

Supporting Documents for Collaborative Activities during 2016-21



Pub Kamrup Collge

Baihata Chariali

Kamrup-781381

Assam



Group photographs of the student exchange program between Suren Das College, Hajo and Pub Kamrup College.

Sr.No.	Name	Designation	Phone Numbers
01.	Dr. H. K. Sarma	Principal	9435124475
02.	Dr. Ali Akbar Hossain	Vice-Principal	8011268633
03.	Mr. Nagesh Ch.	Assoc. Prof & HOD	9365424034
04.	Dr. Ripina Buzarbama	Assoc. Prof. Pt. Sc.	9101540742
05.	Diganta K. Rabha	Associate Prof. Geog.	7578075791
06.	Aditya Ch. Saha	Assoc. Prof.	986424081
07.	Dhriti Smita Kalita	3rd Sem	9954347471
08.	Gaminan Gama	3rd Sem	9127891980
09.	Dhanjit Kakati	3rd Sem	9896153417
10.	Ankur Bikash Deka	3rd Sem	6003562437
11.	Bethika Devi	3rd Sem	6003550990
12.	Nahida Akhbar	3rd Sem	6900999534
13.	Dhruaj Dutta	3rd Sem	6002997408
14.	Bandita Rajbongshi	3rd Sem	7086571372
15.	Pangki Patowary	3rd Sem	8811007756
16.	Deepasthi Deka	3rd Sem	9723953128

Sr.No.	Name	Semester	Phone No.
17.	Suman Raj Deka	3rd Sem	9968792661
18.	Himel Jyoti Deka	3rd Sem	9639867946
19.	Jimlee Deka	3rd Sem	6003673796
20.	Jenny Sharma	3rd Sem	8011203637
21.	Kushika Kakati	3rd Sem	8403971236
22.	Hemita Baro	3rd Sem	6001567541
23.	Sagarika J Nath	3rd Sem	6003917044
24.	Jyotirmita Devi	3rd Sem	9894924660
25.	Deivy Kumar	3rd Sem	8011878920
26.	Priyanka Rani Devi	3rd Sem	8486373617
27.	Rahul Dutta	3rd Semester	8011927852
28.	Jitu Deka	3rd Semester	6002587993
29.	Siddhanti Barika	3rd Semester	7578024606
30.	Soraya Begum	3rd Semester	8471896643
31.	Mojahiddin Ahmed	3rd Semester	8811907653
32.	Dhanjit Jai	3rd Semester	9101180947
33.	Prakash Deka	3rd Semester	8011937118
34.	Ankur Choudhury	3rd Semester	9360667999
35.	Samik Bh. Praptha	3rd Sem	8486722241
36.	Niraj Deka	3rd Sem	7099779624
37.	Rakibul Hossain	1st Sem	8472013618
38.	Biki Baruah	1st Sem	9101497645
39.	Parishmita Das	1st Sem	6000477411
40.	Alpanjit Kalita	3rd Sem	8822361118
41.	Anshana Patowary	3rd Sem	6003295525
42.	Shruti Chandray	3rd Sem	8723946780
43.	Dhruvati Choudhury	3rd Sem	600299687
44.	Parishmita Medhi	3rd Sem	7577068613
45.	Sikha Kalita	4th Sem	9909557085
46.	Shruti Malakar	1st Sem	7637093702
47.	Neha Deka	1st Sem	6002482934
48.	Jinti Moni Das	1st Sem	8493914164

Signatures of a part of students



Student exchange program between MNC College, Nalbari and Pub Kamrup College

মত বিনিময় অনুষ্ঠান, ২০২০
 উদ্যোগ: পূব কামৰূপ মহাবিদ্যালয়
 অসমীয়া বিভাগ
 আয়োজনকাৰী
 মহাবিদ্যালয়: অসমীয়া বিভাগ
 মহাবিদ্যালয়: অসমীয়া বিভাগ, পূব কামৰূপ
 তাৰিখ: ২৭/১২/২০
 উদ্দেশ্য: দুয়োটা মহাবিদ্যালয়ৰ মাজত
 অসমীয়া বিভাগৰ উন্নয়নৰ বাবে
 দুয়োটা মহাবিদ্যালয়ৰ মাজত
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 দুয়োটা মহাবিদ্যালয়ৰ মাজত
 অসমীয়া বিভাগৰ উন্নয়নৰ বাবে

উল্লিখিত ছফটওয়্যার/নামাংকিত ছফটওয়্যার
 ১/ নাম/প্ৰাঙ্গণ /নামাংকিত ছফটওয়্যার
 ২/ ফোন নম্বৰ
 ৩/ ইমেইল ঠিকনা
 ৪/ প্ৰাঙ্গণ নম্বৰ
 ৫/ ইমেইল ঠিকনা
 ৬/ ফোন নম্বৰ
 ৭/ ইমেইল ঠিকনা
 ৮/ ফোন নম্বৰ
 ৯/ ইমেইল ঠিকনা
 ১০/ ফোন নম্বৰ
 ১১/ ইমেইল ঠিকনা
 ১২/ ফোন নম্বৰ

ক্রমিক নং	নাম	ফোন নম্বৰ
১	অসমীয়া বিভাগ	৯৮৭৬৫৪৩২১
২	অসমীয়া বিভাগ	৯৮৭৬৫৪৩২১
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৫০	অসমীয়া বিভাগ	৯৮৭৬৫৪৩২১

Student signatures



Group photograph of students and teachers of Saraighat College and Pub Kamrup College

Date: 22.06.2019

Student Exchange Programme

Venue and Host : Pub Kamrup College
Department of English

Serial No.	NAME OF THE STUDENT & INSTITUTION	CLASS	SIGNATURE
01.	Rumi Nath, Saraighat college	3rd sem	Rumi Nath
02.	Kaveri Rajbongshi Pub Kamrup College	3rd sem	Kaveri Rajbongshi
03.	Tubeen Nath Pub Kamrup college	3rd sem	Tubeen Nath
04.	Himanka Deka. Pub - Kamrup College	3rd sem	Himanka Deka.
05.	Bhabana Devi pub Kamrup college	3rd Sem	Bhabana Devi
06.	Reema Nath Pub - kamrup College	3rd Sem	Reema Nath
07.	Amrita Mandal pub - kamrup college	3rd sem	Amrita Mandal
08.	Arjuna yasmin Pub: kamrup college	3rd sem	Arjuna yasmin

Signature of the attendees



COTTON UNIVERSITY
Research & Development
Panbazar, Guwahati- 781001, Assam, India
Website: www.cottonuniversity.ac.in

Ref: CU/R&D/Conf/WS/Meet/01

Date: 05/02/2021

From:

Prof G C Wary
Dean, R&D, Cotton University, Guwahati

To:

Dr. B. K. Dev Choudhury
Principal, Pub Kamrup College, Baihata Chariali, Kamrup, Assam

Subject: Endorsement of CUPAC-NE accelerator project from your University.

Respected Sir,

Greetings from R&D, Cotton University, Guwahati, Assam

First of all, I am very excited to inform you that "Cotton University Particle Accelerator Centre-NE Collaboration" (CUPAC-NE Collaboration) is proposing to construct a world class accelerator facility at Cotton University and for that, a project proposal have been prepared. The focus of the proposal is:

- Constructing a discovery class accelerator facility with beam lines for research in Neutron Science, Archeology, Quaternary Geology, Chemistry, Life Sciences and Nano Engineering, Physics, Chemistry, Nuclear Materials and Nuclear Medicines
- Implementing the project in 3-phases at a total cost of Rs. 301 Cr during 2021-2036 in a 5 acre land at Cotton University Bongara campus, Mirza
- The proposal was jointly prepared by Cotton University in active collaboration with faculties from:
 - North East Universities: Manipur University, Tripura University, Mizoram University, RGU (Arunachal Pradesh), NEHU(Meghalaya), Nagaland University, Assam University, Sikkim University (inviting), NERIST (Arunachal Pradesh), Bodoland University, Tezpur University, Gauhati University, Dibrugarh University, CPP-IPR, Sonapur, Guwahati, State Cancer Institute, Guwahati Medical College, B. Borooh Cancer Institute, Guwahati
 - National Laboratories: Bhabha Atomic Research Centre, Mumbai; Inter University Acceleration Centre, New Delhi; Tata Institute of Fundamental Research, Mumbai; Saha Institute of Nuclear Physics, Kolkata have now also joined the collaboration
- We have got the project reviewed by leading accelerator experts of the Nation. The most important outcome of the review was:
 - **The CUPAC-NE accelerator facility will be India's first and only 2nd in the World (as of now).**
- The Executive Summary of the Project Proposal is included for your kind perusal.
- We are now ready to submit the proposal to Government of India for funding.

As Dean R&D of the University, I am very proud of the proposed work and congratulate the CUPAC-North East Collaboration for their exemplary work. I also feel obliged to help us whatever way we can to materialize the dream. I personally believe that our case will be made stronger if we, all the Vice-Chancellors/Heads of Institutions of the associated universities/institutions of North East, strongly endorse the initiative and request Govt. of India to expeditiously fund the proposal.

So, may I request you kindly to send a letter of endorsement in favor of the project to me so that the team could enclose this with their proposal.

With best regards,

Dean,
Research & Development
Cotton University
Guwahati-781001
(Prof G C Wary)
Dean, Cotton University, Guwahati

Teachers' collaboration with Cotton University



OFFICE OF THE PRINCIPAL
PUB-KAMRUP COLLEGE
P.O. BAIHATA CHARIALI ☎:03621-286300
DIST. KAMRUP (ASSAM), PIN-781381 09435119315
principal@pubkamrupcollege.org
hdevchoudhury@yahoo.com

Endorsement Letter

Keeping development as a priority, like the other states, all the states of North-Eastern Region have geared up with various state-of-the-art projects pertaining to education. The direct encouragement received from the New Education Policy, 2020 has opened many pathways in introducing numerous post-graduation courses in the State.

Pub Kamrup College (PKC), Baihata Chariali, Assam, a Rural Model Degree College followed this path in introducing a M.Sc. in Physics with specialization of high-energy physics and astrophysics, one year back. This brings a new ray of hope and encouragement to the institution and the students to carry out specialized research in these fields.

Hence, with a lot of hope and commitment for the North-Eastern region and education in general, I endorse and welcome the upcoming project – Cotton University Particle Accelerator Centre- NE Collaboration (CUPAC - NE Collaboration) – to be constructed in Cotton University, Guwahati.


(Dr. B.Kr. Dev Choudhury)
Principal
Pub Kamrup College

Principal
Pub Kamrup College
P.O. Baihata Chariali

Place: Baihata Chariali, Assam
Date: 08th Feb. 2021



Copy of endorsement letter



विज्ञान एवं प्रौद्योगिकी उच्च अध्ययन संस्थान

(भारत सरकार के विज्ञान एवं प्रौद्योगिकी विभाग के अधीन एक स्वायत्त संस्थान)
विज्ञान पथ, पश्चिम बोरगाँव, गारचुक, गुवाहाटी-781035, असम - भारत

INSTITUTE OF ADVANCED STUDY IN SCIENCE AND TECHNOLOGY

AN AUTONOMOUS R & D INSTITUTE OF DEPARTMENT OF SCIENCE & TECHNOLOGY, GOVT. OF INDIA
VIGYAN PATH, PASCHIM BORAGAON, GARCHUK, GUWAHATI-781035, ASSAM, INDIA



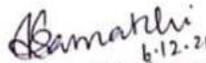
No. IASST/Acad/2021-22/10067.

Date: 06.12.2021

Certificate

This is to certify that **Violina Sarmah** from **Department of Biophysics, Pub-Kamrup College under Gauhati University, Assam** has completed project work at IASST, Guwahati on the topic "**AQUEOUS IONIC LIQUID SOLUTIONS FOR EFFICIENT EXTRACTION OF SERICIN FROM MULBERRY AND NON MULBERRY SILK**" under the guidance of **Dr. Kamatchi Sankaranarayanan, Assistant Professor-II, PSD** during **16th March to 15th July, 2021.**

He/She is sincere and hardworking and we wish him/her success in life.


(Dr. Kamatchi Sankaranarayanan)
Assistant Professor-II
PSD, IASST


(H. Bailung)
Professor, PSD &
Chairman, Academic Committee,
IASST



Summer Internship Documents



विज्ञान एवं प्रौद्योगिकी उच्च अध्ययन संस्थान

(विज्ञान तथा प्रौद्योगिकी विभाग, भारत सरकार के तहत एक स्वशासी संस्थान)
विज्ञान पथ, पश्चिम बड़गाँव, गड़चुक, गुवाहाटी- 781035, असम, भारत

**INSTITUTE OF ADVANCED STUDY IN SCIENCE AND
TECHNOLOGY**

(AN AUTONOMOUS INSTITUTE UNDER DST, GOVT. OF INDIA)



TO WHOMSOEVER IT MAY CONCERN

This is to certify **Mr. Manashjyoti Deka** was working as a project intern in my Biophysics laboratory at Institute of Advanced Study in Science and Technology, Guwahati during the period **March 2021** to **July 2021**. He worked on the project titled "*Polyoxometalates Based Novel Drug Delivery System*". During his stay he learnt many biophysical techniques like UV-visible spectroscopy, Fluorescence spectroscopy, Dynamic Light Scattering, Zeta sizer, Quartz crystal microbalance, Rheometer etc. I found his conduct good during the period. He is sincere and dedicated to his work.

I wish him good luck in his future endeavours.

Date: 6.12.2021

Dr. Kamatchi Sankaranarayanan

Assistant Professor

Physical Science Division



विज्ञान एवं प्रौद्योगिकी उच्च अध्ययन संस्थान

(भारत सरकार के विज्ञान एवं प्रौद्योगिकी विभाग के अधीन एक स्वशासी संस्थान)
विज्ञान पथ, पश्चिम बड़ागाँव, गड़चुक, गुवाहाटी -781035, असम : भारत

INSTITUTE OF ADVANCED STUDY IN SCIENCE AND TECHNOLOGY

AN AUTONOMOUS R & D INSTITUTE OF DEPARTMENT OF SCIENCE & TECHNOLOGY, GOVT. OF INDIA
VIGYAN PATH, PASCHIM BORAGAON, GARCHUK, GUWAHATI-781035, ASSAM, INDIA.



No. IASST/Acad/2021-22/ 10068.

Date: 06.12.2021

Certificate

This is to certify that Ashim Jyoti Bharati from Department of Biophysics, Pub-Kamrup College under Gauhati University, Assam has completed project work at IASST, Guwahati on the topic "COLD ATMOSPHERIC PLASMA AND IT'S EFFECT ON PROTEINS" under the guidance of Dr. Kamatchi Sankarananarayanan, Assistant Professor-II, PSD during 16th March to 15th July, 2021.

He/She is sincere and hardworking and we wish him/her success in life.

Kamatchi
6.12.21

(Dr. Kamatchi Sankarananarayanan)
Assistant Professor-II
PSD, IASST

H Bailung

(H Bailung)
Professor, PSD &
Chairman, Academic Committee,
IASST



Phone : +91-361-2270095, 2273054 Fax : +91-361-2273062
Website : www.iasst.gov.in; E-mail : registrar@iasst.gov.in ; registrar@iasst@gmail.com

Summer Internship Documents



BioZeneca™ Pharmaceuticals

PHONE: +91 8876903787
E-mail : biozeneca2018@gmail.com
Web : www.biozeneca.co.in

Date: 8th May 2021

TO WHOM IT MAY CONCERN

This is to certify that Mr. Alok Pandit, student of Bachelor of Business Administration (B.B.A) of Pub Kamrup College, Gauhati University, has successfully completed a summer internship from 10th March 2021 to 8th May 2021 under the guidance of Mr. Debasish Deb (Manager).

During the period of his internship program with us he had been exposed to different process was found punctual, hard working and inquisitive.

We wish him every success in his life and career.



Alokesh Datta

Founder, M.D
Biozeneca Pharmaceuticals

Summer Internship Documents



York Print Pvt. Ltd., 301, Orion Tower, Christian Basti, GS Road, Guwahati, Assam-781005
☎ 0361-2343845/46, www.yorkprint.in

Date : 05.05.2021

TO WHOM IT MAY CONCERN

This is to certify that ROKIBUL ISLAM, a student of BBA 5th Semester of Pub Kamrup College, Baihata Chariali, Assam has successfully completed three months' summer training project in our organization.

His project title was "A Summer Training Project on Training and Development in York Print Pvt. Ltd."

During the period of his summer training with us we found him sincere and hardworking with all his work he had done and wish him all the best for his future endeavours.

For and on behalf of,
York Print Private Limited

Rahul Aron
Quality Manager



Regd. Office : 9th Mile, GS Road, Baridua, Dist.- Ri-Bhoi, Meghalaya, Shillong, Pin-793101
CIN NO. U21029ML2002PTC006726

Summer Training Document of Rokibul



York Print Pvt. Ltd., 301, Orion Tower, Chetkin Bazar, GS Road, Guwahati, Assam-781005
☎ 0361 2143845/46, www.yorkprint.in

Date: 05.05.21

TO WHOM IT MAY CONCERN

This is to certify that Jonali Haldar, a student of BBA 5th semester of Pub Kamrup Collage, Baihata Chariali has successfully completed three-month summer training project in our organization.

Her project title was "A Summer Training Project on Job Satisfaction in York Print Pvt. Ltd".

During the period of her summer training with us we found her sincere and hardworking with all her works she had done and wish her all the best for her future endeavors.

and on behalf
York Print Pvt. Ltd.
2021/05/05

Summer Training Document of Jonali Halder

Office of the Principal /C and Secretary
GORESWAR COLLEGE



P.O.- Goreswar, Dist.- Baksa (BTAD), Assam, Pin- 781366

Office E-mail ID: goreswarcollege@gmail.com

www.goreswarcollege.in

Ph: (+91) 3621 282221

Memo :

Date

From :-

MR JADAB CH. GOSWAMI, M. Sc, M Phil, B. Ed.
Principal /C & Secretary, Goreswar College
P.O - Goreswar, Dist - Baksa (BTAD) Assam. Pin- 781366

To,

The Principal, Pub- kamrup College, Baihata Chariali, kamrup, Assam
(Through Co- ordinator, DBT, Supported Advance Level Institutional
Biotech Hub, Pub-Kamrup College)

Sub: Use of DBT supported Biotech Hub Facility

Sir,

With due respect and humble submission I would like to request you for giving permission to 3 students of B.Sc 5th sem , Deptt. Of Zoology to use some facility in the Biotech Hub for the partial fulfillment of B.Sc project report during Summer Vacation (1st July to 31st July, 2019). As I am aware that Biotech Hub community gives such type of facility to the students for enhancing their research mind. Therefore I request you kindly to accord permission for use of the facility in Biotech Hub.

Name of the Students :

1. Ajit Boro
2. Abhilash Roy
3. Rosy Rani Sarania

Thanking You

Yours Faithfully

Principal in charge
Goreswar College

Request Letter for Resource Sharing



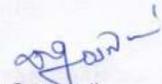
INSTITUTE OF ADVANCED STUDY IN SCIENCE AND TECHNOLOGY
(AN AUTONOMOUS INSTITUTE UNDER DST, GOVT. OF INDIA)

PASCHIM BORAGAON, GARCHUK, GUWAHATI- 35

OFFICE ORDER

The Director, IASST is pleased to allow Kaushik Sarkar, Bhaswati Sharma and Bhagyashree Deka, M.Sc. Biophysics (4th sem) students from Pub Kamrup College to carry out project work at IASST during June-July, 2019 under the supervision of Dr. Biswajit Choudhury, PSD, IASST.

After the completion of the work, the students will submit a copy of the report to the library and give a presentation of the work done. The students would have to pay an amount of Rs. 1000/- per month at the time of joining.


(D. Goswami)

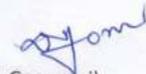
Registrar

Date: 27/05/2019

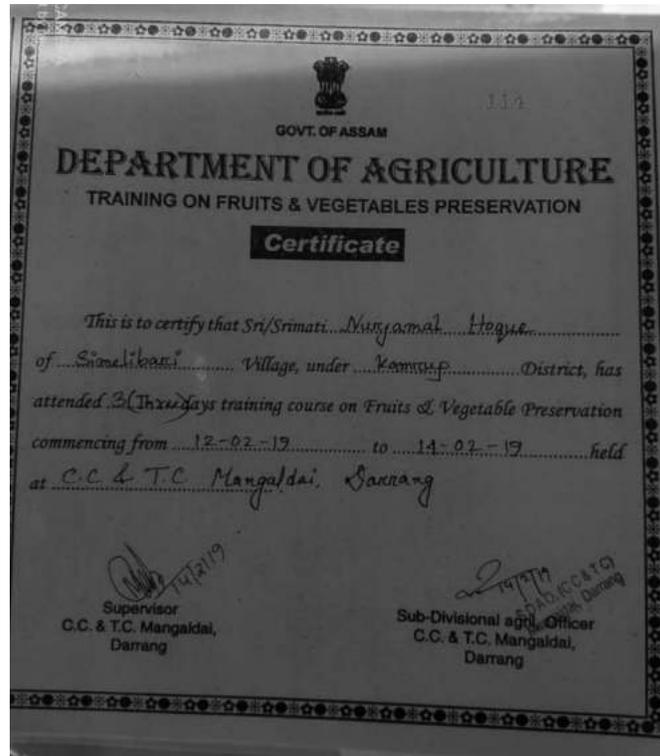
Memo No. IASST/Acad/2019-20/ 2326-2328.

Copy to:

1. PS to the Director, IASST
2. The Chairman, Academic Committee, IASST
3. Concerned File


(D. Goswami)

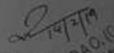
Office Order from IASST for Summer Internship Program




120
 GOVT. OF ASSAM
DEPARTMENT OF AGRICULTURE
 TRAINING ON FRUITS & VEGETABLES PRESERVATION
Certificate

This is to certify that Sri/Srimati Nelish Kumar Sarma
 of Parampara Village, under Barrang District, has
 attended 3 (Three) days training course on Fruits & Vegetable Preservation
 commencing from 12-02-19 to 14-02-19 held
 at C.C. & T.C. Mangaldai, Barrang

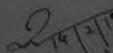

 Supervisor
 C.C. & T.C. Mangaldai,
 Darrang

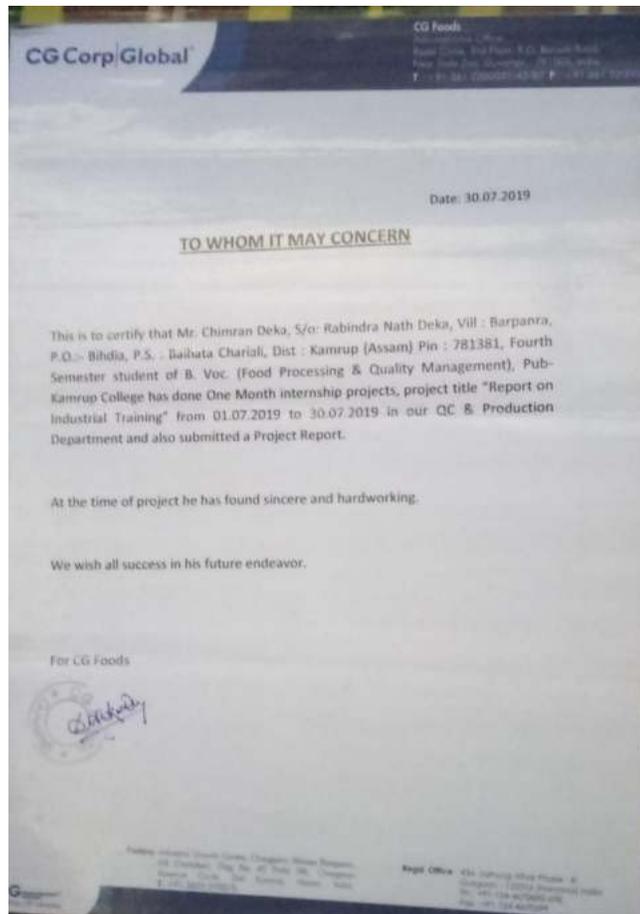

 Sub-Divisional agri. Officer
 C.C. & T.C. Mangaldai,
 Darrang


112
 GOVT. OF ASSAM
DEPARTMENT OF AGRICULTURE
 TRAINING ON FRUITS & VEGETABLES PRESERVATION
Certificate

This is to certify that Sri/Srimati Shikha Rani Sika
 of Loch Village, under Kamrup District, has
 attended 3 (Three) days training course on Fruits & Vegetable Preservation
 commencing from 12-02-19 to 14-02-19 held
 at C.C. & T.C. Mangaldai, Barrang


 Supervisor
 C.C. & T.C. Mangaldai,
 Darrang


 Sub-Divisional agri. Officer
 C.C. & T.C. Mangaldai,
 Darrang



Date: 30.07.2019

TO WHOM IT MAY CONCERN

This is to certify that Mr. Nitul Choudhury, S/o: Narayan Choudhury, Vill : Dagaon, P.O.: Dagaon, P.S : Rangia, Dist : Kamrup (Assam) Pin : 781133, Fourth Semester student of B. Voc. (Food Processing & Quality Management), Pub-Kamrup College has done One Month internship projects, project title "Report on Industrial Training" from 01.07.2019 to 30.07.2019 in our QC & Production Department and also submitted a Project Report.

At the time of project he has found sincere and hardworking.

We wish all success in his future endeavor.

For CG Foods



Factory address: Douth Corner, Choumah, Near Bongaon,
18, Choumah, Eng. No. 40, P.O. No. 14, Dogaon,
Assam - Guwahati, India
T : +91 961 2250031

Regd. Office : 4th, Gokulnagar Road, B.
Guwahati - 781001, Assam
T : +91 961 2250031
E : +91 961 2250008



CERTIFICATE OF INTERNSHIP

Date:- 10-08-2019

This is to certify that Ms. Lipika Baruah has successfully completed her internship with us.

Her internship term was between June 25th to July 10th August 2019.

As part of the internship program, she was placed with the Quality department.

During this period, she was actively involved in, "Industrial Training for Production and Maintaining Quality".

During the internship, she was found to be punctual, positive and performance oriented.

The training on evaluation fulfills all the stated criteria and the student's findings are her original work.

Ms. Lipika Baruah has completed her training with commitment and sincerity.

We wish success in her career.

For Tulsi Speciality Foods,



Authorized Signatory



SRD NUTRIENTS PRIVATE LIMITED
(An ISO 22000 : 2005 Certified Company)

Works :
Industrial Area, Mangaloo
District : Darrang - 784 125 (Assam)
Toll Free : (0371) 230 870
e-mail : hr@srdnutrients.com

Head Office :
L.N.S. Road, Mangaloo
District : Darrang - 784 125 (Assam)
Phone : (0371) 232 127
PIN : AAGC52941
GST No. : 18AAGC52947121
C.No. : U1549AS2001PTC006591

Ref: SRDN/HR/IT/034/19-20/096

Date: 15.11.2019

TO WHOM IT MAY CONCERN

This is to certify that MR. DHRUBA JYOTI KALITA of 5th Semester, BBA, Pub Kamrup College, has successfully completed 90 days internship at our organization starting from 13th August 2019 to 13th November 2019.

He was found to be sincere, enthusiastic and hard working. We wish him good luck for his future endeavor.

For & on behalf of,
SRD Nutrients Private Ltd.

Shyamali Goswami
15/11/2019

Shyamali Goswami
HR & Admin Department

Guwahati Office : Repose Foods Private Limited, Opp. Sankardev Kalakshetra, Panjabari, Guwahati - 781 037 (Assam)
Phone : (0361) 233 2670, 233 0141

98	Upasana	u (BSc)	u		9:00am	6:00pm	21/11
99	Upasana	"	"		7:00am	9:00am	21/11
100	Biswasjit Kalita	MSc 1st sem	BAV	DNA	12:00pm	12:40pm	21/11
101	upasana Hazarika	Biophysics 3rd sem	project		6:pm	6:30pm	UPD 19/12/19
102	karishma T.	"	"		3:00 pm	3:30pm	21/11
103	Abhispa Bora	JRF, Rangia College		Backlog sample	3:10 pm		A. Bora 21/11
104	Upasana	Biophysic		AUNP	3:20 pm	5:10pm	21/11
105	Upasana	"	"	"	5:30 pm	6:00pm	21/11
106	upasana	"	"	Project	2:00 pm	2:30pm	UPD 23/12/19
107	Liza	"	"	"	1pm	3:30pm	25-02-19
108	Pranamika	"	"	"	1:15 pm	3:00pm	25-02-19
109	Abhispa Bora	MSc 1st Sem Biophysics	Practical exam	9401455122	Whole day		21/11/19
110	Upasana H	" BSc	AUNP		10:10 am	5:00pm	21/11/19
111	Liza B	"	Project		12:00 pm	1:15pm	23/11/19
112	Pranamika	"	Project		2:00 pm	3:15pm	21/11/19



तेजपुर विश्वविद्यालय / TEZPUR UNIVERSITY
(केन्द्रीय विश्वविद्यालय / A Central University)

• कृतज्ञता का सर्वोच्च विषयविद्यालय पुरस्कार, 2016 और एनजाइएएफ अवार्ड सत्र 2016: नं. 05
• Visitor's Best University Award, 2016 and NIRF India Rankings 2016: No. 05
परीक्षा नियंत्रक का कार्यालय / OFFICE OF THE CONTROLLER OF EXAMINATIONS
तेजपुर-784028 :: असम / TEZPUR-784028 :: ASSAM

F.20-46/3/2007(Acad)/441-A

Date: 31.05.2019

NOTIFICATION
SUMMER INTERNSHIP PROGRAMME -2019

The following candidates have been selected for the Summer Internship Programme, 2019 to be held during the period from 9th June to 8th July, 2019.

Sl. No	Name & Address of the Candidate	Institute of the Candidate	Name of the Dept. of TU for Internship Programme
1.	Ms. Tadar Yadar, Length Loth, Nyapin, Kurung Kumey, Arunachal Pradesh-791118	NIT, Yupia, Arunachal Pradesh	MBBT
2.	Ms. Techu Yapu, Ganga Village, Itanagar, Arunachal Pradesh-791110.	NIT, Yupia, Arunachal Pradesh	MBBT
3.	Ms. Akanksha Banerjee.604/B1, City Heart Apartment, SRB Road, Lachit Nagar, Ghy-781007	University of Hyderabad	MBBT
4.	Ms. Jmli Sarma, malikuchi, Nalbari-781335	Nalbari College	MBBT
5.	Mr. Malaya Pegu, Latiborchuk, Kekuripomua, Dhokukhaha-785008	Jorhat Kendriya Mahavidyalaya, Kenduguri	MBBT
6.	Mr. Abhilash Talukdar, AAU Campus, Qtr No. VF/2 Jorhat-785013	Jorhat Kendriya Mahavidyalaya, Kenduguri	MBBT
7.	Ms. Neha Hazarika, Sootea, Biswanath	Biswanath College	MBBT
8.	Ms. A. Anamika Devi, Lanka, Rajbari, Nagaon-782446	Jorhat Kendriya Mahavidyalaya, Kenduguri	MBBT
9.	Mr. Palash Jyoti Chaliha, Hatibandhia, Biswanath-784172	Chaiduar College	MBBT
10.	Ms. Tommayuri Handique, Sundarpur, East Milan Nagar, Dibrugarh-786003	Jagannath Barooah College, Jorhat	MBBT
11.	Mr. Samasis Dev Sarma, Bam parbatia, Parvat Nagar, Tezpur-01	Cotton University	Physics
12.	Mr. Abhijit Talukdar, Porakuchi, Sondha, Nalbari-781337	Nalbari College	Physics

13.	Mr. Gitartha Das, Metuakuchi, Barpeta-781301	Cotton University	Physics
14.	Ms. Pratiksha Dey, H. No- 93, Barua Bari, Sonapur, Kamrup	Cotton University	Physics
15.	Mr. Nilpan Kalita, Alhiaboi, Pub-Boska, Kamrup@-7891101	Pub Kamrup College, Baihata Charali	Physics
16.	Mr. Abhilash Kaushik	B. Barooah College	Physics
17.	Ms. Angelina Saikia, Krishna Nagar, Goreswar, Baksa- 781366	Pub Kamrup College, Baihata Charali	Physics
18.	Ms. Rupiyoti Pegu, Kachua Charigharia, Dholpur	Chaiduar College	Env. Science
19.	Ms. Ansumwi Basumatary, No. 1 Bijoypur, Alupara, Gohpur	Chaiduar College	Env. Science
20.	Ms. Kaberi Rajkhowa, Kamdewal	Chaiduar College	Env. Science
21.	Ms. Ami Bordoloi, Deerichuk, Hawajan-784169	Chaiduar College	Env. Science
22.	Ms. Debosmita Saha, Subashpally Main Road Bilasipara, Dhubri	Bilasipara College	Env. Science
23.	Mr. Priyanka Borah, Nakari, North Lakhimpur-787001	Chaiduar College	Env. Science
24.	Mr. Suraj Aryan, Parnala Kumbhartoli, Hazaribag-825301.	Central University of Jharkhand	Energy
25.	Mr. Suvit Verma, B/386, Road No. 4, ASHOK Nagar, Ranchi- 834002	Central University of Jharkhand	Energy
26.	Ms. Suman Upadhyay, Chandmari, Tezpur-01	Darrang College	Math. Science
27.	Mr. Chiranjeev Das, Kachari Gaon, Tezpur-784001	Gauhati University Institute of Science & Technology	CSE
28.	Ms. Rituparna Dutta, Rajlakhmi Bhawan, Misripatty, Luming	Kaziranga University	CSE
29.	Ms. Akshita Paul, Santipur, Biswanath Charali, Biswanath-784176	Kaziranga University	CSE
30.	Ms. Borsia Saikia, Borhula Kachari, Na-Deogharia, Tengakhata, Assam-786103	Kaziranga University	CSE
31.	Ms. Rami Kumari, 1542, Patidoiverela, Misamari, Sonitpur-784506	Cotton University	CSE
32.	Mr. Harinanda N. Prasad, H/No. 05, Bijulee Mill, Manipuri Basti, Ghy-14	Gauhati University Institute of Science & Technology	CSE
33.	Mr. Uddipta Khatanar, H. No. 28, Panjabari, Ghy- 37	Cotton University	Chemical Science
34.	Ms. Upasana Boruah, Qtr No. B-55, ONGC Colony, Sivasagar	Sivasagar Girls College	Chemical Science

ASSAM SCIENCE AND TECHNOLOGY UNIVERSITY

(A State University of Govt of Assam constituted by "Assam Science and Technology University Act 2009)

Tetelia Road, Jalukbari, Guwahati-781 013, Assam



Certificate of Internship

This is to certify that

Mr. Alakjyoti Patowary

has successfully completed his internship program

on

"A Study on Non-Thermal Air Plasma in Experimental Glow Discharge Reactor"

at META Laboratory, Dept of Energy Engineering, ASTU, Guwahati
from 03/07/2019 to 24/08/2019.

During the span, he demonstrated good design skills with self-motivated attitude to learn new things. His performance was satisfactory.

We wish him all the best for future endeavours.

(Dr. B. R. Phukan)
Academic Registrar



(Dr. Bharat Kakati)
Guide/Supervisor

Date of Issue: 19/10/2019



भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
गुवाहाटी 781 039, असम, भारत
Indian Institute of Technology Guwahati,
Guwahati 781 039, Assam, India.

Phone Nos.: +91-361- 258 2082

Fax No. : +91-361- 258 2089

e-mail : dornd@iitg.ernet.in

Prof Gopal Das

Dean Research and Development & the

Coordinator, NECBH Programme

IIT Guwahati

Assam 781039

Ref: NECBH/2019-20/176

Date : 29-04-2019

Office of Dean Research and
Development Section

Sanction Letter

PI Name: Dr Julie Saikia

Category: Sunrise

Project ID: 176

Project Title: Development of a Cloud Computing Based Wireless Sensor for Patient Monitoring System in Health Care Engineering

Duration: 2 years

Total Sanction amount: 1086750.00

Account Head	For Principal Investigator	For CO PI IITG	For CO PI OTHERS
Non-Recurring	200000.00	NIL	NIL
Man Power	300000.00	NIL	NIL
Consumables	70000.00	70000.00	30000.00
Travel	30000.00	NIL	20000.00
Contingency	70000.00	50000.00	30000.00
Total	670000.00	120000.00	80000.00
Overhead	75000.00	NIL	NIL
Instrument Maintenance		141750.00	
Grand Total		1086750.00	

Sincerely Yours,

Gopal Das

Terms and conditions

1. The principal investigator (PI) has to acknowledge project number BT/COE/34/SP28408/2018 of Department of Biotechnology (DBT), Govt. of India for the financial support.
2. Funds will be released in subsequent installation subject to satisfactory performance of the project and availability of fund.
3. The Institute/PI would furnish a Utilization Certificate and an audited statement of expenditure duly signed by the PI, the Head of the Institute and the Head of the Finance wing, pertaining to the grant at the end of each financial year as well as a consolidated statement of expenditure at the end of the completion of the project or whenever it is required.
4. The PI is not permitted to seek or utilize funds from any other organization (Government, Semi Government, Autonomous or Private) for this research project.
5. Any unspent part of amount would be surrendered to the **Research and Development Section, IITG** and carry forward of funds of the next financial year for utilization for the same project may be considered only with the specific approval of the **Research and Development Section, IITG and Department of Biotechnology (DBT)**.
6. IIT Guwahati or DBT reserves the right to terminate the grant at any stage and also to recover the amounts already paid if it is convinced that the grant has not been properly utilized or the work on the project has been suspended for any unduly long period or appropriate progress is not being made.
7. The project will become operative with effect from April 29, 2019.
8. A copy of progress report has to be sent in the month of January till the completion of project or whenever it is required.
9. Travel should be used mainly for sample collection, discussion among the PIs not for other purpose. No international Travel will be undertaken from the sanctioned project grant.
10. If the Investigator to whom a grant for a project has been sanctioned leaves the institution where the project is being implemented, PI shall submit five copies of complete and detailed report of the work done by him on the project and the money spent till the date of his/her release and shall also arrange to refund the unspent balance, if any to IIT Guwahati.

Review

BiFeO₃-Based Relaxor Ferroelectrics for Energy Storage: Progress and Prospects

Bipul Deka^{1,2,3,*}  and Kyung-Hoon Cho^{1,2,*}

- ¹ Research Institute of Advanced Materials, Kumoh National Institute of Technology, Gumi 39177, Korea
² School of Materials Science and Engineering, Kumoh National Institute of Technology, Gumi 39177, Korea
³ Department of Physics, Pub Kamrup College, Kamrup, Assam 781381, India
* Correspondence: bipul.deka@kumoh.ac.kr (B.D.); khcho@kumoh.ac.kr (K.-H.C.)

Abstract: Dielectric capacitors have been widely studied because their electrostatic storage capacity is enormous, and they can deliver the stored energy in a very short time. Relaxor ferroelectrics-based dielectric capacitors have gained tremendous importance for the efficient storage of electrical energy. Relaxor ferroelectrics possess low dielectric loss, low remanent polarization, high saturation polarization, and high breakdown strength, which are the main parameters for energy storage. This article focuses on a timely review of the energy storage performance of BiFeO₃-based relaxor ferroelectrics in bulk ceramics, multilayers, and thin film forms. The article begins with a general introduction to various energy storage systems and the need for dielectric capacitors as energy storage devices. This is followed by a brief discussion on the mechanism of energy storage in capacitors, ferroelectrics, anti-ferroelectrics, and relaxor ferroelectrics as potential candidates for energy storage. The remainder of this article is devoted to reviewing the energy storage performance of bulk ceramics, multilayers, and thin films of BiFeO₃-based relaxor ferroelectrics, along with a discussion of strategies to address some of the issues associated with their application as energy storage systems.



Citation: Deka, B.; Cho, K.-H. BiFeO₃-Based Relaxor Ferroelectrics for Energy Storage: Progress and Prospects. *Materials* **2021**, *14*, 7188. <https://doi.org/10.3390/ma14237188>

Academic Editors: Marc Cretin, Sophie Tingry and Zhenghua Tang

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Keywords: energy storage; BiFeO₃; relaxor ferroelectrics; domain engineering; polymorphic nanodomain

1. Introduction

Global warming poses potential threats to the planet Earth's future. The continuous burning of fossil fuels has increased the concentration of CO₂ and other greenhouse gases in the Earth's atmosphere, leading to a warmer atmosphere and climate change. In addition, the depletion of fossil fuel resources, the dominant candidate in the energy market, poses the risk of an energy crisis in a world where the number of consumers is increasing day by day. Considering the serious threats to the lives on Earth and the risk of an energy crisis posed by the use of fossil fuel resources, the transition to clean energy is a serious consideration. However, renewable energy sources such as solar, wind, tides, and geothermal energy are intermittent by nature. Therefore, harnessing and storing renewable energy for future access is a challenging task.

Electrical energy harvested from renewable sources offers enormous opportunities for meeting future energy demands and the feasibility of the transition to clean energy. However, the usefulness of the electrical energy generated depends on its efficient storage, which is necessary for around-the-clock use. An efficient electrical energy storage (EES) system is the heart of the commercial and residential grid-based utilization of electrical energy. Therefore, the development of advanced EES systems is critically important for meeting the growing energy demands and effectively leveling the cyclic nature of such energy sources [1]. For over 200 years, batteries have been widely used in EES systems and are still being widely used. Solid oxide fuel cells (SOFCs), electrochemical capacitors (ECs), superconducting magnetic energy storage (SMES) systems, flywheels, and electrostatic capacitors (dielectric capacitors) are common current energy storage technologies [2].

A perfect energy storage device is characterized by high energy and power densities. A comparison of the storage efficiency of the technologically relevant candidates for EES systems can be realized from the Ragone plot shown in Figure 1, which displays the status of EES systems according to their energy and power densities. As can be seen, SOFCs and batteries exhibit a high energy density with low power density, while dielectric capacitors exhibit the opposite behavior, that is, high power density and low energy density. The ECs, SMES, and flywheel have medium power and energy densities. In addition to the high power and energy density, the charge/discharge rate is a deciding factor for EES systems. The energy storage and delivery in SOFCs/batteries are based on the chemical reaction process and may take 1–100 h of time. Dielectric capacitors typically exhibit fast charge/discharge rates, between μs and ms , whereas those for ECs, flywheels, and SMES are between 1 s and 1 h. The fast charge/discharge rate of dielectric capacitors is associated with the separation of comparatively fewer heavy bound charges under the influence of the electric field to be stored. Thus, to summarize, no individual EES candidate possesses both high power and energy densities simultaneously. Therefore, the technological relevance of each candidate as an EES may be determined by the final requirements. However, among the various potential candidates for EES, dielectric capacitors have the advantage of withstanding high-voltage and large-scale applications because of their lower cost [3,4].

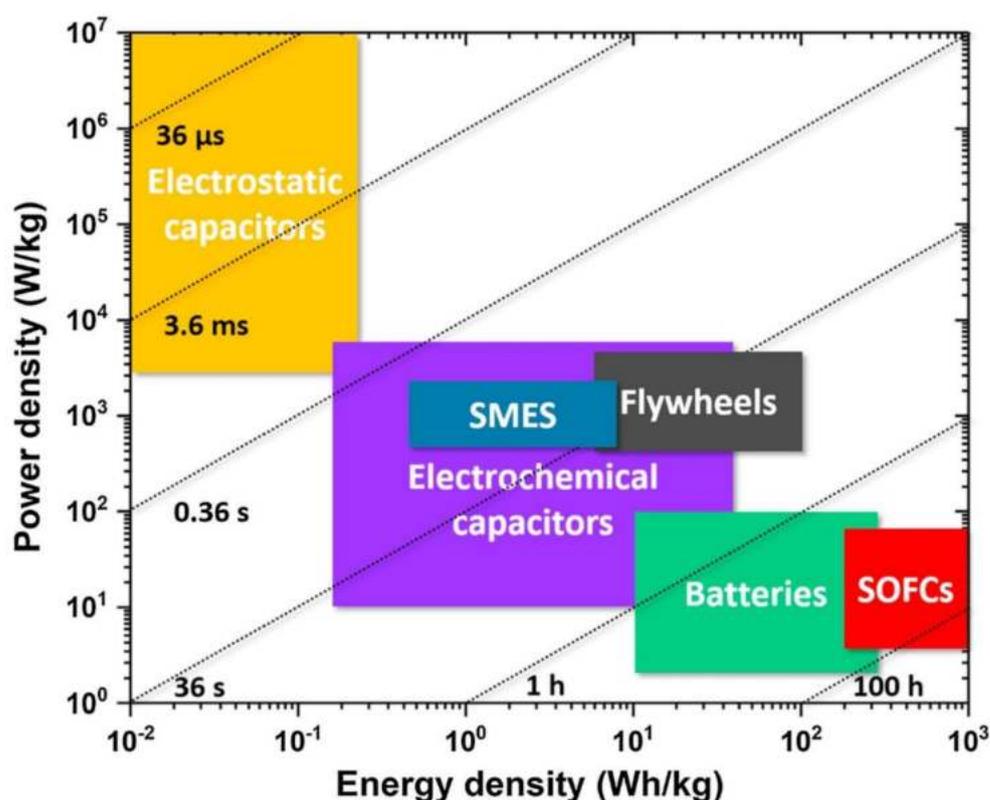


Figure 1. Ragone plot of various energy storage devices: electrostatic capacitors, electrochemical capacitors, SMES, flywheels, batteries, and SOFCs. The straight dashed lines and the associated times correspond to the characteristic times. Reused with permission from [2]. © 2021 Elsevier Ltd.

Dielectric capacitors are one of the key components in modern communication technology, with applications in electronic circuits, warfare, distributed power systems, hybrid electric vehicles, clean energy storage, high-power applications, etc. [5–11]. Among the various EES systems, dielectric capacitors exhibit the fastest discharge speed; therefore, they can generate intense pulse power [11–14]. The fast discharge speed and high fatigue resistance of dielectric capacitors enable their potential applications in various electronic systems. This includes medical equipment such as defibrillators, pacemakers, surgical lasers, and X-

ray units; scientific research equipment such as high-power accelerators and high-intensity magnetic fields; commercial system devices such as camera flash, underground oil and gas exploration, avionics, transportation (hybrid cars, space shuttle power systems), transversely excited atmospheric lasers, and advanced electromagnetic systems [15].

The current review discusses the recent progress on the development of high-energy storage dielectric capacitors based on the relaxor ferroelectric (RFE) of BiFeO₃. The two important figures of a capacitor that determine its energy storage performance are the recoverable energy density (U_{rec}) and energy efficiency (η), which depend on the saturation polarization (P_{max}), remnant polarization (P_r), and breakdown strength (BDS) of the materials. Linear dielectric (LD), ferroelectric (FE), and anti-ferroelectric (AFE) materials are widely used for the fabrication of ceramic capacitors. Although the LDs possess excellent values of BDS, their U_{rec} values are quite low due to weak polarization. FE materials, on the other hand, possess quite a large P_{max} and P_r . As can be seen in Section 2, the large values of both P_{max} and P_r result in a low U_{rec} value. Moreover, the ferroelectric materials suffer large hysteresis loss, which has a significant detrimental effect on the energy efficiency of the capacitors. AFE materials behave like LDs in the low field regime, undergoing a field-induced FE state, yielding a high P_{max} at a high electric field with large hysteresis loss. Therefore, the issues associated with the AFE for their applications in the high-energy storage application are essentially similar to that of LDs at low electric fields and to that of FEs at high electric fields. However, the problem of hysteresis loss inherent to FE and AFE materials is found to be minimized in RFEs while maintaining a significantly large value of P_{max} . This motivates the scientific community to turn their heads towards the RFEs in search of high-energy storage capacitors.

Ceramic dielectric capacitors based on BiFeO₃ have recently gained interest in the field of energy storage applications because of the high polarization ($\sim 90 \mu\text{C cm}^{-2}$) predicted in BiFeO₃, along with its high ferroelectric Curie temperature (T_C) ($\sim 830 \text{ }^\circ\text{C}$) [16]. The advantage of having a high T_C is that the materials do not lose their ferroelectric (FE) nature at such high temperatures, which is essential for applications in the high-temperature regime. Temperature stability is an important issue that needs to be addressed while designing a capacitor for operation in the high-temperature regime. For example, ceramic-polymer composites have excellent storage performance; however, their performance degrades very rapidly as the temperature approaches $100 \text{ }^\circ\text{C}$ [15]. Pb-based ferroelectrics often have the disadvantage of adverse harmful effects on the environment and human beings. Pb-oxide, which is a main component of Pb-based ferroelectrics, is highly toxic and volatile at high temperatures, causing environmental pollution during the fabrication process. Disposal and recycling of Pb-based materials and devices at an industrial scale also creates atmospheric problems due to the difficulty of Pb removal. Exposure to the heavy metal Pb causes detrimental effects such as kidney and brain damages, and chronic exposure may lead to damages to the central nervous system and affect blood pressure, vitamin D metabolism, etc. Young children are more vulnerable to Pb exposure, as the absorption of Pb in children's bodies is 4–5 times higher than in an adult body. Therefore, to reduce the use of hazardous materials such as Pb, various countries have adopted different restrictions on hazardous materials [17,18]. Although there are a few reviews on dielectrics for energy storage in general, to the best of our knowledge, there has been no such review for BiFeO₃-based relaxor ferroelectrics. Here, we present a review of the recent progress on BiFeO₃-based relaxor ferroelectric for energy storage, discussing various issues to meet practical applications. We first discuss the fundamentals of energy storage in dielectrics and the pros and cons of various nonlinear dielectrics with respect to their applications in energy storage. We then discuss the characteristics of relaxor ferroelectrics and their importance in energy storage, followed by a brief discussion of the basic properties of BiFeO₃. Following this, we present the recent progress in energy storage studies on BiFeO₃ and strategies for further enhancement.

2. Fundamentals of the Energy Storage Mechanism in Dielectrics

The energy storage mechanism of dielectrics is based on their polarization under the application of an electric field. A dielectric under an applied electric field is polarized such that equal amounts of positive and negative charges accumulate at the surfaces of the dielectrics. In other words, an electric field opposite to the applied field is induced inside the dielectric. The strength of the induced field grows exponentially with time until its magnitude is equal to that of the external field. This process is known as charging the capacitor. Thus, the induced electrostatic energy is stored in the dielectric and can be used for application upon discharge through a load. The amount of stored energy (U) can be obtained from the potential difference (V) across the dielectrics and the charge (q) induced at the electrode on the surface of the dielectrics using the following equation:

$$U = \int_0^{q_{max}} V dq \quad (1)$$

where q_{max} is the maximum amount of charge accumulated at the electrode when the capacitor is fully charged, and dq is the increment of charge during charging. A figure-of-merit (FOM), which signifies the energy storage performance of a capacitor, is represented in terms of energy storage density (U_{st}), defined as the energy stored per unit volume. Mathematically,

$$U_{st} = \frac{\int_0^{q_{max}} V dq}{Ad} = \int_0^{D_{max}} EdD \quad (2)$$

where A is the electrode area of the capacitor, d is the distance between the electrodes (thickness of the dielectric layer), and D is the electric displacement of the capacitor. For a weak electric field, D is related to the external electric field (E) and polarization (P) as follows:

$$D = P + \epsilon_0 E \quad (3)$$

where ϵ_0 represents the permittivity of a vacuum. Materials obeying Equation (3) are classified as linear dielectrics. For a linear dielectric, P is assumed to be a linear function of E :

$$P = \epsilon_0 \chi E \quad (4)$$

where the quantity χ is termed the linear dielectric susceptibility. At a high electric field, it is necessary to consider the nonlinear contribution of susceptibility, and Equation (4) takes the most general form as:

$$P = \epsilon_0 (\chi E + \chi^{(2)} E^2 + \chi^{(3)} E^3 + \dots) \quad (5)$$

where $\chi^{(2)}$ and $\chi^{(3)}$ are higher-order susceptibilities, giving rise to nonlinear effects. Using linear approximation, the stored energy density of a dielectric material with a high dielectric constant ($D \approx P$) can be calculated as follows:

$$U_{st} = \int_0^{P_{max}} EdP \quad (6)$$

Equation (6) indicates that the electric polarization as a function of the electric field should be measured to calculate U_{st} . In other words, it is necessary to measure the polarization-electric field (P - E) hysteresis loop to obtain the stored energy density, as shown in Figure 2. Therefore, the shape and size of the P - E loop and the nature of the dipole/domain structures determine the energy storage performance of dielectric materials. However, the dynamics of the polarization vector, growth of domains, and domain wall movements for $E = 0 \rightarrow E_{max}$ and $E = E_{max} \rightarrow 0$ directions in the P - E measurement protocol are different from each other. This leads to a non-zero value of polarization, even

at $E = 0$, known as remanent polarization (P_r). As a result, a part of the stored energy is lost, which appears as the hysteresis of the P – E loop. In other words, it is impossible to recover the stored energy density to its fullest amount when it is discharged. The loss part of the stored energy or energy loss density (U_{loss}) is given by the area of the loop. The recoverable energy density is calculated as follows:

$$U_{\text{rec}} = \int_{P_r}^{P_{\text{max}}} E dP \quad (7)$$

Another FOM signifying the energy storage performance is the efficiency (η), which represents the amount of stored energy density available for use as recoverable energy density. It is defined as the ratio of the recoverable energy density to the total stored energy density:

$$\eta = \frac{U_{\text{rec}}}{U_{\text{st}}} \times 100\% = \frac{U_{\text{rec}}}{U_{\text{rec}} + U_{\text{loss}}} \times 100\% \quad (8)$$

Equation (7) suggests that a combination of high P_{max} , low P_r , and high breakdown strength are necessary to obtain a high U_{rec} value. In addition, Equation (8) requires a dielectric with low hysteresis loss to obtain a large efficiency value. Therefore, Equations (7) and (8) are often considered the governing equations for designing dielectric materials for high-performance energy storage. However, a dielectric with high ϵ usually features high dielectric loss, leading to heat generation during electric field cycling and the possibility of thermal breakdown during operation.

Typical P – E loops of LDs, FEs, AFEs, and RFEs are shown in Figure 2. LDs are characterized by very low values of polarization and a high BDS. Some of the widely studied LDs are CaTiO_3 [19,20], SrTiO_3 [21], and CaTiO_3 – CaHfO_3 [22]. Because of the low value of polarization, the recoverable energy density of LD is quite low. Therefore, LDs are not suitable for application in the field of high-energy storage application. Over the years, FE and anti-ferroelectric (AFE) materials have been extensively studied for application in energy storage systems, and efforts to enhance their performance have surged. FE materials exhibit spontaneous polarization, a large value of P_{max} , and a coercive field (E_c). A typical P – E loop of FE materials is shown in Figure 2b. On the microscopic scale, FEs are composed of a large number of domains separated by domain walls. The dipoles in a domain are oriented in the same direction, and the directions of the domain polarizations can be switched by applying an electric field. However, the energy loss density is quite high in the FEs because of their high coercivity. Moreover, the P_r and P_{max} values have the same order of magnitude, resulting in a very small value of $P_{\text{max}} - P_r$. Therefore, the U_{rec} and η of the FEs are not promising. Because of this, single-phase FEs have not gained much interest in energy storage devices. Among the various FEs, representative compositions studied for energy storage are based on $(\text{Bi,Na})\text{TiO}_3$ [23–26], $\text{Ba}(\text{Zr,Ti})\text{O}_3$ [27–29], BaTiO_3 [30,31], and $(\text{K,Na})\text{NbO}_3$ [32]. Unlike FEs, AFE materials lack a net polarization because of the anti-parallel alignment of the spontaneous polarization vectors in their domain. The typical P – E loops of AFE materials are shown in Figure 2c. The electric dipoles align anti-parallel to each other in the AFE domain, as shown in the inset of Figure 2c. At a low electric field, the polarization of the AFE materials varies linearly with the applied field. At a sufficiently high electric field, the electric dipoles in a domain rotate to align in the parallel direction, and the AFE behaves similarly to an FE with a further increase in the field strength. This is known as the field-induced AFE-FE transition. Once the electric field is removed, the induced FE phase reverts to the AFE state, thereby producing double hysteresis in the P – E loop. The high electric field for the AFE-FE phase transition ($E_{\text{AFE-FE}}$) coupled with the high P_{max} and low P_r indicates the possibility of achieving high storage capacity in AFE materials. The most intensively studied AFE systems are based on $(\text{Pb, Zr})\text{O}_3$ [33–36], $(\text{Bi, Na})\text{TiO}_3$ [37–39], and AgNbO_3 [40–42]. However, the $E_{\text{AFE-FE}}$ for some AFEs is higher than their BDS at room temperature, signifying a breakdown before the transition to the highly polarized FE phase. Moreover, AFE materials cannot withstand

large charge-discharge cycles, which is an important aspect in practical operations because such cycling leads the materials to undergo several alternate AFE-FE transitions, leading to physical cracks [43]. Moreover, the high-field FE phase often suffers from severe energy loss, which is particularly observed in AgNbO₃-based AFEs [44].

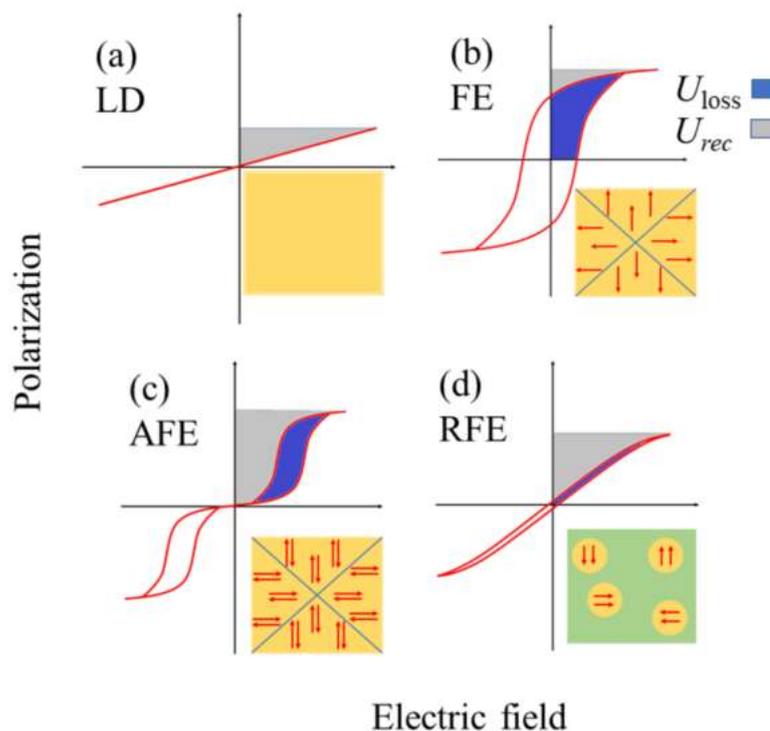


Figure 2. Typical P - E loops for (a) LD (b) FE, (c) AFE, and (d) RFE. Insets are schematics of domains with the alignment of polarization vectors (arrowheads). In RFEs, polar nanoregions (shown in circular patches) are sparingly distributed in a non-ferroelectric matrix (green area in the inset).

3. Relaxor Ferroelectrics

Relaxor ferroelectrics (RFEs) are an important class of materials that have attracted significant interest in energy storage applications. RFEs exhibit nanosized polar regions embedded in a nonpolar matrix. The polar nanoregions (PNRs) exhibit spontaneous polarization; however, the inter-PNR interaction is very weak [45]. The typical size of a PNR is 2–10 nm. PNRs are highly dynamic and sensitive to external stimuli. Because of the lack of inter-PNR interactions, PNRs under an electric field evolve independently of nearby PNRs. Therefore, the polarization state can return to its initial state after the electric field is removed. The P - E loop for a typical RFE is shown in Figure 2d, which features $P_r \sim 0$, a considerably high P_{max} , and a small hysteresis loop.

RFEs feature (i) a broad maximum in ϵ around T_m (maximum temperature in the ϵ - T curve); (ii) strong frequency dispersion of ϵ and loss tangent ($\tan \delta$) peaks, i.e., shifting of the peaks toward higher temperatures while measured at lower to higher frequencies; and (iii) low P_r [46,47]. Therefore, RFEs are FE materials that simultaneously exhibit dielectric relaxation and ferroelectricity. However, unlike normal FEs, where the paraelectric-FE phase transition can be explained by Curie's law, the temperature dependence of χ in RFEs in the paraelectric phase obeys the following:

$$\chi = \frac{C}{(T - T_c)^\gamma} \quad (9)$$

where the parameter γ ($1 < \gamma < 2$) represents the broadness of the dielectric peak. For a normal FE, $\gamma = 1$. Several models have been proposed to explain the peculiar characteristics

of RFEs, such as the diffuse phase transition model [48], super paraelectric model [49], dipolar glass model [50], random-field model [51], random-site model [52], bi-relaxation model [53], and spherical random-bond-random-field model [54]. However, the underlying mechanism of RFEs is yet to be clearly understood.

4. Energy Storage Performance of BiFeO₃-Based Relaxor Ferroelectrics

BiFeO₃ exhibits a distorted perovskite structure, as shown in Figure 3a. It possesses a rhombohedral structure (point group: R3c) at room temperature with an $a^-a^-a^-$ tilt system, in which the neighboring oxygen octahedra rotate anti-clockwise about the [111] direction [55,56]. The rhombohedral unit cell is described with lattice constants $a = b = c = 3.965 \text{ \AA}$ and $\alpha = \beta = \gamma = 89.3\text{--}89.4^\circ$ [57]. There are two formula units of BiFeO₃ in the rhombohedral cell, with three atoms in its asymmetric unit occupying Wyckoff positions: $6a$ (Bi³⁺ and Fe³⁺) and $18b$ (O²⁻) [58]. In a hexagonal frame of reference with the hexagonal c -axis parallel to the diagonals of the cubic perovskite with the lattice constants $a_{\text{hex}} = 5.58$ and $c = 13.90 \text{ \AA}$ [57].

The R3c symmetry permits long-range FE order in BiFeO₃ along the threefold axis [111]. Various experiments have confirmed the ferroelectricity in BiFeO₃ below $T_C = 1143 \text{ K}$ [55,59]. The constituent atoms Bi, Fe, and O are displaced from their centrosymmetric positions along the threefold axis, and Bi ions have the largest displacement with respect to O ions [55]. The lone-pair-active Bi ions in BiFeO₃ are displaced to a large extent in comparison with other FE compounds with non-lone-pair-active cations. Therefore, a large value of spontaneous polarization, on the order of $90 \mu\text{C cm}^{-2}$, has been predicted in BiFeO₃ from ab initio calculations [16,60]. However, a polarization value close to the calculated values could not be obtained until recently [61], after a series of initial experimental failures to achieve spontaneous polarization of BiFeO₃, as predicted by theory [62–67]. Lebeugle et al. [61] measured a very large saturated polarization (approximately $60 \mu\text{C cm}^{-2}$) in a high-quality single-crystal BiFeO₃ at room temperature, as shown in Figure 3b.

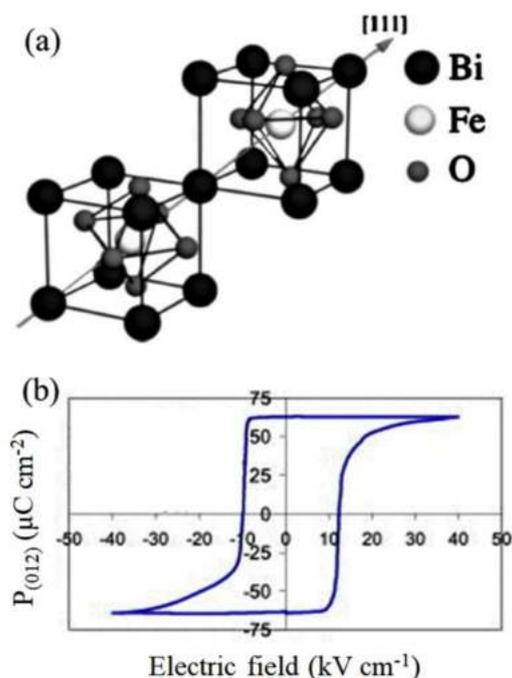


Figure 3. (a) Structure of R3c BiFeO₃. (b) P-E loop of BiFeO₃ bulk single crystal. Figures reproduced with permission from [55] and [61], respectively. © 2021 American Physical Society (a) and 2007 American Institute of Physics (b).

BiFeO_3 possesses the highest values of spontaneous polarization and T_C among Pb-free FEs. As discussed in Section 2, high P_{\max} and large $P_{\max} - P_r$ are among the most important factors for obtaining a high storage capacity. Therefore, BiFeO_3 with a large P_r in its naturally occurring FE phase is not suitable for energy storage applications, which is a drawback of all FE materials in general. One way to obtain a small P_r is to break the long-range FE order such that it becomes an RFE. Many researchers have reported this method to create PNRs embedded in a non-FE matrix and obtain a significant reduction in the P_r value. In addition, there are always issues pertaining to the leakage current in pure BiFeO_3 , which eventually limits its high breakdown strength. Various successful methods to enhance the resistivity in phase-pure BiFeO_3 , such as doping at the A-site and the addition of Mn, have been discussed in the literature. In the following sections, considering these issues, the energy storage performance of BiFeO_3 -based materials, with special emphasis on the RFEs, are reviewed.

4.1. BiFeO_3 -Based Binary System

BiFeO_3 – BaTiO_3 solid solutions have been widely investigated as promising candidates in the field of ceramic dielectrics-based energy storage materials. A remarkable feature of BiFeO_3 -based solid solutions is the morphotropic phase boundary (MPB), where the solid solution displays a composition-driven structural transition in its phase diagram. The crystal structure changes abruptly across the MPB, and various physical properties, such as piezoelectric coefficients and polarization, are maximal at the MPB. The MPB of the BiFeO_3 – BaTiO_3 system is shown in the phase diagram in Figure 4, where the rhombohedral and tetragonal phases coexist in the MPB region [68–70]. Careful optimization of the BaTiO_3 content produces excellent ferroelectric and piezoelectric properties in MPB compositions.

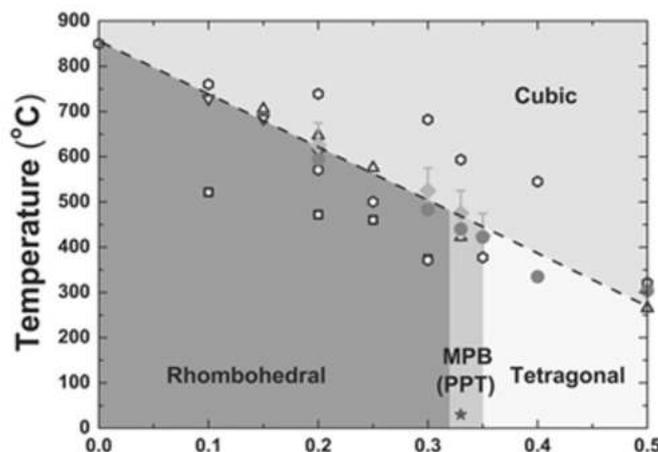


Figure 4. Phase diagram of $(1-x)\text{BiFeO}_3$ - $x\text{BaTiO}_3$ solid solution. Reused with permission from [68]. © 2021 Willey-VCH Verlag GmbH & Co.

However, BiFeO_3 - BaTiO_3 also possesses a high P_r [71] and high dielectric loss, which are detrimental for energy storage. Previous studies have shown that doping small amounts of La_2O_3 , MnO_2 , and Nb_2O_5 in BiFeO_3 can significantly enhance the electrical resistivity and energy loss density [72,73], which is beneficial for energy storage. Wang et al. [74] reported a large enhancement of resistivity in Nb_2O_5 -modified BiFeO_3 - BaTiO_3 , i.e., $(1-x)(0.65\text{BiFeO}_3-0.35\text{BaTiO}_3)-x\text{Nb}_2\text{O}_5$ ($x = 0, 1, 3, 5$ mol%) by several orders ($\sim 10^{10}$ – 10^{14} Ω cm) compared with the undoped BiFeO_3 - BaTiO_3 ($\sim 10^8$ Ω cm). The compounds with $x = 0.01$ and 0.03 exhibited slimmer P - E loops, similar to RFEs, with $x = 0.03$ exhibiting the highest P_{\max} (25.21 $\mu\text{C cm}^{-2}$) and lowest P_r (5.53 $\mu\text{C cm}^{-2}$). They obtained a maximum U_{rec} of 0.71 J cm^{-3} at $E = 90$ kV cm^{-1} . Zhu et al. [75] found a significant improvement in the BDS of 0.52BiFeO_3 - 0.48BaTiO_3 ceramic up to 130 – 140 kV cm^{-1} by adding La_2O_3 and MnO_2 . Under this condition, they obtained $U_{\text{rec}} = 1.22$ J cm^{-3} with

$\eta = 58\%$ for $0.52\text{Bi}_{0.98}\text{La}_{0.02}\text{FeO}_3\text{-}0.48\text{BaTiO}_3 + 0.3 \text{ wt.}\% \text{ MnO}_2$ compound, whereas undoped $0.52\text{BiFeO}_3\text{-}0.48\text{BaTiO}_3$ exhibited $U_{\text{rec}} = 1.08 \text{ J cm}^{-3}$ with $\eta = 49\%$. They found that the addition of La_2O_3 and MnO_2 increased the amount of the FE phase, reduced the grain size, and facilitated densification, which helped to induce large ΔP ($P_{\text{max}} - P_{\text{r}}$) as well as BDS compared with undoped compounds. This phenomenon was found to be more pronounced when Nd was substituted for Bi sites in MnO_2 -added $\text{BiFeO}_3\text{-BaTiO}_3$ solid solution, as shown in Figure 5. Wang et al. [76] synthesized highly dense (relative density $\rho_{\text{r}} = 95\%$ to 97.6%) $0.75\text{BiFeO}_3\text{-}0.25\text{BaTiO}_3$ ceramics by Nd substitution with $0.1 \text{ wt.}\% \text{ MnO}_2$ addition that could endure a high electric field up to 180 kV cm^{-1} , as shown in Figure 5. The solid solution with $15 \text{ mol}\%$ Nd content featured the highest value of $U_{\text{st}} = 4.1 \text{ J/cm}^3$ and $U_{\text{rec}} = 1.82 \text{ J cm}^{-3}$; however, it had a low value of $\eta = 41.3\%$. Recently, Chen et al. [77] successfully synthesized highly dense Sm-doped $\text{BiFeO}_3\text{-BaTiO}_3$ binary ceramics that can endure a very high electric field of up to 200 kV cm^{-1} . Sm substitution significantly reduced the grain size and enhanced the density, which is believed to be the reason for the high BDS. The binary solid solutions exhibit excellent U_{st} and U_{rec} ; however, their low efficiency limits practical device applications.

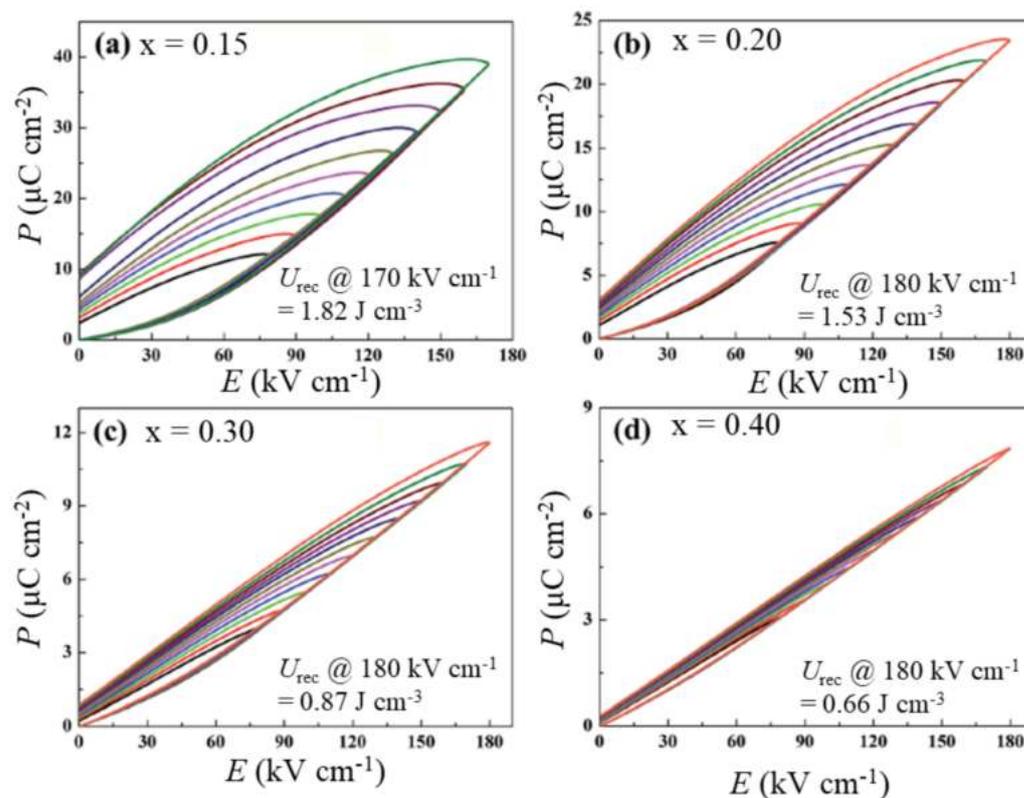


Figure 5. Unipolar P-E loops for $0.75\text{Bi}_{1-x}\text{Nd}_x\text{FeO}_3\text{-}0.25\text{BaTiO}_3 + 0.1 \text{ wt}\% \text{ MnO}_2$ system: (a) $x = 0.15$, (b) $x = 0.20$, (c) $x = 0.30$, and (d) $x = 0.40$. Reproduced with permission from [76]. © 2021 The Royal Society of Chemistry.

4.2. BiFeO_3 -Based Ternary System

4.2.1. Bulk Ceramics

The addition of a third perovskite oxide to binary $\text{BiFeO}_3\text{-MTiO}_3$ ($M = \text{Ba}$ and/or Sr) as the end member of the ternary system has been found to be very promising for inducing the relaxor phase and enhancing the energy storage performance [78–84]. Zheng et al. [78] reported the successful induction of the relaxor phase in $\text{BiFeO}_3\text{-BaTiO}_3$ as a result of the substitution of $\text{BaMg}_{1/3}\text{Nb}_{2/3}\text{O}_3$. The relaxor $0.61\text{BiFeO}_3\text{-}0.33\text{BaTiO}_3\text{-}0.06\text{BaMg}_{1/3}\text{Nb}_{2/3}\text{O}_3$ exhibited a U_{rec} of 1.56 J cm^{-3} at $E = 125 \text{ kV cm}^{-1}$, with $\eta \sim 75\%$. This compound also exhibited good temperature stability for energy storage and efficiency in the temperature

range of 25 °C to 190 °C. In a similar effort, Zheng et al. [79] reported an improved storage performance with a U_{rec} of 1.66 J cm^{-3} at 130 kV cm^{-1} and $\eta \sim 82\%$ in highly dense ($\rho_r > 97\%$) $0.61\text{BiFeO}_3\text{-}0.33\text{BaTiO}_3\text{-}0.06\text{LaMg}_{1/2}\text{Ti}_{1/2}\text{O}_3$ ceramics. Meanwhile, Liu et al. [80] reported enhancement of relaxor characteristics in terms of broader peaks of dielectric permittivity (Figure 6) and significant enhancement of energy storage performance in $(0.66 - x)\text{BiFeO}_3\text{-}0.34\text{BaTiO}_3\text{-}x\text{BaZn}_{1/3}\text{Ta}_{2/3}\text{O}_3$ for $x > 0$. They reported slim P - E loops for $x > 0$ with the highest BDS of $E = 160 \text{ kV cm}^{-1}$ and a high U_{rec} of 2.56 J cm^{-3} for the $x = 0.06$ composition (Figure 7). Tang et al. [84] reported a BDS of 180 kV cm^{-1} and $U_{\text{rec}} = 1.62 \text{ J cm}^{-3}$ for $0.85(0.65\text{BiFeO}_3\text{-}0.35\text{BaTiO}_3)\text{-}0.15\text{Ba}(\text{Zn}_{1/3}\text{Nb}_{2/3})\text{O}_3$ bulk ceramics. Sun et al. [85] reported similar values of $U_{\text{rec}} = 2.11 \text{ J cm}^{-3}$ at $E = 195 \text{ kV cm}^{-1}$ with $\eta = 84\%$ in a highly dense $0.56\text{BiFeO}_3\text{-}0.30\text{BaTiO}_3\text{-}0.14\text{AgNbO}_3\text{+}5 \text{ mol\% CuO}$ system prepared by a modified thermal quenching technique.

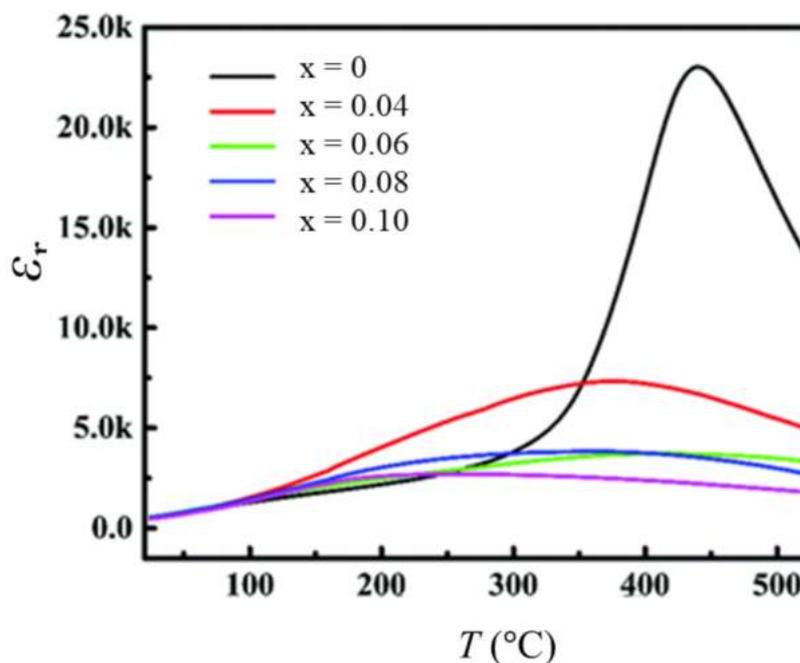


Figure 6. Induction of relaxor phase characterized by diffused phase transition in $(0.66-x)\text{BiFeO}_3\text{-}0.34\text{BaTiO}_3\text{-}x\text{BaZn}_{1/3}\text{Ta}_{2/3}\text{O}_3$ systems. Reproduced with permission from [80]. © 2021 The Royal Society of Chemistry.

Yu et al. [86] studied the effect of the microstructure on the energy storage performance of a $\text{BiFeO}_3\text{-BaTiO}_3\text{-Bi}(\text{Mg}_{2/3}\text{Nb}_{1/3})\text{O}_3$ system. They prepared coarse-grained (grain size ~ 2 to $4 \mu\text{m}$) and fine-grained (~ 0.55 to $0.9 \mu\text{m}$) microstructures using planetary ball milling and high-energy ball milling processes, respectively. $\text{BiFeO}_3\text{-BaTiO}_3\text{-Bi}(\text{Mg}_{2/3}\text{Nb}_{1/3})\text{O}_3$ solid solutions with a fine-grained microstructure exhibited higher ΔP ($\sim 30 \mu\text{C cm}^{-2}$) and BDS ($\sim 110 \text{ kV cm}^{-1}$) than the coarse-grained samples ($\Delta P \sim 10 \mu\text{C cm}^{-2}$, BDS $\sim 50 \text{ kV cm}^{-1}$). Under such drastic microstructural evolution, they reported a higher U_{rec} of 1.26 J cm^{-3} in fine-grained samples, compared with $U_{\text{rec}} = 0.16 \text{ J cm}^{-3}$ for coarse-grained samples. Yang et al. [87] showed that utilizing a liquid-phase sintering mechanism can significantly enhance the BDS while maintaining the relaxor characteristics and high dielectric permittivity. Using 2 wt% $\text{BaCu}(\text{B}_2\text{O}_5)$ (BCB) as the low melting point additive in 0.1 wt% MnO_2 -added $(0.67 - x)\text{BiFeO}_3\text{-}0.33(\text{Ba}_{0.8}\text{Sr}_{0.2})\text{TiO}_3\text{-}x\text{La}(\text{Mg}_{2/3}\text{Nb}_{1/3})\text{O}_3$ solid solution, they achieved a BDS of 230 kV cm^{-1} for $x = 0.06$. With the use of such a high field, the compound exhibited $U_{\text{rec}} = 3.38 \text{ J cm}^{-3}$ with $\eta = 59\%$. BCB formed large amounts of liquid phase at the grain boundaries during sintering and significantly reduced the average grain size down to the submicron range, as shown in Figure 8, by impeding grain growth at lower sintering temperatures. The high density of grain boundaries in the microstructure of the submicron grain size offered high electrical resistivity, resulting in enhanced BDS (Figure 8). Moreover,

low-temperature sintering with the addition of MnO_2 helped to decrease $\text{Fe}^{3+} \leftrightarrow \text{Fe}^{2+}$ valence fluctuations by minimizing Bi_2O_3 loss during synthesis, which was also critical for enhancing the BDS. This compound exhibited good temperature stability, with $U_{\text{rec}} = 1.15\text{--}1.27 \text{ J cm}^{-3}$ in the temperature range of $30 \text{ }^\circ\text{C}$ to $170 \text{ }^\circ\text{C}$. Using the PVA-assisted viscous polymer process (VPP) route, Liu et al. [88] obtained high $\rho_r \sim 99\%$ 15 mol% $\text{Sr}_{0.7}\text{Bi}_{0.3}\text{FeO}_3$ -modified $0.85(0.65\text{BiFeO}_3\text{-}0.35\text{BaTiO}_3)$ system with a fine grain microstructure. The ultra-high ρ_r and uniform submicron grains significantly enhanced the BDS, with a value of 330 kV cm^{-1} , compared with that of the sample prepared without VPP (180 kV cm^{-1}). Under this condition, they obtain an ultra-high U_{rec} of 4.95 J cm^{-3} with $\eta \sim 73\%$. The calculated U_{rec} from the charge-discharge cycling test was 2.36 J cm^{-3} at 300 kV cm^{-1} . Likewise, Sm doping has been found to be very effective in reducing the grain size and increasing the density of sintered ceramics. Chen et al. [78] reported a significant decrease in the average grain size in the $0.67\text{Bi}_{1-x}\text{Sm}_x\text{FeO}_3\text{-}0.33\text{BaTiO}_3$ system with an increase in x , resulting in a BDS of 200 kV cm^{-1} at $x = 0.1$. This resulted in an $U_{\text{rec}} = 2.8 \text{ J cm}^{-3}$ for $x = 0.1$; however, it had low efficiency, $\eta = 55.8\%$. In another report, Li et al. [89] reported an ultra-high $U_{\text{rec}} = 3.2 \text{ J cm}^{-3}$ at $E = 206 \text{ kV cm}^{-1}$ with high efficiency, $\eta = 92\%$, in a highly dense ($\rho_r \sim 98\%$) solid solution of $(1-x)\text{Bi}_{0.83}\text{Sm}_{0.17}\text{Fe}_{0.95}\text{Sc}_{0.05}\text{O}_3\text{-}x(0.85\text{BaTiO}_3\text{-}0.15\text{Bi}(\text{Mg}_{0.5}\text{Zr}_{0.5})\text{O}_3)$ with $x = 0.75$. A similar $U_{\text{rec}} \approx 3.06 \text{ J cm}^{-3}$ at $E = 167 \text{ kV cm}^{-1}$ with $\eta \approx 92\%$ associated with the improvement of BDS has been reported in $(1-x)\text{BiFeO}_3\text{-}x(0.85\text{BaTiO}_3\text{-}0.15\text{Bi}(\text{Sn}_{0.5}\text{Zn}_{0.5})\text{O}_3)$ with $x = 0.65$ [90].

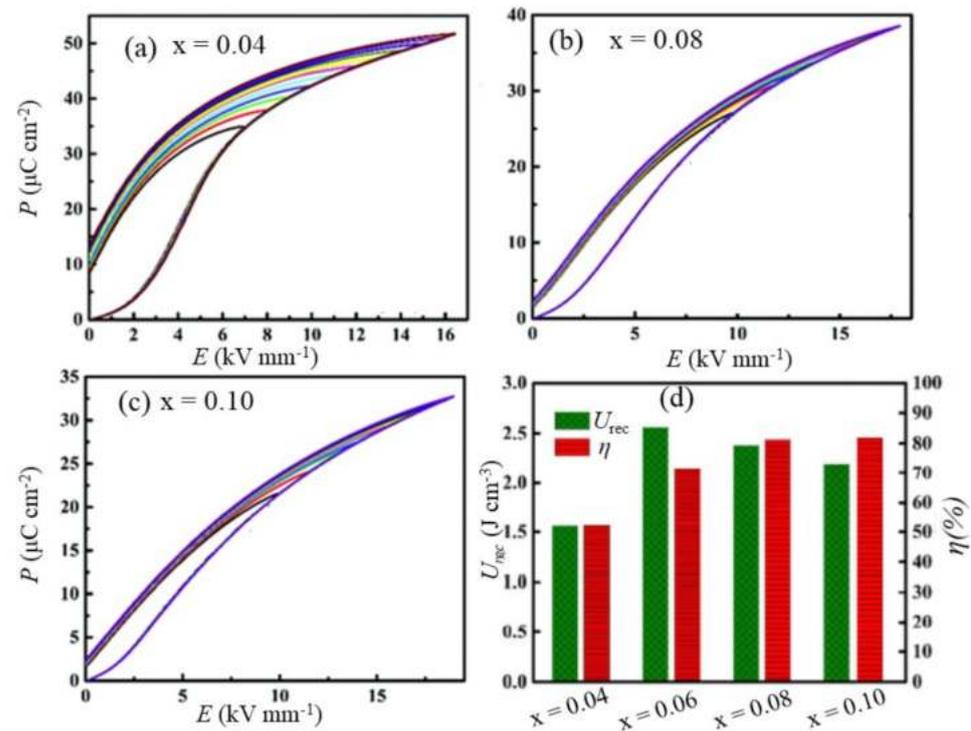


Figure 7. $\text{BaZn}_{1/3}\text{Ta}_{2/3}\text{O}_3$ modification to $\text{BiFeO}_3\text{-BaTiO}_3$ leads to slimmer $P\text{-}E$ loops. Unipolar $P\text{-}E$ loops for $(0.66\text{-}x)\text{BiFeO}_3\text{-}0.34\text{BaTiO}_3\text{-}x\text{BaZn}_{1/3}\text{Ta}_{2/3}\text{O}_3$ with (a) $x = 0.04$, (b) $x = 0.08$, and (c) $x = 0.10$. (d) The optimum recoverable energy density and efficiencies. Reproduced with permission from [80]. © 2021 The Royal Society of Chemistry.

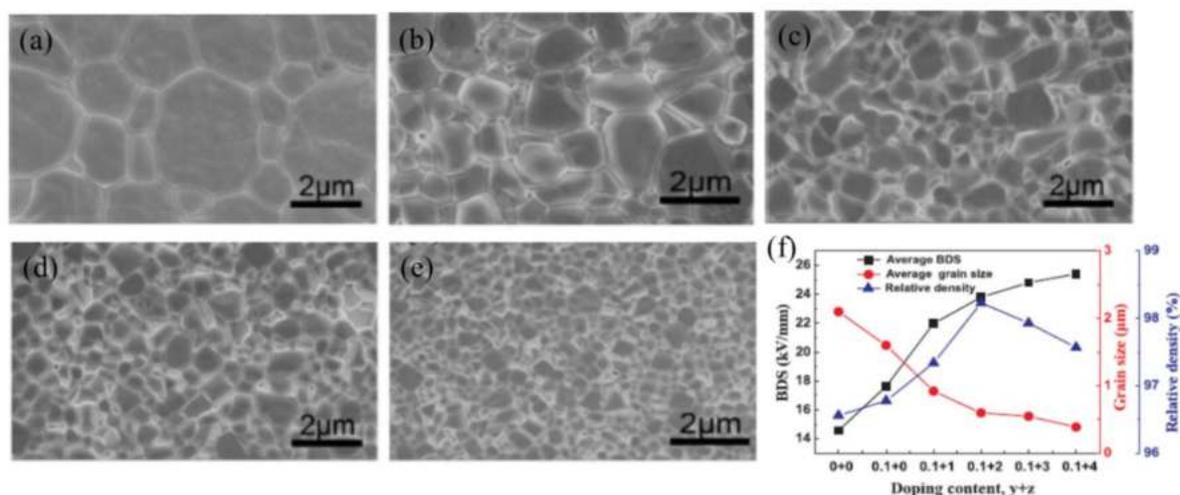


Figure 8. SEM images of $0.61\text{BiFeO}_3\text{-}0.33(\text{Ba}_{0.8}\text{Sr}_{0.2})\text{TiO}_3\text{-}0.06\text{La}(\text{Mg}_{2/3}\text{Nb}_{1/3})\text{O}_3 + y \text{ wt.}\% \text{MnO}_2 + z \text{ wt.}\% \text{BaCu}(\text{B}_2\text{O}_5)$ solid solution sintered at their optimum temperatures: (a) $y = z = 0$, (b) $y = 0.1$ and $z = 1$, (c) $y = 0.1$ and $z = 2$, (d) $y = 0.1$ and $z = 3$, and (e) $y = 0.1$ and $z = 4$. (f) Variations of BDS, grain size, and relative density with $y + z$. Reused with permission from [87]. © 2021 Elsevier Ltd.

Designing a specific microstructure has been found to be highly effective for enhancing energy storage performance. Microstructure strongly influences the BDS of dielectric materials and their relaxor characteristics. Wang et al. [81] designed core-shell microstructure (Figure 9a) with BaTiO_3 -rich shells and BiFeO_3 -rich cores in $(0.7-x)\text{BiFeO}_3\text{-}0.30\text{BaTiO}_3\text{-}x\text{Bi}(\text{Zn}_{2/3}\text{Nb}_{1/3})\text{O}_3 + 0.1\text{wt}\% \text{Mn}_2\text{O}_3$ ceramics that could withstand an electric field as high as 190 kV cm^{-1} . They found that the shells and cores in the solid solutions were different in structure and electrical characteristics. The shell exhibited a pseudo-cubic structure, which is paraelectric in nature, whereas the core parts had a ferroelectric R3c structure. The core-shell structure and the cationic charge disorder at the B-sites helped to establish the relaxor phase in $0.70\text{BiFeO}_3\text{-}0.30\text{BaTiO}_3$ (Figure 9a). Substitution of $\text{Bi}(\text{Zn}_{2/3}\text{Nb}_{1/3})\text{O}_3$ further exacerbated the long-range order, thereby inducing a highly disordered RFE phase while maintaining the polarizability as high as $P_{\text{max}} = 36.7 \mu\text{C cm}^{-2}$ and $\Delta P = 32.8 \mu\text{C cm}^{-2}$. They obtained $U_{\text{st}} = 3.7 \text{ J cm}^{-3}$, $U_{\text{rec}} = 2.06 \text{ J cm}^{-3}$ at 180 kV cm^{-1} and $U_{\text{st}} = 2.9 \text{ J cm}^{-3}$, $U_{\text{rec}} = 1.98 \text{ J cm}^{-3}$ at 190 kV cm^{-1} for 5 mol% and 8 mol% $\text{Bi}(\text{Zn}_{2/3}\text{Nb}_{1/3})\text{O}_3$ -doped compounds, respectively. The solid solutions could also successfully deliver discharge energy within $0.5 \mu\text{s}$. Wang et al. [82] reported relaxor behavior in chemically inhomogeneous, but electrically homogeneous $(0.7-x)\text{BiFeO}_3\text{-}0.3\text{BaTiO}_3\text{-}x\text{Nd}(\text{Zr}_{0.5}\text{Zn}_{0.5})\text{O}_3$ for $x = 0.05, 0.08$, and 0.10 , with a core-shell structure, and studied the energy storage performance at room temperature both in ceramics and multilayers prepared by a solid-state reaction route. The substitution of $\text{Nd}(\text{Zr}_{0.5}\text{Zn}_{0.5})\text{O}_3$ induced chemical inhomogeneity, revealed as a (Bi, Fe)-rich core for $x = 0.05$ and (Ba,Ti)-rich cores for $x = 0.1$, and complex multiphase microstructures with both (Bi, Fe)-rich and (Ba,Ti)-rich cores for $x = 0.08$. A high degree of chemical inhomogeneity and better electrical homogeneity of grains existed at $x = 0.08$, which led to a high ΔP and provided a difficult current path for electrical breakdown. As a result, $x = 0.08$ exhibited $U_{\text{rec}} \sim 2.45 \text{ J cm}^{-3}$ at $E = 240 \text{ kV cm}^{-1}$ with $\eta = 72\%$. Lu et al. [91] demonstrated excellent energy storage properties in a series of solid solutions composed of BiFeO_3 , SrTiO_3 , Nb_2O_5 , and $\text{BiMg}_{2/3}\text{Nb}_{1/3}\text{O}_3$ exhibiting a core-shell structure. Their study successfully demonstrated that Nb_2O_5 doping into $\text{BiFeO}_3\text{-SrTiO}_3$ and employing the third perovskite end member $\text{BiMg}_{2/3}\text{Nb}_{1/3}\text{O}_3$ (BMN) could induce an insulating relaxor phase at room temperature without reducing the average ionic polarizability of the solid solution. It was found that the substitution of 1–3% Nb^{5+} for Ti^{4+} (B sites) in $0.6\text{BiFeO}_3\text{-}0.4\text{SrTiO}_3$ suppressed the formation of oxygen vacancies and significantly reduced p -type conductivity compared with that of the undoped compound. A similar reduction in the p -type conductivity was observed for the $0.56\text{BiFeO}_3\text{-}0.4\text{SrTiO}_3\text{-}0.04\text{BiMg}_{2/3}\text{Nb}_{1/3}\text{O}_3\text{-}x\text{Nb}_2\text{O}_5$

($x = 0-0.05$) solid solution, and an enhanced BDS of 360 kV cm^{-1} was obtained at an optimized Nb_2O_5 content ($x = 0.03$). Such a high BDS was attributed to two factors: (i) the improved insulating character caused by Nb doping at B-sites related to the suppression of the formation of oxygen vacancies, and (ii) a core-shell microstructure with electrical homogeneity throughout the grains. The $x = 0.03$ composition exhibited a high performance of $U_{\text{rec}} = 6 \text{ J cm}^{-3}$ with $\eta = 74.6\%$. Then, a much-improved U_{rec} value with similar η could be achieved by optimizing the $\text{BiMg}_{2/3}\text{Nb}_{1/3}\text{O}_3$ content in $(0.6-y)\text{BiFeO}_3-0.4\text{SrTiO}_3-0.03\text{Nb}_2\text{O}_5-y\text{BiMg}_{2/3}\text{Nb}_{1/3}\text{O}_3$ ($y = 0.02-0.12$) solid solutions. For $y = 0.1$, the BDS was enhanced further up to 460 kV cm^{-1} , producing $U_{\text{rec}} = 8.2 \text{ J cm}^{-3}$ and $\eta = 74.6\%$. A core-shell microstructure design provides a large BDS and large U_{rec} , but at the same time, it has low efficiency because of the not-very-fast response of the PNRs to the electric field.

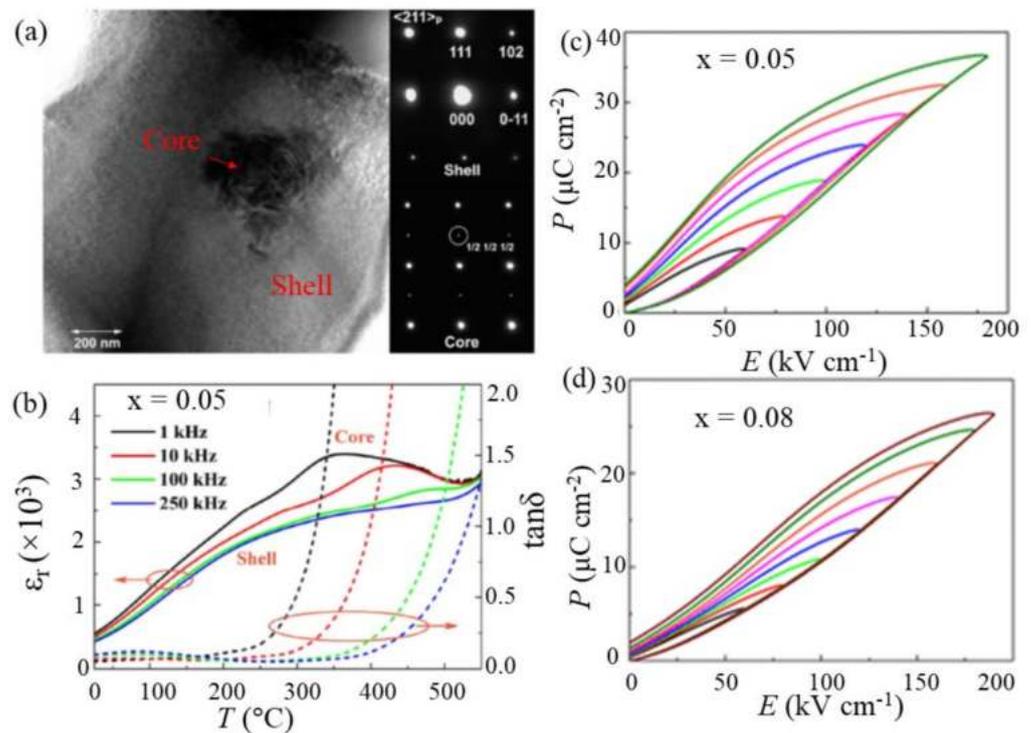


Figure 9. (a) Bright-field TEM image of a grain in $(0.70-x)\text{BiFeO}_3-0.30\text{BaTiO}_3-x\text{Bi}(\text{Zn}_{2/3}\text{Nb}_{1/3})\text{O}_3$ with $x = 0.05$, illustrating a BiFeO_3 -rich core and BaTiO_3 -rich shell. (b) Broad dielectric anomalies associated with the core-shell structure. P-E loops for (c) $x = 0.05$ and (d) $x = 0.08$, respectively. Reproduced with permission from [81]. © 2021 American Chemical Society.

Qi et al. [92] employed a domain engineering technique to optimize the microstructure at the domain level and showed that this technique was very effective for enhancing U_{rec} and η . Using it, they obtained large P_{max} , large ΔP , and superior energy storage performance in $0.57\text{BiFeO}_3-0.33\text{BaTiO}_3-0.1\text{NaNbO}_3$ with the addition of 0.1 wt% MnO_2 and 2 wt% $\text{BaCu}(\text{B}_2\text{O}_5)$. Nanodomain engineering produced stripe-like PNRs embedded in featureless nanodomains. The stripe-like PNRs were rich in BiFeO_3 , whereas the matrix domains were rich in BaTiO_3 and NaNbO_3 . An HR-TEM image of the solid solution is shown in Figure 10a. Stripe-like PNRs rich in BiFeO_3 were dispersed in BaTiO_3 - and NaNbO_3 -rich featureless nanodomains. This structural heterogeneity at the domain level led to a rapid polarization response to the external E -field, unlike in the core-shell microstructure, and produced a hysteresis-free $P-E$ loop, as well as a large P_{max} . Moreover, NaNbO_3 substitution increased the bandgap and helped to obtain a uniform and fine-grained microstructure, which was beneficial to enhance BDS up to 360 kV cm^{-1} , producing $U_{\text{rec}} \approx 8.12 \text{ J cm}^{-3}$ with $\eta \approx 90\%$. This solid solution also exhibited excellent thermal stability, with $U_{\text{rec}} = 8.12 \text{ J cm}^{-3} \pm 10\%$ in the temperature range $-25 \text{ }^\circ\text{C}$ to $250 \text{ }^\circ\text{C}$, and an ultrafast discharge rate ($< 100 \text{ ns}$).

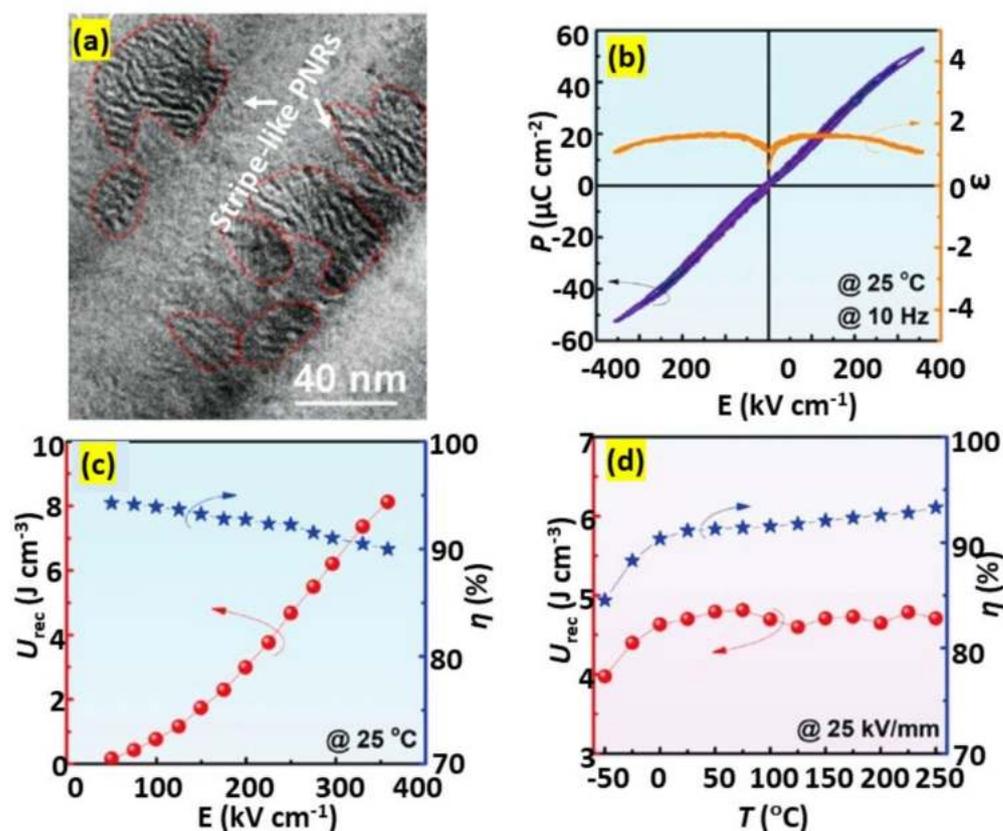


Figure 10. (a) Domain morphology exhibiting stripe-like PNRs in $0.57\text{BiFeO}_3\text{-}0.33\text{BaTiO}_3\text{-}0.1\text{NaNbO}_3$ with the addition of 0.1 wt.% MnO_2 and 2 wt.% $\text{BaCu}(\text{B}_2\text{O}_5)$. (b) Room-temperature P - E loops and ϵ measured under various electric fields for the same compound. U_{rec} and η measured at (c) various electric fields and (d) temperatures. Figures reused with permission from [92]. © 2021 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

4.2.2. Thin Films

In the past few decades, thin films have gained enormous scientific importance in a plethora of applications. The obvious advantages thin films possess over their bulk counterparts are that they save material and have reduced weight. In addition, it is well known that material properties drastically change when they are deposited in thin film forms, which paves the way for industrial applications. Dielectric thin films with thicknesses on the nano- or submicron scale have shown promising potential in the field of energy storage for low-power small devices. This is because of their extraordinarily high BDS (1 MV/cm) and energy density compared with bulk dielectrics.

Correia et al. [93] deposited a thin film of $0.4\text{BiFeO}_3\text{-}0.6\text{SrTiO}_3$ onto a SrRuO_3 -electroded (100)- SrTiO_3 substrate using the pulsed laser deposition (PLD) method, which can endure an electric field as large as 0.972 MV cm^{-1} . Under such a high electric field, the film exhibited $U_{\text{rec}} = 18.6\text{ J cm}^{-3}$ with $\eta > 85\%$. It also featured a small temperature coefficient of capacitance (TCC < 11%) over a wide range of temperatures up to 200 °C. Pan et al. [94] demonstrated that the BDS of the same material could be enhanced more than by three times, up to 3.6 MV cm^{-1} , when doped with Mn and deposited onto a Nb-doped SrTiO_3 (001) substrate by the PLD technique. The high BDS of the Mn-doped $0.4\text{BiFeO}_3\text{-}0.6\text{SrTiO}_3$ thin film was attributed to (i) a dense, uniform, and crack-free microstructure, (ii) high-quality epitaxial growth, and (iii) low leakage current by reducing the $\text{Fe}^{3+}/\text{Fe}^{2+}$ valence fluctuation with Mn substitution. They obtained a colossal $U_{\text{rec}} = 51\text{ J cm}^{-3}$ and $\eta = 64\%$, which are comparable to those of lead-based thin films ($U_{\text{rec}} = 61\text{ J cm}^{-3}$ and $\eta = 33\%$) [95]. The thin film also featured high fatigue endurance quality over 2×10^7 cycles and good thermal stability over a wide range of temperatures, from $-40\text{ }^{\circ}\text{C}$ to $140\text{ }^{\circ}\text{C}$. In another

report, Pan et al. [96] utilized a domain engineering method to obtain strong relaxor behavior in $(1-x)\text{BiFeO}_3-x\text{SrTiO}_3$ thin films ($x = 0.3-0.75$) deposited by the PLD technique and found that the BDS of the films could be enhanced further, up to 4.46 MV cm^{-1} , by increasing the SrTiO_3 content. Atomic-scale microstructure analysis based on the STEM of $\text{BiFeO}_3\text{-SrTiO}_3$ films revealed that SrTiO_3 disrupted the long-range FE order, and this disruption cascaded with an increase in SrTiO_3 content. The incorporation of SrTiO_3 could transform the micrometer-scale FE domains into nanoscale PNRs. Paraelectric SrTiO_3 acts as a matrix for embedded PNRs and separates the PNRs such that the inter-PNR interaction almost vanishes. Because there are no inter-PNR interactions, the PNRs are very dynamic under an external electric field and produce slim P - E loops with very small P_r values. The size of the PNRs continued to decrease with increasing SrTiO_3 content, forming an almost domain-less feature for $x = 0.75$. This domain evolution reduced the domain switching energy, producing a slim P - E loop, while maintaining a large P_{max} value and a colossal BDS. In addition to the domain perspective, SrTiO_3 substitution enhanced the insulating character of the films by stabilizing the $\text{Fe}^{3+}/\text{Fe}^{2+}$ valence fluctuation and reducing the formation of oxygen vacancies, leading to further enhancement of BDS. For example, the BDS value of $(1-x)\text{BiFeO}_3-x\text{SrTiO}_3$ films increased from 2.77 MV cm^{-1} to 4.46 MV cm^{-1} as the SrTiO_3 content increased from for $x = 0.3$ to $x = 0.75$. At such a high electric field, the films with $x = 0.6$ and 0.75 exhibited a giant $U_{\text{rec}} \sim 70 \text{ J cm}^{-3}$.

Domain engineering techniques have been found to be more fruitful in thin films that exhibit polymorphic nanodomains, e.g., rhombohedral (R) and tetragonal (T) domains in a cubic paraelectric matrix. If these polymorphs have competitive free energy, Landau phenomenological theory predicts the weakening of polarization anisotropy and lowering of the energy barrier between the R and T polarization states [97]. It facilitates a flatter energy profile for polymorphic nanodomain RFEs compared with classic FEs and nanodomain RFEs, which minimizes the hysteresis while maintaining a high polarization (Figure 11). Pan et al. [97] demonstrated that the polymorphic domain engineering technique can produce ultra-high energy density with high efficiency in thin films of a $(0.55-x)\text{BiFeO}_3-x\text{BaTiO}_3-0.45\text{SrTiO}_3$ solid solution ($x = 0$ to 0.4). Here, BiFeO_3 and BaTiO_3 were the hosts for the R and T domains, whereas SrTiO_3 provided a cubic paraelectric matrix. The relaxor nature and energy storage performance of the $(0.55-x)\text{BiFeO}_3-x\text{BaTiO}_3-0.45\text{SrTiO}_3$ solid solutions are shown in Figure 12. The incorporation of BaTiO_3 gradually enhanced the relaxor nature, as can be seen from the wider peaks in the ϵ - T plots (Figure 12a), as well as the BDS for higher BaTiO_3 contents. The BDS increased up to 4.9 MV cm^{-1} for $x = 0.3$ and 5.3 MV cm^{-1} for $x = 0.4$, compared with 3.2 MV cm^{-1} for the $x = 0$ compound. This resulted in a maximum U_{rec} of 112 J cm^{-3} and 110 J cm^{-3} for $x = 0.3$ and 0.4 , respectively, with $\eta > 80\%$ (Figure 12). Moreover, the enhancement of the relaxor nature resulted in good temperature stability for $x = 0.3$ and 0.4 regarding their energy storage performance over a wide range of temperatures. Kurusumovic et al. [98] employed a combined defect engineering method to explore the energy storage performance of relaxor thin films of $\text{BiFeO}_3\text{-BaTiO}_3$ solid solutions doped with Mn. The combined approach of defect engineering consisted of an interval mono-layer by mono-layer deposition (LLD) and Mn addition. The LLD produced highly stoichiometric and perfectly crystalline films compared with standard deposited films, while the addition of Mn reduced the leakage current by creating vacancy trap centers. Using this method, they obtained an ultra-high value of $U_{\text{rec}} = 80 \text{ J cm}^{-3}$ at a BDS of 3.1 MV cm^{-1} with $\eta = 78\%$ in 2.5 mol.% Mn-doped $0.25\text{BiFeO}_3-0.75\text{BaTiO}_3$ thin films.

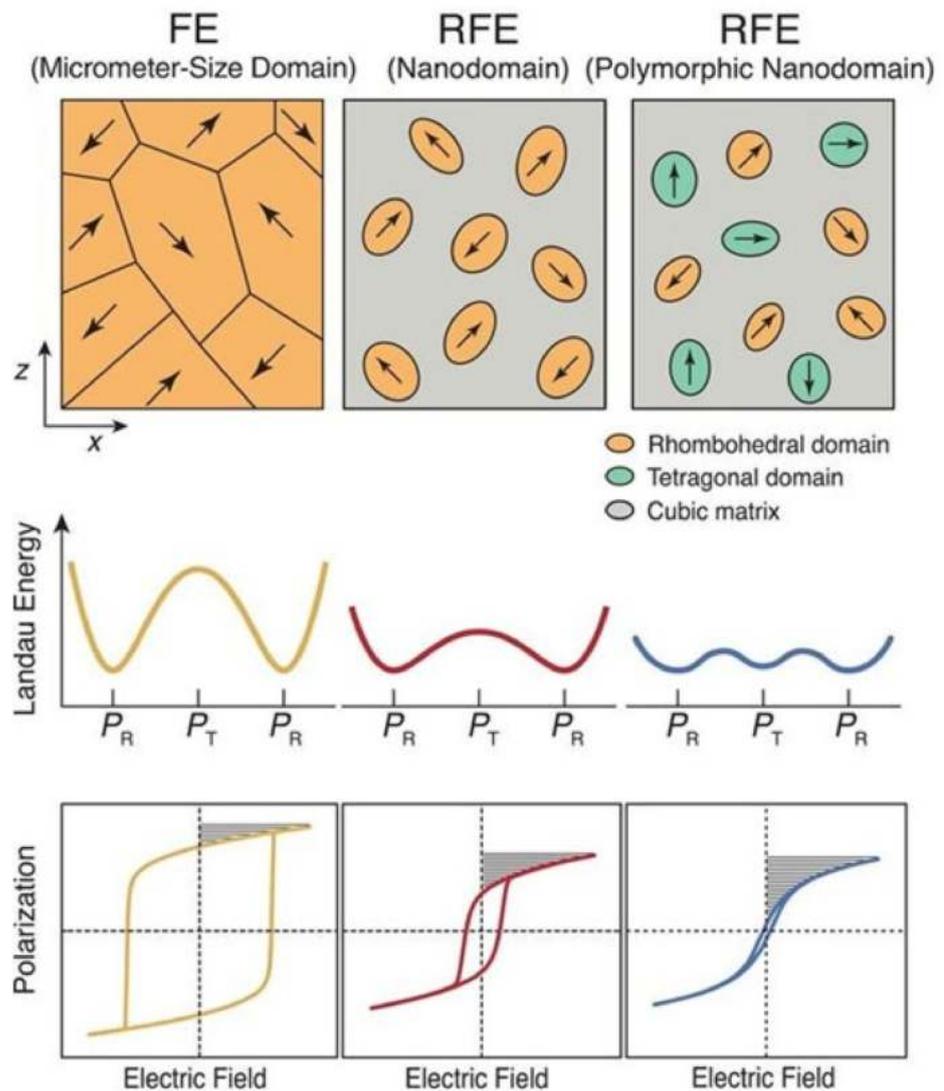


Figure 11. Design of RFEs via polymorphic nanodomain design. Comparative display of Landau energy profiles and $P-E$ loops of an FE with micrometer-sized domains, an RFE with nanodomains, and an RFE with polymorphic nanodomains. The P_R represents the polarization states along the rhombohedral (R) directions, and P_T is along the tetragonal (T) direction. The shadowed area in the $P-E$ loops represents the recoverable energy density. Figures reproduced with permission from [97]. © 2021 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science.

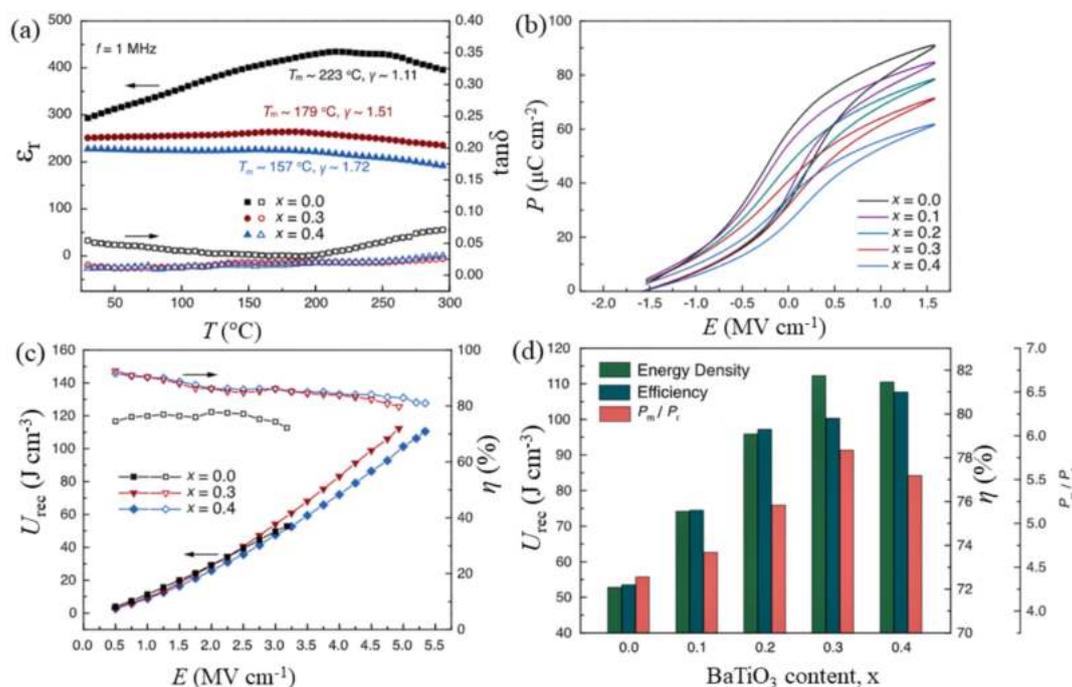


Figure 12. Characteristics of $(0.55-x)\text{BiFeO}_3-x\text{BaTiO}_3-0.45\text{SrTiO}_3$ ($x = 0.0-0.4$) films. (a) Temperature-dependent dielectric permittivity and loss tangent at a frequency of 1 MHz, (b) first-order reversal curve (FORC) $P-E$ loops, (c) energy density and efficiency values with respect to applied electric fields up to breakdown fields, and (d) comparison of the energy storage performance at breakdown fields. Figures reproduced with permission from [97]. © 2021 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science.

4.3. Multilayered Structure

Although the energy density of thin films is superior to that of bulk ceramics, the usability of thin films is limited for low-power applications because of their small volume. In this context, multilayered structures have received great attention because the technology behind them is well known and inexpensive. A multilayered ceramic consists of a number of thin ceramic layers with thicknesses on the micrometer scale and internal electrode layers stacked in parallel and connected through terminal electrodes. It features both high BDS (on the MV cm^{-1} level) and large volume; therefore, it is very promising for practical high-power energy storage applications.

Wang et al. [76] reported a large improvement in the energy storage performance of a multilayered ceramic composed of $0.75(\text{Bi}_{0.85}\text{Nd}_{0.15}\text{FeO}_3)-0.25\text{BaTiO}_3 + 0.1\text{wt.}\% \text{MnO}_2$ and Pt internal electrodes, compared with its bulk ceramic counterpart, as shown in Figure 13. With nine active layers having a total thickness of ~ 0.78 mm, they obtained a significant enhancement of the BDS to 540 kV cm^{-1} with $U_{\text{st}} \sim 8.75 \text{ J cm}^{-3}$, $U_{\text{rec}} \sim 6.74 \text{ J cm}^{-3}$, and $\eta \sim 77\%$. Yan et al. [99] reported similar energy storage properties in $(1-x)(0.67\text{BiFeO}_3-0.33\text{BaTiO}_3)-x\text{Na}_{0.73}\text{Bi}_{0.09}\text{NbO}_3$ multilayered ceramics with A-site cation vacancies. For an optimized content of $\text{Na}_{0.73}\text{Bi}_{0.09}\text{NbO}_3$, i.e., $x = 0.12$, the multilayer exhibited $U_{\text{rec}} = 5.57 \text{ J cm}^{-3}$ at $E = 410 \text{ kV cm}^{-1}$ with $\eta = 83.8\%$. A multilayer ceramic with 7- μm -thick $0.61\text{BiFeO}_3-0.33\text{Ba}_{0.8}\text{Sr}_{0.02}\text{TiO}_3-0.06\text{La}(\text{Mg}_{2/3}\text{Nb}_{1/3})\text{O}_3$ dielectric layers was reported to exhibit a much higher BDS, $> 740 \text{ kV cm}^{-1}$ [100]. This device featured a high U_{rec} of 10 J cm^{-3} with $\eta \sim 72\%$ at $E = 730 \text{ kV cm}^{-1}$. Wang et al. reported a large ΔP of $\sim 34 \mu\text{C cm}^{-2}$ and a high BDS of 700 kV cm^{-1} in a multilayered ceramic composed of 16- μm -thick electrically homogeneous $0.62\text{BiFeO}_3-0.3\text{BaTiO}_3-0.08\text{NdZr}_{1/2}\text{Zn}_{1/2}\text{O}_3$ ceramic layers with a core-shell microstructure [82]. With seven ceramic layers having an active electrode area of 33 mm^2 , U_{rec} as high as 10.5 J cm^{-3} with $\eta = 87\%$ was obtained. Lu et al. [91] obtained BDS $> 1 \text{ MV cm}^{-1}$ in a multilayered ceramic with 10 mol% $\text{Bi}(\text{Mg}_{2/3}\text{Nb}_{1/3})\text{O}_3$ and 3 mol% Nb_2O_5 -doped $0.6\text{BiFeO}_3-0.4\text{SrTiO}_3$ with a core-shell microstructure. The device, with 8- μm -

thick dielectric layers, exhibited $U_{\text{rec}} = 15.8 \text{ J cm}^{-3}$ under $E > 1 \text{ MV cm}^{-1}$ with $\eta = 75.2\%$. Wang et al. [101] reported a high BDS of 953 kV cm^{-1} in a multilayered ceramic with $8\text{-}\mu\text{m}$ -thick $0.57\text{BiFeO}_3\text{-}0.3\text{BaTiO}_3\text{-}0.13\text{Bi}(\text{Li}_{0.5}\text{Nb}_{0.5})\text{O}_3$ layers (Figure 14) having a core-shell structure and a 5-mm^2 active electrode area, which was greatly improved compared with that of the bulk ceramic counterpart (260 kV cm^{-1}). While the bulk ceramic featured a $U_{\text{rec}} \sim 3.64 \text{ J cm}^{-3}$ at $E \sim 260 \text{ kV cm}^{-1}$ with $\eta \sim 75\%$, the multilayered ceramic exhibited a $U_{\text{rec}} = 13.8 \text{ J cm}^{-3}$ with $\eta = 81\%$ because of the large enhancement of the BDS. The multilayered ceramic showed good temperature stability ($< 10\%$) and frequency independence ($< 5\%$) of U_{rec} from 0.01 to 1 Hz, as well as fatigue resistance ($< 5\%$) during 10^4 cycles of unipolar $P\text{-}E$ loop tests in the temperature range from RT to 100°C at $E = 400 \text{ kV cm}^{-1}$.

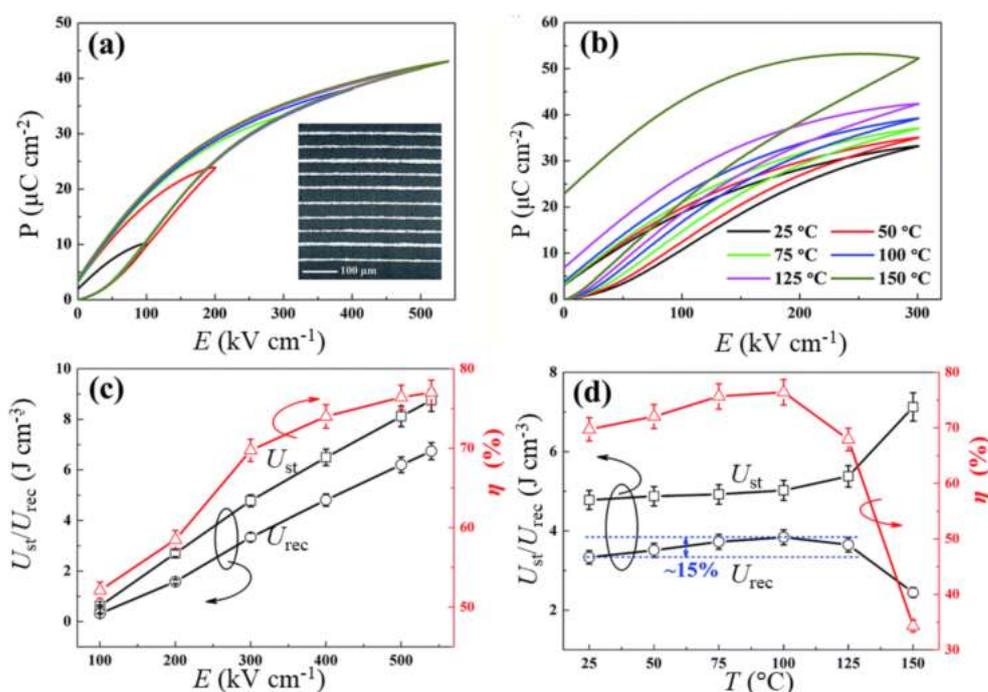


Figure 13. Energy storage performance of $0.75(\text{Bi}_{0.85}\text{Nd}_{0.15})\text{FeO}_3\text{-}0.25\text{BaTiO}_3$ multilayers. (a) $P\text{-}E$ loops at various electric fields at room temperature, (b) $P\text{-}E$ loops at various temperatures. U_{st} , U_{rec} , and η with (c) electric field and (d) temperature. An SEM image of the multilayers is shown in the inset of (a). Figures reproduced with permission from [76]. © 2021 The Royal Society of Chemistry.

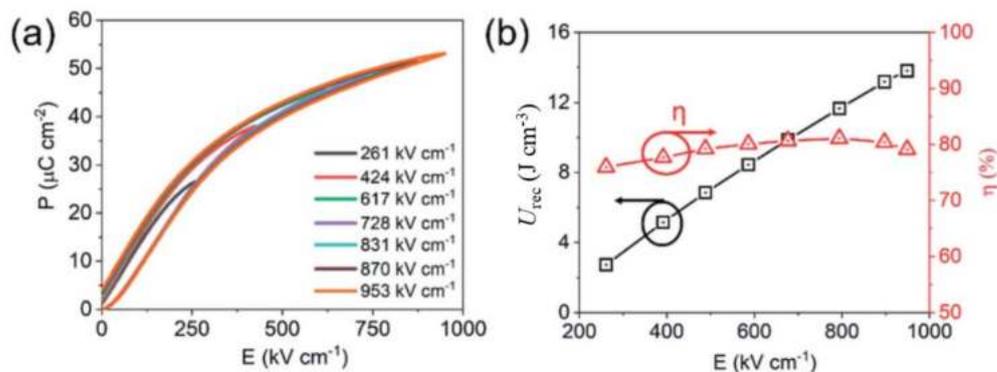


Figure 14. (a) Room temperature unipolar $P\text{-}E$ loops at various electric fields and (b) calculated energy storage properties of $0.57\text{BiFeO}_3\text{-}0.3\text{BaTiO}_3\text{-}0.13\text{Bi}(\text{Li}_{0.5}\text{Nb}_{0.5})\text{O}_3$ multilayers. Figures reused under Creative Commons Attribution 3.0 Unported Licence [101]. © 2021 The Royal Society of Chemistry.

5. Critical Issues and Strategy

5.1. Leakage Current Control

High discharge energy density and energy efficiency are the primary requirements of an EES system. However, most BiFeO₃-based RFEs suffer from a low efficiency (<85%) despite having ultra-high discharge energy densities. Leakage-related high conductivity in BiFeO₃-based RFEs produces apparent large values of P_r and wide hysteresis loops, which lead to a higher loss density. The conductivity usually increases at high temperatures, limiting their potential for high-temperature applications.

The high leakage current in BiFeO₃-based compounds is associated with the loss of Bi₂O₃ during its synthesis at elevated temperatures (950–1050 °C), which creates ionic vacancies and Fe³⁺/Fe²⁺ valence fluctuation [102–105]. Aliovalent doping in BiFeO₃-based compounds has been effective for reducing the leakage current density by several orders of magnitude [104,105]. However, these compounds are fired at high temperatures for synthesis in both bulk ceramics and multilayered structures, exposing them to Bi₂O₃ loss. Adopting a low-temperature sintering method is expected to reduce the Bi₂O₃ loss and the associated leakage current densities by a few more orders. The addition of appropriate glass additives and/or low melting point compounds is expected to significantly reduce the sintering temperature [106], thereby reducing the possibility of Bi₂O₃ volatilization. Low-temperature sintering is also beneficial for the enhancement of BDS, as discussed in Section 5.2.

5.2. Microstructure Engineering

In Figure 15, we plot U_{rec} as a function of BDS for BiFeO₃-based binary and ternary solid solutions fabricated in bulk ceramics, ceramic multilayers, and thin films. A high BDS usually provides a higher recoverable energy density. Therefore, enhancing the BDS is one of the most effective ways to increase the energy storage performance of RFEs. Microstructure engineering, such as the design of core-shell structures and domain engineering, has been found to be very effective for enhancing the BDS and realizing a dynamic relaxor ferroelectric phase. The BDS depends on the grain size ($BDS \propto 1/\sqrt{G}$ (G = average grain size)) and size distribution. Therefore, it is imperative to design a fine-grained microstructure with a uniform size distribution to obtain a high BDS. Another way to improve the BDS is to prepare a highly dense microstructure. Pores or cavities present in microstructures are usually filled with gaseous or liquid phases with lower permittivity than those of solid dielectrics. As a result, the voltage across the cavities or pores (V_c) is enhanced as per the following relation [107]:

$$V_c = \frac{V_{app}}{\left[1 + \frac{\epsilon_c}{\epsilon_r} \left(\frac{d}{t} - 1\right)\right]} \quad (10)$$

where V_{app} is the applied voltage, ϵ_c and ϵ_r are the permittivity of the cavity and dielectric, respectively, and t and d are the size of the cavity and the thickness of the dielectric, respectively. A small pore can create a large electric field across it and cause local breakdown and internal discharge even at a low external voltage. Therefore, a highly dense microstructure is essential. Because BiFeO₃-based materials are prone to the loss of Bi and Fe valence fluctuations during sintering at high temperatures, resulting in high electrical conductivity, sintering at low temperatures could be very beneficial. However, a detailed investigation of the microstructure control for the purpose of enhancing the energy storage performance employing the low-temperature sintering technique in BiFeO₃-based dielectrics is yet to be conducted. The two-step sintering (TSS) method modified by Chen and Wan [108] is one of the most cost-effective and simple methods to produce ultra-high-density materials and fine grains. In this technique, high-temperature heating is performed for a few minutes, and then the material is allowed to cool to the sintering temperature, where the sample is sintered for a prolonged time. However, the sintering temperature should be wisely chosen so that densification without further grain growth occurs.

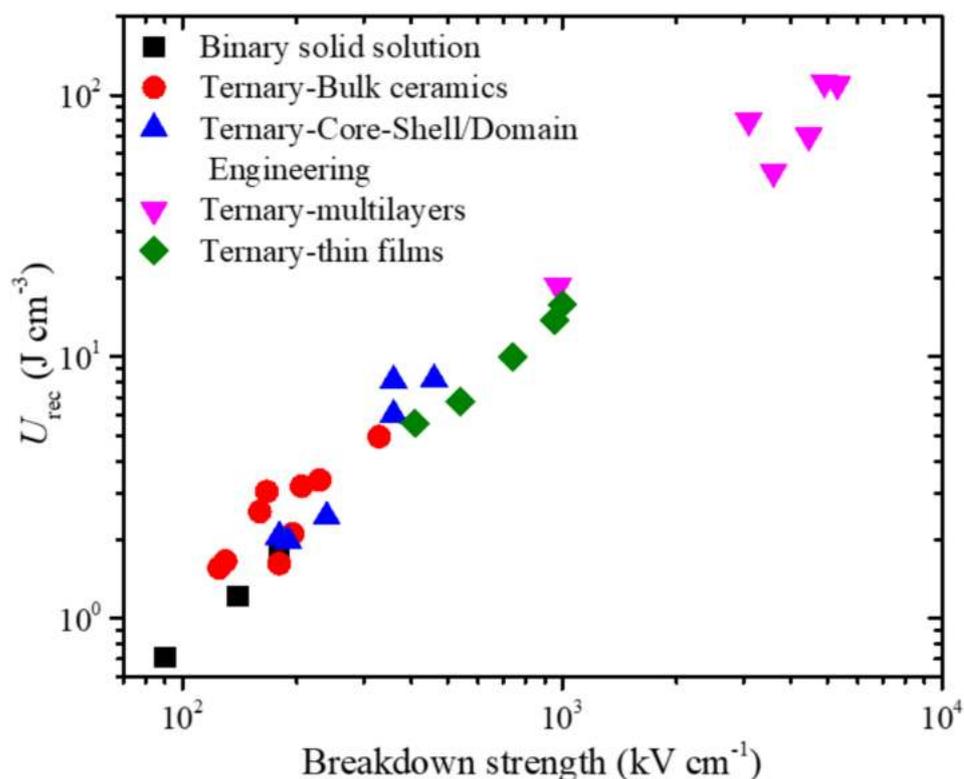


Figure 15. Recoverable energy density as a function of breakdown strength for BiFeO₃-based bulk ceramics of binary solid solutions and bulk ceramics, microstructure-designed bulk ceramics, and multilayers and thin films of ternary solid (TS) solutions.

5.3. Band Gap Engineering

Electronic breakdown is a crucial intrinsic mechanism for the breakdown of a dielectric in a large electric-field regime. Above a certain electric field, electrons in the valence band gain sufficient energy to jump to the conduction band. This results in an increase in the electron density in the conduction band and leads to a large current discharge. Therefore, an insulator exhibiting a wide forbidden energy gap can withstand a high electric field. The empirical relation between the BDS and energy band gap is given by the following relation [109]:

$$E_B = 24.442 \exp\left(0.315\sqrt{E_g\omega_{max}}\right) \quad (11)$$

where E_g is the energy bandgap, and ω_{max} is the maximum phonon frequency. Pure BiFeO₃ has a direct bandgap of 3 eV [110]. Only a few studies have attempted to enhance the BDS of BiFeO₃-based RFEs via modulation of the energy bandgap. Qi et al. [92] reported the enhancement of BDS by doping of high-band-gap materials such as NaNbO₃ ($E_g \sim 3.28$ eV) in 0.67BiFeO₃-0.33BaTiO₃ solid solutions. They demonstrated that the bandgap of the solid solutions (0.67-x)BiFeO₃-0.33BaTiO₃-xNaNbO₃ ($0 \leq x \leq 0.15$) increases monotonically with increases in x from ~ 2.6 eV for $x = 0$ to ~ 2.95 eV for $x = 0.15$. The enhancement of BDS followed a similar trend with an increase in NaNbO₃ content, where the average BDS increased from 230 kV cm⁻¹ for $x = 0$ to 420 kV cm⁻¹ for $x = 0.15$. Further studies on bandgap engineering can be explored to enhance the BDS and energy storage performance of BiFeO₃-based relaxor ferroelectrics.

5.4. Electromechanical Breakdown

Another issue that has not gained much attention but is very critical in BiFeO₃-based relaxor ferroelectrics is the electromechanical breakdown. Because a high electric field is required to obtain a large recoverable energy density, the dielectrics are under extreme electrostrictive strain, increasing the mechanical breakdown. This issue should be taken very seriously from the device viewpoint, as the devices undergo a large number of charge-discharge cycles. Although high recoverable energy density with high efficiency is obtained at high electric fields under laboratory conditions, the same samples might not be suitable for application purposes where they totally collapse because of mechanical failure under a large number of charge-discharge cycles. However, systematic studies on the issues of electromechanical breakdown in BiFeO₃-based dielectrics are lacking. Rare-earth-ion doped BiFeO₃ compounds with their composition lying across the morphotropic phase boundary could be interesting in this regard as these compounds feature high electromechanical strain. For example, Walker et al. [111] reported cycle-dependent large electromechanical strain in Sm-doped BiFeO₃ polycrystalline samples, associated with the electric field-induced phase transition and ferroelectric/ferroelastic domain switching.

6. Summary

BiFeO₃-based relaxor ferroelectrics are projected to be potential Pb-free candidates for application in the field of high-energy-density storage and high-power-delivery systems. They are mostly fabricated in the form of ceramics, multilayers, and thin films from binary or ternary solid solutions with other perovskite oxides. BiFeO₃-BaTiO₃ and BiFeO₃-SrTiO₃, with their compositional ratios lying in the morphotropic phase boundary, are the two most widely studied BiFeO₃-based binary solid solutions for high-energy-density storage. However, the typical value of recovering energy density of bulk ceramics of BiFeO₃-based binary solid solutions is well below 3 J cm⁻³, with low efficiency (typically below 50%). Ternary solid solutions exhibiting specific microstructures, such as core-shell structures and stripe-like nanodomains, have shown significant enhancement of the energy density properties. For example, 0.5BiFeO₃-0.4SrTiO₃-0.03Nb₂O₅-0.1BiMg_{2/3}Nb_{1/3}O₃ bulk ceramic with a core-shell microstructure exhibited excellent energy storage properties, with $U_{\text{rec}} \sim 8.2 \text{ J cm}^{-3}$ and $\eta \sim 74\%$. The nanodomain-engineered bulk ceramic 0.57BiFeO₃-0.33BaTiO₃-0.1NaNbO₃ with the addition of 0.1 wt% MnO₂ and 2 wt% BaCu(B₂O₅) also featured a similar value of U_{rec} ($\sim 8.12 \text{ J cm}^{-3}$); however, it had a higher value of $\eta \sim 90\%$. The microstructure design approach has been found to be attractive for enhancing the energy storage properties of thin films and multilayers. The BDS values of thin films and multilayers can be as high as MV cm⁻¹, which is very helpful for further increasing the recoverable energy density. Thin films of a (0.55-x)BiFeO₃-xBaTiO₃-0.45SrTiO₃ solid solution ($x = 0-0.4$) containing polymorphic nanodomains showed a recoverable energy density of $\sim 110 \text{ J cm}^{-3}$ at a BDS $\sim 5 \text{ MV/cm}$ with an efficiency of $\sim 80\%$, which is the highest among BiFeO₃-based systems. The achievement of such excellent energy storage properties is very encouraging for applications in low-power, small-size devices. However, for large-scale applications, it is necessary to focus on the fabrication of multilayers, as they deliver high power and are easy to fabricate. Although relatively few studies have been conducted on BiFeO₃-based multilayers, their energy storage performance is very encouraging ($U_{\text{rec}} \sim 15 \text{ J cm}^{-3}$), with a high BDS of $\sim 1 \text{ MV/cm}$. More studies should be conducted in the field of BiFeO₃-based multilayers to optimize structural parameters such as the thickness of dielectric layers and number of layers so that a better energy storage device that can deliver high output power can be fabricated at a low cost.

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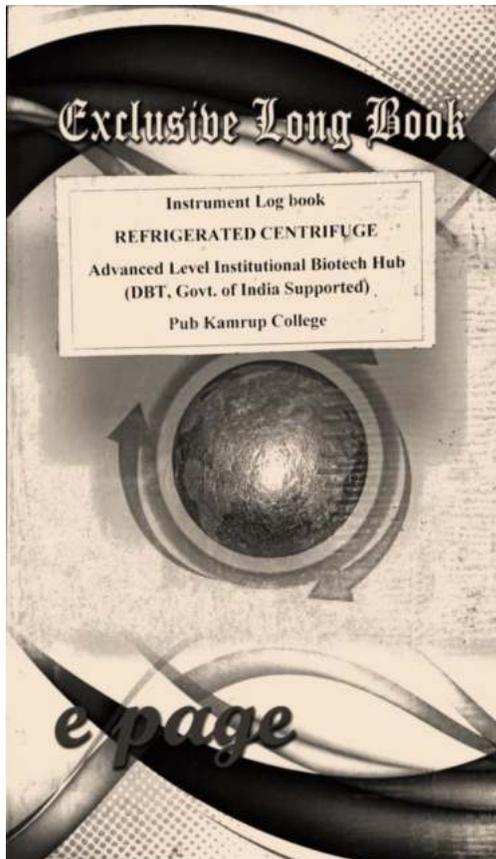
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Name	Department	Co. No.	Type of Sample	In time	Out time	Signature
20) Rita Mishra	Zoo Dept. GU	910642005	Std. for Mitochondrial Isolation	2:30pm	5:30pm	20/10/18
21) Rita Mishra	Zoo Dept. GU	910642005	Animal Tissue	2:15pm	3:00pm	20/10/18
24) Rita Mishra	Zoo Dept. GU	910642005	Animal Tissue	1:00pm	3:00pm	20/10/18
25) Rita Mishra	Zoo Dept. GU	910642005	Animal Tissue	10:am	1:pm	20/10/18
25) Rita Mishra	Zoo Dept. GU	910642005	"	11:40am	11:45am	20/10/18
27) Rita Mishra	"	"	"	2:00pm	4:00pm	20/10/18
28) Namisha Goh	Zoology Dept	910642005	"	2:00pm	2:00pm	20/10/18
29) Bilqis Bano	Biophysics Dept	910642005	DNA Extraction	3pm	5pm	20/10/18
30) Upasana	Biophysics 3 rd Sem	"	ANMP Blood	5:00pm	6:45pm	20/10/18
31) Upasana	"	"	"	7:00pm	7:30pm	20/10/18
32) Upasana	Biophysics 3 rd Sem	"	ANMP	5:00pm	5:45pm	20/10/18
33) Upasana	"	"	"	5:00pm	5:55pm	20/10/18
34) Upasana	"	"	"	8:30am	10:30am	20/10/18
35) Upasana	"	"	"	9:00pm	6:00pm	20/10/18
36) Shampa Bhattacharya	R.S.	911120185	Blood	2:12pm	2:30pm	20/10/18
37) Shampa Bhattacharya	R.S.	"	"	11:00AM	1:30 PM	20/10/18
38) Bilqis Bano	Department of Biophysics	910642005	ANMP	2:45 pm	4:30 pm	20/10/18
39) Shampa	Biophysics	911120185	DNA	10:44AM	12:55 PM	20/10/18
31) Upasana	"	"	ANMP	12:45	6:11PM	20/10/18
32) Upasana	"	"	"	11:30pm	2:00pm	20/10/18
33) Upasana	"	"	"	4:45 pm	5:15pm	20/10/18
34) Upasana	"	"	"	5:45 pm	5:30pm	20/10/18
35) Upasana	"	"	"	10:00 pm	5:00pm	20/10/18
36) Bilqis Bano	Biophysics (3 rd Sem)	910642005	DNA Extraction	12:35 pm	1:00pm	20/10/18
37) Upasana	" (3 rd Sem)	"	ANMP	9:00pm	6:00pm	20/10/18
38) Upasana	"	"	"	7:00am	9:00am	20/10/18
39) Bilqis Bano	Biophysics (3 rd Sem)	910642005	DNA Extraction	11:40 am	11:30 am	20/10/18
40) Kavishma Jyoti	Biophysics (3 rd Sem)	"	DNA Extraction	2:30 pm	4:30 pm	20/10/18

Sl. No.	Name	Department	Co. No. & Number	Type of Sample (Name)	In. Time	Out Time	Signature & Date
1.	Msc 2nd Sem (16)	Biophysics	91257962	Blood	12:15	2:15	20/10/18
2.	Chayanika	R.S.	"	Enzyme	2:30	3:00	20/10/18
3.	Chayanika	R.S.	"	Enzyme	2:15	2:30	20/10/18
4.	Chayanika	R.S.	"	Enzyme	3:45	4:10	20/10/18
5.	Kavishma Jyoti	Restriction digestion	"	Restriction digestion	2:10 pm	2:30 pm	20/10/18
6.	Hrushika	Biophysics	"	Enzyme	3:00 pm	3:30 pm	20/10/18
7.	Hrushika	Biophysics	"	Blood	2:30 pm	2:50 pm	20/10/18
8.	Anindita	Biophysics	"	Blood	4:10 pm	4:30 pm	20/10/18
9.	Chayanika	Biophysics	"	Tissue Protein	3:30	6:00	20/10/18
10.	Upasana	"	"	LB agar bacteria	1:00pm	3:50pm	20/10/18
11.	Kavishma Jyoti	Biophysics	"	RBC - Lipid	2:15	2:30	20/10/18

Fw: Reg-Fold Scope JRF Recruitment

3 messages

J saikia <jsaikia2000@yahoo.co.in>
To: "bipul.ph@gmail.com" <bipul.ph@gmail.com>

Tue, Jul 5, 2022 at 3:05 PM

----- Forwarded message -----

From: kamal sarma <kml.sarma9@gmail.com>
To: jsaikia2000 <jsaikia2000@yahoo.co.in>
Sent: Tuesday, 5 July, 2022 at 12:43:00 pm IST
Subject: Fwd: Reg-Fold Scope JRF Recruitment

----- Forwarded message -----

From: kamal sarma <kml.sarma9@gmail.com>
Date: Sun, 3 Apr 2022, 9:53 pm
Subject: Fwd: Reg-Fold Scope JRF Recruitment
To: kamal sarma <kml.sarma9@gmail.com>

----- Forwarded message -----

From: vijay basker <vbreddyasuh@yahoo.com>
Date: Thu, 14 Jun 2018, 11:05 pm
Subject: Re: Reg-Fold Scope JRF Recruitment
To: kamal sarma <kml.sarma9@gmail.com>

Sir,
Thank you. I shall initiate the procedure for purchase of consumables in July once I am back from vacation. Meanwhile I have asked Pankaj to prepare the list of requirements.

Thank you.

Dr. P. Vijaya Bhaskar Reddy,
Assistant professor,
Dept. of Life Science & Bio-Informatics,
Assam University (A central University),
Diphu Campus, Diphu-782462, Assam.
Ph: +91-9577578788; +91-8179996671

On Thu, 6/14/18, kamal sarma <kml.sarma9@gmail.com> wrote:

Subject: Re: Reg-Fold Scope JRF Recruitment
To: "vijay basker" <vbreddyasuh@yahoo.com>
Date: Thursday, June 14, 2018, 9:50 AM

Dear Dr Reddy,

Thank you for your mail. Sorry for the late reply of your mail. I was busy with the Practical examinations and admission process. We have discussed all the aspects relating to the project. No such official formalities are required for the time being. We have arranged the official accommodation of the research.

<https://mail.google.com/mail/u/0/?ui=bc3d0eb35&view=pt&search=wl&permthid=thread-F63A1737504869241670027&siml=msg-F63A1737504869...> 1/3

Dear Dr. Kamal
Sarma,
(Co-PI),

With due respect I bring to your notice that Ms. Chayanika Devi, has been appointed as JRF in the DBT funded project titled "To investigate the interaction between microbes and microbial product and mosquito larvae for controlling larval population in vivo" under the DBT's Programme. Please find the appointment letter here with attached for your information.

In addition, I request you to kindly allow Mr. Hiral Jyothi Kakati, who will be working as a research trainee under the appointed JRF, Ms. Chayanika Devi. However both these scholars will be able to use the consumables only from this above mentioned project and not from either your institute or Biotech Hub, PKC.

Hence, I sincerely request you to accommodate these scholars to work in your laboratory till the completion of my lab establishment in my university campus which is under progress. This would enable us to help and train budding scholars to be scientifically equipped and motivate them into the field of research.

Kindly let me know if any formalities are to be followed in this regard.

Thanking you in anticipation

PVB
Reddy

Dr. P. Vijaya Bhaskar Reddy, Assistant professor, Dept. of Life Science & Bio-Informatics, Assam University (A central University), Diphu

<https://mail.google.com/mail/u/0/?ui=bc3d0eb35&view=pt&search=wl&permthid=thread-F63A1737504869241670027&siml=msg-F63A1737504869...> 2/3



From: vijay basker <vbreddyasuh@yahoo.com>
Date: Thu, 2 Aug 2018, 8:34 am
Subject: Fw: Request for temporary lab space to set up my project equipment
To: Kamal Sarma <kml.sarma9@gmail.com>

Dr. P. Vijaya Bhaskar Reddy,
Assistant professor,
Dept. of Life Science & Bio-Informatics,
Assam University (A central University),
Diphu Campus, Diphu-782462, Assam.
Ph: +91-9577578788;+91-8179996671

----- Forwarded Message -----

From: vijay basker <vbreddyasuh@yahoo.com>
To: bdevchoudhury@yahoo.com <bdevchoudhury@yahoo.com>
Sent: Thursday, August 2, 2018, 8:16:55 AM GMT+5:30
Subject: Request for temporary lab space to set up my project equipment

Respected Sir,

With due regards, I would like to inform you that I have been awarded a research project from DST SERB. My project requires continuous/uninterrupted power supply for the maintenance of my cell cultures and to perform my experiments. Due to the limitations in the proper and uninterrupted supply of power in my institute namely, Assam University Diphu Campus (AUDC), I am looking for alternatives for setting my laboratory with the permission of the competent authority of my university for the purpose of smooth running of my project. In this regard, since your institute is equipped with solar power, I am approaching you with a request to give me a laboratory space temporarily for a brief period for running my project smoothly. For running my project all the

[ps://mail.google.com/mail/u/0/?ik=b4c340e835&view=pt&search=all&permthid=thread-f%3A1737504851825598872&simpl=msg-f%3A1737504851...](https://mail.google.com/mail/u/0/?ik=b4c340e835&view=pt&search=all&permthid=thread-f%3A1737504851825598872&simpl=msg-f%3A1737504851...)

7/12/22, 9:53 AM

Gmail - Fw: Request for temporary lab space to set up my project equipment

consumables will be purchased and used from my project fund and no chemicals from your end will be used. Therefore I kindly request you to allow me to set my instruments in your college until the end of the project period or until a continuous/improved power supply is provided at AUDC, whichever is earlier. All the equipment will be brought back to AUDC as soon as the project terminates. This will greatly help me to run the project in a better way.

Thanking you in anticipation

Yours Sincerely

Dr. PVB Reddy

Dr. P. Vijaya Bhaskar Reddy,
Assistant professor,
Dept. of Life Science & Bio-Informatics,
Assam University (A central University),
Diphu Campus, Diphu-782462, Assam.
Ph:+91-8179996671; 7780406712



Focused Intensive Physics Camp for BSc Students



Center for Excellence in Science and Mathematics Education
Pt. MADAN MOHAN MALAVIYA NATIONAL MISSION ON TEACHERS AND TEACHING

11 - 22 June, 2018

Certificate of Participation

This is to certify that

Mr./Miss..... **Bhargav Nath** from..... **Pub Kamrup College, Kamrup**
has participated in the "Focused Intensive Physics Camp for BSc Students" organised by Department of
Physics & Centre for Educational Technology, Indian Institute of Technology Guwahati, in association with
"Indian Association of Physics Teachers"(IAPT). He/She was actively involved in all the activities of this
Physics Camp.

Prof. Sunil Khijwania
Principal Coordinator, CESME, PMMMNMTT
Head, CET
IIT Guwahati



Certificate

This is to certify that
Mr. Nipan Deka (Voter card -XXXXXXX1228)
Has successfully cleared the assessment for the Job role of
Field Technician - Computing and Peripherals (QP No: ELE/Q4601)
conforming to National Skills Qualification Framework Level - 4
with Grade B

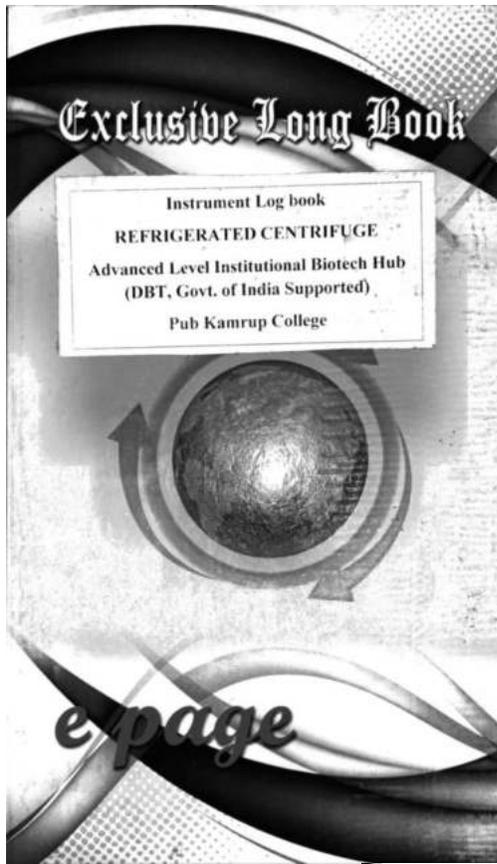
January 10, 2019
System Identification Number S-AS0354E-00000E2
Training Facilitated by TOOL ROOM & TRAINING CENTRE
Assessed by C&K Management Limited



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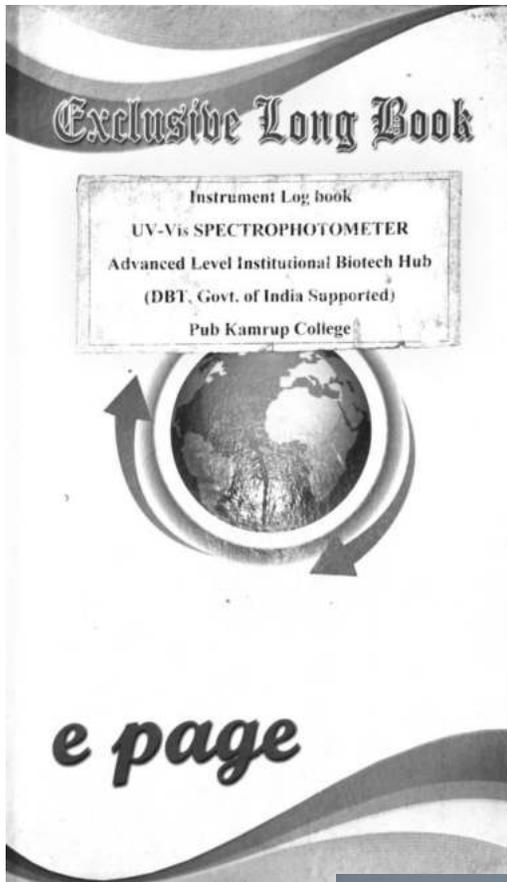


Ajai Chowdhry
Chairman
Electronic Sector Skill Council of India



Name	Department	Co. No.	Type of Sample	Income	Outtime	Signature
20. Rita Mishra	Xos Deptt. GU	9106434023	Sol for Micrograph	2:30pm	5:30pm	[Signature]
23. Rita Mishra	Xos Deptt. GU	9106434023	Animal Tissue	2:15pm	3:00pm	[Signature]
24. Rita Mishra	Xos Deptt. GU	9106434023	Animal Tissue	1:00pm	2:00pm	[Signature]
25. Rita Mishra	Xos Deptt. GU	9106434023	Animal Tissue	10:00am	1:00pm	[Signature]
25. Rita Mishra	Xos Deptt. GU	9106434023	"	11:40am	11:45am	[Signature]
41. Rita Mishra	"	"	"	2:00pm	4:00pm	[Signature]
88. Manisha Deka	Zoology Dept	9106434023	"	2:00pm	2:00pm	[Signature]
29. Bitapan Baro	Biophysics Dept	9106434023	DNA Extraction	3pm	5pm	[Signature]
30. Upasana	Biophysics	"	Blood	5:00pm	6:45pm	[Signature]
31. AnuK + 2	"	"	"	4:00pm	4:30pm	[Signature]
32. Upasana	Biophysics	"	ANMP	5:00pm	5:45pm	[Signature]
33. Upasana	"	"	"	4:00pm	5:55pm	[Signature]
34. Upasana	"	"	"	8:30am	12:30pm	[Signature]
35. Upasana	"	"	"	9:00pm	6:00pm	[Signature]
26. Shampa Bhalla	R.S	9106434023	Blood	2:55pm		[Signature]
27. Shampa Bhalla	"	"	"	11:00am	1:30pm	[Signature]
37. Bitapan Baro	Department of Biophysics	9106434023	ANMP	3:45pm	6:30pm	[Signature]
38. Shampa	Biophysics	9106434023	B. DNA	10:40am	12:55pm	[Signature]
39. Upasana	"	"	ANMP	12:45pm	6:10pm	[Signature]
32. Upasana	"	"	"	11:30am	2:00pm	[Signature]
33. Upasana	"	"	"	4:45pm	5:15pm	[Signature]
34. Upasana	"	"	"	5:45pm	5:30pm	[Signature]
35. Upasana	"	"	"	10:00pm	5:00pm	[Signature]
36. Bitapan Baro	Biophysics (at Gu)	9106434023	DNA Extraction	12:35pm	1:00pm	[Signature]
39. Upasana	" (30am)	"	ANMP	9:00pm	6:00pm	[Signature]
38. Upasana	"	"	"	7:00am	9:00am	[Signature]
39. Bitapan Baro	Biophysics (at Gu)	9106434023	DNA Extraction	11:00am	11:30am	[Signature]
39. Bishamajyoti Baro	Biophysics (at Gu)	9106434023	DNA Extraction	2:30pm	4:30pm	[Signature]

Sl. No.	Name	Department	Co. No.	Type of Sample	Income	Outtime	Signature
62.	Jyotishmita Kumar	Dept of Zoology	9106434023	Sol for Micrograph	11:30-11:45		[Signature]
	Sulana Hajes min	"	"	"	"	"	[Signature]
	Angita Devi	"	"	"	"	"	[Signature]
	Pabitra Baro	"	"	"	"	"	[Signature]
63.	Chayanika Nath	Dept of Zoology	9106434023	"	11:30-11:45		[Signature]
	Bituparna Baruah	"	"	"	"	"	[Signature]
	Deepina Devi	"	"	"	"	"	[Signature]
	Nibedita Deka	"	"	"	"	"	[Signature]
	Kakali Choudhary	"	"	"	"	"	[Signature]
64.	AnuK + 6	Biophysics	9106434023	"	4:00PM	5PM	[Signature]
65.	Mridul Das	Dept of Zoology	9106434023	"	12:10		[Signature]
	Nibedita Deka	"	"	"	12:30		[Signature]
	Deepina Devi	"	"	"	"	"	[Signature]
	Trishna Kakali	"	"	"	"	"	[Signature]
66.	Manisha Meeki	Dept of Bio	9106434023	"	11:00am		[Signature]
	Trishna Kakali	Dept of Zoology	9106434023	"	12:00		[Signature]
	Trishna Kakali	"	"	"	"	"	[Signature]
	Nibedita Deka	"	"	"	"	"	[Signature]
	Karabi Krishna Kalita	"	"	"	"	"	[Signature]
	Shabnam Akhanda	"	6000012696	"	"	"	[Signature]
	Sibani Deka	"	"	"	"	"	[Signature]
68.	Bitapan Baro + 6	Biophysics	9106434023	"	9:30-10:00am	11:00am	[Signature]
69.	AnuK + 2	Biophysics	9106434023	"	2:00pm	4:00pm	[Signature]
70.	Bishamajyoti Baro	Biophysics	9106434023	"	11:00-11:05		[Signature]
71.	Chayanika Nath	Biophysics	9106434023	"	2:50	3:20	[Signature]
72.	Upasana	"	"	"	7:00	6:45pm	[Signature]
73.	Upasana	"	"	"	7:00	6:45pm	[Signature]



113	Himani Chakrabarti	B.Sc 4th Sem	Project	8638273930	4.00	5.30	15
114	Himani Chakrabarti	B.Sc 4th Sem	"	242672167	"	"	15
115	Jiya Bhaskaraj	M.Sc Bioprocess Technology	"	"	12.00pm	2.00pm	15
116	Siddhanti Sanna	B.Sc (Hons)	"	"	1.00-2.00	"	15
117	Pinku Nath	B.Sc (Hons)	"	700239090	1.00; 3.00	"	15
118	Ritu Mishra	Zoo 6th	"	940643489	3.30	4.30	15
119	Biswajit Das	B.Sc (Hons) (Biochem)	Project	"	4.00 pm	5.00	15
120	Ritu Mishra	Zoo 6th	R/S	940643489	1.00 pm	1.15 pm	15
121	Ritu Mishra	"	"	"	11.00am	12.00pm	15
122	Ritu Mishra	"	"	"	12.00pm	12.45pm	15
123	Ujjwal H	Biology (3rd)	Project	"	12.30pm	2.00pm	15
124	Ritu Mishra	"	"	"	4.00pm	4.30pm	15
125	Ritu Mishra	"	"	"	11.00am	12.00pm	15
126	Ritu Mishra	"	"	"	2.30pm	"	15
127	Ritu Mishra	"	"	"	1.30-2pm	"	15
128	Pranami Liza	Biochem + Gen	Project	"	7.15.30pm	"	15
129	Bhargyathi Das + 16	JV Sem	NO3 Solution	"	4.00 PM	5.45	15
130	Ritu Mishra	R/S (2nd)	Engg. mech	"	1-2pm	"	15
131	vagpradha + C	4th Sem	NO3	"	9.45-3pm	3pm	15
132	Ritu Mishra	R/S (2nd)	"	"	9-3pm	"	15
133	Biswajit Das + 5	2nd Sem (Biochem)	Nucleic Acid	940145512	1-1.30pm	1.15pm	15
134	Ritu Mishra	"	"	"	1-2pm	"	15
135	Biswajit Das + 2	2nd Sem (Biochem)	DNA	940145512	3.30pm-4.00pm	"	15
136	Biswajit Das + 2	2nd Sem (Biochem)	DNA	940145512	10.30am-11.00am	"	15
137	Himanshu Das	Zoo (6th)	Project (2nd)	936570350	1.00-2.30pm	"	15
138	Ritu Mishra	"	"	"	3.00-4.15pm	"	15
139	Ritu Mishra	"	"	"	9-4.00pm	"	15
140	Himanshu	(Zoo 6th)	Project	946570250	2-3.15	"	15
141	Himanshu	"	"	"	2: 3:30	"	15
142	Shank + 5	2nd Sem	Protein	813589018	5.30-6.15	"	15
143	Shank + 2	2nd Sem	Protein	813589018	2.00-4.00	"	15
144	Ujjwal H	4th Sem	Project	"	"	"	15


विज्ञान एवं प्रौद्योगिकी उच्च अध्ययन संस्थान
 (आर्य समाज के विज्ञान एवं प्रौद्योगिकी विभाग के अंतर्गत एक स्वायत्त संस्थान)
 विज्ञान एवं प्रौद्योगिकी, गुवाहाटी, गुवाहाटी-781035, असम ; भारत
INSTITUTE OF ADVANCED STUDY IN SCIENCE AND TECHNOLOGY
 AN AUTONOMOUS R & D INSTITUTE OF DEPARTMENT OF SCIENCE & TECHNOLOGY, GOVT. OF ASSAM
 WEYAN PATH, PASCHIM SOARGAON, GUWAHATI, GUWAHATI-781035, ASSAM, INDIA

No. IASST/Acad/2018-19/C.T.G/1 Date: 31 July, 2018

Certificate

This is to certify that Mrinal Das from Pub Kamrup College has completed Summer Training (SSP-2018) at IASST, Guwahati on the topic **DNA: The thread of life** under the guidance of **Dr. Rosy Mondal, INSPIRE Faculty** during 13th June-31st July, 2018.

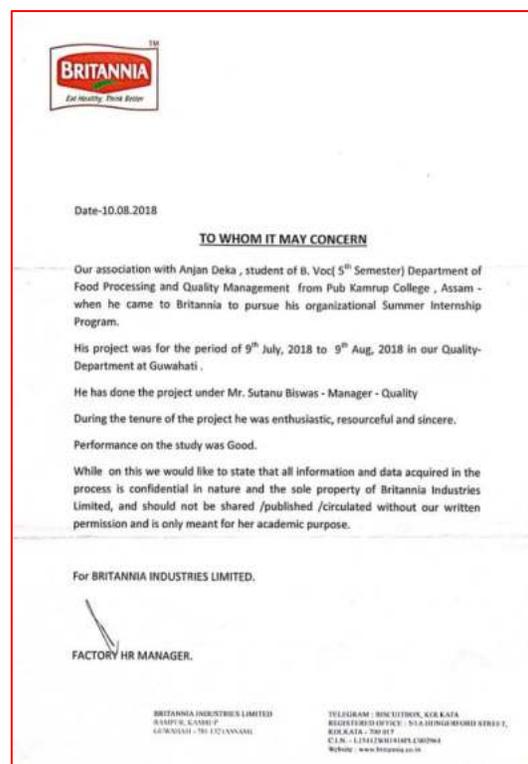
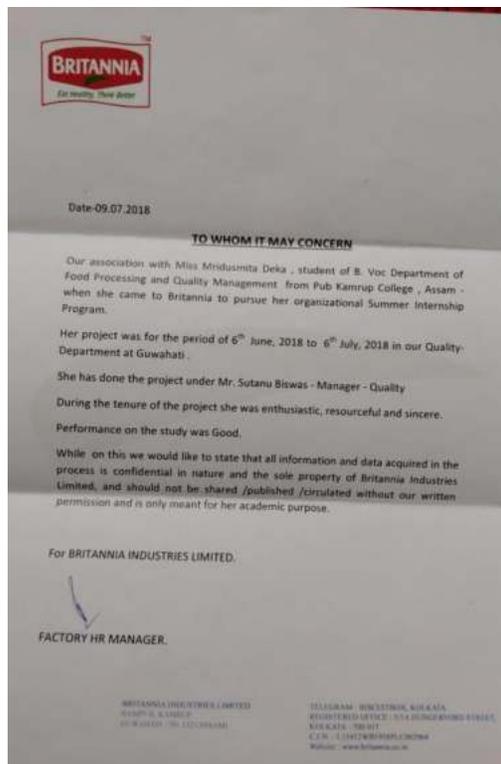
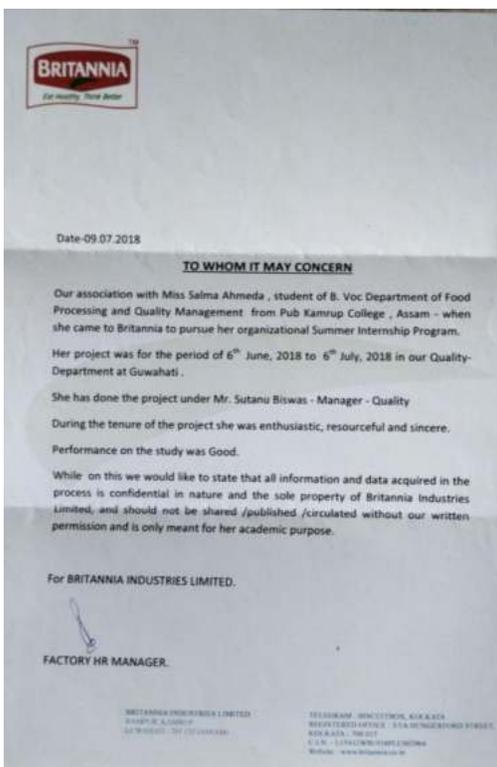
He/She is sincere and hardworking and we wish him/her success in life.


 (H. Bailung)
 Chairman
 Academic Committee, IASST


 (N.C. Talukdar)
 Director
 IASST



Phone : +91-361-2273008, Fax : +91-361-2273002
 Web Site : www.iasst.gov.in, E-mail : dr.iasst@nic.in
 5317 / 2017-18





Date-10.08.2018

TO WHOM IT MAY CONCERN

Our association with Pawan Kumar , student of B. Voc(5th Semester) Department of Food Processing and Quality Management from Pub Kamrup College , Assam - when he came to Britannia to pursue his organizational Summer Internship Program.

His project was for the period of 9th July, 2018 to 9th Aug, 2018 in our Quality-Department at Guwahati.

He has done the project under Mr. Sutanu Biswas - Manager - Quality

During the tenure of the project he was enthusiastic, resourceful and sincere.

Performance on the study was Good.

While on this we would like to state that all information and data acquired in the process is confidential in nature and the sole property of Britannia Industries Limited, and should not be shared /published /circulated without our written permission and is only meant for her academic purpose.

For BRITANNIA INDUSTRIES LIMITED.

FACTORY HR MANAGER.

BRITANNIA INDUSTRIES LIMITED
FACILITY MANAGER
GUWAHATI

TELEGRAM: @BRITANNIA_S&A_01
BAGHATI BOLDIPUR, 17/A HEMBAROY STREET,
KOLKATA - 700 017
CIN: 1210001899/INDIA
Website: www.britannia.co.in



Date-30.08.2018

TO WHOM IT MAY CONCERN

Our association with Prabal Sarma , student of B. Voc(5th Semester) Department of Food Processing and Quality Management from Pub Kamrup College , Assam - when he came to Britannia to pursue his organizational Summer Internship Program.

His project was for the period of 8th Aug, 2018 to 29th Aug, 2018 in our Quality-Department at Guwahati .

He has done the project under Mr. Sutanu Biswas - Manager - Quality

During the tenure of the project he was enthusiastic, resourceful and sincere.

Performance on the study was Good.

While on this we would like to state that all information and data acquired in the process is confidential in nature and the sole property of Britannia Industries Limited, and should not be shared /published /circulated without our written permission and is only meant for her academic purpose.

For BRITANNIA INDUSTRIES LIMITED.

FACTORY HR MANAGER.

BRITANNIA INDUSTRIES LIMITED
FACILITY MANAGER
GUWAHATI

TELEGRAM: @BRITANNIA_S&A_01
BAGHATI BOLDIPUR, 17/A HEMBAROY STREET,
KOLKATA - 700 017
CIN: 1210001899/INDIA
Website: www.britannia.co.in



Date-30.08.2018

TO WHOM IT MAY CONCERN

Our association with Musahidur Rahman , student of B. Voc(5th Semester) Department of Food Processing and Quality Management from Pub Kamrup College , Assam - when he came to Britannia to pursue his organizational Summer Internship Program.

His project was for the period of 8th Aug, 2018 to 29th Aug, 2018 in our Quality-Department at Guwahati .

He has done the project under Mr. Sutanu Biswas - Manager - Quality

During the tenure of the project he was enthusiastic, resourceful and sincere.

Performance on the study was Good.

While on this we would like to state that all information and data acquired in the process is confidential in nature and the sole property of Britannia Industries Limited, and should not be shared /published /circulated without our written permission and is only meant for her academic purpose.

For BRITANNIA INDUSTRIES LIMITED.

FACTORY HR MANAGER.

BRITANNIA INDUSTRIES LIMITED
FACILITY MANAGER
GUWAHATI

TELEGRAM: @BRITANNIA_S&A_01
BAGHATI BOLDIPUR, 17/A HEMBAROY STREET,
KOLKATA - 700 017
CIN: 1210001899/INDIA
Website: www.britannia.co.in

SHOT ON: iNOTE 5

Admin Order

Sanction of the President is hereby accorded, under Rule 18 of the Delegation of Financial Powers Rules, 1978, for the payment of Rs.3120.00 Lakhs (Rupees Thirty One Crore Twenty Lakhs Only) to Biotech Consortium India Limited (BCIL), 3rd Floor, Anant Bhawan, 210, Dron Doyal Upadhyay Marg, New Delhi - 110002 towards the "Towards disbursement of Micro grant for implementation of projects under the Foldscope scheme" as per break-up given below:

Sr. No.	Item	Number of Schools/Colleges/Institute/University	Total budget per School/Colleges/Institute/University	Total Budget	(Rs. in Lakhs)	
					1 st Installment (75% of total budget)	2 nd Installment (25% of total budget)
I	NER Schools (Category-A)	33	4.00	132.00	98.00	34.00
II	Other Regions of India Schools (Category-A)	84	4.00	336.00	252.00	84.00
III	NER Colleges/Institute / Universities (Category-B)	81	8.00	648.00	486.00	162.00
IV	Other Regions of India Colleges/Institute / Universities (Category-B)	247	8.00	1976.00	1483.00	493.00
Total (A)				3092.00	2319.00	773.00
Budget for the Project Secretariat to BCIL, (B)				28.00	28.00	0.00
Grand Total (A+B)				3120.00	2347.00	773.00*

*The second installment will be released after the review of technical & scientific progress report and submission of UCSE after 6 months.

2. The list of approved School/Colleges/Institute/ Universities of category A & B may be seen at Annexure-I to IV.

✓

Annexure-III

The following Universities/ Colleges/ Institutes have been shortlisted for funding under Category 'B':

Area: Biodiversity and conservation

Sr. No.	PI Name	Institute Name	City/State
1.	Dr. Prasanta Nanda	Devi Narayn Government College	Bongaigaon, Arunachal Pradesh
2.	Mr. Shantanu Rahman	Carson College State University	Guraibhat, Assam
3.	Dr. Prasenjit Puri Prasad	Nagaland University	Litimom, Nagaland
4.	Dr. Jatin Saravali	Bokhland University	Kohbarah, Assam
5.	Mr. Pankaj Jyoti Hazarika	Sibsagar Commerce College	Sivasagar, Assam
6.	Dr. Bhuloli Khaitor	Gauhati University	Gowahati, Assam
7.	Dr. Saikat Jyoti Mahanta	Sibsagar Commerce College	Assam
8.	Dr. R.K. Rajeshwari Devi	Orissa College	Imphal, Manipur
9.	Dr. Anjana Singh Narayan	Cotton College State University	Gowahati, Assam
10.	Dr. Tushar Kumar Bhawanick	National Institute of Technology	Agartala, Tripura
11.	Dr. Sh. Victoria Devi	Regional Institute of Pharmaceutical and Nursing Sciences	Aizawl, Mizoram
12.	Dr. Measom Sanku	Anandam Dental Phosook College (A.D.P. College)	Nagaw, Assam
13.	N. Sanku Devi	Kohima Khanna College	Khanna, Manipur
14.	Dr. O. Lakshmi Singh	Namdeb L. Sanku College	Namdeb, Manipur
15.	Dhanubha Lyngdoh	Saint Anthony's College	Shillong, Meghalaya
16.	Prof. Asha Gupta	Manipur University	Imphal, Manipur
17.	Dr. Dharaj Narayan Singh	Dakshin Kamrup College	Mirza, Assam
18.	Dr. Arvind Kumar Nayal	Bokhland University	Kohbarah, Assam
19.	Dr. Sooma Sarkar	Laksharuk Chooi Ranao Das College	Smitpur, Assam
20.	Dr. Kewal Sanjay Kumar	Mizoram University	Aizawl, Mizoram
21.	Dr. Ashish Kap	TERI North Eastern Regional Centre	Gowahati, Assam
22.	Dr. Keshabdas B	ICAR Research Complex for NEH Region	Umiam, Meghalaya
23.	Dr. Sanjay Kr. Deka	Orissa College	Imphal, Assam
24.	Dr. Salim Khogeer Singh	S. Kuli Women's College	Namdeb, Manipur
25.	Dr. Albert Chhang	Institute Of Biotechnology And Sustainable Development (IBSD)	Imphal, Manipur
26.	Dr. Manu Das	Gauhati University	Gowahati, Assam
27.	Prof. Karabi Datta	Gauhati University	Gopinath Borahoh Naga, Assam

Area: Food & Nutrition

28.	Dr. Jyotsna Gupta	Assam down town University	Guraibhat, Assam
29.	Dr. Ananta Borah	Brijnagar Mahavidyalaya	Bongaigaon, Assam
30.	Dr. Durga Prasad Awaroti	College of Agriculture	Lensabohra, Tripura
31.	Dr. B.K. Moha	North-Eastern Hill University	Shillong, Meghalaya
32.	Dr. Karishma Sood	Dibrugarh University	Dibrugarh, Assam
33.	Dr. Ratul Nath	Bongaigaon college	Smitpur, Assam

Area: Human Health

34.	Dr. Rishi Parra	Indian Institute of Information Technology	Gowahati, Assam
35.	Dr. Anantika Bhattacharyya	Assam University	Dikrua, Assam
36.	Dr. Nandini Khatunoyan	Regional Institute of Medical Sciences	Imphal, Manipur
37.	Dr. M. Bhobanchoini Devi	D.M. College of Science	Imphal, Manipur
38.	Dr. Puchi Vijaya Bhaskar Singh	Assam University	Diphu, Assam
39.	Prof. N. Medhali Maran	Manipur University	Imphal, Manipur
40.	Prof. N. Senthil Kumar	Mizoram university	Aizawl, Mizoram
41.	Dr. Jale Sharma	Assam University	Cachar, Assam

Area: Environment and pollution

42.	Dr. Pritam Meender Singh	Devi Narayn Govt. College	Bongaigaon, Arunachal Pradesh
43.	Dr. Diparmita Choudhary Sii	Holy Cross College	Lensabohra, Tripura
44.	Dr. N. L. Egan	Assam University Diphu Campus	Diphu, Assam
45.	Dr. Vikas Kumar Roy	Mizoram University	Aizawl, Mizoram
46.	Mr. M. Prabha Devi	ICAR Research Complex for North eastern Hill Region	Umiam, Meghalaya
47.	Dr. Mridul Bhattacharya	Lakhimpur Girls' College	Lakhimpur, Assam
48.	Dr. Krishna Lijon Devi	Presidency College	Manipur
49.	Dr. Madhukumar B	Mizoram University	Aizawl, Mizoram
50.	Dr. O. Premlal Chaoi	Maidam College	Imphal
51.	Ms. Dilipkanta	Hondapur Girls' College	Gowahati, Assam

Area: Sanitation

52.	Dr. Ajit Hazarika	Chandni College,	Imtepur, Assam
53.	Dr. Albin Monogor Akhand	Jaria college,	Nagaw, Assam
54.	Dr. Palanishaban Githanjali Devi	Imphal College	Imphal, Manipur
55.	Dr. Ranjan Haraban	Kamakhya Women College	Imphal, Manipur
56.	Mr. Prabir Sanku	L.T.R. College	Lakhimpur, Assam

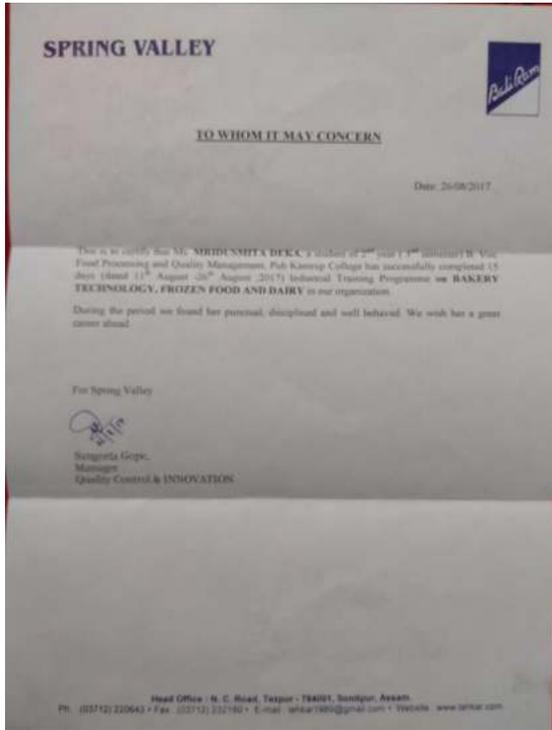
Area: Animal Health

57.	Ranjan Mech	Gauhati University	Gowahati, Assam
58.	Mr. Dipak Das	Ramkrishna Mahavidyalaya-Gowalpara	Kailashah, Tripura
59.	Dr. Lali Mohan Goswami	Sivasagar College	Nagaw, Assam
60.	Dr. Jagabrat Das	Gowalpara College	Gowalpara, Assam
61.	Dr. Sewali Pathak	Bijni College	Bijni, Assam
62.	Dr. Anir Kumar Tiwari	Mizoram University	Aizawl, Mizoram

Area: Agriculture

63.	Dr. Bijay Boraog	State Horticulture Research & Development Institute	Bongaigaon, Arunachal Pradesh
64.	Dr. Liberty P. Bhatia	Sikkim Government College	Gangtok, Sikkim
65.	Mohi Mathin Sangma	District and Local Research Station and Laboratory	Tura, Meghalaya





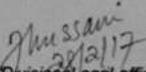


DEPARTMENT OF AGRICULTURE
TRAINING ON FRUITS & VEGETABLES PRESERVATION

CERTIFICATE

This is to certify that Sri/Srimati.....Salma Ahamed.....
of Bahubalchandi Village, under Khatup (S) District,
has
attended 3 (three) days training course on Fruits & Vegetables Preservation
commencing from 28-5-17 to 28-5-17 field
at Supervisory training centre, Darrang (Mangaldai)


Supervisor
C.C.&T.C. Mangaldai,
Darrang


Sub-Divisional agril officer
C.C.&T.C. Mangaldai,
Darrang

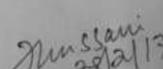


DEPARTMENT OF AGRICULTURE
TRAINING ON FRUITS & VEGETABLES PRESERVATION

CERTIFICATE

This is to certify that Sri/Srimati.....River Kohari.....
of Bahubalchandi Village, under Khatup (S) District,
has
attended 3 (three) days training course on Fruits & Vegetables Preservation
commencing from 28-5-17 to 28-5-17 field
at Supervisory training centre, Darrang (Mangaldai)


Supervisor
C.C.&T.C. Mangaldai,
Darrang


Sub-Divisional agril officer
C.C.&T.C. Mangaldai,
Darrang

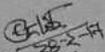


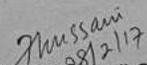
GOVT. OF ASSAM

**DEPARTMENT OF AGRICULTURE
TRAINING ON FRUITS & VEGETABLES PRESERVATION**

Certificate

This is to certify that Sri/Smt. Riyaz Ahmed
of Seok Kueki Village, under Koochup (R) District, has
attended 3 (three) days training course on Fruits & Vegetables
Preservation commencing from 29-2-17 to 28-3-17 held
at Supervisory Training Centre Mangaldai Darrang.


Supervisor
C.C. & T.C. Mangaldai,
Darrang


Sub-Divisional Agril Officer
C.C. & T.C. Mangaldai,
Darrang

OPPO A155

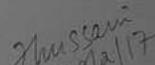


**DEPARTMENT OF AGRICULTURE
TRAINING ON FRUITS & VEGETABLES PRESERVATION**

CERTIFICATE

This is to certify that Sri/Srimati Arabi Sarna
of Bali Chhatrai Village, under Koochup (R) District,
has
attended 3 (three) days training course on Fruits & Vegetables Preservation
commencing from 29-2-17 to 28-3-17 held
at Supervisory Training Centre Mangaldai Darrang


Supervisor
C.C. & T.C. Mangaldai,
Darrang


Sub-Divisional agril officer
C.C. & T.C. Mangaldai,
Darrang

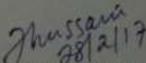


DEPARTMENT OF AGRICULTURE
TRAINING ON FRUITS & VEGETABLES PRESERVATION

CERTIFICATE

This is to certify that Sri/Srimati Arumina Deka.....
of Barak..... Village, under Kaokung (P)..... District,
has
attended 3 (Three)..... days training course on Fruits & Vegetables Preservation
commencing from 26-2-17..... to 28-2-17..... held
at Supervisor Training Centre Jorhat (Mangaldai)


Supervisor
C.C.&T.C. Mangaldai
Darrang


Sub-Divisional agril officer
C.C.&T.C. Mangaldai,
Darrang



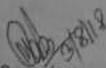
101

GOVT. OF ASSAM

DEPARTMENT OF AGRICULTURE
TRAINING ON FRUITS & VEGETABLES PRESERVATION

Certificate

This is to certify that Sri/Srimati Chimran Deka.....
of Barakpeta..... Village, under Darrang..... District, has
attended 2 (Two) days training course on Fruits & Vegetable Preservation
commencing from 12-02-2018..... to 14-02-2018..... held
at Supervisor Training Centre,


Supervisor
C.C. & T.C. Mangaldai,
Darrang


Sub-Divisional agril. Officer
C.C. & T.C. Mangaldai,
Darrang



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GOVT. OF ASSAM

DEPARTMENT OF AGRICULTURE

TRAINING ON FRUITS & VEGETABLES PRESERVATION

Certificate

This is to certify that Sri/Srimati Shanmoumi Deka
 of Mangaldai Village, under Darrang District, has
 attended 3 (Three) days training course on Fruits & Vegetable Preservation
 commencing from 12-02-2018 to 14-02-2018 held
 at Supervisor Training Centre, Mangaldai,


 Supervisor
 C.C. & T.C. Mangaldai,
 Darrang


 Sub-Divisional agril. Officer
 C.C. & T.C. Mangaldai,
 Darrang



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GOVT. OF ASSAM

DEPARTMENT OF AGRICULTURE

TRAINING ON FRUITS & VEGETABLES PRESERVATION

Certificate

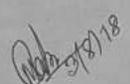
This is to certify that Smt. Manjula Rahman
 of Simsalhari Village, under Bongaigaon District, has
 attended 3 (Three) days training course on Fruits & Vegetable Preservation
 commencing from 12-02-18 to 14-02-18 held
 at C.C. & T.C. Mangaldai, Darrang

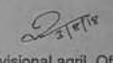

 Supervisor
 C.C. & T.C. Mangaldai,
 Darrang


 Sub-Divisional agril. Officer
 C.C. & T.C. Mangaldai,
 Darrang


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 GOVT. OF ASSAM
DEPARTMENT OF AGRICULTURE
 TRAINING ON FRUITS & VEGETABLES PRESERVATION
Certificate

This is to certify that Sri/Srimati Lipika Baruah
 of Rihdia Village, under Kamrup District, has
 attended 2 (Two) days training course on 'Fruits & Vegetable Preservation'
 commencing from 12-02-2018 to 14-02-2018 held
 at Super-visor Training centre, Mangaldai.

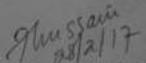

 Supervisor
 C.C. & T.C. Mangaldai,
 Darrang


 Sub-Divisional agril. Officer
 C.C. & T.C. Mangaldai,
 Darrang


DEPARTMENT OF AGRICULTURE
 TRAINING ON FRUITS & VEGETABLES PRESERVATION
CERTIFICATE

This is to certify that Sri/Srimati Muralidhar Barua
 of Barua Village, under Darrang District,
 has
 attended 3 (Three) days training course on 'Fruits & Vegetables Preservation'
 commencing from 20-2-18 to 28-2-18 held
 at Super-visor Training centre, Mangaldai.


 Supervisor
 C.C. & T.C. Mangaldai
 Darrang


 Sub-Divisional agril officer
 C.C. & T.C. Mangaldai,
 Darrang

SHOT ON NOTE 5
 INFINIX CAMERA

From: vijay basker <vbreddyasuh@yahoo.com>
Date: Fri, 12 May 2017, 9:34 pm
Subject: Request for Summer training of two students
To: bdevchoudhury@yahoo.com <bdevchoudhury@yahoo.com>
Cc: kml.sarma9@gmail.com <kml.sarma9@gmail.com>

Dear Sir,

I am glad to hear that the Department of Biophysics has been approved to your college and will soon start its session. Congratulations for your successful initiation and establishment.

I would like to place before you that two of my students Mr. Hirak Jyothi, and Mr. Chittaranjan Nath, would like to work in your Biotech hub laboratory for their summer training project during June-July. It would be a great opportunity for these young students to learn few techniques. These students are enthusiastic, hardworking, intelligent and fits into any team easily. This would definitely instigate a sense of awareness as well as motivation to take up research more as their professional career with enhanced passion, seriousness and responsibility.

I kindly request you to accommodate them in your Biotech Hub Laboratory and help their career building. Kindly let me know your decision so that I can inform the students accordingly.

Thanking You
Sincerely

Dr. PVB Reddy

Dr. P. Vijaya Bhaskar Reddy,
Assistant professor,
Dept. of Life Science & Bio-Informatics,
Assam University (A central University),
Diphu Campus, Diphu-782462, Assam.
Ph: +91-8179996671

