LUNAR MAGNETIC ANOMALY MODEL COMPARISON

Project report submitted to the

UNIVERSITY OF CALICUT

In partial fulfillment of the requirement for the award of degree in

MASTER OF SCIENCE IN PHYSICS

By

AKHILA RAPHAEL

Reg. No: CCAWMPH001

Under the guidance of

Dr. DHANYA M. B

Scientist/Engineer - SF

Space Physics Laboratory, Vikram Sarabhai Space Centre (VSSC)

Indian Space Research Organisation (ISRO),

Thiruvananthapuram - India

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AKHILA RAPHAEL

Reg. No: CCAWMPH001

Examiners 1:

2:

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SPACE PHYSICS LABORATORY

डॉ. धन्या एम. बी. /Dr. Dhanya M B
वैज्ञानिक/ इंजीनियर 'एसएफ'/Scientist/Engineer-SF

08 July 2024

CERTIFICATE

This is to certify that the project report titled "**LUNAR MAGNETIC ANOMALY MODEL COMPARISON**" is a bonafide record of the investigations carried out by **Ms. AKHILA RAPHAEL, Reg. No: CCAWMPH001** under my supervision and guidance, towards the partial fulfillment for the award of the degree of Master of Science in Physics from the Christ College (Autonomous), Irinjalakuda, Thrissur.

(धन्या एम. बी. /Dhanya M B)

VSSC-SPACE PHYSICS LABORATORY ★ GOVT. OF INDIA, DEPT. OF SPACE ★ THIRUVANANTHAPURAM

DEPARTMENT OF PHYSICS

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

CERTIFICATE

This is to certify that the project work entitiled " **LUNAR MAGNETIC ANOMALY MODEL COMPARISON**" is an authentic record of the work carried out by **AKHILA RAPHAEL** (**(Regn. No: CCAWMPH001)** under the supervision and guidance of **Dr.DHANYA M.B**, Scientist/Engineer - SF Space Physics Laboratory, Vikram Sarabhai Space Centre (VSSC), Indian Space Research Organisation (ISRO) in partial fulfillment of requirements for the M.Sc in Physics at Christ College (Autonomous), Irinjalakuda, affiliated to University of Calicut during period of 2022-2024.

Place :

Date :

Dr. EDWIN JOSE
Department of Physics (Aided)
Christ College (Autonomous), Irinjalakuda

ACKNOWLEDGEMENT

I would want to sincerely thank everyone who helped to see this project through to completion. Above all, I want to sincerely thank God for giving me the courage, discernment, and persistence it took to finish this project. All of this would not have been feasible without his blessings.

I owe a huge debt of gratitude to Dr. Dhanya M.B., Scientist/Engineer - SF, Space Physics Laboratory, Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram, for her steadfast advice, knowledge, and assistance during this project. Her guidance has been extremely helpful in determining the course and means of carrying out this project.

I want to extend my gratitude to Dr.R. Rubia, Inspire Faculty Fellow in the Space Physics Laboratory at VSSC. Her unwavering assistance from the start of this project to its conclusion has been extremely beneficial and deeply thankful.

My heartfelt gratitude is also extended to Dr Aneesh, Dr Mathin Yadav, Ms. Sangeetha, Ms. Suchithra, Mrs Nimmy for their invaluable advice and assistance during this project.

I also want to express my gratitude to my friends and family, whose unwavering encouragement and support have served as my compass. I appreciate your patience, understanding, and unwavering faith in me. Your encouragement and kindness have been invaluable during these trying times.

ABSTRACT

The Moon, the only natural satellite of Earth, has many unique characteristics, including, atmosphere temperature and density. Although there was once a magnetic field connecting Earth and the Moon, this is no longer the case, and the anomalies of the Moon's magnetic field present an interesting field of study among its many mysteries. This research is based on two main models, the Purucker and Tsunakawa models, to investigate the magnetic anomalies on the Moon. The polar-orbiting Lunar Prospector, which was in low (11–66 km) orbit, enabled the first global mapping of the lunar magnetic field. In 2007, and 2008, Japan's Kaguya satellite succeeded Lunar Prospector, utilizing a triaxial fluxgate magnetometer to investigate the magnetic fields at 100 km altitude and lower. Using numerical simulations and observational data, these models characterize the magnetic anomalies on the Moon's surface and provide varying perspectives on the variations in the magnetic field. Analysis and visualisation of data by using Python programming language, the similarities and differences between the two models' magnetic field strengths are examined.

EXPLORING CRYSTAL STRUCTURES AND INVESTIGATION OF AlSb UNDER HIGH PRESSURE

Submitted by

Aleena A S

Reg No: CCAWMPH002

Department of Physics

Christ College Irinjalakuda (Autonomous)

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN PHYSICS

Under the guidance of,

Dr. Balmukund Shukla

High Pressure Studies Section

Condensed Matter Physics Division

Indira Gandhi Centre for Atomic Research [IGCAR]

Kalpakkam

Government of India
Department of Atomic Energy

Indira Gandhi Centre for
Atomic Research
Materials Science Group
Kalpakkam 603 102

Materials Science Group

Bonafide Certificate

*This is to certify that the project work entitled "**Exploring Crystal Structures and Studying AlSb under High Pressure Conditions**" is the bonafide record of research work done by Aleena A S, Department of Physics, Christ College (Autonomous), Irinjalakuda under my guidance and supervision at the High Pressure Studies Section, Condensed Matter Physics Division, Materials Science Group, Indira Gandhi Centre for Atomic Energy, Kalpakkam during the period April 2024 to June 2024.*

Dr. Balmukund Shukla
Scientific Officer SO/E
High Pressure Studies Section
Condensed Matter Physics Division

CERTIFICATE

This is to certify that the project work entitled **"EXPLORING CRYSTAL STRUCTURES AND STUDYING AlSb UNDER HIGH PRESSURE CONDITIONS"** is a bonafide record of the project work done by **ALEENA A S (CCAWMPH002)** under the guidance of **Dr. BALMUKUND SHUKLA**, Scientific Officer E, High Pressure Studies Section, Condensed Matter Physics Division, Indira Gandhi Centre for Atomic Research [IGCAR], in partial fulfillment of the requirements for the M.Sc. in Physics at Christ College (Autonomous), Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Dr.Sudheer Sebastian K

Professor

Place :

Head of Department

Date :

Christ College, Irinjalakuda

Examiners:

1.

2.

DECLARATION

I, **Aleena A S,** hereby declare that the project report entitled **"EXPLORING CRYSTAL STRUCTURES AND STUDYING AlSb UNDER HIGH PRESSURE CONDITIONS"** submitted by me in partial fulfillment of the requirements for the Masters of Science in Physics, is an original work done by me under the guidance of **Dr. Balmukund Shukla**, Scientific Officer E, High Pressure Studies Section, Condensed Matter Physics Division, Indira Gandhi Centre for Atomic Research [IGCAR].

ALEENA A S

Reg No: CCAWMPH002

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to everyone who has contributed to the successful completion of this project.

I sincerely thank my guide Dr. Balmukund Shukla (Scientific Officer E, IGCAR) for his invaluable guidance, support, and encouragement. He made my project equally informative and enjoyable.

I also extend my gratitude to Dr. N. R. Sanjay Kumar (Head, High Pressure Studies Section), Dr. A. N. Arpita Aparajita and all other members of HPSS for their technical expertise and support.

A special thanks to Ms. Susmitha Bose (JRF) and Ms. Sanitha K (JRF) for their assistance and support throughout my project.

I express my sincere thanks to Fr. Dr. Jolly Andrews, principal, Christ College (Autonomous), Irinjalakuda, Thrissur, for granting me the permission to carry out my project work at Indira Gandhi Centre for Atomic Research [IGCAR], Kalpakkam, Tamil Nadu. I also express my deep and sincere thanks to our Head of the Department, Dr. Prof. Sudheer Sebastian K and my internal guide Dr. Ajith R and all other staffs from Christ College (Autonomous), Irinjalakuda, for their valuable support and encouragement provided for the successful completion of this project.

I sincerely thank my parents and my friends for being there with me throughout supporting me in every possible manner.

ABSTRACT

X-Ray Diffraction (XRD) is a versatile, non-destructive analytical technique used to analyze physical properties such as phase composition, crystal structure, and orientation of powder, solid, and liquid samples. In this study, XRD analysis was performed on various compounds from different crystal systems, and their lattice parameters were calculated.

Pressure, like temperature, is another important thermodynamic parameter with the widest range. It is quite important to know about the materials under pressure since the effect is more prominent compared to that induced by temperature. X-Ray diffraction measurements have been made on Aluminium Antimonide (AlSb) at high pressure upto 12 GPa and at room temperature in a Diamond Anvil Cell (DAC) using Molybdenum source and mar345 image plate detector. The initial Zinc Blende structure of AlSb was found to transform at 8.6 GPa into an orthorhombic structure with a space group *cmcm* and the reduction in volume, interplanar spacing, lattice parameter for the zinc blende structure were plotted. The Bulk modulus B_0 and the pressure derivative B_1 were deduced from the equation of state using a non linear fitting method.

EFFECT OF ETCHING IN SILICA CAPILLARY BASED LASING SYSTEM

Submitted to

UNIVERSITY OF CALICUT

In partial fulfilment of the requirements for the award of the Degree of

MASTER OF SCIENCE

IN

PHYSICS

Submitted by

ALEENA K J

Register number: CCAWMPH003

Under the guidance of

Prof. M. KAILASNATH

International School of Photonics

Cochin University of Science and Technology

Cochin-682022, Kerala, India

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled "**EFFECT OF ETCHING IN SILICA CAPILLARY BASED LASING SYSTEM**" is a bonafide record of the project work done by **ALEENA K J (CCAWMPH003)** under the guidance of **Prof. M KAILASNATH**, Dean, Faculty of Technology, International School of Photonics, Cochin University of Science and Technology, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place :

Date :

Prof. Sudheer Sebastian K.
Head of the Department
Department of Physics
Christ College, Irinjalakuda

Examiners
1.
2.

CERTIFICATE

This is to certify that this project work entitled "**EFFECT OF ETCHING IN SILICA CAPILLARY BASED LASING SYSTEM"** is an authentic work carried by Ms. **ALEENA K J** of Department of Physics, Christ College Irinjalakuda, Thrissur in partial fulfilment of the Degree in MSc Physics from University of Calicut under my guidance and supervision.

Place:

Date :

Prof. M. Kailasnath
Professor and Dean, Faculty of Technology
International School of Photonics
Cochin University of Science & Technology
Cochin.

DECLARATION

I, ALEENA K J, hereby declare that the project work entitled "**EFFECT OF ETCHING IN SILICA CAPILLARY BASED LASING SYSTEM"** is a record of my project work carried out under the guidance of **Prof. M. Kailasnath**, Dean, Faculty of Technology, International School of Photonics, Cochin University of Science and Technology and that to the best of my knowledge and belief, it contains no materials previously published or written by any other person, except where acknowledgement has been made in the text.

ALEENA K J

Reg No: CCAWMPH003

ACKNOWLEDGEMENT

First, I thank the God Almighty for showering his immense blessings all through my life.

I would like to express my heartfelt gratitude to our respected supervising guide, Prof. M. Kailasnath, Dean, Faculty of Technology International School of Photonics, Cochin University of Science and Technology, Cochin, for having enthused confidence in me for executing the project successfully. I wish to thank Dr. Saji K J, Director, International School of Photonics, Cochin University of Science and Technology, Cochin, for providing the facilities of the department for carrying out the project work. I am forever thankful to Mr. Vinod P, Research Scholar, International School of Photonics, Cochin University of Science and Technology, Cochin, for teaching me initial lessons in research and for always being a source of support and encouragement at all stages ever since I have been acquainted to him. I would also like to express my sincere gratitude to Mrs. Mitty George, Research Scholar, who helped me a lot in the experimental works.

I express my sincere thanks to Fr. Dr. Jolly Andrews, Principal, Christ College (Autonomous), Irinjalakuda, Thrissur, and for granting me permission to carry out my project work at International School of Photonics, Cochin University of Science and Technology, Cochin, Ernakulam. I take this opportunity to express my sincere thanks to Prof. Sudheer Sebastian K, Head of the Department of Physics, Christ College (Autonomous), Thrissur, for the co-operation and encouragement provided for the successful completion of this project. I would also like to thank other teachers and staff from Christ College, Irinjalakuda, for the help rendered.

I also extend my sincere gratitude to my friends for their constant support and encouragement. Finally, I express my sincere gratitude to my family for their valuable encouragement and also for being a source of inspiration.

ALEENA K J

NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS

Submitted to,

UNIVERSITY OF CALICUT

In partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

IN

PHYSICS

Submitted by,

ASHLY JOSEPH

Register number: CCAWMPH004

Under the guidance of

Dr. PRIYA ROSE T

International school of photonics, CUSAT

Cochin-682022, Kerala, India

CHRIST COLLEGE (AUTONOMOUS), IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled "**NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS**" is a bonafide record of the project work done by **ASHLY JOSEPH (CCAWMPH004)** under the guidance of **Dr. PRIYA ROSE T**, Assistant professor, International School of Photonics, CUSAT, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college (Autonomous), Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place: Dr. Sudheer Sebastian K

Date : Head of Department

Christ College, Irinjalakuda

Examiners

1.

2.

CERTIFICATE

This is to certify that this project work entitled "**NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS"** is an authentic work carried by Ms. ASHLY JOSEPH of PG Department of Physics, Christ College (Autonomous), Irinjalakuda, Thrissur in partial fulfilment of the degree in MSc Physics from University of Calicut under my guidance and supervision.

Dr. Priya Rose T

Assistant Professor

International School of Photonics

CUSAT, Kochi

Ernakulam-682022

Place :

Date :

DECLARATION

I, ASHLY JOSEPH, hereby declare that the project work entitled "**NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS"** is a record of my project work that was conducted under the supervision of **Dr. Priya Rose T**, an Assistant Professor at the International School of Photonics, Cochin University of Science And Technology. Additionally, it asserts that to the best of the author's knowledge, the content of the work does not include any materials that have been previously published or written by someone else, unless proper acknowledgment has been given in the text. Essentially, it's a declaration of originality and acknowledgment of guidance received during my project.

ASHLY JOSEPH

Reg No: CCAWMPH004

ACKNOWLEDGEMENT

First and foremost, I express my gratitude to God, the Almighty for showering his immense blessings all through my life.

I express my sincere gratitude and hearty thanks to DR. PRIYA ROSE T, Assistant Professor, International School of Photonics, Cochin University of Science And Technology, Cochin, for having enthused confidence in me for executing the project successfully. Iam forever thankful to Mr. ARUN PAPPACHAN, Research Scholar, International School of Photonics, CUSAT, Cochin, for teaching me initial lessons in research and for always being a source of support and encouragement at all stages ever since I have been acquainted to him.

I express my heartfelt thanks to Fr. Dr. JOLLY ANDREWS, principal, Christ College (Autonomous), Irinjalakuda, Thrissur, and for granting me permission to carry out my project work at International School of Photonics, CUSAT, Cochin, Ernakulam. I seize this chance to convey my sincere gratitude to Dr. SUDHEER SEBASTIAN K sir, Head Of the Department of Physics, Christ College (Autonomous), Thrissur, for the co-operation and inspiration provided for the successful completion of this project. I would like to thank my tutor Dr. XAVIER JOSEPH sir and other teachers and staff from Christ College, Irinjalakuda, for the help rendered.

I also extend my sincere gratitude to my friends for their continuous help and motivation. Finally, I convey my sincere thanks to my family for their valuable encouragement and also for being a source of inspiration.

ASHLY JOSEPH

CONTENTS

DESIGN AND SIMULATION OF LEAD FREE PEROVSKITE SOLAR CELL USING SCAPS 1-D

Project report submitted to the

UNIVERSITY OF CALICUT

In partial fulfillment of the requirement for the award of degree in

MASTER OF SCIENCE IN PHYSICS

By

CLEMENT DAVIS

Reg. No: CCAWMPH005

Under the guidance of

Dr.SUDHEER SEBASTIAN K

Professor

Post Graduate and Research Department of Physics, Christ College (Autonomous) Irinjalakuda

2022-2024

DEPARTMENT OF PHYSICS

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

CERTIFICATE

This is to certify that the project work entitiled " **DESIGN AND SIMULATION OF LEAD FREE PEROVSKITE SOLAR CELL USING SCAPS 1-D**" is an authentic record of the work carried out by **CLEMENT DAVIS** (Regn. No: CCAWMPH005) under my supervision and guidance in the Department of Physics,Christ College (Autonomous) Irinjalakuda.

Place :
Date :

Dr.SUDHEER SEBASTIAN K
Department of Physics (Aided)
Christ College (Autonomous), Irinjalakuda

ACKNOWLEDGEMENT

I extend my sincere appreciation to all those who have contributed to the completion of this project. First and foremost, I would like to express my deepest gratitude to God for providing me with the strength, wisdom, and perseverance to complete this project. Without His blessings, none of this would have been possible.

I am deeply grateful to Dr.Sudheer Sebastian K, Professor, Department of Physics, Christ College (Autonomous) Irinjalakuda, for his unwavering guidance, expertise, and support throughout the duration of this endeavor. His mentorship has been invaluable in shaping the direction and execution of this project.

I would like to use a special word to extend a heartfelt thank you to Ms. Denet Davis, Research Scholar in the Physics Department at Christ College Irinjalakuda. Her constant support from the very beginning to the completion of this project, have been incredibly valuable and sincerely appreciated very much.

I would also like to thank my family and friends, your endless support and encouragement have been my anchor. Thank you for your understanding, patience, and for always believing in me. Your love and motivation have been crucial during the challenging times.

ABSTRACT

Special research has been carried out on lead-free materials to find more efficient and environmentally friendly alternatives to conventional lead-based perovskite solar cells. This work draws attention, focuses on the design and fabrication of lead-free perovskite solar cells using SCAPS-1D software, with methylammonium tin with specific emphasis on iodide as the reactant.

The traditional silicon-based solar cells dominate the market due to their high efficiency and long-term stability. However, the high cost of manufacturing and the complexity of the design are major drawbacks. Perovskite solar cells have emerged as promising options due to low manufacturing cost, flexible operating procedures and high energy conversion efficiencies. Regardless of these advantages, there are lead related toxicity and environmental concerns which are affecting the perovskite solar cells.

Methylammonium tin iodide is a promising candidate due to excellent optoelectronic properties, including adequate bandgap and high absorption coefficient, which are essential for efficient solar energy conversion but require investigating challenges such as physical properties and material's environmental impacts are effectively and efficiently carried out.

In this study, the design of devices are simulated to evaluate the performance of perovskite solar cells based on $CH_3NH_3SnI_3$. Key parameters such as layer thickness, doping concentration, bandgap, temperature and defect density are analyzed and studied in this. The simulations also provide insights into charge transport mechanisms and highlight potential efficiency gains through custom-designed devices.

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NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS

Submitted to,

UNIVERSITY OF CALICUT

In partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

IN

PHYSICS

Submitted by,

E A ATHIRA

Register number: CCAWMPH006

Under the guidance of

Dr. PRIYA ROSE T

International school of photonics, CUSAT

Cochin-682022, Kerala, India

CHRIST COLLEGE (AUTONOMOUS), IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled "**NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS**" is a bonafide record of the project work done by **E A ATHIRA (CCAWMPH006)** under the guidance of **Dr. PRIYA ROSE T**, Assistant professor, International School of Photonics, CUSAT, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college (Autonomous), Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Dr.Sudheer Sebastian K

Place :

Head of Department

Date:

Christ College, Irinjalakuda

Examiners

1.

2.

CERTIFICATE

This is to certify that this project work entitled "**NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS"** is an authentic work carried by Ms. E A ATHIRA of PG Department of Physics, Christ College (Autonomous), Irinjalakuda, Thrissur in partial fulfilment of the degree in MSc Physics from University of Calicut under my guidance and supervision.

Dr. Priya Rose T

Assistant Professor

International School of Photonics

CUSAT, Kochi

Ernakulam - 682022

Place :

Date :

DECLARATION

I, E A ATHIRA, hereby declare that the project work entitled "**NUMERICAL STUDY OF ONE-DIMENSIONAL PHOTONIC CRYSTAL USING COMSOL MULTIPHYSICS"** is a record of my project work carried out under the guidance of **Dr. Priya Rose T**, Assistant Professor, International School of Photonics, Cochin University of Science And Technology and that to the best of my knowledge and belief, it contains no materials previously published or written by any other person, except where acknowledgement has been made in the text.

E A ATHIRA

Reg No: CCAWMPH006

ACKNOWLEDGEMENT

First of all, I thank the God Almighty for showering his immense blessings all through my life.

I express my sincere gratitude and hearty thanks to Dr. Priya Rose T, Assistant Professor, International School of Photonics, Cochin University of Science And Technology, Cochin, for having enthused confidence in me for executing the project successfully. Iam forever thankful to Mr. Arun Pappachan, Research Scholar, International School of Photonics, CUSAT, Cochin, for teaching me initial lessons in research and for always being a source of support and encouragement at all stages ever since I have been acquainted to him.

I express my sincere thanks to Fr. Dr. Jolly Andrews, principal, Christ College (Autonomous), Irinjalakuda, Thrissur, and for granting me permission to carry out my project work at International School of Photonics, CUSAT, Cochin, Ernakulam. I take this opportunity to express my sincere thanks to Dr. Sudheer Sebastian K sir, Head of the Department of Physics, Christ College (Autonomous), Thrissur, for the co-operation and encouragement provided for the successful completion of this project. I would like to thank my Internal Project guide Dr. Xavier Joseph sir and other teachers and staff from Christ College, Irinjalakuda, for the help rendered.

I also extend my sincere gratitude to my friends for their constant support and encouragement. Finally, I express my sincere gratitude to my family for their valuable encouragement and also for being a source of inspiration.

E A ATHIRA

Development of $ZnTiO_3$ – PB Composite Laminates for Microwave Applications

A PROJECT REPORT

Submitted to

Christ College (Autonomous), Irinjalakuda

In Partial fulfillment of the requirements

for the award of the Degree of

MASTER OF SCIENCE IN PHYSICS

by

GOKUL DAS

(Reg No. CCAWMPH007)

Under the guidance of

Dr. DNYANDEO PAWAR

SCIENTIST

CENTRE FOR MATERIALS FOE ELECTRONICS TECHNOLOGY

(C-MET) THRISSUR

CHRIST COLLEGE (AUTONOMOUS), IRINJALAKUDA

THRISSUR, KERALA

DECLARATION

I, Gokul Das hereby declare that this work entitled **"Development of $ZnTiO_3$ – PB composite laminates for microwave applications"**, submitted to Christ College (Autonomous), Irinjalakuda, Thrissur in the partial fulfilment of the requirement for the award of the degree of *Master of Science in Physics* is a record of original work done by me under the guidance of **Dr. Dnyandeo Pawar**, Scientist, Centre for Materials for Electronics Technology (C-MET), Thrissur. I further declare that the results embodied in this project report have not been submitted to any other University or Institution for the award of any degree or diploma.

Thrissur

Date: 10/07/2024 Gokul Das

CHRIST
COLLEGE (AUTONOMOUS)
IRINJALAKUDA, KERALA
Reaccredited by NAAC with 'A++' grade

CERTIFICATE

This is to certify that the work entitled **"Development of $ZnTiO_3$ – PB composite laminates for microwave applications "**is a bonafide record of the work done by Gokul Das, Christ College (Autonomous), Irinjalakuda, Thrissur under the guidance of **Dr. Dnyandeo Pawar**, Scientist, Centre for Materials for Electronics Technology (C-MET), Thrissur in partial fulfilment for the award of the degree of **Master of Science in Physics**. I further certify that the work presented in this report has not been submitted for any degree or diploma earlier.

Thrissur

July 10, 2024

Prof. Dr. Sudheer Sebastian

Head of The Department

Christ College (Autonomous)

Irinjalakuda, Thrissur

ACKNOWLEDGEMENT

I am glad to express my whole hearted gratitude and indebtedness to my guide Dr. Dnyandeo pawar, Scientist, Centre for Materials for Electronic Technology (C-MET) Thrissur, under whose expert guidance I carried out my work.

I gratefully acknowledge the encouragement and all academic support extended t me by Prof. Dr. Sudheer Sebastian, Head of the department, Christ College (Autonomous), Irinjalakuda, Thrissur, for giving me an opportunity to do my project work at C-MET, Athani, Thrissur. I also express my sincere gratitude to the entire teaching, non-teaching staffs and all technical staffs for their support during my study and project.

My heartfelt thanks to Mr. Prasad and Mr. Arun of microwave group for their valuable help, wholehearted support and advice during this course of project work. I extend my sincere thanks to all staffs in C-MET for their help and support.

I am also thankful to my parents, friends, classmates and all well-wishers who have helped me in this project.

Gokul Das

ABSTRACT

In this project work, an attempt has been made to develop $ZnTiO_3$ filler based polybutadiene composites for microwave PCB substrate applications. Ceramic filler based polymer matrix has great importance in electronic and communication field. Pure phase ceramic filler materials like $ZnTiO_3$ was prepared through conventional solid state ceramic route. The composite laminates of different filler fractions have been prepared through well mixing and then followed by thermal – lamination. The density of the composites have been measured using Archimedes method. The density varied with filler concentration. The distribution of the filler in the PB matrix has been studied by Scanning Electron Microscope technique (SEM). The dielectric properties of the ceramic filled composite laminates have been studied by Vector Network Analysis (VNA). The prepared substrates can be used as an ideal material for microwave applications.

CONTENTS

CHAPTER 1

SEMI AUTOMATED PHASE DETERMINATION AND AMORPHOUS CONTENT ESTIMATION USING SAED IMAGE ANALYSIS

Project report submitted by,

HELMA SEBASTIAN

(Reg No: CCAWMPH008)

In partial fulfillment of the requirements for the award of

MASTER OF SCIENCE IN PHYSICS

Department of Physics

Christ College (Autonomous), Irinjalakuda

CALICUT UNIVERSITY, JULY 2024

Under the guidance of

Dr. Bindu M Krishna

Chief Research Officer

Centre for research and innovation in multidisciplinary science (CRIMS)

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled **"SEMI AUTOMATED PHASE DETERMINATION AND AMORPHOUS CONTENT ESTIMATION USING SAED IMAGE ANALYSIS"** is a bonafide record of the project work done by done by **HELMA SEBASTIAN (CCAWMPH008)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer, Centre For Research And Innovation in Multidisciplinary Sciences, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college (Autonomous) Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place :

Date :

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Examiners
1.
2.

CENTRE FOR RESEARCH AND INNOVATION
IN MULTIDISCIPLINARY SCIENCES
KOCHI-22

CERTIFICATE

This is to certify that the project work entitled "**SEMI AUTOMATED PHASE DETERMINATION AND AMORPHOUS CONTENT ESTIMATION USING SAED IMAGE ANALYSIS**" is a bonafide record of the project work done by **HELMA SEBASTIAN (CCAWMPH008)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer, Centre For Research And Innovation in Multidisciplinary Sciences, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place: Kochi

Date: 08.07.2024

Dr. Bindu M Krishna

Chief Research Officer

CRIMS

DECLARATION

I HELMA SEBASTIAN, hereby declare that the project report entitled **"SEMI AUTOMATED PHASE DETERMINATION AND AMORPHOUS CONTENT ESTIMATION USING SAED IMAGE ANALYSIS"**, being submitted in partial fulfillment for the award of degree of Master of Science in Physics, is the original work carried out by me under the supervision of Dr. Bindu M Krishna, Chief Research Officer, CRIMS. This work has not been submitted elsewhere for the award of any degree.

HELMA SEBASTIAN
Reg No: CCAWMPH008

ACKNOWLEDGEMENT

First and foremost, praises and thanks to God Almighty for his shower of blessings throughout my project to complete the project successfully.

I would like to extend sincere and heartfelt gratitude to the supervising guide, Dr. Bindu M Krishna, Chief Research Officer (CRIMS), for her valuable guidance, encouragement and constant support throughout the project work. Her constant guidance and willingness to share and vast knowledge helped me understand this project and its manifestations in great depths helped complete the assigned task on time.

I express my sincere thanks to Fr. Dr. Jolly Andrews, Principal, Christ College (Autonomous), Irinjalakuda, for his continuos support and advise. I take this opportunity to express my sincere thanks to Prof. Sudheer Sebastian K, Head of the Department of Physics, Christ College (Autonomous), Thrissur, for the co-operation and encouragement provided for the successful completion of this project. I would also like to thank other teachers and staff from Christ College, Irinjalakuda, for the help rendered.

I also extend my sincere gratitude to my friends for their constant support and encouragement. Finally, I express my sincere gratitude to my family for their valuable encouragement and also for being a source of inspiration.

HELMA SEBASTIAN

ABSTRACT

We present a simple and fast method for determining the amorphous content in nano samples. Current methods, such as Fluctuation Electron Microscopy (FEM), are not widely accessible and are too expensive. They also require specialized software for image processing. X-ray diffraction (XRD) is also an effective method for this, but it is more accessible at the bulk level than at the nano level. Hence, electron diffraction is preferable to XRD, as the electron has a much shorter wavelength than the X-ray wave. Thus, we proposed a method based on Selected Area Electron Diffraction (SAED) image analysis to quantify the amorphous content of nano samples. The analysis is based on multiple SAED images of the same sample, which yields more accurate results. Our semi-automated algorithm uses two parameters, area and entropy, to estimate the amorphous phase within a nanosample. Here, we tested this algorithm on several SAED images of three different samples: SiO_2, carbon nano, and Pt-Ir. Results from the standard carbon nano sample were compared with XRD results, showing high agreement. Additional findings are strongly supported by diffraction theory. The proposed algorithm was performed in MATLAB. Our results indicate that the proposed algorithms have significant potential for future advancements. Although our main aim is to determine the amorphous content, in this paper we have also proposed an additional semi-automated algorithm that processes multiple SAED images of a nano sample to produce the interplanar spacing (d value). Even if XRD is a well-established method for phase determination, electron diffraction is more precise at the nanoscale. These d values were compared with standard XRD values from the JCPDS dataset and showed good agreement. From the indexed SAED images, we determined the corresponding phases. We applied this procedure to two known samples, TiO_2 (titanium oxide) and BiSn (bismuth tin), identifying the anatase and rutile phases of TiO_2. By analyzing multiple images, the course information regarding the major chemical phase can be identified. This methodology represents a basic step in structure determination with promising development prospects.

ENHANCED PAPAYA MATURITY DETECTION USING TCS34725 COLOR SENSOR, DIGITAL IMAGE PROCESSING, AND AI-DRIVEN CLASSIFICATION

Project report submitted by,

HELNA SEBASTIAN

Reg No: CCAWMPH009

in partial fulfilment of the requirements for the award of

MASTER OF SCIENCE IN PHYSICS

Department of Physics

Christ College (Autonomous), Irinjalakuda

CALICUT UNIVERSITY, JULY 2024

Under the guidance of

Dr.Bindu M Krishna

Chief Research Officer

Centre for research and innovation in multidisciplinary science (CRIMS)

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled **"ENHANCED PAPAYA MATURITY DETECTION USING TCS34725 COLOR SENSOR, DIGITAL IMAGE PROCESSING, AND AI-DRIVEN CLASSIFICATION"** is a bonafide record of the project work done by done by **HELNA SEBASTIAN (CCAWMPH009)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer, Centre For Research And Innovation in Multidisciplinary Sciences, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college (Autonomous) Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

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Date :

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Place: Kochi
Date: 08.07.2024

Dr. Bindu M Krishna
Chief Research Officer
CRIMS

DECLARATION

I affirm that the project report entitled "ENHANCED PAPAYA MATURITY DETECTION USING TCS34725 COLOR SENSOR, DIGITAL IMAGE PROCESSING, AND AI-DRIVEN CLASSIFICATION", being submitted in partial fulfilment for the award of degree of Master of Science in Physics, is the original work carried out by me under the supervision of Dr. Bindu M Krishna , Chief Research Officer, CRIMS. This work has not been submitted elsewhere for the award of any degree.

Place: HELNA SEBASTIAN

Date: Reg No.: CCAWMPH009

ACKNOWLEDGEMENT

First and foremost, praises and thanks to God Almighty for his shower of blessings throughout my project to complete the project successfully.

I would like to extend sincere and heartfelt gratitude to the supervising guide, Dr. Bindu M Krishna, Chief Research Officer (CRIMS), for her valuable guidance, encouragement and constant support throughout the project work. Her constant guidance and willingness to share and vast knowledge helped me understand this project and its manifestations in great depths helped complete the assigned task on time.

I express my sincere thanks to Fr. Dr. Jolly Andrews, Principal, Christ College (Autonomous), Irinjalakuda, for his continuos support and advise. I take this opportunity to express my sincere thanks to Prof. Sudheer Sebastian K, Head of the Department of Physics, Christ College (Autonomous), Thrissur, for the co-operation and encouragement provided for the successful completion of this project. I would also like to thank other teachers and staff from Christ College, Irinjalakuda, for the help rendered.

I also extend my sincere gratitude to my friends for their constant support and encouragement. Finally, I express my sincere gratitude to my family for their valuable encouragement and also for being a source of inspiration.

HELNA SEBASTIAN

ABSTRACT

Accurately determining the ripeness of fruits is crucial for optimizing their quality, nutritional value, and marketability. Traditional methods of ripeness assessment, based on visual inspection and tactile evaluation, are often subjective and inconsistent. This project explores an innovative approach that integrates the TCS34725 color sensor, image processing techniques using MATLAB, and artificial intelligence (AI) to develop a precise and reliable method for detecting papaya maturity stages. Initially, the maturity detection of papayas was conducted using the TCS34725 color sensor, interfaced with an ESP32 microcontroller, to capture detailed color information. Additionally, high-resolution video footage was captured using a smartphone and processed with MATLAB to extract relevant color features. Comparative analysis revealed that the image processing method provided higher accuracy in detecting papaya ripeness stages compared to the TCS34725 color sensor alone. Building on these findings, further analysis was conducted on an additional 19 papaya samples. The dataset's image-derived color information was used to train Support Vector Machine (SVM) algorithms. This AI-driven approach enabled the precise classification of papayas into various ripeness stages based on the combined data. Preliminary results indicate that the integration of image processing techniques and SVM can provide a highly accurate and reliable method for detecting papaya maturity. This approach leverages the strengths of sensor technology, advanced image processing, and AI, offering a scalable and precise solution for ripeness detection. The implications of this research extend beyond papayas, presenting a promising method for maturity assessment in other fruits and agricultural products. This approach also opens up a wide range of applications in various other sectors.

STRUCTURE AND DYNAMICS ACROSS GLASS TRANSITION IN DENSE MICROGEL SUSPENSION

Submitted by

Krishnapriya T. L

Reg No: CCAWMPH010

Department of Physics

Christ College Irinjalakuda (Autonomous)

In partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN PHYSICS

Under the guidance of,

Dr. R.G. Joshi

Light Scattering Studies Section

Condensed Matter Physics Divison

Indira Gandhi Centre for Atomic Research [IGCAR]

Kalpakkam

Government of India
Department of Atomic Energy

Indira Gandhi Centre for Atomic Research
Materials Science Group
Kalpakkam 603 102

Materials Science Group

Bonafide Certificate

This is to certify that the project work entitled **"STRUCTURE AND DYNAMICS ACROSS GLASS TRANSITION IN DENSE MICROGEL SUSPENSION"** ***is the bonafide record of the project work done by Krishnapriya T. L, Department of Physics, Christ College (Autonomous), Irinjalakuda, Thrissur under my guidance and supervision at the Light Scattering Studies Section, Condensed Matter Physics Division, Indira Gandhi Centre for Atomic Research [IGCAR], Kalpakkam during the month of April 2024.***

Dr. R.G. JOSHI

Scientific Officer SO/F

Light Scattering Studies Section

Condensed Matter Physics Division

CERTIFICATE

This is to certify that the project work entitled **"STRUCTURE AND DYNAMICS ACROSS GLASS TRANSITION IN DENSE MICROGEL SUSPENSION"** is a bonafide record of the project work done by **KRISHNAPRIYA T. L (CCAWMPH010)** under the guidance of **Dr. R.G. JOSHI**, Scientific Officer F, Light Scattering Studies Section, Condensed Matter Physics Division, Indira Gandhi Centre for Atomic Research [IGCAR], in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college (Autonomous), Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Dr.Sudheer Sebastian K

Professor

Place :

Head of Department

Date :

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Examiners:

1.

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DECLARATION

I, **Krishnapriya T. L,** hereby declare that the project report entitled **"STRUCTURE AND DYNAMICS ACROSS GLASS TRANSITION IN DENSE MICROGEL SUSPENSION"** submitted by me in partial fulfilment of the requirements for the Masters of Science in Physics, is an original work done by me under the guidance of **Dr. R.G. Joshi**, Scientific Officer F, Light Scattering Studies Section, Condensed Matter Physics Division, Indira Gandhi Centre for Atomic Research [IGCAR].

KRISHNAPRIYA T. L

Reg No: CCAWMPH010

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to everyone who has contributed to the successful completion of this project.

Firstly, I extend my heartfelt thanks to my guide, Dr. R.G Joshi (Scientific Officer F, IGCAR) for his valuable guidance, support and encouragement. His insights made my project both informative and enjoyable.

I am also grateful to Dr. Awadhesh Mani (Head, Light Scattering Section) and Dr. Deepak Kumar Gupta (Scientific Officer) for their assistance and support.

A special thanks to Mrs. Saraswathi M (Scientific Assistant), Ms. Sathyavani S (JRF), Mr. Sarath Kumar (JRF), Mr. Vignesh (JRF) for their consistent help throughout my project.

I express my sincere thanks to Fr. Dr. Jolly Andrews, principal, Christ College (Autonomous), Irinjalakuda, Thrissur, for granting me the permission to carry out my project work at Indira Gandhi Centre for Atomic Research [IGCAR], Kalpakkam, Tamil Nadu. I am also deeply thankful to our Head of the Department, Dr. Prof. Sudheer Sebastian K and my internal guide Dr. Ajith R and all other staff from Christ College (Autonomous), Irinjalakuda, for their valuable support and encouragement throughout this project.

Finally, I thank my parents and my friends for their unwavering support and encouragement during this endeavor.

CONTENTS

DISCRIMINATING HEALTHY INDIVIDUALS AND INDIVIDUALS AFFECTED WITH DYSARTHRIA BASED ON RECURRENCCE QUANTIFICATION ANALYSIS OF VOICE

Submitted by

Ms. Meera P

Reg No: CCAWMPH011

Under the guidance of

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Chief Research Officer

Center for Research and Innovation in Multidisciplinary Sciences

CALICUT UNIVERSITY

JULY 2024

In partial fulfilment of the

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MASTER OF SCIENCE IN PHYSICS

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled **'DISCRIMINATING HEALTHY INDIVIDUALS AND INDIVIDUALS AFFECTED WITH DYSARTHRIA BASED ON RECURRENCCE QUANTIFICATION ANALYSIS OF VOICE',** is a bonafide record of the project work done by **MEERA P (CCAWMPH011)** under the guidance of Dr. Bindu M Krishna, Chief Research Officer, Centre for Research And Innovation in Multidisciplinary Sciences (CRIMS), in partial fulfilment of the requirements for the M.Sc. in Physics at Christ College Irinjalakuda, affiliated to university of Calicut during the period 2022-2024.

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Date:

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Examiners

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CENTRE FOR RESEARCH AND INNOVATION IN MULTIDISCIPLINARY SCIENCES KOCHI-22

CERTIFICATE

This is to certify that the project work entitled **'DISCRIMINATING HEALTHY INDIVIDUALS AND INDIVIDUALS AFFECTED WITH DYSARTHRIA BASED ON RECURRENCE QUANTIFICATION ANALYSIS OF VOICE',** is a bonafide record of the project work done by **MEERA P (CCAWMPH011)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer, Centre For Research And Innovation in Multidisciplinary Sciences in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place: Kochi

Date: 08.07.2024

Dr. Bindu M Krishna

Chief Research Officer

CRIMS

DECLARATION

I, MEERA P, affirm that the project report entitled '**RECURRENCE QUANTIFICATION ANALYSIS FOR DISCRIMINATING HEALTHY INDIVIDUALS AND INDIVIDUALS AFFECTED WITH DYSARTHRIA**', being submitted in partial fulfilment for the award of degree of Master of Science in Physics, is the original work carried out by me under the supervision of Dr. Bindu M Krishna, Chief Research Officer, and CRIMS. This work has not been submitted elsewhere for the award of any degree.

Irinjalakuda — MEERA P

07-07-2024 — Reg No: CCAWMPH011

ACKNOWLEDGEMENT

This project was made possible by the contributions and support of many individuals. I take this opportunity to express my gratitude to everyone who provided their insights, resources and time to help me for the completion of this work.

I would like to express my deepest gratitude to Dr. Bindu M Krishna, Chief Research Officer (CRIMS), for her valuable guidance, encouragement and constant support throughout the project work.

I express my gratitude to Fr. Dr. Jolly Andrews, Principal, Christ College (Autonomous), Irinjalakuda, Thrissur for his continuous support. I am immensely grateful to Prof. Sudheer Sebastain K, Head of Department of Physics, Christ College, Irinjalakuda, for the help provided.

I extend my thanks to all the teaching and non teaching staffs in the Department of Physics, Christ College, Irinjalakuda, for their support. I wish to thank my family and classmates for their support and encouragement throughout the project work.

MEERA P

Contents

EFFECT OF OUTER SPLIT CAPACITANCE ON THE RESONANCE BEHAVIOUR OF SPLIT RING RESONATOR METAMATERIAL STRUCTURE

Submitted by

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Reg No : CCAWMPH012

Under the guidance of

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CALICUT UNIVERSITY

JULY 2024

In partial fulfillment of the

requirements for the award of the degree of

MASTER OF SCIENCE IN PHYSICS

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF OUTER SPLIT CAPACITANCE ON THE RESONANCE BEHAVIOUR OF SPLIT RING RESONATOR METAMATERIAL STRUCTURE"** is a bonafide record of the research work carried out by **MONICA M S (CCAWMPH012)** under my supervision in the Electromagnetic Metamaterial Research Lab (EMRL), Department of Physics, Christ College (Autonomous), Irinjalakuda in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE IN PHYSICS** of calicut university.

Dr. Fr. JOLLY ANDREWS
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DECLARATION

I **MONICA M S**, hereby declare that the work presented in this thesis entitled **"EFFECT OF OUTER SPLIT CAPACITANCE ON THE RESONANCE BEHAVIOUR OF SPLIT RING RESONATOR METAMATERIAL STRUCTURE"** is based on the original work done by me under the guidance of Dr. Fr. Jolly Andrews, Associate Professor, PG and Research Department of Physics, Christ College (Autonomous), Irinjalakuda and has not included in any other thesis submitted previously for the award of any other degree.

Date: 10/07/2024

Name : MONICA M S

Reg No : CCAWMPH012

ACKNOWLEDGEMENT

First and foremost, praises and thanks to God, the Almighty, for his showers of blessings to complete the project successfully.

I would like to extend my sincere and heartfelt gratitude to my project guide, Dr. Fr. Jolly Andrews, Principal and Associate Professor, PG and Research Department of Physics, Christ College (Autonomous) Irinjalakuda, who has helped me in this endeavor, his constant guidance and willingness to share his vast knowledge made me to understand this project and helped me to complete the assigned tasks on time. Without his corporation, guidance and encouragement, the project could not have been what it evolved to be.

I am extremely grateful to Dr. V P Joseph, Professor, Department of Physics, Christ College (Autonomous) Irinjalakuda, for his invaluable mentor-ship and unwavering support throughout this research journey.

Special thanks to Mrs. Anju Sebastian and Mrs. Aswathi P V, Assistant Professors, Department of Physics, Christ College (Autonomous) Irinjalakuda, for helping me during various phases of project completion and providing me great suggestions and advice whenever needed.

I am thankful to Dr.Sudheer Sebastian K, Professor and Head of Department, Department of Physics, Christ College (Autonomous) Irinjalakuda, for his unlisted encouragement and timely support.

Lastly, I extend my sincere appreciation to all those who have contributed to the completion of this project.

Date: 10/07/2024

Name : MONICA M S

Reg No : CCAWMPH012

ABSTRACT

Metamaterials are artificially created composite materials that possesses extraordinary electromagnetic characteristics that are non-existent in nature. Magnetic permeability (μ) and electric permittivity (ϵ) are the two basic parameters characterizing the electromagnetic properties of a medium. In metamaterials, either both of these factors are negative or any one of them is negative. The negative permeability metamaterial structure called Split Ring Resonator (SRR) can be used as electromagnetic sensors by manipulating their structural parameters. Applying a time-varying electromagnetic field to the structure causes the induced charge and current distributions to form capacitance and inductance, which leads SRR to function as a LC resonant circuit. Therefore, the intrinsic values of the capacitance (C) and inductance (L) determine the resonant frequency of SRR. Among L and C, the value of C has more significance. The overall capacitance of the SRR is determined by several factors. Capacitance due to spacing between rings (C_d) and capacitance due to split width (C_s) are the most significant factors. Among C_d and C_s, changes in C_s has more importance. Both the inner and outer split widths contribute to the changes in C_s. The objective of the present work is to investigate the capacitive contribution of outer split gap on the resonance of SRR. By changing the widths of the inner and outer splits of an SRR structure, the variations in resonant frequencies are examined. Additionally, the variations in resonance frequency are investigated when a dielectric sample is fitted in the inner and outer split gaps. All these investigations shows that the outer split gap has more impact on the resonance of SRR. Hence, we are able to develop a wide range of sensors based on SRR for specific applications.

The entire study make use of the HFSS software to construct and simulate the SRR structure. Also, the results are experimentally verified using VNA. This project is divided into 5 chapters. A basic overview of metamaterials and split ring resonators is provided in **Chapter 1**. The theoretical analysis of SRR is covered in **Chapter 2**, along with an introduction to simulation methodologies and experimental techniques. **Chapter 3** deals with the findings of simulation and experimental studies. Conclusions of work are presented in **Chapter 4**.

SYNTHESIS AND CHARACTERISATION OF COPPER SULFIDE/REDUCED GRAPHENE OXIDE, ELECTRODE FOR SUPERCAPACITOR APPLICATIONS

Project report submitted to the

UNIVERSITY OF CALICUT

In partial fulfillment of the requirement for the award of degree in

MASTER OF SCIENCE IN PHYSICS

By

SANIGHA T T

Reg. No: CCAWMPH013

Under the guidance of

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Asst. Professor

Post Graduate and Research Department of Physics, Christ College

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2022-2024

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This is to certify that the project work entitled " **SYNTHESIS AND CHARACTERISATION OF COPPER SULFIDE/REDUCED GRAPHENE OXIDE, ELECTRODE FOR SUPERCAPACITOR APPLICATIONS**" is an authentic record of the work carried out by **SANIGHA T T** (Regn. No: CCAWMPH013) under my supervision and guidance in the Department of Physics, Christ College (Autonomous) Irinjalakuda.

Dr.ANJU PAULSON

Department of Physics (Aided)

Christ College (Autonomous), Irinjalakuda

DECLARATION

I SANIGHA T T, hereby declare that the work presented in this thesis entitled "SYNTHESIS AND CHARACTERISATION OF COPPER SULFIDE/REDUCED GRAPHENE OXIDE, ELECTRODE FOR SUPERCAPACITOR APPLICATIONS" is based on the original work done by me under the guidance of Dr.Anju Paulson, Associate Professor, Post Graduate and Research Department of Physics, Christ College(Autonomous), Irinjalakuda and has not included in any other thesis submitted previously for the award of any other degree.

SANIGHA T T

Reg.No:CCAWMPH013

ACKNOWLEDGEMENT

I admire God almighty with deepest gratitude, who guided me throughout my journey. I am immensely grateful to my research guide Dr.Anju Paulson, Assistant Professor, Department of Physics, Christ College(Autonomous), Irinjalakuda for her guidance and support. I am indebted to Dr.Edwin Jose(Assistant professor, Department of Physics, Christ col- lege(Autonomous)), who helped me for completing my project.

Special thanks to the Centre for Materials for Electronics Technology Thrissur (C-MET) for their invaluable support and resources. Additionally, I am deeply grateful to the Department of Chemistry, Christ College (Autonomous)Irinjalakuda for their guidance and contributions. Your assistance has been instrumental in the successful realization of this project.

I am deeply grateful to my teammates and teachers, especially Dr. Sudheer Sebastian K, (Professor at Christ College (Autonomous)), Irinjalakuda, for their invaluable support. I also extend my heartfelt appreciation to my friends and family for their unwavering encouragement.

Finally, I would like to express my sincere thanks to everyone who directly and indirectly assisted me in completing my project.

SANIGHA T T

Reg.No:CCAWMPH013

ABSTRACT

The increasing demand for efficient energy storage solutions has propelled research into advanced materials, such as supercapacitors, known for their high power density and rapid charge-discharge cycles. This project focuses on synthesizing graphene oxide (GO) using a modified Hummers method and the subsequent development of Copper Sulfide/Reduced Graphene Oxide (CuS/rGO) nanocomposites to enhance supercapacitor performance.

Firstly, graphene oxide is synthesized through an improved Hummers method, which involves the oxidation of graphite using a combination of strong oxidizers. This modified approach ensures a higher yield and better quality of graphene oxide with fewer structural defects. The synthesized GO is then reduced and combined with copper sulfide (CuS) to form CuS/rGO nanocomposites.

The synthesized materials are characterized using techniques such as X-ray diffraction (XRD), and Fourier transforms infrared spectroscopy (FT-IR) to analyze their structural and morphological properties. Electrochemical performance tests, including cyclic voltammetry (CV) and galvanostatic charge-discharge (GCD), are conducted to evaluate the supercapacitive behavior of the CuS/rGO nanocomposites. Preliminary results indicate that the CuS/rGO nanocomposites exhibit significantly improved electrochemical performance compared to pristine rGO, showcasing their potential as promising materials for high-performance supercapacitors. This research contributes to the ongoing efforts to develop efficient, cost-effective, and scalable solutions for energy storage applications.

CHARACTERISATION OF SLEEP STAGE BASED NON LINEAR ANALYSIS OF EEG

Submitted by

Ms. SONA K SANTHOSH

Reg. No: CCAWMPH014

Under the guidance of

Dr. Bindu M Krishna

Chief Research Officer

Center for Research and Innovation Multidisciplinary Sciences

CALICUT UNIVERSITY

JULY 2024

In partial fulfillment of the

Requirements for the award of the degree of

MASTER OF SCIENCE IN PHYSICS

CHRIST COLLEGE (AUTONOMOUS)
IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled **'CHARACTERISATION OF SLEEP STAGES BASED ON PERMUTION ENTROPY BASED NONLINEAR ANALYSIS OF EEG'**, is a bonafide record of the project work done by **SONA K SANTHOSH (CCAWMPH014)** under the guidance of Dr. Bindu M Krishna, Chief Research Officer, Centre for Research And Innovation in Multidisciplinary Sciences (CRIMS), in partial fulfilment of the requirements for the M.Sc. in Physics at Christ College Irinjalakuda, affiliated to university of Calicut during the period 2022-2024.

Place: Irinjalakuda
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Department of physics
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This is to certify that the project work entitled **"CHARACTERISATION OF SLEEP STAGES BASED ON PERMUTION ENTROPY BASED NONLINEAR ANALYSIS OF EEG"** is a bonafide record of the project work done by **SONA K SANTHOSH (CCAWMPH014)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer, Centre for Research And Innovation in Multidisciplinary Sciences, in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place: Kochi
Date: 08.07.2024

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Chief Research Officer
CRIM

DECLARATION

I **SONA K SANTHOSH** hereby declare that the Project report '**CHARACTERISATION OF SLEEP STAGES BASED ON PERMUTION ENTROPY BASED NONLINEAR ANALYSIS OF EEG'**, submitted for partial fulfillment of the requirements for the award of degree of Master of Science in Physics, is the original work carried out by me under the supervision of **Dr. Bindu M Krishna**, Chief Research Officer, Center for Research and Innovation in Multidisciplinary Sciences.

This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources.

I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

IRINJALAKUDA

11-07-2024

SONA K SANTHOSH

Abstract

Sleep is a complicated process that renews both the body and the intellect. EEG signals may be used to analyze sleep by detecting minute variations throughout different phases. Characterizing the EEG signal during different periods of sleep, and its relevance. All of these approaches rely on frequency information to characterize EEGs. Nonlinear approaches may effectively analyze EEG features under different neurological situations. This paper talks about sleep paralysis and lucid dreams in Rem Stage. Sleep paralysis is a state, during waking up or falling asleep, in which a person is conscious but in a complete state of full-body paralysis. [1][2]. Lucid dream is discussing about when a person is asleep but aware that they are dreaming. Nonlinear approaches, such as Permutation Entropy and Dispersion Entropy, may detect dynamic changes in real-world signals, including EEG, using ordinal pattern analysis. This research evaluates the effectiveness of approaches for detecting sleep stages by analyzing changes in their ordinal patterns. Our investigation found little differences in sleep phases across age groups.

Acknowledgement

This project was made possible by the contributions and support of many individuals. I take this opportunity to express my gratitude to everyone who provided their insights, resources and time to help me for the completion of this work.

I would like to express my deepest gratitude to Dr. Bindu M Krishna, Chief Research Officer (CRIMS), for her valuable guidance, encouragement and constant support throughout the project work.

I express my gratitude to Fr. Dr. Jolly Andrews, Principal, Christ College (Autonomous), Irinjalakuda, Thrissur for his continuous support. I am immensely grateful to Prof. Sudheer Sebastain K, Head of Department of Physics, Christ College, Irinjalakuda, for the help provided.

I extend my thanks to all the teaching and nonteaching staffs in the Department of Physics, Christ College, Irinjalakuda, for their support. I wish to thank my family and classmates for their support and encouragement throughout the project work.

SONA K SANTHOSH

ANALYZING EEG SIGNALS WITH CROSS PERMUTATION ENTROPY FOR SLEEP STAGE IDENTIFICATION AND DISORDER DETECTION

Submitted by

SREELAKSHMI S

Reg No: CCAWMPH015

Under the guidance of

Dr. Bindu M Krishna

Chief Research Officer
Centre For Research And Innovation in Multidisciplinary Sciences

CALICUT UNIVERSITY

JULY 2024

In partial fulfilment of the

requirements for the award of the degree of

MASTER OF SCIENCE IN PHYSICS

CHRIST COLLEGE (AUTONOMOUS) IRINJALAKUDA

(Affiliated to University of Calicut)

CERTIFICATE

This is to certify that the project work entitled "**ANALYZING EEG SIGNALS WITH CROSS PERMUTATION ENTROPY FOR SLEEP STAGE IDENTIFICATION AND DISORDER DETECTION**" is a bonafide record of the project work done by **SREELAKSHMI S (CCAWMPH015)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer Centre For Research And Innovation in Multidisciplinary Sciences in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place:
Date:

Prof. Sudheer Sebastian K.
Head of the Department
Department of Physics
Christ College,Irinjalakuda

Examiners

1.

2.

CENTRE FOR RESEARCH AND INNOVATION
IN MULTIDISCIPLINARY SCIENCES
KOCHI-22

CERTIFICATE

This is to certify that the project work entitled "**ANALYZING EEG SIGNALS WITH CROSS PERMUTATION ENTROPY FOR SLEEP STAGE IDENTIFICATION AND DISORDER DETECTION**" is a bonafide record of the project work done by **SREELAKSHMI S (CCAWMPH015)** under the guidance of **Dr. Bindu M Krishna**, Chief Research Officer Centre For Research And Innovation in Multidisciplinary Sciences in partial fulfilment of the requirements for the M.Sc. in Physics at Christ college Irinjalakuda, affiliated to University of Calicut during the period of 2022-2024.

Place: Kochi
Date: 08.07.2024

Dr. Bindu M Krishna
Chief Research Officer
CRIMS

DECLARATION

I, SREELAKSHMI S, affirm that the project report entitled '**ANALYZING EEG SIGNALS WITH CROSS PERMUTATION ENTROPY FOR SLEEP STAGE IDENTIFICATION AND DISORDER DETECTION**', being submitted in partial fulfilment for the award of degree of Master of Science in Physics, is the original work carried out by me under the supervision of Dr. Bindu M Krishna, Chief Research Officer, and CRIMS. This work has not been submitted elsewhere for the award of any degree.

Irinjalakuda
08.07.2024

SREELAKSHMI S
Reg No: CCAWMPH015

ACKNOWLEDGEMENT

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SREELAKSHMI S