues, polymers and cements. In the present work, wrought aluminum alloys 2014 and 2219 have been subjected to attenuation studies at 59.5, 661.6, 1173, 1332keV photon energies to estimate the corresponding effective atomic number values for total photon interactions. Two different theoretical techniques, semi empirical approach and XCOM programme have been used for obtaining the calculated values.

2. EXPERIMENTAL:

Transmission experiments with the narrow beam (good-geometry) setup were used for measuring the incident and transmitted intensities to determine the attenuation coefficient. In the present work the total attenuation coefficient was measured at 59.5, 661.6, 1173, 1332keV photon energies using ^{137}Cs, ^{60}Co and ^{241}Am sources. The alloys studied in the present work were prepared by ingot metallurgy route. The alloys were melted in the air, in the induction furnace and cast iron moulds were used to obtain ingots. These ingots were subsequently homogenized at about 813K and hot rolled to obtain 12mm - 15mm thick plates. These alloy plates were precipitation strengthened by heat treatment (aging).

The alloy 6061 has been heat treated at 813K for solutionizing. It has been soaked at that temperature for 24 hours. For precipitation strengthening it has been water quenched. For aging, the alloy has been heat treated at 433K for 18 hours, and at 448K for 8 hours. Annealing has been done at 685K for 3 hours and has been allowed to cool naturally. The alloy 2219 has been heat treated at 805K for solutionizing and it was followed by cold water quenching. The alloy has been aged at 463K for 36 hours followed by cooling in air. Annealing has been done at 685K for 3 hours and has been allowed to cool naturally. For alloy 2014 solution heat treatment has been done at 807K followed by cold water quenching. Annealing has been done at 685K for 3 hours followed by cooling at the rate of 10K per hour down to 533K and then allowed to natural cooling.

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ARTICLE

Temperature Dependent Gamma Ray Attenuation Study on Caesium Halides

A. S. Madhusudhan Rao[1], **K. Narender**[2], **K. Gopal Kishan Rao**[3] **and N. Gopi Krishna**[2,*]

[1]*Department of Physics, Vaagdevi Reddy College of Engineering, Warangal 506005, India*
[2]*Department of Physics, Kakatiya University, Warangal 506009, India*
[3]*CIC, Kakatiya University, Warangal 506009, India*

ABSTRACT

The temperature dependence of linear attenuation coefficient, density and thermal expansion of Caesium Halides (CsCl, CsBr, and CsI) has been studied by γ-ray attenuation technique in the temperature range 300 K–850 K. The γ-ray attenuation studies have been carried out using a γ-ray densitometer. The linear attenuation coefficients (μ_l) of CsCl, CsBr, and CsI as a function of temperature have been determined. The variation of density and coefficients of temperature dependence of density have been reported. The variations of thermal expansion of CsCl, CsBr, and CsI studied in the present work have been compared with results obtained from other methods. The variation in these thermophysical properties have been represented by linear equations. Volume thermal expansion coefficients and mass attenuation coefficients (μ) have been reported.

KEYWORDS: Linear Attenuation Coefficient, Density, Thermal Expansion, γ-Ray Densitometer, Mass Attenuation Coefficient.

1. INTRODUCTION

The study of temperature dependence of fundamental thermophysical properties such as density and thermal expansion of solids is very important for understanding temperature variation of other properties like elastic constants, refractive indices, dielectric constants, thermal conductivity, diffusion coefficients and other heat transfer dimensionless numbers. Thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material in high temperature applications in science and technology. Number of methods have evolved for the determination of density and thermal expansion of solids at high temperatures like Archimedean method, pycnometry, dilatometry, electromagnetic levitation, Method of maximum pressure in gas bubble, method of sessile drop, hydrostatic weighing, high temperature electrostatic levitation and gamma ray densitometry. Thermal expansion studies on alkali halides have been reported by several workers using X-ray diffraction, dilatometry, Fabry-Perot interference method and by other models. Such studies on alkali halides by γ-ray attenuation technique are lacking. Using γ-ray attenuation technique Drotning measured thermal expansion of solid materials at high temperatures. He studied thermal expansion of Aluminium and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state. The γ-radiation attenuation technique for the determination of thermo physical properties in the condensed state offers several advantages over other methods at high temperatures. This is possible because the γ-ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and in addition eliminates sample and probe compatibility problem. The γ-ray attenuation technique has been used to carry out the studies on temperature dependence of γ-ray attenuation, density and thermal expansion of CsCl, CsBr and CsI. In this communication, we report the linear attenuation coefficient of γ-radiation, density and thermal expansion of CsCl, CsBr and CsI as a function of temperature in the temperature range 300 K–850 K. A γ-ray densitometer and a programmable temperature controlled furnace which can reach up to a temperature of 1300 K have been designed and fabricated in our laboratory to carry out the work. The data on temperature dependence of coefficient of linear thermal expansion of these alkali halides have been compared with selected experimental and theoretical data in literature.

*Author to whom correspondence should be addressed.
Email: ngopikrishna@yahoo.com
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Study on Temperature Variation of Densities of Antimony and Bismuth Using Gamma Ray Attenuation Technique

By K. Gopal Kishan Rao, K.Narendar, A.S. Madhusudhan Rao, N. Gopi Krishna & K. Ashoka Reddy

Abstract - The densitometer was designed and fabricated with the underlying principle of gamma (γ) ray attenuation produced on passing a collimated beam of monochromatic gamma radiation through any material. After standardization, the gamma ray attenuation coefficient (μ) was calculated to determine changes in densities as a function of temperature of Sb and Bi in solid phase. The density of Sb and Bi at room temperature are 6.697×10^3 Kgm^{-3} and 9.79×10^3 Kgm^{-3}, and their melting points are 903.78 K and 544.7 K respectively. The measurements were conducted below melting point. The experimental results are in reasonable agreement with published data and may be used as reference data on variation of densities at various temperatures of solids.

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STUDY ON TEMPERATURE VARIATION OF DENSITIES OF ANTIMONY AND BISMUTH USING GAMMA RAY ATTENUATION TECHNIQUE

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Thermophysical Properties of Rubidium and Lithium Halides by γ-Ray Attenuation Technique[1]

S. Ammiraju, R. Madhusudhan[a], K. Narender[b], K. G. K. Rao[c], and N. G. Krishna[b]

[a] *Department of Physics, Varadha Reddy College of Engg., Warangal, 506009 India*

[b] *Department of Physics, Kakatiya University Warangal*

[c] *CIC, Kakatiya University Warangal, India*

e-mail: madhuammiraju@yahoo.co.in

Abstract—The temperature dependence of linear attenuation coefficient, density and thermal expansion of rubidium halides (RbCl, RbBr and RbI) and lithium halides (LiCl, LiBr and LiF) has been studied by γ-ray attenuation technique. The γ-ray attenuation studies have been carried out using a γ-ray densitometer. The mass attenuation coefficients (μ_m) of rubidium and lithium halides have been determined using γ-beam of different energies viz. (0.0595, 0.662, 1.173 and 1.332 MeV) respectively. The variation of density and coefficients of temperature dependence of density have been measured using Cs (0.662 MeV) source. The values of density at different temperatures have been used to estimate the values of linear attenuation coefficients (μ_l) of the alkali halides studied in the present work for other γ-energies. The variation of thermal expansion of alkali halides studied in the present work has been compared with the results obtained from other methods. The variation in these thermophysical properties have been represented by linear equations. Volume thermal expansion coefficients and mass attenuation coefficients (μ_m) of these compounds for the different energies have been reported and compared with data calculated by empirical and experimental method.

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INTRODUCTION

The interaction of high energy photons with matter is important in radiation, medicine and biology, nuclear engineering and space technology. The knowledge of physical parameters such as mass attenuation coefficients, linear attenuation coefficients, atomic and electronic crosssections plays an important role in understanding the physical properties of composite materials like inorganic compounds. They are invaluable in many applied fields, such as nuclear diagnostics, radiation protection, nuclear medicine and radiation dosimetry. The mass attenuation coefficient is a measurement of how strongly a chemical specie or substance absorbs or scatters radiation at a given wavelength, per unit mass. Mass attenuation coefficient is a fundamental tool to derive many other photon interaction parameters. The linear attenuation coefficient (μL) describes the fraction of a beam of X-rays or γ-rays that is absorbed or scattered per unit thickness of the absorber. The researchers have focused on the studying of photon interaction parameters with matter [1–3].

The study of thermophysical properties such as density and thermal expansion of solids and their temperature dependence is very important for understanding variation of other properties like elastic constants, refractive indices, and dielectric constants, thermal conductivity, diffusion coefficients and other heat transfer dimensionless numbers as a function of temperature. Temperature dependent thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material for high temperature applications in science and technology. The density and thermal expansion of solids at high temperature can be determined by number of methods like Archimedean method, pycnometry, dilatometry, and electromagnetic levitation, Method of maximal pressure in gas bubble, method of sessile drop, hydrostatic weighing, high temperature electrostatic levitation [4] and gamma ray densitometry [5–9]. Thermal expansion studies on alkali halides have been reported by several workers using X-ray diffraction [10, 11], dilatometry [12, 13], Fabrey-Perot interference method [14] and by other theoretical models [15–22]. Such studies on alkali halides by γ-ray attenuation technique are lacking. Using γ-ray attenuation technique, Drotning [23] measured thermal expansion of solid materials at high temperatures. He studied thermal expansion of several solids at high temperatures and such studies have been extended by him to study the thermal expansion of metals of low density and glasses in the condensed state [24]. The gamma ray attenuation technique is a method utilizing the gamma beam only as a probe, which is neither in physical nor in thermal contact with the sample. The

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Mass Attenuation Coefficients, Effective atomic and Electron Numbers of Alkali Halides for Multi-Energetic Photons

A.S. Madhusudhan Rao[1], K. Narender[2] K. Gopal Kishan Rao[3], N. Gopi Krishna[2] and Radha Krishna Murthy[3]
[1] Department of Physics, Varadha Reddy College of Engineering, Warangal, INDIA
[2] Department of Physics, Kakatiya University, Warangal, INDIA
[3] CIC, Kakatiya University, Warangal, INDIA

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Abstract

Mass attenuation coefficients (μ_m) for alkali halides (RbCl, RbBr and RbI) were determined experimentally using narrow collimated beam transmission method. The samples were irradiated with radioactive point source of different γ-energies viz. Cs (0.662MeV), Am (0.0595MeV), Co (1.173MeV and 1.332MeV). The transmitted γ- photons were detected and recorded by a NaI(Tl) scintillation detector with resolution of 8.5% for 0.662MeV of ^{137}Cs. Theoretical mass attenuation coefficients were estimated using mixture rule. The experimental values reported for all the alkali halides in the present work are compared with the calculated values and the values obtained from X-COM. Linear attenuation coefficient (μ_l), total atomic cross-section (σ_t), electronic cross-section (σ_e), effective atomic number (Z_{eff}), electron density (N_{eff}) and photon mean free-path (λ) were determined with semi-empirical relations using mass attenuation coefficients obtained experimentally and theoretically. Experimental values of parameters reported for all alkali halides investigated in the present work using different γ-energies are compared with the estimated theoretical data.

Keywords: Mass attenuation coefficient, linear attenuation coefficient, effective atomic number, effective electron density.

Introduction

The interaction of high energy photons with matter is important in radiation, medicine and biology, nuclear engineering and space technology. The knowledge of parameters such as mass attenuation coefficient (μ_m), linear attenuation coefficient (μ_l), total atomic cross-section (σ_t), electronic cross-section (σ_e), effective atomic number (Z_{eff}), electron density (N_{eff}), mean free path (λ) plays an important role in understanding the physical properties of composite materials. They are invaluable in many applied fields, such as nuclear diagnostics, radiation protection, nuclear medicine and radiation dosimetry. The quantities can be evaluated theoretically and experimentally. Mass attenuation coefficient is a measurement of how strongly a chemical specie or substance absorbs or scatters radiation at a given wavelength, per unit mass. Mass attenuation coefficient is a useful parameter to derive many other physical parameters. Linear attenuation coefficient (μ_l) describes the fraction of a beam of X-rays or γ- rays that is absorbed or scattered per unit thickness of the absorber. Researchers have focused on the studying of photon interaction parameters with matter.

There have been a great number of experimental and theoretical investigations to determine (μ_m) values in various elements and compounds/mixtures. Hubbel[1] reported (μ_m) values for 40 elements and 45 mixtures and compounds over the energy range from 1keV to 20MeV. These tables were replaced with Hubbel and Seltzer tabulation for all elements (Z=1-92) and 48 additional substances of dosimetric interest[2]. Berger and Hubbel developed the theoretical tables and computer program (XCOM) for calculating attenuation coefficients for elements, compounds and mixtures for photon energies from 1keV to 100GeV[3]. This program was transformed to the Windows platform by Gerward et al.[4] and the Windows version is being called WinXcom.

Scattering and absorption of X-ray and γ-radiation are related to the density and atomic numbers of an element. In composite materials, it is related to the effective atomic number (Z_{eff}) and the electron density (N_{eff}). In composite material, a single number cannot represent the atomic number uniquely across the entire energy range, as the partial interaction cross-section have different atomic number, Z, dependence[5]. This number is called the effective atomic number, (Z_{eff}), which is very useful parameter for many fields. Effective atomic number is a convenient parameter for representing the attenuation of X-rays and γ- rays in a composite medium and particularly for the calculation of dose in radiation therapy[6]. This number is very useful in choosing a substitute composite material in place of an element for a given energy depending on the requirement. Several investigators[7-19] have made extensive (Z_{eff}) studies in variety of composite materials such as biologically important materials, semiconductors, alloys, dosimetric compounds and glasses. In literature, there are almost no reports on the study of (Z_{eff}) of Alkali Halides. This prompted us to carry out this work.

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Temperature Dependence of Density and Thermal Expansion of Wrought Aluminum Alloys 7041, 7075 and 7095 by Gamma Ray Attenuation Method

Kethireddy Narender[1], Ammiraju Sowbhagya Madhusudhan Rao[2], Kalvala Gopal Kishan Rao[3], Nallacheruvu Gopi Krishna[1]
[1]Department of Physics, Kakatiya University, Warangal, India
[2]Varadha Reddy College of Engineering, Warangal, India
[3]CIC, Kakatiya University, Warangal, India
Email: ngopikrishna2012@yahoo.com

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ABSTRACT

The gamma quanta attenuation studies have been carried out to determine mass attenuation coefficients of 7041, 7075 and 7095 wrought aluminum alloys. The temperature dependence of linear attenuation coefficient, density and thermal expansion of these wrought aluminum alloys in the temperature range 300 K - 850 K have been reported. The measurements were done by using a gamma ray densitometer designed and fabricated in our laboratory. The data on variation of density and linear thermal expansion with temperature have been represented by linear equations. Volume thermal expansion coefficients have been reported.

Keywords: Density; Thermal Expansion; Linear Attenuation Coefficient; Mass Attenuation Coefficient

1. Introduction

Number of methods [1-13] have evolved for the determination of density and thermal expansion of solids at high temperature like Archimedean method, pycnometry, dilatometry, electromagnetic levitation, Method of maximal pressure in a gas bubble, method of sessile drop, hydrostatic weighing, high temperature electrostatic levitation and gamma ray densitometry. Thermal expansion studies on isotropic solids have been reported by several workers using X-ray diffraction [1,2], dilatometry [3,4], Fabrey-Perot interference method [6] and by other theoretical models [6-13]. Density and Thermal expansion are fundamental thermo physical properties of solids. The study of temperature dependence of these properties is very important in understanding the temperature variation of other properties like elastic constants, refractive indices, dielectric constants, thermal conductivity, diffusion coefficients and other heat transfer dimensionless numbers. Thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material for the construction of metrological instruments and in the choice of container material in nuclear fuel technology.

Aluminum alloys are very important and extremely useful engineering materials with very good physical properties and finds many applications in modern technology. 7041, 7075 and 7095 aluminum alloys have wide range of applications in aerospace, military and nuclear industry. The gamma radiation attenuation technique for the determination of thermo physical properties in the condensed state offers several advantages over other methods at high temperatures. This is possible because the gamma ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and this condition eliminates sample and probe compatibility problem. Using this technique Drotning [14] measured thermal expansion of isotropic solid materials at high temperatures. He studied thermal expansion of Aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state [14,15]. Recently the gamma radiation attenuation technique has been used to measure the temperature dependence of density of metals [16-19], alloys [20-27] at high temperatures. It is desirable to study the thermophysical properties of new materials at high temperatures for their use in practical applications. There is no study on the temperature variation of thermo physical properties of 7041, 7075 and 7095 aluminum alloys and as such, in the present article, we report the

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Thermal Expansion of Alkali Halides by Gamma-Ray Attenuation

A. S. Madhusudhan Rao[1], K. Narender[1], K. Gopal Kishan Rao[2], and N. Gopi Krishna[1,*]

[1]Department of Physics, Kakatiya University, Warangal 506009 India
[2]CIC, Kakatiya University Warangal, India

The temperature dependence of linear attenuation coefficient, density and thermal expansion of KCl, KBr, KF and KI has been studied by γ-ray attenuation technique in the temperature range 300 K–1000 K. The γ-ray attenuation studies have been carried out using a γ-ray densitometer. The linear attenuation coefficients (μ_l) of KCl, KBr, KF and KI as a function of temperature have been determined using Cs (0.66 MeV), Am (0.595 MeV), CO (1.173 MeV and 1.332 MeV) different energies of γ-beam. The variation of density and coefficients of temperature dependence of density have been reported. The variation of thermal expansion of these alkali halides studied in the present work has been compared with the results obtained from other methods. The variation in these thermophysical properties have been represented by linear equations. Volume thermal expansion coefficients and mass attenuation coefficients (μ) of these compounds for the different energies have been reported and compared with data calculated by other method.

KEYWORDS: Linear Attenuation Coefficient, Density, Thermal Expansion, γ-Ray Densitometer, Programmable Temperature Furnace.

1. INTRODUCTION

The study of thermophysical properties such as density and thermal expansion of solids and their temperature dependence is very important for understanding variation of other properties like elastic constants, refractive indices, and dielectric constants, thermal conductivity, diffusion coefficients and other heat transfer dimensionless numbers as a function of temperature. Thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material for high temperature applications in science and technology. The density and thermal expansion of solids at high temperature can be determined by number of methods like Archimedean method, pycnometry, dilatometry, and electromagnetic levitation, Method of maximal pressure in gas bubble, method of sessile drop, hydrostatic weighing, high temperature electrostatic levitation and gamma ray densitometry. Recently Thermal Expansion of ZrW_2O_8/Polyimide Hybrid Films was determined.[1] Thermal expansion studies on alkali halides have been reported by several workers using X-ray diffraction,[2–4] dilatometry,[5,6] Fabrey-Perot interference method[7] and by other theoretical models.[8–15] Such studies on alkali halides by γ-ray attenuation technique are lacking. Using γ-ray attenuation technique Drotning[16] measured thermal expansion of isotropic solid materials at high temperatures. He studied thermal expansion of Aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state.[17] The γ-radiation attenuation technique for the determination of thermo physical properties in the condensed state has several advantages over other methods at high temperatures. This is possible because the γ-ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and in addition eliminates sample and probe compatibility problem.

The γ-ray attenuation technique has been used to carry out the studies on temperature dependence of γ-ray attenuation, density and thermal expansion of KCl, KBr, KF and KI. In this communication, we report the linear attenuation coefficient of γ-radiation of different energies, density and thermal expansion of KCl, KBr, KF and KI as a function of temperature in the temperature range 300 K–1000 K. A γ-ray densitometer and a programmable temperature controlled furnace (PTC) which can reach high temperature has been designed in our laboratory to carry out the work. The data on temperature dependence of coefficient of

*Author to whom correspondence should be addressed.
Email: ngopikrishna@yahoo.com
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Research Article

Studies on Thermophysical Properties of CaO and MgO by γ-Ray Attenuation

A. S. Madhusudhan Rao[1] and K. Narender[2]

[1] *Department of Physics, Varadha Reddy College of Engineering, Warangal 506009, India*
[2] *Kakatiya University, Warangal 506009, India*

Correspondence should be addressed to A. S. Madhusudhan Rao; madhusudhanammiraju@yahoo.com

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The study on temperature dependent γ-ray attenuation and thermophysical properties of CaO and MgO has been carried out in the temperature range 300 K–1250 K using different energies of γ-beam, namely, Am (0.0595 MeV), Cs (0.66 MeV), and Co (1.173 MeV and 1.332 MeV) on γ-ray densitometer fabricated in our laboratory. The linear attenuation coefficients (μ_l) for the pellets of CaO and MgO as a function of temperature have been determined using γ-beam of different energies. The coefficients of temperature dependence of density have been reported. The variation of density and linear thermal expansion of CaO and MgO in the temperature range of 300 K–1250 K has been studied and compared with the results available in the literature. The temperature dependence of linear attenuation coefficients, density, and thermal expansion has been represented by second degree polynomial. Volume thermal expansion coefficients have been reported.

1. Introduction

Density and thermal expansion are fundamental thermophysical properties of solids. The study of temperature dependence of these properties is very important in understanding the temperature variation of other properties like elastic constants, refractive indices, dielectric constants, thermal conductivity, diffusion coefficients, and other heat transfer dimensionless numbers. Thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material for the construction of metrological instruments and the choice of container material in nuclear fuel technology. A number of methods have evolved for the determination of density and thermal expansion of solids at high temperature like Archimedean method [1–3], pycnometry [4–8], dilatometry [9–12], electromagnetic levitation [13], method of maximal pressure in gas bubble [14–18], method of sessile drop [19], hydrostatic weighing [20, 21], high temperature electrostatic levitation [22], and gamma ray densitometry [23–34]. Using γ-ray attenuation technique Drotning [23] measured thermal expansion of solid materials at high temperatures. He studied thermal expansion of aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state [24]. The γ-radiation attenuation technique for the determination of thermophysical properties in the condensed state has several advantages over other methods at high temperatures. This is possible because the γ-ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and in addition eliminate sample and probe compatibility problem.

We extended, for the first time, the γ-ray attenuation technique, to carry out the studies on temperature dependence of γ-ray attenuation and thermophysical properties of CaO and MgO. In the present communication, we report the temperature dependence of linear attenuation coefficient for different energies of γ-beam [Am (0.0595 MeV), Cs (0.66 MeV), Co (1.173 MeV and 1.332 MeV)], density, and thermal expansion of CaO and MgO in the temperature range 300 K–1250 K. In order to carry out this work, we have fabricated in our laboratory a γ-ray densitometer and

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Thermal Properties of Sb, Bi And Sn in Solid Phase by Gamma Ray Attenuation Technique

* Kalvala Gopal Kishan Rao ** Ammiraju Sowbhagya Madhusudhan Rao *** Kethireddy Narender **** Nallacheruvu Gopi Krishna ***** K. Ashoka Reddy

* Central Instrumentation Centre, Kakatiya University, Warangal, (A.P) -506009 -India.

** Varadha Reddy College of Engineering, Hasanparthy, Warangal(A.P)- 506009 –India

*** Government Junior College, Hanamkonda,Warangal(A.P)- 506001 –India

**** Department of Physics, Kakatiya University,Warangal , (A.P) -506009 – India

***** Kakathiya Institute of Technology & Science,Warangal, (A.P) India.

ABSTRACT

The gamma ray densitometer was designed and fabricated to carry out gamma ray attenuation studies and determine changes in linear attenuation coefficients (μl) of Sb, Bi and Sn as a function of temperature in the range 298K-873K. The variation of density with temperature of Sn in solid phase in the temperature range 298K- 448K has been reported. The temperature dependence of density of Sn has been represented by linear equation and it's coefficient of volume thermal expansion has been determined. The experimental results on variation of density with temperature in solid phase of Sn have been extrapolated into liquid phase for comparison

Keywords: Linear attenuation coefficient, Density, Thermal expansion.

1.Introduction

Metals and alloys constitute basic engineering materials for innumerable applications in day to day life. It is very interesting to investigate the variation of gamma attenuation coefficients of engineering materials as a function of temperature and this study can be used for determination of thermo-physical properties of materials which are useful in a variety of scientific and technological applications

The gamma radiation attenuation technique has been widely used to study the variation of density as a function of temperature for several materials [1-4]. This technique also been extended for the measurement of thermal expansion of isotropic solids at very high temperatures [5]. In this technique the gamma beam is used as a probe which is not in thermal or physical contact with the sample under investigation. This non contacting feature makes this technique a very advantageous one for high temperature studies, since the thermal losses are minimized and probe sample compatibility problem does not arise. We have undertaken γ-ray attenuation studies on the pellets of Sb, Bi, and Sn. The variation of density of Sb, Bi with temperature by using γ-ray attenuation technique was reported [6]. In present communication, the variation of linear attenuation coefficients (μl) of the metals with temperature by using mono energetic gamma photon with energy 0.662 MeV has been reported and the density variation of Sn with temperature has been studied.

2. Experimental Details

The samples studied in the present work were in the form of pellets. In all the cases, the pellets were prepared under different pressures out of the same quantity of powder to obtain pellets of different thicknesses. These pellets were subjected to γ – attenuation studies and it was observed that the density remained the same for all the pellets involving the same quantity of powder irrespective of thickness of the pellet. Such trials were conducted for all the metals in the present work. The pellets were prepared using a carborundum steel die set. A hydraulic press was used for compressing the powder samples.

For preparing the pellet, fine metal powder was put into cylinder of the die set above the pin, with its polished surface facing the metal powder and then the piston was introduced into the cylinder of the die set over the powder sample. The die set was placed in position under the hydraulic press piston and locked. The lever of the hydraulic press was slowly operated increasing the pressure on the piston. The applied pressure on the sample can be read from a pressure gauge mounted on the oil sump of the hydraulic press. After reaching the required pressure, the die set was unlocked and the metal pellet formed was taken out from the cylinder. The thickness and weight of the pellets were measured carefully. The cylinder and piston of the die set were cleaned properly every time for its use to prepare pellets of other samples. In this fashion metal pellets were prepared in all the cases with a diameter of 20mm with varying thicknesses.

The surface of the metal pellets was cleaned before mounting it on the sample holder. The pellet was then mounted on the round sample holder made of flat stainless steel strip whose two ends are fixed firmly in a stainless steel tube. The sample temperature was measured using a thermocouple sensor whose tip was mounted on the sample holder ensuring a perfect physical contact with the sample for recording precise sample temperature. The sample holder and the tube along with the metal pellet and the thermocouple was then slid through a cork into an air tight quartz tube and was fixed firmly. A diffusion pump was then connected to the quartz tube for evacuation and then argon gas was introduced into the quartz tube for inert atmosphere. Then the quartz tube assembly along with the sample was introduced into the PTC(Programmable Temperature Controlled) furnace and fixed at the appropriate position marked earlier for ensuring a perfect alignment of collimation on either sides.

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Temperature Dependent Density and Thermal Expansion of Wrought Aluminum Alloys 5070, 5083 and 5483 by Gamma Ray Attenuation Technique

K. Narender[1], A. S. Madhusudhan Rao[2], K. Gopal Kishan Rao[3], and N. Gopi Krishna[1,*]

[1]*Department of Physics, Kakatiya University, Warangal 506009, India*
[2]*Varadha Reddy College of Engineering, Warangal 506009, India*
[3]*CIC, Kakatiya University, Warangal 506009, India*

The density and thermal expansion of 5070, 5083 and 5483 wrought aluminum alloys have been reported from 300 K–800 K by measuring attenuation in gamma beam of energy 662 keV. The gamma ray attenuation studies have been carried out using a gamma ray densitometer. The temperature dependence of linear attenuation coefficient (μ_l) in the temperature range 300 K–800 K for the alloys has been calculated. The variation of density and thermal expansion of these alloys as a function of temperature have been represented by linear equations. The coefficients of temperature dependence of density, Volume thermal expansion coefficients have been reported and experimental values of mass attenuation coefficients determined in the present work are compared with X-COM values for the alloys.

KEYWORDS: γ-Ray Attenuation, Linear Attenuation Coefficient, Density, Thermal Expansion.

1. INTRODUCTION

The knowledge of temperature dependence of density and thermal expansion of metals and alloys is very important for understanding their thermophysical properties like thermal conductivity, specific heats, diffusion coefficients, thermo elastic constants and their applications in various fields. Density and thermal expansion are the basic parameters in discussing nature and behavior of any materials. Density values are necessary to the process of computer simulation, the calculation of other physical properties and extracting quantitative structural information from diffraction spectra.

Temperature dependence of density and thermal expansion can be investigated by employing different techniques, which have evolved for the determination of density and thermal expansion of solids at high temperature. Some of the techniques are Archimedean method, pycnometry, dilatometry, electromagnetic levitation, Method of maximal pressure in a gas bubble, method of sessile drop, hydrostatic weighing, high temperature electrostatic levitation and gamma ray densitometry. Thermal expansion studies on isotropic solids have been reported by researchers using X-ray diffraction,[1–3] dilatometry,[4,5] Fabrey–Perot interference method[6] and by other theoretical models.[7–11] The gamma radiation attenuation technique for the study of thermo physical properties in the condensed state has several advantages over other methods at high temperatures. This is possible because the gamma ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and this condition eliminates sample and probe compatibility problem. Drotning[14] measured thermal expansion of isotropic solid materials at high temperatures by this technique He studied thermal expansion of Aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state.[15,16] A number of other techniques have been used by various researchers to measure the temperature dependence of density of metals,[17–20] alloys[21–28] at high temperatures. Recently the behavior of thermal expansion of carbon fiber reinforced 6061 aluminum alloy has been reported[29] and mechanical properties of alloy 2219 have also been reported.[30] The thermal expansion of ZrW_3O_x/Polyimide Hybrid Films was determined.[31] The authors recently reported the temperature dependence of density and thermal expansion of the Potassium halides from γ-ray attenuation studies.[12] In the present communication we report the densities and thermal expansion of Al–Mg alloys 5070, 5083 and 5483 in the temperature range 300 K to 800 K determined from gamma ray attenuation technique, as these 5xxx series

*Author to whom correspondence should be addressed.
Email:
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Scientific Research

Thermophysical Properties of NaCl, NaBr and NaF by *γ*-Ray Attenuation Technique

Ammiraju Sowbhagya Madhusudhan Rao[1], Kethireddy Narender[1], Kalvala Gopal Kishan Rao[2], Nallacheruvu Gopi Krishna[1]
[1]Department of Physics, Kakatiya University, Warangal, India
[2]Central Instrumentation Centere (CIC), Kakatiya University, Warangal, India
Email: ngopikrishna2012@yahoo.com

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ABSTRACT

The *γ*-ray densitometer has been designed and fabricated in our laboratory and carried out studies on temperature dependent *γ*-ray attenuation and thermo physical properties of NaCl, NaBr and NaF. The linear attenuation coefficients (μl) for the pellets of NaCl, NaBr and NaF as a function of temperature have been determined. The coefficients of temperature dependence of density have been reported. The variation of density and thermal expansion of NaCl, NaBr and NaF in the temperature range of 300 K - 1000 K have been studied and compared with results available in the literature. The temperature dependence of density and thermal expansion has been represented by linear equations. Volume thermal expansion coefficients have been reported.

Keywords: Linear Attenuation Coefficient; Density; Thermal Expansion; *γ*-Ray Densitometer

1. Introduction

Density and Thermal expansion are fundamental thermo physical properties of solids. The study of temperature dependence of these properties is very important in understanding the temperature variation of other properties like elastic constants, refractive indices, dielectric constants, thermal conductivity, diffusion coefficients and other heat transfer dimensionless numbers. Thermal expansion of solids is of technical importance as it determines the thermal stability and thermal shock resistance of the material. In general the thermal expansion characteristics decide the choice of material for the construction of metrological instruments and in the choice of container material in nuclear fuel technology. Number of methods have evolved for the determination of density and thermal expansion of solids at high temperature like Archimedean method, pycnometry, dilatometry, electromagnetic levitation, Method of maximal pressure in gas bubble, *method of sessile drop, hydrostatic weighing,* high temperature electrostatic levitation and gamma ray densitometry. Thermal expansion studies on alkali halides have been reported by several workers using X-ray diffraction [1-3], dilatometry [4,5], Fabrey-Perot interference method [6] and by other theoretical models [7-14]. Using *γ*-ray attenuation technique W. D. Drotning [15] measured thermal expansion of isotropic solid materials at high temperatures. He studied thermal expansion of Aluminum and type 303 stainless steel at high temperatures and such studies have been extended by him to study the thermal expansion of metals and glasses in the condensed state [16]. The *γ*-radiation attenuation technique for the determination of thermo physical properties in the condensed state offers several advantages over other methods at high temperatures. This is possible because the *γ*-ray is not in any kind of physical or thermal contact with the material and hence the thermal losses are also reduced and in addition eliminates sample and probe compatibility problem.

As NaCl, NaBr and NaF are isotropic solids; we extended, for the first time, the *γ*-ray attenuation technique, to carry out the studies on temperature variation of *γ*-ray attenuation and thermo physical properties of NaCl, NaBr and NaF. In this communication, we report the temperature dependence of linear attenuation coefficient of *γ*-radiation, density and thermal expansion of NaCl, NaBr and NaF *in the temperature range 300 K - 1000 K*. In order to carry out this work, we have designed and fabricated a *γ*-ray densitometer and a programmable temperature controlled furnace (PTC) which can reach up to a temperature of 1300 K in our laboratory. The data obtained in the present work for coefficient of linear thermal expansion of NaCl, NaBr and NaF as a function of temperature have been compared with experimental and theoretical data available in literature.

Thermo physical properties of Wrought Aluminum alloys 2419 and 2124 by Gamma ray Attenuation method

K. Narender[1], A.S. Madhusudhan Rao[2], K. GopalKishan Rao[3], N. GopiKrishna[4]

[1]Department of Physics, Kakatiya University, [2]Department of Physics, Kakatiya University, [3]CIC,KakatiyaUniversity ,[4]Department of Physics, Kakatiya University, Warangal-506009.

e.mail:kethireddyn@yahoo.com

Abstract

The temperature dependence of linear attenuation coefficient, density and thermal expansion of 2419 and 2124 aluminum alloys have been studied by gamma ray attenuation technique in the temperature range of 300 K -850 K. The gamma ray attenuation studies have been carried out using a gamma ray densitometer designed and fabricated in our laboratory. The linear attenuation (μ_l) for the alloys as a function of temperature is determined; the coefficients of temperature dependence of density have been reported. The variation of density and thermal expansion of these alloys have been represented by linear equations. Volume thermal expansion coefficient has been reported.

Introduction

Density and Thermal expansion are very important thermo physical properties of solids. The study of temperature dependence of these properties is very useful in a variety of scientific and technological applications. The aim of this paper is to report the temperature dependence of density and thermal expansion of 2419 and 2124 aluminum alloy determined from gamma ray attenuation technique. Earlier several workers

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Determination of Effective Atomic Number and Mass Attenuation Coefficient of 5070 wrought Aluminum alloy with Multi Energetic photons

Narender K.[1], Madhusudhan Rao A.S.[2], Gopal Kishan Rao K.[3], Gopi Krishna N.[4] and Ashok reddy K.[4]
[1]Department of Physics, Kakatiya University, Warangal-506009, INDIA
[2]Varadha Reddy College of Engg. Warangal-506009, INDIA
[3]CIC, KakatiyaUniversity Warangal-506009, INDIA
[4]KITS Warangal-506009, INDIA

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Abstract

The total mass attenuation coefficients μ_m, for wrought aluminum alloy 5070 were measured at 59.5, 661.16, 1173, 1332keV photon energies. The sample was exposed with ^{137}Cs, ^{60}Co and ^{241}Am radioactive point sources using narrow beam transmission arrangement. The gamma-rays were counted by a NaI (Tl) detector with resolution of 8% of photon energy. Total atomic and electronic cross-sections (σ_t and σ_e), effective atomic number (Z_{eff}), electron density (N_{el}) and photon mean free path (λ) have been determined using the obtained μ_m values for 5070 aluminum alloy. The experimental values have been compared with theoretical values estimated from mixture rule and XCOM, and the agreement is found to be good

Keywords: Mass attenuation coefficient, effective atomic number, effective electron number, total atomic electronic cross section.

Introduction

In view of the extensive use of the radioactive sources in medicine, agriculture, industry etc., the study of photon atom interaction in different materials has gained importance in recent years. Since these interactions involve various compounds with different compositions, that the effective atomic number of a material composed of several elements cannot be expressed by a single number, it can be concluded that it is an energy dependent parameter due to the different partial photon interaction processes with matter for which the various atomic numbers in the material have to be weighted differently. The effective atomic number Z_{eff} for the total and partial gamma ray interactions in alloys are equally important. A number of investigations on effective atomic numbers for total and partial photon interactions have been reported in the literature. Including both theoretical[1-10] and experimental[11-25] studies covering a wide range of energies from a few keV up to several GeVs. There was a study on few compounds in which the effective atomic number has been determined using the ratio of elastic-to-inelastic scattering[26-27]. Similar studies have been carried out on various types of mixtures like metallic alloys, compounds; other composite materials including biological tissues, polymers, cements etc. In the present work, wrought aluminum alloy 5070 is subjected to attenuation studies at 59.5, 661.6, 1173, 1332keV photon energies to estimate the corresponding effective atomic number values for total photon interactions. Two different theoretical techniques, semi empirical approach, XCOM programme have been used for obtaining the values and these are in good agreement with experimental values.

Material and Methods

Transmission experiments with the narrow beam (good geometry) setup were used for measuring the incident and transmitted intensities, to determine the attenuation coefficient. Further calculations of the cross sections (atomic and electronic), effective atomic numbers and electron densities were performed. Three gamma sources were used in the present work so that the above parameters were studied at four different energies. The alloy studied in the present work was prepared by ingot metallurgy route. The alloy was melted in the air, in the induction furnace and cast iron moulds were used to obtain ingots. These ingots were subsequently homogenized at about 813 K and hot rolled to obtain 12mm - 15mm thick plates. These alloy plates were precipitation strengthened by heat treatment (aging). The chemical composition of 5070 is Al 92.55% Cu 0.25% Mg 4.5 Si 0.25% Fe 0.4% Mn 0.8% Cr 0.3% Zn 0.8% Ti 0.15% The sample material was shaped in to a cuboid, for measuring the attenuation, this cuboid slice is stacked on the detector, the intensities of the transmitted photons were determined by choosing the counting time as 30 minutes, counts were recorded under the photo peaks, as statistical uncertainty was to be kept as low as possible. The dimensions of the samples were measured with a screw gauge with the tolerance of ±0.01mm.

The experiment was performed at the Radiation Application Laboratory at Central Instrumentation Centre at Kakatiya University, Warangal, India. The experimental setup in the present work is shown in figure-1. The gamma rays are well collimated using collimators of cylindrical shape and a circular aperture of 6mm diameter between the source and the detector