



CRS/2022-23/1251

Chosen Centre: Mumbai

Project details	
Project title:	Synthesis and thermoelectric Characterization of In/Sn/Ge doped Bismuth Chalcogenide films prepared by DC magnetron sputtering
Type of Project:	In-house facilities of Mumbai Centre
Name(s) of Principal Collaborator from UGC-DAE CSR:	Dr. P D Babu
Names(s) of other Collaborator(s) from UGC-DAE CSR (if any):	Dr Raghavendra reddy,
Is there an ongoing CRS project of UGC-DAE CSR as a PI?	No
Financial support required from UGC-DAE CSR?	Yes
Require Fellowship for a Student?	Yes
Consumable (MAX 50,000/- PER YEAR):	1,50,000
contingency (MAX 15,000/- PER YEAR):	45000
Do you have any ongoing/submitted project with SERB/UGC/CSIR/BRNS or other funding agencies?	No
Personal Information	
Name of the Principal Investigator (PI):	Dr Ganesh Shridhar Hegde
Date of Birth:	1995-01-10
Designation:	Assistant Professor
Affiliation:	KLE Society's S Nijalingappa College
Official E-mail address:	358ganeshhegde@gmail.com
Postal address:	Post rajaji nagara KLE nijalingappa college 560010
Co-Principal Investigator	
Name of the Principal Investigator (PI):	Dr Ashwatha Narayana Prabhu
Date of Birth:	
Designation:	Assistant Professor Selection grade
Affiliation:	Manipal Academy of Higher Education
Official E-mail address:	ashwatha.prabhu@manipal.edu
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Bank Details	
Beneficiary Name	Principal KLE Society's S Nijalingappa College
Account Number	8418101084983
Bank Name	CANARA BANK
IFSC Code	CNRB0008418
Branch Name	RAJAJI NAGARA
Finance Authorities	

Account Officer's Name	Vinay N Reddy
Account Officer's Email	info@klesnc.org

1. **Title of the CRS proposal:** Synthesis and thermoelectric Characterization of doped Bismuth Chalcogenide films prepared by DC magnetron sputtering in the temperature range 250-400 K.

2. **A brief introduction/origin of the proposal (one paragraph):**

Recently thermoelectric energy resources are gaining importance due to the intensified demand for energy supply, increasing greenhouse gas effects, and reduction in carbon constructed energy sources. Thermoelectricity is one of the best promising energy sectors, which converts waste heat to electrical energy. The In and Se/Te co-doped  $\text{Bi}_2\text{Te}_3/\text{Se}_3$  has not been investigated till now. The thermoelectric figure of merit (ZT) is the parameter that decides suitability of thermoelectric materials for device applications. It is observed that the temperature is one of the important parameters to qualify the ZT value. The ZT value of the basic compounds can be enhanced by doping or composition method in which Bismuth, Tellurium, Selenium, Indium based compounds provide better ZT at the low and near room temperature range 10 - 350K. Since the chalcogenides like  $\text{Bi}_2\text{Se}_3$  and  $\text{Bi}_2\text{Te}_3$  are bonded with Vander Waals force between layers, the extra layer should be introduced to stack  $\text{Bi}_2\text{Se}_3/\text{Bi}_2\text{Te}_3$  superlattice.

The effect of germanium substitution led to increase in the carrier concentration and the localized electronic states in crystal, which alters electronic properties of the alloys, which motivates us to study co-doping effects in chalcogenides. The method of co-sputtering has been not extensively utilized for the investigation of thermoelectric device properties of In/Sn/Ge and Te/Se co-doped  $\text{Bi}_2\text{Te}_3$  and  $\text{Bi}_2\text{Se}_3$  at room temperature. The present investigation is focused on Synthesis and thermoelectric Characterization of In/Sn/Ge doped Bismuth Chalcogenide films prepared by DC magnetron sputtering. This is a proposal to analyse and investigate the effects of sputtering pressure on structural and thermoelectric properties such as electrical resistivity, thermal conductivity, Seebeck coefficient etc. of Indium and Selenium co-doped Bismuth Telluride thin films sputtering in the temperature range 250-400 K.

3. **Objectives (5-6 bullets)**

- To prepare In/Sn/Ge and Te/Se co-doped  $\text{Bi}_2\text{Te}_3$  and  $\text{Bi}_2\text{Se}_3$  round shaped pellet by hot pressing method
- To sputter the Bi-In-Se-Te thin films on flexible substrates or quartz/glass by DC magnetron sputtering systems.
- To optimize the electrical resistivity, thermal conductivity, and thermo-electric power
- To estimate and analyse the thermoelectric figure of merit (ZT).
- To demonstrate thermoelectric module based proto-type refrigeration.

4. **Novelty of the objectives (one paragraph)**

Due to the recent rise in energy supply demand, escalating greenhouse gas impacts, and decline in carbon-based energy sources, thermoelectric energy resources are becoming more and more significant. One of the most promising energy technologies is thermoelectricity, which turns waste heat into electrical energy. This is a proposal to analyses and research the impacts of sputtering pressure on structural and thermoelectric characteristics of indium and selenium co-doped bismuth telluride thin films, such as electrical resistivity, thermal conductivity, Seebeck coefficient, etc.  $\text{Bi}_2\text{Te}_3/\text{Se}_3$  that is co-doped with In and Se/Te has not yet been studied.

## **5. Methodology (max 1 page)**

$\text{Bi}_2\text{Te}_3$  and  $\text{Bi}_2\text{Se}_3$  were created by solid state reaction. The agate mortar is used to grind the precursors in a stoichiometric ratio for two hours. In order to prepare thin films for DC magnetron sputtering without altering the stoichiometric ratio, 50 mm diameter target plates are created using the hot-pressing process. Deionized water is used to adequately clean the substrates before a 15-minute alcohol ultrasonic treatment. Pre-deposition pressure needs to be kept below  $5 \times 10^{-4} \text{ Pa}$ . By pre-sputtering for ten minutes, surface contaminations are prevented. Targets  $\text{Bi}_2$  through  $\text{Te}_3$  will be 50 mm apart. The chamber's pressure was less than  $2.5 \times 10^{-3} \text{ Pa}$ . There has been a pressure range of 0.6 Pa to 1.6 Pa. The thickness of the Bi-Te films was kept  $1.3 \mu\text{m}$ . Sputtering module was evacuated with a trapped diffusion pump to a base pressure of less than  $8 \times 10^{-6} \text{ Torr}$  ( $1 \times 10^{-3} \text{ Pa}$ ). Indium targets of 2.5 cm and 0.10 cm diameter and thickness are used. Chamber is maintained as the final pressure of 1.5 and 2.5 atm. The sputtering pressure was examined with a capacitance at 50 *mTorr*,

### **X-ray Diffraction (XRD)**

Crystallographic properties like lattice parameters, bond angle, and the bond length will be analysed through X-ray diffraction (XRD).

### **High-Resolution X-ray diffraction (HRXRD)**

The defects and layered structure of thin films will be analysed through HRXRD.

### **Resistivity measurement**

The temperature dependent resistivity of the thin films will be measured using the conventional four-probe method.

### **Thermal conductivity**

Thermal conductivity of the thin films will be performed using physical property measurement system (PPMS).

### **Seebeck coefficient**

Seebeck coefficient will be performed using physical property measurement system (PPMS).

# Curriculum Vitae

**Dr. Ganesh Shridhar Hegde**

**Ph.D., M.Sc.**

**Assistant Professor**

Dept of Physics

Post Graduate Centre

KLE Society's S Nijalingappa College

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[ganesh.hegde@learner.manipal.edu](mailto:ganesh.hegde@learner.manipal.edu)

## Personal information

Date of Birth : 10-01-1995

Nationality : Indian

Gender : Male

Marital status : Single

Languages known : English, Kannada (Mother tongue), Hindi, Marathi

Present address : Post Manipal, Prabhu House, Udupi, Karnataka.  
576104

Permanent address : Post Gudeangadi, Kumta, hireoni cross,  
Uttara Kannada, 581351

## Present Position

Assistant Professor

National College Jayanagar

Banglore 560069.

## Academic profile

### 1) Ph. D.

**Awarded on 15<sup>th</sup> Sept 2022**

Department of Physics

**MIT, MAHE, Manipal**

**Research Supervisor:** Dr. Ashwatha Narayana Prabhu

Assistant professor (Selection grade)

Dept Physics

MIT, MAHE, Manipal

## 2)M.Sc. in Physics (Astrophysics)

Dept of Physics

Fergusson college affiliated to Savitribai Pule Pune University

Completed in 2018 with CGPA:8.22

## 3)B.Sc. (Physics, Chemistry, Maths)

Dr. A. V. Baliga college of arts and science, Kumta

Completed in 2016 with 78% (Distiction)

## 10+2 (Physics, Chemistry, Maths, Biology)

Dr.A. V. Baliga PU College of arts and science, Kumta

Completed in 2013 with 67.5%

## SSLC

CVSK High school, Kumta

Completed in 2011 with 95.36%

## Research Experience:

My work is focused on **comparative study of thermoelectric properties of single crystals and polycrystalline systems of Low temperature thermoelectric Bismuth metal chalcogenides.**

**Single Crystals:** I have synthesized **high quality single crystal samples of metal bismuth chalcogenides** using the **melt growth technique** and analysed their structural, morphological, and thermoelectric properties in the temperature range 10-350 K.

**Polycrystalline materials:** Polycrystalline samples of **metal bismuth chalcogenides** have been prepared **using solid-state reaction** and studied their structural, morphological, and thermoelectric properties in the temperature range 10-350 K.

**I have worked in Materials Synthesis Lab at UGC-DAE, Mumbai under Dr. P D Babu for PPMS thermoelectric characterizations, Mossbauer Lab at UGC-DAE, Indore under Dr. V R Raghavendra Reddy for HR-XRD Studies and at Materials Research Centre, IISc Bengaluru under Dr. Arun M Umarji for vacuum sealing of thermoelectric materials.**

Till now I have published **9 research articles as first author** and **I have attended and presented my research works in 2 International, 4 National and 1 state level conferences.**

## Education Details *(starting from the highest degree)*

Qualification	Year of Passing	Board / University	Percentage/CGPA Scored
Ph.D.	2022(Aug)	Manipal Academy of Higher Education	<b>Defended successfully</b>
M.Sc (Physics)	2018	Fergusson college Pune University	8.2 CGPA
B.Sc (Physics, Chemistry, Maths)	2016	Dr. A. Baliga college of arts and science	78

## Research Publications: *(Scopus, Web of Science, H-Index)*

## List of Publications in Journals

Sl. No.	Title of the Project	Authors	Journal Name	Volume	Page No.	Year of Publication	Impact Factor
1	Enhancement of thermoelectric performance of In doped $\text{Bi}_2\text{Te}_{2.7}\text{Se}_{0.3}$ compounds	<b>Hegde, Ganesh</b> Shridhar, A. N. Prabhu, Ashok Rao, and P. D. Babu	Physica B: Condensed Matter	584	412087	2020	2.436
2	Reduction in thermal conductivity and electrical resistivity of indium and tellurium co-doped bismuth selenide thermoelectric system	<b>Hegde, G. S.,</b> Prabhu, A. N., Huang, R. Y., & Kuo, Y. K.	Journal of Materials and Materials in Electronics	31	19525	2020	2.47
3	Potential thermoelectric materials of indium and tellurium co-doped bismuth selenide single crystals grown by melt growth technique	<b>Hegde, G. S.,</b> Prabhu, A. N., Gao, Y. H., Kuo, Y. K., & Reddy, V. R	Journal of Alloys and Compounds	866	158814	2021	5.316
4	Enhancement in thermoelectric figure of merit of bismuth telluride system	<b>Hegde, Ganesh</b> Shridhar, A. N. Prabhu, Ashok Rao, and M. K. Chattopadhyay.	Materials Science and Semiconductor Processing	127	105645	2021	3.97
5	Improved electrical conductivity and power factor in Sn and Se co-doped melt- grown $\text{Bi}_2\text{Te}_3$ single crystal	<b>Hegde, Ganesh</b> Shridhar, A. N. Prabhu, and M. K. Chattopadhyay.	Journal of Materials Science and Materials in Electronics	20	24871	2021	2.47
6	Reduction in electrical resistivity of bismuth selenide single crystal via Sn and Te co-doping	<b>Hegde, Ganesh</b> Shridhar, A. N. Prabhu, R. Y. Huang, and Y. K. Kuo	Materials Chemistry and Physics	278	125675	2022	4.094
7	A Review on Doped/Composite Bismuth Chalcogenide Compounds for Thermoelectric Device Applications: Various Synthesis Techniques and Challenges	<b>Hegde, Ganesh</b> <b>Shridhar,</b> and A. N. Prabhu.	Journal of Electronic Materials	51	2014	2022	1.98
8	Structural and optical characterization of novel nitro substituted D- $\pi$ -A- $\pi$ -A type chalcone single crystal showing second-order and third-order nonlinear optical properties..	Parol, V., Upadhyaya, V., <b>Hegde, G. S.,</b> Lokanath, N. K., & Prabhu, A. N.	Physica B: Condensed Matter	580	4598	2019	2.9
9	Thermoelectric properties of co-doped ( $\text{Bi}_{0.98}\text{In}_{0.02}$ ) $_2\text{Te}_{2.7}\text{Se}_{0.3}$ /reduced graphene oxide composites prepared by solid-state reaction	<b>Hegde, Ganesh</b> <b>Shridhar,</b> Vinay Parol, Ashok Rao, A. N. Prabhu,	Materials research Bulletine	145	111517	2022	4.64

		Joshua JB Levinsky, and Graeme R. Blake.					
10	Investigation of near room and high temperature thermoelectric properties of (Bi <sub>0.98</sub> In <sub>0.02</sub> )- <sub>2</sub> Se <sub>2.7</sub> Te <sub>0.3</sub> /Bi <sub>2</sub> Se <sub>3</sub> composite system	Ganesh Hegde, Ashok Rao, A. N. Prabhu, Gurukrishna K, Deepika S	Journal of Materials Science and Materials in Electronics	Accepted	Accepted	Accepted	Accepted

### Conferences/Seminars/Workshops/Faculty development programme

Sl. No.	Name of the Event	National/ International	Date	Name of the Organizer	Credits Earned
1	One week international webinar on materials characterization and analysis	International	25-31, 2020	Dept of Physics, Indore	Participation
2	Online workshop on Rietveld refinement	International	22-24,2020	UGC DAE INDORE, MUMBAI	Participation
3	9 <sup>th</sup> national conference on condensed matter physics	National	16-17, Sept, 2021	MAHE, Manipal	Poster presentation
4	8 <sup>th</sup> national conference on condensed matter physics	National	26, Sept, 2020	MAHE, Manipal	Poster presentation
5	8 <sup>th</sup> national conference on condensed matter physics	National	16, 17 Sept 2020	MAHE, Manipal	Poster presentation
6	7 <sup>th</sup> national conference on condensed matter physics	National	16, 17 Sept 2020	MAHE, Manipal	Oral presentation
7	Thermoelectric materials and application for energy harvesting and power generation	International	14 <sup>th</sup> Dec 2021	School of Mechanical Engineering Katra	Participation
8	Physics in Every day life	International	9-11, 2021	Medi caps Indore	Participation
9	International Conference on advanced materials	International	1,2 July	Calicut University	Oral presentation
10	International conference on Advanced materials science and application	International	3-4 Sept 2020	M. S. Rammaya institute of technology	Best oral presentation award
11	State level kannada vijnana sammelana	State	16-17 Sept 2021	Mangalore University	Best research article
12	International winter school on frontiers in materials	international	6-10 Dec 2021	JNCASR	Poster presentation
13	Faculty development programme	National	20 <sup>th</sup> June - 24 <sup>th</sup> June	Christ academy, Bangalore	participant
14	Innovative experiment for physics teachers	Regional	10-July 2022	Maharani laksmi ammani college Bangalore	First prize
15	Resource person in Faculty development Programme	National	Oct 11 <sup>th</sup> 2022	BMS Institute of science and management	

Apart from these, I had been an NCC Cadet, cleared C Certificate exam which has taught me discipline, teamwork, critical thinking, and tackle challenges logically. These qualities have helped me in carrying out my research work in an organized manner.

By all these, I believe I am an ideal candidate for the present position.



**Reference****(Prof) Dr. Vasudeva Siruguri**

Former Centre Director,  
UGC-DAE Consortium for Scientific Research Mumbai Centre  
Mumbai, Maharashtra  
Contact No: 9969303262  
Email id: [siruguri@csr.res.in](mailto:siruguri@csr.res.in)

**(Prof) Dr. Ashok Rao**

Associate Director  
Research and Consultancy  
Manipal Institute of Technology  
MAHE, Manipal  
Contact No.: 9916067593  
Email Id: [a.rao@manipal.edu](mailto:a.rao@manipal.edu)

**Dr. RAJEEV SHESHA JOSHI**

Assistant Professor  
School of Physical Sciences,  
Central University of Karnataka,  
Aland Road, Kadaganchi,  
Gulbarga, Karnataka-585311  
Email Id: [rajeevsj@cuk.ac.in](mailto:rajeevsj@cuk.ac.in)

**Dr. Ashwatha Narayana Prabhu**

Assistant Professor (Selection grade)  
Crystal growth lab in charge  
Department of Physics  
Manipal Institute of Technology  
MAHE  
Contact No.: 9964586628  
Email id: [ashwatha.prabhu@manipal.edu](mailto:ashwatha.prabhu@manipal.edu)

**Declaration:**

**I hereby declare that the details stated above are true and correct to the best of my knowledge.**

# ASHWATHA NARAYANA PRABHU. MSc, PhD.



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AICTE ID: 1-431218261

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## Teaching Experience:

1. Worked as a Lecturer in Physics at Bhandarkars College, Kundapura, Udupi from 19<sup>th</sup> July 1999 to 31<sup>st</sup> March 2003.
2. Worked as a Lecturer in Physics at Sharada Residential PU College, Kunjibettu, Udupi from 2<sup>nd</sup> June 2003 to 8<sup>th</sup> July 2008.
3. Presently working as Asst. Professor-Selection Grade in Physics at Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal from 18<sup>th</sup> August 2008.

**Total teaching experience: 23 Years**

## Research guidance:

Ph D

Guided: 01

Guiding: 02

M.Sc ----- 10

BSc -----01

## Research Co-guidance:

Ph D

Guided: 01

## Responsibilities held at MIT:

- Departmental Coordinator, AMS / SLCM
- Departmental Coordinator, Time table committee
- Departmental Coordinator, NAAC/NBA/NIRF
- Section coordinator – First year B Tech
- Group coordinator – Inspire programme, May 2015
- Member – Departmental Academic audit committee (2011-2012)
- Member – Departmental Stock verification committee
- Member, Institute level Anti-ragging squad
- Teacher Guardian
- Treasurer – National conference, CMPA March 2015 & CMPA May 2016
- Departmental coordinator – Annual Day 2015
- Co-Convener – National conference, CMPA Sep 2017
- Convener – National conference, CMPA Sep 2018
- Department Coordinator, Quality & Compliance
- Question paper scrutiny – MET 2018, 2019, 2020, 2021, 2022
- OBE draft preparation \_MSc Physics course
- COVID line tracing duty at MIT \_ March 2021

## Educational Profile

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### Ph. D. in Physics

Title of the thesis: **Synthesis and Characterization of Nonlinear Optical Crystals of Chlorine and Bromine Substituted Chalcone Derivatives**

Year of Award: January 2014

University: **Manipal University, Manipal.**

### M.Sc in Physics- 63.28% (1<sup>st</sup> Class)

Year : 1999

University : Mangalore University, Mangalagangothri.

### B.Sc (Physics, Maths and Statistics) – 60.2% (1<sup>st</sup> Class)

Year : 1997

University : Mangalore University, Mangalagangothri.

## Publications:

### Journal Papers

1. **A. N. Prabhu, A. Jayarama, T. N. Guru Row and V. Upadhyaya**

*“(2E)-1-(5-Chlorothiophen-2-yl)-3-(2,4,5-trimethoxyphenyl)prop-2-en-1-one”*

**Acta Crystallogr. E67, 2086, 2011 (I.F 0.347).**

2. **A. N. Prabhu, A. Jayarama, Ravish Sankolli, T. N. Guru Row and V. Upadhyaya**  
 “(2E)-1-(5-Chlorothiophen-2-yl)-3-(2,3-dimethoxyphenyl)prop-2-en-1-one”  
**Acta Crystallogr. E67, 2665, 2011 (I.F 0.347).**
3. **A. N. Prabhu, V. Upadhyaya, A. Jayarama, M Srinivasulu, K B Manjunatha, G. Umesh**  
 “Synthesis, growth and characterization of 1-(5-Chlorothiophen-2-yl)-3-(2,4,5-trimethoxyphenyl)prop-2-en-1-one single crystal: A potential NLO material”  
**Optics: Phenomena, Materials, Devices and Characterization, AIP conf. proc. 1391, 538-540, 2011.**
4. **A. N. Prabhu, V. Upadhyaya, K. S. Girisha, C. S. Naveena and T. N. Guru Row**  
 “2,2,2-Trichloro-N-(3-nitrophenyl)- acetamide”  
**Acta Crystallogr. E68, 2832, 2012.**
5. **A.N. Prabhu, A. Jayarama, K Subrahmanya Bhat, V. Upadhyaya**  
 “Growth, characterization and structural investigation of a novel nonlinear optical crystal”  
**Journal of Molecular Structure 1031, 79–84, 2013 (I.F 1.599).**
6. Naveena. C. S, Boja poojary, Arulmoli, Manjunatha, **A.N.Prabhu**, Nalilu Suchetha Kumari  
 “Synthesis and evaluation of biological and nonlinear optical properties of some novel 2,4-substituted (1,3)-thiazoles carrying 2-(aryloxymethyl)phenyl moiety”  
**Medicinal Chemistry Research 22, 1925-1937, 2013 (I.F 1.72).**
7. **A.N. Prabhu, V. Upadhyaya, A. Jayarama, K. Subrahmanya Bhat**  
 “Synthesis, growth and characterization of  $\pi$  conjugated organic nonlinear optical chalcone derivative”  
**Materials Chemistry and Physics 138, 179 – 185, 2013 (I.F 2.129).**
8. **A. N. Prabhu, A. Jayarama, K. Subramanya Bhat, V. Upadhyaya, K B Manjunatha, G. Umesh,**  
 “Physicochemical Studies on Thienyl Chalcone Derivative for Nonlinear Optical Application”  
**Indian Journal of Materials Science, Volume 2013, Article ID 151230, 5 pages, 2013.**  
<http://dx.doi.org/10.1155/2013/151230>.
9. **A. N. Prabhu, A. Jayarama, K Subramanya Bhat, V. Upadhyaya**  
 “Growth, Characterization and Molecular Hyperpolarizabilities of Novel Nonlinear Optical Chalcone Crystals”  
**Chemical Science Transactions 3(2), 530-539, 2014.**
10. **A. N. Prabhu, A. Jayarama, K Subramanya Bhat, V. Upadhyaya**  
 “Third order NLO property of thienyl chalcone derivative: Physicochemical analysis and crystal structure determination”  
**Molecular Crystals and Liquid Crystals, 637, 76-86, 2016 (I.F 0.571).**

11. **A.N. Prabhu**, Pramoda Kumara Shetty, Indudhar Panduranga Vali, Hemanth Kumar, Sowmyasree Udupa  
“Gamma and neutron irradiation effects on the structural and optical properties of potash alum crystals”  
**Nuclear Inst. and Methods in Physics Research, B 413, 37-41, 2017 (I.F 1.109).**
12. Pramoda Kumara Shetty, P.P. Vinaya, Raviraja Nakshatri, **A.N. Prabhu** “Effect of gamma and neutron irradiation on structural and optical properties of ammonium dihydrogen phosphate single crystals”  
**Optik – International Journal for Light and Electron Optics, 156, 224-230, 2018 (I.F 1.191).**
13. P.P Vinaya, **A.N. Prabhu**, K. Subrahmanya Bhat, V.Upadhyaya “ Design, Growth and characterization of D- $\pi$ -A- $\pi$ -D based efficient nonlinear optical single crystal for optical device applications”  
**Journal of Physics and Chemistry of Solids, 123, 300-310, 2018 (I.F 3.442).**
14. P.P Vinaya, **A.N. Prabhu**, K. Subrahmanya Bhat, V.Upadhyaya “Synthesis, growth and characterization of a long-chain  $\pi$ -conjugation based methoxy chalcone derivative single crystal; a third order nonlinear optical material for optical limiting applications”  
**Optical Materials, 89, 419-429, 2019 (I.F 2.779).**
15. Vinay Parol; V Upadhyaya; Ganesh Sridhar Hegde; Lokanath N.K.; **A N Prabhu**, “Structural and optical characterization of novel nitro substituted D- $\pi$ -A- $\pi$ -A type chalcone single crystal showing second-order and third order nonlinear optical properties”  
**Physica B: condensed matter, 580, 411830, 2020 (I.F 1.902).**
16. Ganesh Shridhar Hegde, **A. N. Prabhu**, Ashok Rao, P. D. Babu, “Enhancement of thermoelectric performance of In doped Bi<sub>2</sub>Te<sub>2.7</sub>Se<sub>0.3</sub> compounds”  
**Physica B: condensed matter, 584, 412087, 2020 (I.F 1.902).**
17. Vinay Parol, V. Upadhyaya, **A.N. Prabhu**, N. K. Lokanath, Md Abu Taher, Sri Ram G Naraharisetty, “A long-chain based bromo and methyl substituted chalcone derivatives; experimental and theoretical approach on nonlinear optical single crystals”  
**Materials Research Express, 7 (2020) 055101 (I.F 1.929).**
18. Vinay Parol, **A.N. Prabhu**, Md Abu Taher, Sri Ram G Naraharisetty, N. K. Lokanath, V. Upadhyaya, “A third-order nonlinear optical single crystal of 3,4-dimethoxy substituted chalcone derivative with high laser damage threshold value; a potential material for optical power limiting”  
**Journal of Materials Science: Materials in Electronics, 31(2020) 9133–9150 (I.F 2.22).**
19. G. S. Hegde, **A. N Prabhu**, R, Y. Huang, Y. K. Kuo “Reduction in thermal conductivity and electrical resistivity of Indium and Tellurium co-doped Bismuth Selenide thermoelectric system”, **Journal of Materials Science: Materials in Electronics, 31 (2020) 19511–19525 (DOI: 10.1007/s10854-020-04383-7) (I.F 2.22).**

20. Kumar, R., Karthick, T., Parol, V., Rawat, P., Tandon, P., Gupta, A., **Prabhu A N**, Upadhyaya V, “Spectroscopic characterization and structural insights of 4-[(1E)-3-(4-methoxyphenyl)-3-oxoprop-1-en-1-yl]phenyl 4-methylbenzene-1-sulfonate using vibrational, electronic spectra and quantum chemical calculations” **Journal of Molecular Structure**, **1225 (2021) 129144 (I.F 3.196)**.
21. Ganesh Shridhar Hegde, **A.N. Prabhu**, Ashok Rao, M.K. Chattopadhyay, “Enhancement in thermoelectric figure of merit of bismuth telluride system due to tin and selenium co-doping”, **Materials Science in Semiconductor Processing**, **127(2021) 105645 (I.F 3.927)**.
22. Vinay Parol, V. Upadhyaya, **A.N. Prabhu**, K. Subrahmanya Bhat, “A Chalcone Derivative Single Crystal for the Investigation of Linear and Nonlinear Optical Properties for Laser Assisted Applications”, **DAE Solid State Physics Symposium 2019 AIP Conf. Proc. 2265, 030401-1–030401-4;https://doi.org/10.1063/5.0016911**.
23. G. S. Hegde, **A. N Prabhu**, R, Y. Huang, Y. K. Kuo, “Potential thermoelectric material of indium and tellurium co-doped bismuth selenide single crystals grown by melt growth technique” **Journal of Alloys and Compounds**, **866 (2021) 158814 (I.F 5.316)**.
24. Ganesh Shridhar Hegde, **A. N. Prabhu**, M. K. Chattopadhyay, “Improved electrical conductivity and power factor in Sn and Se co-doped melt-grown Bi<sub>2</sub>Te<sub>3</sub> single crystal” ***Journal of Materials Science: Materials in Electronics***” **J Mater Sci: Mater Electron (2021) 32:24871–24888 (IF: 2.478)**.
25. Ganesh Shridhar Hegde, Vinay Parol, Ashok Rao, **A. N. Prabhu**, Joshua J. B. Levinsky, Graeme R. Blake, “Thermoelectric properties of co-doped (Bi<sub>0.98</sub>In<sub>0.02</sub>)<sub>2</sub>Te<sub>2.7</sub>Se<sub>0.3</sub> / reduced graphene oxide composites prepared by solid-state reaction” **Materials Research Bulletin** **145 (2022) 111517 (IF: 4.641)**.
26. G. S. Hegde, **A. N Prabhu**, C.F. Yang, Y. K. Kuo, “Reduction in electrical resistivity of bismuth selenide single crystal via Sn and Te co-doping” **Materials Chemistry and Physics**, **278 (2022) 125675 (I.F 4.094)**.
27. G. S. Hegde, **A. N Prabhu**, “A review on doped/composite bismuth chalcogenide compounds for thermoelectric device applications: Various synthesis techniques and challenges” **Journal of Electronic Materials**, **51, (2022) 2014–2042 (I.F 1.938)**.
28. Kezhia Thomas, Vinay Parol, P. Karuppasamy, Muthu Senthil Pandian, P. Ramsamy, **A. N. Prabhu**, “Influence of 60Co gamma irradiation on the structural and optical properties of 2-aminopyridinium 4-nitrophenolate 4-nitrophenol crystals” **Current Applied Physics**, **37 (2022) 1-7 (I.F 2.48)**.

29. Hegde, G. S., **Prabhu, A. N.**, Rao, A., Gurukrishna, K. & Deepika Shanubhogue, U, "Investigation of near-room and high-temperature thermoelectric properties of (Bi<sub>0.98</sub>In<sub>0.02</sub>)<sub>2</sub>Se<sub>2.7</sub>Te<sub>0.3</sub>/Bi<sub>2</sub>Te<sub>3</sub> composite system", **Journal of Materials Science: Materials in Electronics**, **33 (2022) 25163-25173 (IF: 2.478)**.

#### **Papers presented at International conferences**

1. **A. N. Prabhu**, "Synthesis, Growth, and Characterization of a Novel Nonlinear Optical Organic Material for Optical Device Applications", International Conference on IES 2019, held during March 13-15, 2019 at Kumamoto University, Japan.
2. **A. N. Prabhu**, "Synthesis, Growth and Characterization of Acetophenone-4-Quinoline-D Chalcone Single Crystal: A Potential Nonlinear Optical Material", International Conference on NANOTECH ME 2017, held during December 4-6, 2017 at Dubai.
3. **A. N. Prabhu**, V. Upadhyaya, "Synthesis and growth of superior characteristic nonlinear optical organic material: 1-(5-chlorothiophen-2-yl)-3-(2, 3-dichlorophenyl) prop-2-en-1-one", International Conference on Metallurgy and Materials engineering, held at Pattaya, Thailand, June 21-22, 2016.
4. **A. N. Prabhu**, V. Upadhyaya, "Synthesis, growth, characterization and molecular hyperpolarizabilities of a novel nlo organic material", International Conference on "Light Manipulating Organic Materials and Devices II, SPIE Organic Photonics + Electronics, SPIE Optics + Photonics 2015", held at San Diego, California, United States, August 9-13, 2015.
5. **A. N. Prabhu**, V. Upadhyaya, A. Jayarama, K B Manjunatha, G. Umesh, "Synthesis, growth and characterization of 1-(5-Chlorothiophen-2-yl)-3-(2,3-dimethoxyphenyl)prop-2-en-1-one single crystal: A potential nlo material", International Conference on X-ray Related Techniques in Research and Industry (ICXR I2012) Penang, Malaysia, July 03-05, 2012.
6. **A. N. Prabhu**, V. Upadhyaya, A. Jayarama, M Srinivasulu, K B Manjunatha, G. Umesh, "Synthesis, growth and characterization of 1-(5-Chlorothiophen-2-yl)-3-(2,4,5-trimethoxyphenyl)prop-2-en-1-one single crystal: A potential NLO material", International Conference on Light-"OPTICS'11," Department of Physics, NIT, Calicut, Kerala, May 23-25, 2011.

#### **Papers presented at National conferences**

1. **A. N. Prabhu**, V. Upadhyaya, "Superior Characteristics of Novel nlo Organic Material," National conference "IFMMT 2014," Department of Mechanical Engineering, Manipal University Jaipur, India, Dec 26-27, 2014.
2. **A. N. Prabhu**, V. Upadhyaya, A. Jayarama, "Synthesis and characterization of organic NLO material", National conference "NCSMTEE 2013," Department of

Mechanical Engineering, Mangalore Institute of Technology & Engineering(MITE), Moodabidri-574225, India, March 08-09, 2013.

3. **A. N. Prabhu**, V. Upadhyaya, A. Jayarama, “Growth, characterization and structural investigation of 1-(5-Bromothiophen-2-yl)-3-(4-nitrophenyl)prop-2-en-1-one”, National Conference on Condensed Matter Physics and Applications “CMPA 2012” Department of Physics, MIT, Manipal, December 27-28, 2012.
4. **A. N. Prabhu**, V. Upadhyaya, A. Jayarama, “Synthesis, growth and characterization of 1-(5-Chlorothiophen-2-yl)-3-(2,3-dichlorophenyl)prop-2-en-1-one single crystal: A potential NLO material”, National Conference “RTMS2011,” JUIT Shimla, October 8-10, 2011.
5. **A. N. Prabhu**, V. Upadhyay, A. Jayarama, K B Manjunatha, G. Umesh, “Synthesis and crystal structure of 1-(5-Chlorothiophen-2-yl)-3-(2,4,5-trimethoxyphenyl)prop-2-en-1-one”, National Conference “CAPSRAA-2011,” Govinda Das College, Surathkal, Sept 16-17, 2011.
6. G. S. Hegde, **A. N. Prabhu\***, A. Rao, P. D. Babu, “Enhancement of cryogenic thermoelectric performance of In doped Bi<sub>2</sub>Te<sub>2.7</sub>Se<sub>0.3</sub> compounds,” CMPA-2019, Department of Physics, Manipal Institute of Technology, Manipal, 27-28 September 2019.
7. G. S. Hegde, **A. N. Prabhu\***, A. Rao, P. D. Babu, “Enhancement in thermoelectric figure of merit of indium and selenium co-doped bismuth telluride,” International conference on Advanced materials Science and applications-2020, M. S. Ramaiah Institute of Technology, Bengaluru, 3-4 September 2020. – Best Paper Award
8. G. S. Hegde, **A. N. Prabhu\***, Y. H. Gao, Y. K. Kuo\*, V. Raghavendra Reddy, “Growth and characterization of indium and tellurium co-doped bismuth selenide single - crystals for thermoelectric applications,” CMPA-2020, Department of applied Physics, Manipal Institute of Technology, Manipal, 26 September 2020.

#### **Faculty Achievements:**

1. Dr Ashwatha Narayana Prabhu, Manipal Institute of Technology received “**Best Session Paper Award**” in International Conference on Mechanical, Metallurgy and Materials Engineering (ICMMME-16), held at Pattaya, Thailand from Jun 21 to 22, 2016 for his paper titled “Synthesis and Growth of Superior Characteristic Nonlinear Optical Organic Material: 1-(5-Chlorothiophen-2-YL)-3-(2,3-Dichlorophenyl)prop-2-en-1-one.”
2. Received conference grant of Rs 30,000/- from BARC Mumbai for the “National conference, CMPA Sep 2018”.



3. Received Rs 25,000/- as seed money grant from Research Directorate Technical MAHE during June 2019 [Grant ID: 00000202].
4. Received external funded research project from UGC DAE CSR, Mumbai, Rs 1,35,000/- [UDCSR/MUM/AO/CRS-M-314/2020/812 letter dated 13 July 2020].
5. Received intramural research fund from Manipal Academy of Higher Education, Manipal Rs 4,50,000/- [letter dated 17 December 2021].

#### **Resource Person:**

- Invited Lecture in International Workshop Thermoelectric Materials and Applications held on 24-25 August 2022 organized by SSN Research Centre, SSN Institutions, Chennai-603110, Tamil Nadu, India.

#### **Professional Training Received:**

- Participated in three days National workshop on “**Advances in Organic Chemistry and Allied Applications**” held at NITK, Surathkal during 16-18 Feb 2009.
- Participated in five days winter school on “**Nanoscience and Nanotechnology: Recent Trends and Perspectives (NSNT-2010)**” at NITK, Surathkal from 22-02-2010 to 26-02-2010.
- Participated in the “**XX Refresher course in Experimental Physics**” organized by Manipal University, Manipal, during May 24-June 9, 2010.
- Participated in the two days Awareness workshop on “The facilities of UGC-DAE Consortium for scientific research” held at Manipal Institute of technology, Manipal University from 6 to 7th September 2010.
- Participated in the 5 days **55<sup>th</sup> DAE-Solid State Physics Symposium** sponsored by BRNS, Dept. of Atomic Energy Government of India, organized by Manipal University, Manipal, during Dec 26-30, 2010.
- Participated in the **5 days Faculty Development Programme-2011 on “Photonics Materials and Devices**”, organized by NIT, Calicut during 28<sup>th</sup> Feb—4<sup>th</sup> March 2011.
- Participated in one day symposium on “**Recent Advances in Photonics**” organized by CAMP, Manipal University on March 29, 2011.
- Participated in one day **Workshop on Materials Characterization** organized by XAPP/USM at Penang, Malaysia, on July 05, 2012.

- Participated in three days “**National workshop on Photonics in Medicine and Biology**” organized by CAMP, Manipal University during August 20-22, 2012.
- Participated in one day workshop on “**Three Dimensional Structure (Drug) determination using X-ray Crystallography**” organized by CAMP, Manipal University on Feb 26, 2013.
- Participated in the **International Winter School on “Organic Electronic Materials & Devices**” jointly organized by Dept. of Physics & Center for Materials Research, NITK Surathkal and Dept. of Physics and Astronomy, Michigan State University, USA, held at NITK, Surathkal during 19-21 Dec 2013.
- Attended a two days workshop on “**Counseling Skills for Teachers**” organized by Dept. of Student Affairs, Manipal University, during February 19-20, 2014.
- Participated in the workshop on “Recent Trends in Optics” held at International School of Photonics, Cochin University of Science and Technology, Kochi, during 26-28 Feb 2015.
- Participated in the Faculty Development Programme (FDP) on “Principles of Photonics and Applications” held at M S Ramaiah Institute of Technology, Bangalore during July 20-24, 2015.
- Attended a three days thematic workshop on “Diffraction methods for structural analysis in materials science” held at PPISR, Bangalore during 25-27 July 2016.
- Participated in a short term course on “X-Ray Crystallography Basics and Applications” held at IISC, Bengaluru during 11-15 September 2017.
- Participated in the workshop on “Sculpting an Academic Teaching Portfolio” held at MCPD during 19 June 2018.
- Participated in the workshop on “Research Awareness Programme level 1” held at MIT during 8 June 2018.
- Participated in the workshop on “Research Awareness Programme level 2” held at MIT during 15 June 2018.
- Participated in a short term course on “Solar Energy Systems” held at IISC, Bengaluru during 1-5 July 2019.
- Attended the Online Scientific Writing Program on the topics “Structuring your manuscript to impress journal editors and Selecting a journal and preparing a great submission package” organized by Editage on 19 June, 2020.
- Attended “Online five days international faculty techno-improvement programme” organized by Netaji Subhashchandra Bose College Nanded, during 22-26 June 2020.

- Participated in One-week Faculty Development Programme “Material Synthesis and Characterization for Device Applications” held from 31st August to 5th September 2020 organized by Department of Physics & Chemistry, NMIT, Bangalore.
- Participated in Online workshop on Universal Human Values – Inculcating Universal Human Values in Technical Education during 21-25 Sep. 2020 (AICTE).
- Participated in Online workshop on “CREATIVITY, PROBLEM SOLVING AND INNOVATION”, during 20-27 July 2021 (Office of the Faculty Development & Welfare (FDW) MIT, MAHE & Anil S Patel, Ph.D., who was supported by Faculty of Management Studies (FMS) at Charotar University of Science and Technology).

### **Responsibilities held, achievements and recognitions outside MIT:**

1. Member of Udupi district first year PU Question bank setting team (2007-2008).
2. Worked as Time table coordinator at Sharada PU College, Kunjibettu, Udupi.
3. Worked as Deputy Chief Examiner (First year PU) at Cross land PU College, Brahmavar.
4. Expert team member \_ Atal Tinkering Lab at Madhava Kripa School Manipal



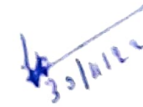
Ref. No. : KLE/SNC/2022-23

Date : 30/11/2022

## DECLARATION

1. As a Principal Investigator (PI), I understand that it is my responsibility to carry out the Collaborative Research Scheme (CRS) project work as per rules and regulations of UGC-DAE CSR.
2. The scientific program of the CRS will be carried out jointly by me and a Principal Collaborator at UGC-DAE CSR. All scientific publications resulting from the CRS, will be communicated with each other's consent. Technical and scientific assistance from UGC-DAE CSR and DAE personnel will be acknowledged, either in the acknowledgements or in authorship.
3. Financial support received from UGC-DAE CSR will be acknowledged explicitly in all publications. Please add following sentence in the acknowledgement section of the manuscript, **“This work was partially/fully carried out using the facilities of UGC-DAE CSR”**
4. Progress reports, extension requests, conclusion documents, etc., will be submitted by me to the UGC-DAE CSR with the consent of the Principal Collaborator.
5. Copies of the publications, thesis, etc., resulting from the CRS will be sent to UGC-DAE CSR.

Place: Bangalore  
Date: 30.11.2022

  
Signature of Principal Investigator



Signature and Seal of Head of  
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Principal

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## **M.Sc. (PCM)**

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