5th ANNUAL ENERGY HARVESTING SOCIETY MEETING (EHS 2022)

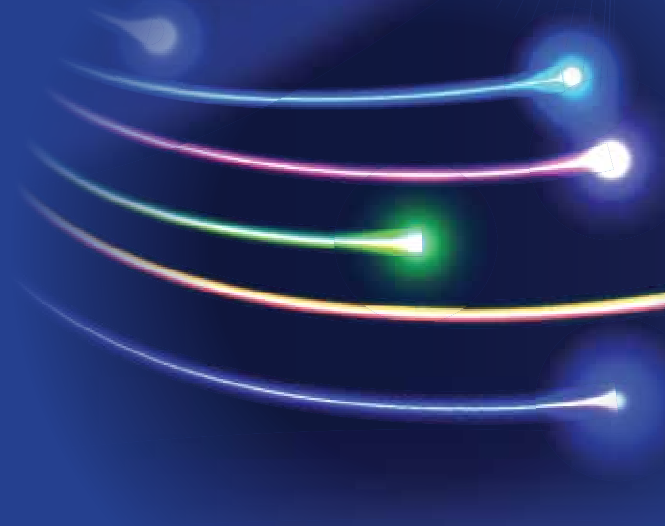
SEPTEMBER 7–9, 2022
Baltimore, Maryland, USA
ceramics.org/ehs22

conference guide

ORGANIZERS

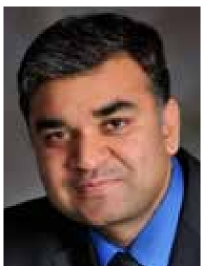
The American Ceramic Society
www.ceramics.org

ENERGY HARVESTING SOCIETY



5th ANNUAL ENERGY HARVESTING SOCIETY MEETING (EHS 2022)

PROGRAM CHAIRS:



Shashank Priya
Penn State University, USA

Jungho Ryu
Yeungnam University, Korea

Yang Bai
University of Oulu, Finland

Huiming Yin
Columbia University, USA

Chris Rahn
Penn State University, USA

Lei Zuo
Virginia Tech University, USA

THANK YOU!

Welcome to the 5th Annual Energy Harvesting Society Meeting. We hope that you will find this meeting relevant towards your professional career development and at the same time find it excellent event for learning about key subjects in the future of energy generation and storage for variety of applications including wireless sensor networks in transportation and buildings, structural health monitoring, Internet of Things, etc. Our organizing committee strives towards developing an informative and engaging agenda that surpasses the expectations of all the attendees.

The Energy Harvesting Society is growing and we are excited to be holding the second in-person meeting since Fall 2019. Our partnership with American Ceramic Society has grown tremendously and we together continue to find ways to strengthen the program for this event. Thanks to Mark Mecklenborg and his team comprising of Greg Geiger, Marilyn Stoltz, and Andrea Ross. They have done phenomenal work in organizing this meeting. Thanks to Jennifer Leedy at Penn State for her great support and assistance throughout the planning and execution phase. She has been dedicated to ensuring the success of this meeting.

Thank you to the sponsors and organizations who support both the society and this meeting. Thank you to all our plenary speakers. We know you are extremely busy so we much appreciate the time and effort. Thank you to the all the participants from multiple academic institutions, industry, and government agencies. Without your strong support this would not be possible. And thank you to our friends and colleagues serving on the international planning committee. Over the past several months, you have provided countless hours in developing this program and continue to refine and improve the agenda. Thank you, team.

We again appreciate your participation and welcome your questions, suggestions, and ideas about how we can collaborate over the coming years to continue to grow the Energy Harvesting Society.

SEPTEMBER 7–9, 2022

Baltimore, Maryland, USA

ceramics.org/ehs22

ORGANIZERS

TABLE OF CONTENTS

Sessions at a glance iii

Schedule at a glance iv

Hotel Floor plan iv

Plenary Speakers v

Symposium Organizers vi

Final Program

Presenting Authors Lists 1

Wed morning/afternoon 2-3

Thur morning/afternoon 3-5

Friday morning 5

Abstracts 1-18

Author index 19

SESSIONS-AT-A-GLANCE

SESSION TITLE	DATE	TIME	LOCATION
OPENING REMARKS AND PLENARY 1	**Sept. 7, 2022**	**8:00 - 9:30 AM**	**Columbia/Frederick/Annapolis**
S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - I	Sept.7, 2022	9:30 AM - 12:20 PM	Columbia/Frederick/Annapolis
S2: Integrated Energy Harvesting and Storage Systems for Wearables and IoT	Sept.7, 2022	9:30 - 10:40 AM	Pratt/Calvert
S5: Piezoelectric and Triboelectric Energy Harvesting using Low-Dimensional Materials	Sept.7, 2022	11:10 - 11:50 AM	Pratt/Calvert
S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - II	Sept. 7, 2022	1:30 - 3:20 PM	Columbia/Frederick/Annapolis
S7: Workshop in Devices, Materials and Structures for Energy Harvesting and Storage	Sept. 7, 2022	1:30 - 5:30 PM	Pratt/Calvert
PLENARY 2	**Sept. 8, 2022**	**8:00 - 9:00 AM**	**Columbia/Frederick/Annapolis**
S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - I	Sept. 8, 2022	9:00 - 11:30 AM	Pratt/Calvert
S4: Thermoelectric Energy Harvesting - I	Sept. 8, 2022	9:00 - 11:50 AM	Columbia/Frederick/Annapolis
S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - II	Sept. 8, 2022	1:30 - 3:20 PM	Pratt/Calvert
S4: Thermoelectric Energy Harvesting - II	Sept. 8, 2022	1:30 - 3:30 PM	Columbia/Frederick/Annapolis
PLENARY 3	**Sept. 9, 2022**	**8:00 - 9:00 AM**	**Columbia/Frederick/Annapolis**
S6: Third generation Photovoltaic Technologies with emphasis on Perovskite Solar Cells and Modules	Sept. 9, 2022	9:00 AM - 1:10 PM	Columbia/Frederick/Annapolis

5th ANNUAL ENERGY HARVESTING SOCIETY MEETING (EHS 2022)

SCHEDULE-AT-A-GLANCE

Tuesday, September 6, 2022

Conference registration	5:00 p.m. – 7:00 p.m.

Wednesday, September 7, 2022

Conference registration	7:30 a.m. – 6:00 p.m.
Opening remarks and Plenary 1	8:00 a.m. – 9:00 a.m.
Coffee break	9:00 a.m. – 9:30 a.m.
Concurrent sessions	9:30 a.m. – 12:20 p.m.
Lunch provided	Noon – 1:30 p.m.
Concurrent sessions	1:30 p.m. – 5:30 p.m.
Coffee break	3:00 p.m. – 3:30 p.m.
Networking Reception with Posters	5:30 p.m. – 6:30 p.m.

Thursday, September 8, 2022

Conference registration	7:30 a.m. – 5:30 p.m.
Plenary 2	8:00 a.m. – 8:45 a.m.

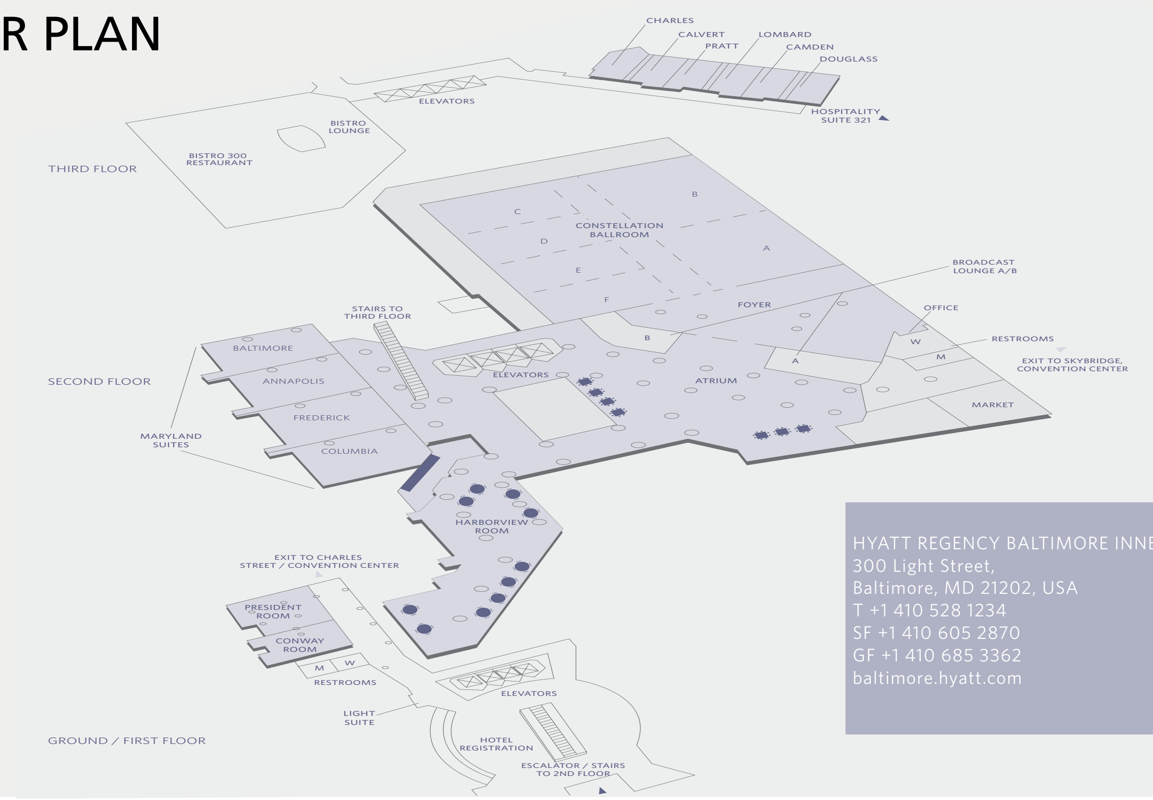
Thursday, September 8, 2022

Coffee break	8:45 a.m. – 9:00 a.m.
Concurrent sessions	9:00 a.m. – Noon
Lunch provided	12:00 p.m. – 1:30 p.m.
Plenary 3	1:30 p.m. – 2:45 p.m.
Coffee service	2:15 p.m. – 2:45 p.m.
Concurrent sessions	2:45 p.m. – 4:45 p.m.

Friday, September 9, 2022

Conference registration	7:30 a.m. – 12:00 p.m.
Plenary 4	8:00 a.m. – 8:45 a.m.
Coffee break	8:45 a.m. – 9:00 a.m.
Concurrent sessions	9:00 a.m. – 12:50 p.m.

FLOOR PLAN



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SEPTEMBER 7–9, 2022

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ORGANIZERS

The American Ceramic Society www.ceramics.org

Energy Harvesting Society

PLENARY SPEAKERS

Opening Remarks daily at 8 a.m.

Wednesday, Sept. 7, 2022

8:20 - 9:00 a.m.

Dr. Sang-Woo Kim

Distinguished Professor (SKKU Fellow) at Sungkyunkwan University (SKKU), Korea

Title: *A new energy solution with triboelectric nanogenerator for powering body-implantable electronics*

Thursday, Sept. 8, 2022

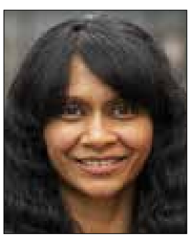
8:05 - 8:45 a.m.

Prof. Shujun Zhang

Distinguished Professor of the Institute for Superconducting and Electronic Materials, Australian Institute for Innovative Materials, University of Wollongong, Australia

Title: *Piezoelectric materials for mechanical energy harvesting applications*

Friday, Sept. 9, 2022



8:05 – 8:45 a.m.

Prof. Sohini Kar-Narayan

Professor of Device & Energy Materials, Department of Materials Science, University of Cambridge, United Kingdom

Title: *Materials-related strategies for highly efficient triboelectric energy generators*

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Journal of the American Ceramic Society – Incorporating Advanced Ceramic Materials and Communications

International Journal of Applied Ceramic Technology

International Journal of Ceramic Engineering & Science

5th ANNUAL **ENERGY HARVESTING** SOCIETY MEETING (EHS 2022)

SYMPOSIUM ORGANIZERS

Program Chairs:
Shashank Priya, Penn State University, USA
Jungho Ryu, Yeungnam University, Korea
Yang Bai, University of Oulu, Finland
Huiming Yin, Columbia University, USA
Chris Rahn, Penn State University, USA
Lei Zuo, Virginia Tech University, USA

S1: PIEZOELECTRIC AND MECHANO-MAGNETO-ELECTRIC ENERGY HARVESTING

– **Jungho Ryu**, Yeungnam University, Korea
– **Shashank Priya**, Pennsylvania State University, USA
– **DaeYong Jeong**, Inha University, Korea
– **Shuxiang Dong**, Peking University, China

S2: INTEGRATED ENERGY HARVESTING AND STORAGE SYSTEMS FOR WEARABLES AND IOT

– **Vikram Pakrashi**, University College Dublin, Ireland
– **Sebastian Bader**, Mid Sweden University, Sweden
– **Zdeněk Hadaš**, Brno University of Technology, Czech Republic
– **Yang Bai**, University of Oulu, Finland

S3: MULTI-FUNCTIONAL ENERGY CONVERSION MATERIALS AND DEVICES FOR ENERGY HARVESTING AND/OR SENSING

– **Chris Bowen**, University of Bath, U.K.
– **Tim W. Button**, University of Birmingham, U.K.
– **Yang Bai**, University of Oulu, Finland

S4: THERMOELECTRIC ENERGY HARVESTING

– **Bed Poudel**, Pennsylvania State University, USA
– **Amin Nozariasbmarz**, Pennsylvania State University, USA
– **Wenjie Li**, Pennsylvania State University, USA
– **Luis Fonseca**, Autonomous University of Barcelona, Spain

S5: PIEZOELECTRIC AND TRIBOELECTRIC ENERGY HARVESTING USING LOW-DIMENSIONAL MATERIALS

– **Miso Kim**, Korea Research Institute of Standards and Science, Korea
– **Sohini Kar-Narayan**, University of Cambridge, U.K.
– **Wenzhuo Wu**, Purdue University, USA
– **Rusen Yang**, Xidian University, China

S6: THIRD GENERATION PHOTOVOLTAIC TECHNOLOGIES WITH EMPHASIS ON PEROVSKITE SOLAR CELLS AND MODULES

– **Kai Wang**, Pennsylvania State University, USA

S7: SPECIAL SYMPOSIUM – WORKSHOP IN DEVICES, MATERIALS, AND STRUCTURES FOR ENERGY HARVESTING AND STORAGE

– **Grzegorz Litak**, Lublin University of Technology, Poland
– **Sebastian Bader**, Mid Sweden University, Sweden
– **Carlo Trigona**, University of Catania, Italy

Oral Presenters

Name	Date	Time	Room	Page Number
		A		
Achadu, O.J.	7-Sep	10:00AM	Columbia/Frederick/Annapolis	2
		B		
Baek, S.	7-Sep	4:30PM	Pratt/Calvert	3
Basset, P.	8-Sep	1:30PM	Pratt/Calvert	4
Brown, T.M.	9-Sep	10:00AM	Columbia/Frederick/Annapolis	5
		C		
Chae, S.	7-Sep	11:10AM	Columbia/Frederick/Annapolis	2
Chae, Y.	7-Sep	10:20AM	Columbia/Frederick/Annapolis	2
Choi, J.	7-Sep	3:30PM	Pratt/Calvert	3
Choi, W.	7-Sep	5:00PM	Pratt/Calvert	3
Chu, Z.	7-Sep	1:30PM	Columbia/Frederick/Annapolis	2
Crane, D.	8-Sep	2:00PM	Columbia/Frederick/Annapolis	5
		D		
Dou, L.	9-Sep	10:30AM	Columbia/Frederick/Annapolis	5
Doumon, N.	9-Sep	9:30AM	Columbia/Frederick/Annapolis	5
		F		
Feldhoff, A.	8-Sep	9:00AM	Columbia/Frederick/Annapolis	4
		G		
Gonzalez, C.	7-Sep	11:30AM	Columbia/Frederick/Annapolis	2
Goyal, G.	8-Sep	10:20AM	Columbia/Frederick/Annapolis	4
Grasberger, J.	7-Sep	10:00AM	Pratt/Calvert	2
		H		
Hou, Y.	9-Sep	11:20AM	Columbia/Frederick/Annapolis	5
		J		
Jang, J.	7-Sep	2:00PM	Pratt/Calvert	3
Jang, J.	8-Sep	9:00AM	Pratt/Calvert	3
		K		
Kang, C.	7-Sep	10:40AM	Columbia/Frederick/Annapolis	2
Kar-Narayan, S.	9-Sep	8:05AM	Columbia/Frederick/Annapolis	5
Karan, S.	8-Sep	10:10AM	Pratt/Calvert	4
Kim, J.	7-Sep	11:30AM	Pratt/Calvert	2
Kim, I.	7-Sep	11:10AM	Pratt/Calvert	2
Kim, S.	7-Sep	8:20AM	Columbia/Frederick/Annapolis	2
Kim, S.	7-Sep	2:30PM	Pratt/Calvert	3
Kim, W.	7-Sep	1:30PM	Pratt/Calvert	3
Kovalevsky, A.	8-Sep	1:30PM	Columbia/Frederick/Annapolis	4
Ksica, F.	8-Sep	10:50AM	Pratt/Calvert	4
		L		
Lee, D.	8-Sep	2:20PM	Pratt/Calvert	4
Lee, G.	8-Sep	10:30AM	Pratt/Calvert	4
Lee, S.	7-Sep	2:40PM	Columbia/Frederick/Annapolis	3
Li, W.	8-Sep	10:00AM	Columbia/Frederick/Annapolis	4
Litak, G.	7-Sep	2:20PM	Columbia/Frederick/Annapolis	3
Liu, N.	8-Sep	2:40PM	Pratt/Calvert	4
Luyao, Z.	8-Sep	11:10AM	Pratt/Calvert	4
Luyao, Z.	9-Sep	11:40AM	Columbia/Frederick/Annapolis	5
		N		
Nahm, S.	7-Sep	9:30AM	Columbia/Frederick/Annapolis	2
Nie, W.	9-Sep	9:00AM	Columbia/Frederick/Annapolis	5
Nozariasbmarz, A.	8-Sep	2:30PM	Columbia/Frederick/Annapolis	5
		P		
Poon, J.	8-Sep	10:40AM	Columbia/Frederick/Annapolis	4
Poudel, B.	8-Sep	3:10PM	Columbia/Frederick/Annapolis	5
		R		
Rajagopalan, R.	7-Sep	9:30AM	Pratt/Calvert	2
Raman, L.	8-Sep	3:00PM	Pratt/Calvert	4
Ryu, J.	7-Sep	11:50AM	Columbia/Frederick/Annapolis	2
		S		
Sharma, S.	7-Sep	3:00PM	Columbia/Frederick/Annapolis	3
Sharma, S.	8-Sep	2:50PM	Columbia/Frederick/Annapolis	5
Singh, S.	8-Sep	11:30AM	Columbia/Frederick/Annapolis	4
Singh, S.	8-Sep	2:00PM	Pratt/Calvert	4
Song, H.	7-Sep	4:00PM	Pratt/Calvert	3
Sosna, P.	7-Sep	2:00PM	Columbia/Frederick/Annapolis	2
Srinivasan, G.	8-Sep	9:50AM	Pratt/Calvert	4
		W		
Wang, K.	9-Sep	12:20PM	Columbia/Frederick/Annapolis	5
Wu, H.	9-Sep	12:00PM	Columbia/Frederick/Annapolis	5
		Y		
Yin, H.	9-Sep	11:00AM	Columbia/Frederick/Annapolis	5
Yu, H.	8-Sep	9:30AM	Pratt/Calvert	4
		Z		
Zebarjadi, M.	8-Sep	9:30AM	Columbia/Frederick/Annapolis	4
Zhang, S.	8-Sep	8:05AM	Columbia/Frederick/Annapolis	3
Zhang, Y.	7-Sep	10:20AM	Pratt/Calvert	2
Zhang, Y.	8-Sep	11:10AM	Columbia/Frederick/Annapolis	4

Poster Presenters

Name	Date	Time	Room	Page Number
		D		
Diaw, A.	7-Sep	5:30PM	Harborview	3
		O		
Okuda, R.	7-Sep	5:30PM	Harborview	3
		W		
Wolszczak, P.	7-Sep	5:30PM	Harborview	3
		Y		
Ye, J.	7-Sep	5:30PM	Harborview	3

Wednesday, September 7,2022

Opening Remarks and Plenary 1

Room: Columbia/Frederick/Annapolis

Session Chair: Shashank Priya, Pennsylvania State University

8:00 AM

Opening Remarks - Prof. Shashank Priya, Program Chair; Prof. Sahn Nahm, Korean Ceramic Society

8:20 AM

(EHS-PLEN-001-2022) A New Energy Solution with Triboelectric Nanogenerator for Powering Body-implantable Electronics

S. Kim*[1]

1. Sungkyunkwan University, Republic of Korea

9:00 AM

Break

S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - I

Room: Columbia/Frederick/Annapolis

Session Chair: Jungho Ryu, Yeungnam University

9:30 AM

(EHS-001-2022) Piezoelectric properties of the [001]-textured (Na, K)Nb-based lead-free piezoceramics and their application to piezoelectric energy harvesters (Invited)

S. Nahm*[1]; S. Go[1]; H. Kim[1]; D. Kim[1]; J. Eum[1]; S. Chae[1]; E. Kim[1]

1. Korea University, Department of Materials Science and Engineering, Republic of Korea

10:00 AM

(EHS-002-2022) Sustainable Bio-Engineered Magnetoelectric Nanogenerator to convert ambient stray magnetic noise to electricity

O. J. Achadu*[1]

1. University of Warwick, Chemistry&IAS, United Kingdom

10:20 AM

(EHS-003-2022) Effect of the metasurface on the output power of the piezoelectric energy harvester

Y. Chae*[1]; D. Kim[1]; H. Lee[2]; H. Seung[3]; M. Kim[4]; S. Nahm[1]

1. Korea University, Materials Science and Engineering, Republic of Korea
2. Korea Research Institute of Standards and Science (KRISS), Ultrasound Standards Team, Republic of Korea
3. Korea Research Institute of Standards and Science (KRISS), AI Metamaterial Research Team, Republic of Korea
4. Sungkyunkwan University, Materials Science and Engineering, Republic of Korea

10:40 AM

(EHS-004-2022) Synergistic effect of room temperature gas sensors and piezoelectric energy harvesting (Invited)

C. Kang*[1]

1. Korea Institute of Science and Technology/Seoul National University, Advanced Materials Research Division, Republic of Korea

11:10 AM

(EHS-005-2022) Piezoelectricity of textured (K, Na)(Nb, Sb)O_3-$CaZrO_3$ thick films for use in piezoelectric energy harvesters

S. Chae*[1]; S. Nahm[1]

1. Korea University, Material Science and Engineering, Republic of Korea

11:30 AM

(EHS-006-2022) Power Source for Wireless Sensor Nodes: Evaluation of Piezoelectric Energy Harvesters Using Complex Beam Geometries

C. Gonzalez*[1]; I. Greeley[1]; A. Trinh[2]; J. Fox[3]; L. Lyle[3]; D. McKinney[4]; J. Deem[4]; M. Fanton[3]; D. Snyder[3]; R. Claus[4]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA
2. Pennsylvania State University, Department of Mechanical Engineering, USA
3. Pennsylvania State University, USA
4. Nanosonic Inc., USA

11:50 AM

(EHS-007-2022) Magneto-Mechano-Electric Generator composed of magnetoelectric composite for IoT sensor driving (Invited)

J. Ryu*[1]

1. Yeungnam University, School of Materials Science and Engineering, Republic of Korea

S2: Integrated Energy Harvesting and Storage Systems for Wearables and IoT

Room: Pratt/Calvert

Session Chair: Filip Ksica, Brno University of Technology

9:30 AM

(EHS-008-2022) Lithium ion capacitors for self powered wearable health sensing platforms (Invited)

R. Rajagopalan*[1]

1. Pennsylvania State University, Engineering-Applied Materials Program, USA

10:00 AM

(EHS-009-2022) Co-design Investigation of a Bottom-Hinged Oscillating-Surge Wave Energy Converter

J. Grasberger*[1]

1. Virginia Tech, Mechanical Engineering, USA

10:20 AM

(EHS-010-2022) An Enhanced Variable Reluctance Energy Harvester for Self-powered Condition Monitoring

Y. Zhang*[1]; J. Cao[1]

1. Xi'an Jiaotong Univeristy, China

S5: Piezoelectric and Triboelectric Energy Harvesting using Low-Dimensional Materials

Room: Pratt/Calvert

Session Chair: Miso Kim, Sungkyunkwan University

11:10 AM

(EHS-011-2022) Low-temperature crystalline $NaNbO_3$ thin film grown on $Sr_2Nb_3O_{10}$ nanosheets for piezoelectric energy harvesters

I. Kim*[1]; S. Nahm[1]

1. Korea University, Material Science and Engineering, Republic of Korea

11:30 AM

(EHS-012-2022) Phase transformations driven by complex interatomic interactions in sodium transition metal oxides

J.C. Kim*[1]

1. Stevens Institute of Technology, Department of Chemical Engineering & Materials Science
2.

S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - II

Room: Columbia/Frederick/Annapolis

Session Chair: Hyun-Cheol Song, KIST

1:30 PM

(EHS-013-2022) Significantly Enhanced Power Generation from Extremely Low-Intensity Magnetic Field via a Clamped-Clamped Magneto-Mechano-Electric Generator (Invited)

Z. Chu*[1]; S. Dong[2]

1. Harbin Engineering University, Innovation and Development Center, China
2. Peking University, China

2:00 PM

(EHS-014-2022) Bifurcation analysis of magnetic separation for optimal design of tuned vibration energy harvesters

P. Sosna*[1]; Z. Hadas[1]

1. Brno University of Technology, Faculty of Mechanical Engineering, Czechia

2:20 PM

(EHS-015-2022) Dynamics of a nonlinear energy harvester with subharmonic responses

G. Litak*[1]
1. Lublin University of Technology, Department of Automation, Poland

2:40 PM

(EHS-016-2022) Hybrid Magneto-Mechano-Electric energy generator with 2nd harmonic bending mode

S. Lee*[1]; J. Ryu[1]; G. Hwang[2]
1. Yeungnam University, Material Science and Engineering, Republic of Korea
2. Pukyong National University, Materials Science and Engineering, Republic of Korea

3:00 PM

(EHS-017-2022) Miniaturized magnetoelectric energy harvester based on $(Fe_{1-y}Ga_y)_{1-x}B_x$ thin films

S. Sharma*[1]; S. Karan[1]; Z. Luyao[1]; K. Wang[1]; B. Poudel[1]; S. Priya[1]
1. Pennsylvania State University, Department of Materials Science and Engineering, USA

S7: Workshop in Devices, Materials and Structures for Energy Harvesting and Storage

Room: Pratt/Calvert

Session Chairs: Shashank Priya, Pennsylvania State University; Grzegorz Litak, Lublin University of Technology

1:30 PM

(EHS-018-2022) Development of ultrafast supercapacitors (Invited)

W. Kim*[1]
1. Korea University, Department of Material Science and Engineering, Republic of Korea

2:00 PM

(EHS-019-2022) Bi-directional water-stream behavior on multifunctional membrane for simultaneous energy generation and water purification (Invited)

J. Jang*[1]
1. Korea Institute of Science and Technology, Electronic Materials Research Center, Republic of Korea

2:30 PM

(EHS-020-2022) Additives and Solvents Engineering of Perovskite Solar Cells (Invited)

S. Kim*[1]
1. Korea University, Department of Material Science and Engineering, Republic of Korea

3:00 PM

Break

3:30 PM

(EHS-021-2022) Transparent thin film lithium ion batteries (Invited)

J. Choi*[1]
1. Korea Institute of Science and Technology, Center for Electronic Materials, Republic of Korea

4:00 PM

(EHS-022-2022) Autonomous resonance tuning mechanism for environmental adaptive energy harvesting (Invited)

H. Song*[1]
1. Korea Institute of Science and Technology, Electronic Materials Research Center, Republic of Korea

4:30 PM

(EHS-023-2022) Epitaxial Piezoelectric Thin Films on Si for Ultrasound Transducers (Invited)

S. Baek*[1]
1. Korea Institute of Science and Technology, Center for Electronic Materials, Republic of Korea

5:00 PM

(EHS-024-2022) Coaxial Piezoelectric Energy Generator (C-PEG) Yarn of Cu/PVDF-TrFE/ PDMS/Nylon/Ag (Invited)

W. Choi*[1]
1. Korea Institute of Science and Technology, Center for Opto-Electronic Materials and Devices, Republic of Korea

Poster Session

Room: Harborview

5:30 PM

(EHS-P001-2022) Double-beams energy harvester with different flexibility of the beams

P. Wolszczak*[1]
1. Lublin University of Tecchnology, Department of Automation, Poland

(EHS-P002-2022) Xenon flash-light annealing of $Pb(Zr,Ti)O_3$/ Metglas Heterostructure for effective Magnetoelectric (ME) coupling

J. Ye*[1]; P. Jakkapally[1]; A. Kumar[1]; D. Patil[1]; J. Lee[1]; J. Ryu[1]
1. Yeungnam University, Material Science & Engineering, Republic of Korea

(EHS-P003-2022) Optimization of Antireflective Layers of Silicon Solar Cells: Studies of the Efficiency between Single and Double Layer at the reference wavelength

A. Diaw*[1]
1. Cheikh Anta Diop University, Physics, Senegal

(EHS-P004-2022) Preliminary modeling and prototyping of a scaled semi-submersible wind platform using tuned inerter dampers for vibration reduction

L. Hall[1]; R. Okuda*[1]; D. Lambert[1]; L. Zuo[1]
1. Virginia Tech, Mechanical Engineering, USA

Thursday, September 8, 2022

Plenary 2

Room: Columbia/Frederick/Annapolis

Session Chair: Shashank Priya, Pennsylvania State University

8:00 AM

Introduction

8:05 AM

(EHS-PLEN-003-2022) Piezoelectric materials for mechanical energy harvesting applications

S. Zhang*[1]
1. University of Wollongong, ISEM, Australia

8:45 AM

Break

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - I

Room: Pratt/Calvert

Session Chair: TBD

9:00 AM

(EHS-025-2022) Reliability study of piezoelectric energy harvesters for stable powering of Internet of Things sensor (Invited)

J. Jang*[1]; W. Yoon[1]; J. Choi[1]
1. Korea Institute of Materials Science, Department of Functional Ceramics, Republic of Korea

9:30 AM

(EHS-026-2022) Structural and dielectric properties of Nb_2O_5 doped $BaTiO_3$-$Bi(Mg_{1/2}Ti_{1/2})O_3$ multilayer ceramics capacitor for the application to electric automobile

H. Yu*[1]; S. Chae[1]; J. Eum[1]; S. Nahm[1]

1. Korea University, Republic of Korea

9:50 AM

(EHS-027-2022) Self-Biased Core-Shell Multiferroic Hexagonal ferrite-Ferroelectirc Nanofibers for Sensors and Energy Harvesters

Y. Liu[1]; P. Zhou[1]; G. Srinivasan*[1]

1. Oakland University, Physics, USA

10:10 AM

(EHS-028-2022) Self-contained multi-source-based hybrid energy harvester

S. Karan*[1]; S. Priya[1]

1. Pennsylvania State University, Materials Science and Engineering, USA

10:30 AM

(EHS-029-2022) Hybrid Thermo-Magneto-Electric Generator coupled with Tribo and Pyroelectric effect

G. Lee*[1]; H. Choi[1]; C. Baek[1]; J. Ryu[1]

1. Yeungnam University, Material Science and Engineering, Republic of Korea

10:50 AM

(EHS-030-2022) Analysis of Smart Metamaterial Structure for Sensing and Energy Harvesting

F. Ksica*[1]; Z. Hadas[1]; L. Pincek[1]; P. Marcián[1]; M. Hrstka[1]

1. Brno University of Technology, Czechia

11:10 AM

(EHS-031-2022) Monitoring Hawkmoth Octopamine Levels During Flight with a Millimeter-Scale Luminiscense-Photodetector Implant

Z. Luyao*[1]; K. Wang[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

11:30 AM

(EHS-058-2022) Phononic Crystals and Metamaterials for Sustainable Power Generation (Invited)

M. Kim*[1]

1. Sungkyunkwan University, School of Advanced Materials Science & Engineering, Korea

S4: Thermoelectric Energy Harvesting - I

Room: Columbia/Frederick/Annapolis

Session Chair: Bed Poudel, Pennsylvania State University

9:00 AM

(EHS-032-2022) Thermoelectric ceramics based on $Ca_3Co_{4-x}O_{9+\delta}$ and large plate-like oxides (Invited)

A. Feldhoff*[1]; Z. Zhao[1]; M. Wolf[1]; M. Jakob[2]; O. Oeckler[2]; R. Hinterding[1]

1. Leibniz University Hannover, Institute of Physical Chemistry and Electrochemistry, Germany
2. University of Leipzig, Institute of Mineralogy, Germany

9:30 AM

(EHS-033-2022) Thermomagnetic energy conversion and refrigeration for low-temperature applications (Invited)

M. Zebarjadi*[1]; M. Akhanda[1]

1. University of Virginia, Electrical and Computer Eng., USA

10:00 AM

(EHS-034-2022) Conformal High-power-density Half-Heusler Thermoelectric Modules: A Pathway towards Practical Power Generator

W. Li*[1]; A. Nozariasbmarz[1]; R. Kishore[2]; H. Kang[1]; H. Zhu[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Materials Science and Engineering, USA
2. National Renewable Energy Laboratory, USA

10:20 AM

(EHS-035-2022) Numerical modeling assisted thermoelectric device design optimization

G. Goyal*[1]; B. Poudel[1]; A. Nozariasbmarz[1]; W. Li[1]; Y. Zhang[1]; S. Singh[1]; S. Priya[1]

1. Pennsylvania State University, Materials Science and Engineering, USA

10:40 AM

(EHS-036-2022) There is Plenty of Room for Higher Thermoelectric Performance in Half-Heusler Alloys (Invited)

M. Mitra[1]; A. Benton[4]; M. Akhanda[2]; M. Zebarjadi[2]; D. J. Singh[3]; J. Poon*[1]

1. University of Virginia, Physics, USA
2. University of Virginia, ECE, USA
3. University of Missouri, Physics, USA
4. Clemson University, Dept. of Physics & Astronomy, USA

11:10 AM

(EHS-037-2022) High Thermoelectric Performance Materials for Cooling Application

Y. Zhang*[1]; B. Poudel[1]

1. Pennsylvania State University, USA

11:30 AM

(EHS-038-2022) Recent Development of High-Performance Thermoelectric Silver Chalcogenides for Energy Harvesting

S. Singh*[1]; K. Hirata[2]; A. Nozariasbmarz[1]; T. Takeuchi[2]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA
2. Toyota Technological Institute, Energy Materials, Japan

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - II

Room: Pratt/Calvert

Session Chair: TBD

1:30 PM

(EHS-039-2022) High-voltage management in triboelectric kinetic energy harvesters (Invited)

P. Basset*[1]

1. Univ Gustave Eiffel, CNRS, ESYCOM lab, France

2:00 PM

(EHS-040-2022) Search of Gd-based Alloys for Development of Thermomagnetic Devices for Energy Harvesting

S. Singh*[1]; N. Liu[1]; Y. Zhang[1]; S. Karan[1]; A. Nozariasbmarz[1]; W. Li[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

2:20 PM

(EHS-042-2022) Developing Ti-Ni-Cu shape memory alloys for low-grade heat engine application

N. Liu*[1]; W. Li[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, USA

2:40 PM

(EHS-043-2022) Refractory high entropy alloy: A potential candidate for high temperature structural material

L. Raman*[1]; W. Li[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Material Science and Engineering, USA

S4: Thermoelectric Energy Harvesting - II

Room: Columbia/Frederick/Annapolis

Session Chair: Bed Poudel, Pennsylvania State University

1:30 PM

(EHS-045-2022) Improved Thermoelectric Performance by using Distributed Transport Properties to Reduce the Detrimental Effects of Joule Heating (Invited)

D. Crane*[1]; B. Madigan[1]; L. Bell[1]

1. DTP Thermoelectrics, USA

2:00 PM

(EHS-046-2022) Introducing Perovskites as Capable Thermoelectric Materials

A. Nozariasbmarz*[1]; Z. Luyao[1]; B. Poudel[1]; K. Wang[1]; W. Li[1]; Y. Zhang[1]; S. Priya[1]
1. Pennsylvania State University, Materials Science and Engineering, USA

2:20 PM

(EHS-047-2022) Thermoelectric thin films fabricated using RF magnetron sputtering technique

S. Sharma*[1]; B. Poudel[1]; S. Priya[1]
1. Pennsylvania State University, Material Science and Engineering, USA

2:40 PM

(EHS-048-2022) Development of high temperature and high performance thermoelectric devices for power generation

B. Poudel*[1]; W. Li[1]; A. Nozariasbmarz[1]; Y. Zhang[1]; S. Priya[1]
1. Pennsylvania State University, Department of Materials Science and Engineering, USA

Friday, September 9, 2022

Plenary 3

Room: Columbia/Frederick/Annapolis
Session Chair: Shashank Priya, Pennsylvania State University

8:00 AM

Introduction

8:05 AM

(EHS-PLEN-002-2022) Materials-related Strategies for Highly Efficient Triboelectric Energy Generators

S. Kar-Narayan*[1]
1. University of Cambridge, Department of Materials Science, United Kingdom

8:45 AM

Break

S6: Third generation Photovoltaic Technologies with emphasis on Perovskite Solar Cells and Modules

Room: Columbia/Frederick/Annapolis
Session Chair: Kai Wang, Pennsylvania State University

9:00 AM

(EHS-049-2022) Perovskite solar module: Efficiency and operational stability (Invited)

W. Nie*[1]
1. Los Alamos National Laboratory, USA

9:30 AM

(EHS-050-2022) Indoor/Outdoor Performance Tracking of Metal-Halide Perovskite Photovoltaic Modules (Invited)

N. Doumon*[1]; J. Berry[2]; L. Schelhas[2]
1. National Renewable Energy Laboratory, Chemistry & Nanoscience, USA
2. National Renewable Energy Laboratory, USA

10:00 AM

(EHS-051-2022) Development of perovskite solar cell architectures specific for efficient light harvesting under indoor illumination (Invited)

T. M. Brown*[1]
1. University of Rome Tor Vergata, Department of Electronic Engineering, Italy

10:30 AM

(EHS-052-2022) Multi-Functional Conjugated Ligand Engineering for Stable and Efficient Perovskite Solar Cells (Invited)

L. Dou*[1]
1. Purdue University, Chemical Engineering, USA

11:00 AM

(EHS-053-2022) Nonlinear elastic design and analysis of large building integrated photovoltaic panels

H. Yin*[1]
1. Columbia University, Civil Engineering and Engineering Mechanics, USA

11:20 AM

(EHS-054-2022) Homogenization of Optical Field in Nanocrystal-Embedded Perovskite Composites

Y. Hou*[1]; J. Zhang[2]; X. Zheng[2]; Y. Lu[2]; J. Piper[2]
1. Pennsylvania State University, Department of Material Science and Engineering, USA
2. Macquarie University, Australia

11:40 AM

(EHS-055-2022) Cost-Effective High-Performance Charge-Carrier-Transport-Layer-Free Perovskite Solar Cells Achieved by Suppressing Ion Migration

Z. Luyao*[1]; T. Ye[1]; S. Priya[1]
1. Pennsylvania State University, Department of Materials Science and Engineering, USA

12:00 PM

(EHS-056-2022) Self-Assembly of 0D/3D Perovskite Bi-Layer from A Micro-Emulsion Ink

Y. Hou[1]; H. Wu*[1]; K. Wang[1]; S. Priya[1]
1. Pennsylvania State University, Department of Material Science and Engineering, USA

12:20 PM

(EHS-057-2022) Halide perovskite: overcoming Shockley-Queisser limit of photovoltaics (Invited)

K. Wang*[1]
1. Pennsylvania State University, USA


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5th Annual Energy Harvesting Society Meeting (EHS 2022)

ABSTRACT BOOK

September 7–9, 2022
Baltimore, MD, USA

The American Ceramic Society
www.ceramics.org

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Refer to the Table of Contents to determine page numbers on which specific session abstracts begin. At the beginning of each session are headings that list session title, location and session chair. Starting times for presentations and paper numbers precede each paper title. The Author Index lists each author and the page number on which their abstract can be found.

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Table of Contents

Opening Remarks and Plenary 1 5

S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - I 5

S2: Integrated Energy Harvesting and Storage Systems for Wearables and IoT 6

S5: Piezoelectric and Triboelectric Energy Harvesting using Low-Dimensional Materials 7

S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - II 8

S7: Workshop in Devices, Materials and Structures for Energy Harvesting and Storage 9

Poster Session 10

Plenary 2 11

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - I 11

S4: Thermoelectric Energy Harvesting - I 13

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - II. 14

S4: Thermoelectric Energy Harvesting - II 15

Plenary 3 16

S6: Third generation Photovoltaic Technologies with emphasis on Perovskite Solar Cells and Modules 16

LATE BREAKING ABSTRACTS 18

Wednesday, September 7, 2022

Opening Remarks and Plenary 1

Room: Columbia/Frederick/Annapolis
Session Chair: Shashank Priya, Pennsylvania State University

8:20 AM

(EHS-PLEN-001-2022) A New Energy Solution with Triboelectric Nanogenerator for Powering Body-implantable Electronics

S. Kim*[1]

1. Sungkyunkwan University, Republic of Korea

In this presentation, I firstly introduce the fundamentals and possible device applications of TENGs, including their basic operation modes. Then the different improvement parameters will be discussed. As main topics, I will report transcutaneous ultrasound energy harvesting using triboelectric technology. Implantable medical devices (IMDs) are designed to perform or augment the functions of existing organs by using monitoring, measuring, processing units, and the actuation control. Conventional IMDs are powered with primary batteries that require frequent surgeries for maintenance and replacement. Therefore, IMDs require a new reliable and safe powering system to avoid the need for frequent surgeries. Recently my group demonstrated that ultrasound was used to deliver mechanical energy through skin and liquids and demonstrated that a thin inplantable vibrating triboelectric nanogenerator (TENG) is able to effectively harvest it. Ultrasound TENG (US-TENG) was triggered with an applied 20-kHz ultrasound at 3 W/cm2 reaching 9.71 $V_{(root\ mean\ square\ [RMS])}$ and 427 mA_{RMS}. The measured output current was enhanced two orders of magnitude compared with conventional TENGs, with a similar level of surface charge density, triggered in low-frequency mechanical environments.

S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - I

Room: Columbia/Frederick/Annapolis
Session Chair: Jungho Ryu, Yeungnam University

9:30 AM

(EHS-001-2022) Piezoelectric properties of the [001]-textured (Na, K)Nb-based lead-free piezoceramics and their application to piezoelectric energy harvesters (Invited)

S. Nahm*[1]; S. Go[1]; H. Kim[1]; D. Kim[1]; J. Eum[1]; S. Chae[1]; E. Kim[1]

1. Korea University, Department of Materials Science and Engineering, Republic of Korea

$0.96(Na_{0.5}K_{0.5})(Nb_{0.93}Sb_{0.07})O_3$-$(0.04-x)BaZrO_3$-$x(Bi_{0.5}Ag_{0.5})ZrO_3$ [NKNS-(0.04-x)BZ-xBAZ] piezoceramics are well textured along the [001] direction using 3.0mol% $NaNbO_3$ seeds. The textured-NKNS-0.02BZ-0.02BAZ piezoceramic has a rhombohedral-orthorhombic-tetragonal (R-O-T) structure with a large proportion of the O-R structure (> 80%). This specimen exhibits the largest values for d_{33} (805 pC/N) and $d_{33}\times g_{33}$ (29.5×10^{-12} m^2/N), which are the largest d_{33} and $d_{33}\times g_{33}$ values of NKN-based piezoceramics to date. It exhibits a large strain (0.17% at 4.0 kV/mm). Therefore, this specimen has an outstanding piezoceramic material for piezoelectric energy harvesters (PEHs). A PEH is fabricated using this specimen. The PEH shows a large power density (4.3 mW/cm^3), which is the largest value among the PEHs produced by lead-free piezoceramics. Therefore, texturing is an excellent technique for improving the piezoelectricity of NKN-based piezoceramics for PEH.

10:00 AM

(EHS-002-2022) Sustainable Bio-Engineered Magnetoelectric Nanogenerator to convert ambient stray magnetic noise to electricity

O. J. Achadu*[1]

1. University of Warwick, Chemistry&IAS, United Kingdom

We are surrounded by low-frequency magnetic fields generated by electrical power lines and consumer electronics. As a by-product of electric current flow, the stray magnetic field causes electromagnetic interference and noise pollution, threatening data security and human health. Similar to sunlight and wind energy, the abundant electromagnetic waste energy can be renewably harvested by using electromagnetic nanogenerators and converted into kinetic energy and useful electricity. Recently, bio-inspired commodity polymer hybrids utilizing bacteria and DNA, as fillers, exhibit high power output and an impressive energy conversion efficiency. This shed lights on the prospects of deploying bio-engineered piezoelectric polymers materials for fabricating energy generators and smart sensors. To overcome the current technical limitations of inorganic materials – based magnetic energy generators, our work develops soft and flexible magneto-mechano-electric (MME) generators by integrating novel 3D nanostructured magnetic materials to bio-organic-inspired semicrystalline organic piezoelectric polymers for efficient and sustainable magnetic energy harvesting and conversion.

10:20 AM

(EHS-003-2022) Effect of the metasurface on the output power of the piezoelectric energy harvester

Y. Chae*[1]; D. Kim[1]; H. Lee[2]; H. Seung[3]; M. Kim[4]; S. Nahm[1]

1. Korea University, Materials Science and Engineering, Republic of Korea
2. Korea Research Institute of Standards and Science (KRISS), Ultrasound Standards Team, Republic of Korea
3. Korea Research Institute of Standards and Science (KRISS), AI Metamaterial Research Team, Republic of Korea
4. Sungkyunkwan University, Materials Science and Engineering, Republic of Korea

Piezoelectric energy harvester (PEH) is generally operated at the off-resonance condition. However, the output power of the PEH at off-resonance is too small to drive the electric devices. It has been suggested that the metasurface, which can focus the input mechanical energy on the PEH, can be used for the enhancement of the output power of the PEH at off-resonance frequency. However, since the size of the metasurface is very large, it is difficult to utilize the metasurface to the realistic PEH. In this study, the add-on-type metasurface with the size of 190 mm × 80 mm was produced and the displacement of add-on type metasurface is 20 times larger than that of the normal metasurface. The add-on-type metasurface was combined to the PEH to increase the output power at off resonance condition. Various piezoceramics with the different $d_{ij}\times g_{ij}$ value have been synthesized and they were used to fabricate the PEHs. Furthermore, the output performance of the PEHs combined with metasurface has been investigated.

10:40 AM

(EHS-004-2022) Synergistic effect of room temperature gas sensors and piezoelectric energy harvesting (Invited)

C. Kang*[1]

1. Korea Institute of Science and Technology/Seoul National University, Advanced Materials Research Division, Republic of Korea

There is a need for the development of self-powered sensing networks that can utilize ambient environmental energy, because such systems have no reliance on batteries or other external power sources. We have developed nanostructured metal oxide gas sensors for low power consumption and vibration based piezoelectric energy generators (PEG) for self-powered. We proposed a novel approach using an ionic-activated sensing mechanism with systematic interpretations. Ionic conduction layers, hydroxide ions, was favorably formed on the SnO_2 surface depending on an applied voltage under humid conditions, significantly enhancing the NO_2 sensing performance. Ionic-activated gas sensors are considered to be promising candidates for enabling gas sensors to operate at 25. Herein, SnO_2 nanorods decorated with Au and Pd nanoparticles were fabricated using a glancing angle deposition method. their ionic-activated sensing properties were evaluated as a function of relative humidity (RH), operating temperature, and applied voltage. The self-powered sensing networks were designed by connecting ionic-activated Au-decorated SnO_2 nanorods with an oval-shaped PEG to generate constant and high DC signals. Our experimental results revealed a sub-parts-per-billion (4.32 ppb) detection level with a rapid and constant recovery time (6 s), regardless of the NO_2 concentration.

11:10 AM

(EHS-005-2022) Piezoelectricity of textured (K, Na)(Nb, Sb)O_3-$CaZrO_3$ thick films for use in piezoelectric energy harvesters

S. Chae*[1]; S. Nahm[1]

1. Korea University, Material Science and Engineering, Republic of Korea

A (K, Na)NbO_3 (KNN)-based lead-free piezoceramic for a piezoelectric energy harvester (PEH) should exhibit a large k_{ij}, Q_m, d_{ij}, and a small ε^T_{33} to generate a large power output. Texturing was used to enhance the piezoelectricity of KNN-based piezoceramics. In particular, the k_{ij} and d_{ij} values of the KNN-based piezoceramics were considerably improved after texturing along the [001] direction, with a small change in the $\varepsilon^T_{33}/\varepsilon_0$ value, indicating that the [001]-textured KNN-based thick films are good candidates for use in PEHs. The $0.97(K_{0.5}Na_{0.5})(Nb_{0.93}Sb_{0.07})O_3$-$0.03CaZrO_3$ [$KN(N_{0.93}S_{0.07})$-CZ] thick film was textured along the [001] direction, and this thick film showed a large k_p (0.57) and $d_{33}\times g_{33}$ (25.7 pm^2/N), which is the largest $d_{33}\times g_{33}$ of the KNN-based piezoceramics reported to date. A cantilever type PEH fabricated using the textured $KN(N_{0.93}S_{0.07})$-CZ thick film exhibited a power density of 21.4 $\mu W/mm^3$ at the resonance frequency. This is the highest power density observed for PEHs fabricated using lead-free piezoceramics. The PEH also exhibited a power density of 0.023 $\mu W/mm^3$ at the off-resonance frequency. Therefore, the [001]-textured $KN(N_{0.93}S_{0.07})$–CZ thick film is a good candidate for use in PEHs

11:30 AM

(EHS-006-2022) Power Source for Wireless Sensor Nodes: Evaluation of Piezoelectric Energy Harvesters Using Complex Beam Geometries

C. Gonzalez*[1]; I. Greeley[1]; A. Trinh[2]; J. Fox[3]; L. Lyle[3]; D. McKinney[4]; J. Deem[4]; M. Fanton[3]; D. Snyder[3]; R. Claus[4]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA
2. Pennsylvania State University, Department of Mechanical Engineering, USA
3. Pennsylvania State University, USA
4. Nanosonic Inc., USA

Wireless sensor nodes are being deployed in a variety of scenarios including buildings, bridges, transportation systems, and industrial machines where there is access to low frequency mechanical vibrations that can be tapped to generate electrical energy. There are multiple ways to convert mechanical energy into electrical energy such as piezoelectric, electromagnetic, triboelectric, electrostatic, and electrets mechanisms. However, the challenge in conversion of mechanical to electrical energy has been the low conversion efficiency and power density. In this paper, we provide a solution to these issues by developing a complex piezoelectric composite beam geometry. Experiments are conducted on a symmetric Arc-Based Cantilever (ABC). The maximum peak power output is investigated for piezoelectric ABC harvesters. The fabrication of complex geometry transducers is performed using piezoelectric macro-fiber composites (MFCs) bonded to a metallic substrate with elastic matching layers combined with a tip mass. A shaker is used to excite the transducers at the desired frequency. Two configurations are investigated with an input base acceleration of 0.1 g. The 102.5x102.5 mm^2 configuration achieves a peak power of 815.9 μW at 600 kΩ with a resonance of 10.1 Hz, while the 57x62 mm^2 configuration achieves a peak power of 13.7 μW at 250 kΩ with a resonance at 23.1 Hz.

11:50 AM

(EHS-007-2022) Magneto-Mechano-Electric Generator composed of magnetoelectric composite for IoT sensor driving (Invited)

J. Ryu*[1]

1. Yeungnam University, School of Materials Science and Engineering, Republic of Korea

The deployment of wireless sensor networks (WSNs) for the internet of things (IoT) and remote monitoring devices made tremendous progress in the last few years. Energy harvesters are being developed to satisfy the power requirement of WSNs and other low power consumption electronics. Among various resources for energy harvesting, the magnetic noise produced by power transmission infrastructures and associated mechanical vibrations are ubiquitous energy sources that could be converted into electricity by energy conversion materials or devices. In this presentation, the status and prospects of emerging magnetic energy harvesting technology, the so-called magneto-mechano-electric (MME) generators, are reviewed. A magneto-mechano-electric (MME) generator is an effective way to get improved electric power density using magnetoelectric (ME) composite composed of piezoelectric single crystal and magnetostrictive shim. Since the piezoelectric phase in the MME generator also responds to mechanical vibration directly, a ME-based energy harvester can harness energy from both mechanical vibrations and magnetic fields simultaneously. The MME generator can be a ubiquitous power source for WSNs and low power electronic devices by harvesting energy from the tiny magnetic fields present as parasitic magnetic noise in an ambient environment.

S2: Integrated Energy Harvesting and Storage Systems for Wearables and IoT

Room: Pratt/Calvert

Session Chair: Vikram Pakrashi, University College Dublin

9:30 AM

(EHS-008-2022) Lithium ion capacitors for self powered wearable health sensing platforms (Invited)

R. Rajagopalan*[1]

1. Pennsylvania State University, Engineering-Applied Materials Program, USA

Lithium ion capacitors with their high energy density, high power density and good cycle life can offer potential standalone energy storage solution when combined with renewable energy harvesting technologies to power wearable health sensor or Internet of things platform. The capacitor with its extremely low self-discharge rate and high load carrying capability can offer unique advantages for pulsed load current applications. The talk will describe electrode development to improve both the specific capacitance and rate capability of the device. The performance of the capacitor is mainly affected by the prelithiation process of the anode. We will compare the performance of a 13 Wh/L packaged 2016 Li-ion coin cell capacitor relative to rechargeable battery of similar form factor for use in wearable health sensor platform for continuous health monitoring. The opportunities and challenges to further develop the technology will be discussed in detail.

10:00 AM

(EHS-009-2022) Co-design Investigation of a Bottom-Hinged Oscillating-Surge Wave Energy Converter

J. Grasberger*[1]

1. Virginia Tech, Mechanical Engineering, USA

A traditional process for wave energy converter (WEC) design consists of determining an optimal geometry by examining hydrodynamics, then a control method to achieve resonance, and a power take-off (PTO) system to facilitate efficient energy transfer to a generator. This design process fails to consider the connectedness of the WEC system. Certain PTO configurations are more conducive to certain control methods, both of which affect optimal shape. Further, constraints, cost, and electrical power need to be considered to accurately model a realistic WEC. Co-design focuses on creating holistic designs that consider an entire system at once. For WECs, co-design requires consideration of geometry, PTO, and controls synchronously to lead to an optimal, holistic WEC design. This study applies co-design to a bottom-hinged oscillating-surge WEC with a linear PTO consisting of a drivetrain and generator and a proportional integral controller. A parameter sweep of height, width, and thickness of the device is carried out while optimizing the drivetrain, generator, and controller for each geometric design. Ultimately, an optimized geometry, PTO, and controller is identified which maximizes usable electrical power while minimizing cost. The concepts of co-design carried out within this study are versatile enough to be applied to any WEC type in order to design a realistic, optimized device.

10:20 AM

(EHS-010-2022) An Enhanced Variable Reluctance Energy Harvester for Self-powered Condition Monitoring

Y. Zhang*[1]; J. Cao[1]

1. Xi'an Jiaotong Univeristy, China

Condition monitoring plays an important role in some key rotational components of machines, such as bearing, shaft, or gear box. To maintain the work of wireless sensor networks, it is necessary to develop a self-powering method. Energy harvesting has attracted much attention to extract external rotational motion. However, due to the compact layout of rotational components, the energy harvesting performance is limited to space constraint. Therefore, an enhanced variable reluctance energy harvester is proposed for condition monitoring. A periodic arrangement of magnets and teeth is employed to achieve frequency up-conversion for performance enhancement under a specific space constraint. In addition, the permeance of air gap is calculated by the combined magnetic field division and substituting angle method, and the output model of the proposed harvester is established to predict the output performance according to the law of electromagnetic induction. The changing of magnetic flux in magnetic circuit is investigated to reveal the mechanism of the proposed harvester from finite element simulation. Experimental testing results show the high output performance of the proposed energy harvester, which can be verified to power wireless sensor nodes for self-powered monitoring in the occasion of low-frequency rotation.

S5: Piezoelectric and Triboelectric Energy Harvesting using Low-Dimensional Materials

Room: Pratt/Calvert

Session Chair: Miso Kim, Sungkyunkwan University

11:10 AM

(EHS-011-2022) Low-temperature crystalline $NaNbO_3$ thin film grown on $Sr_2Nb_3O_{10}$ nanosheets for piezoelectric energy harvesters

I. Kim*[1]; S. Nahm[1]

1. Korea University, Material Science and Engineering, Republic of Korea

The [001]-oriented crystalline $NaNbO_3$ (NNO) film was effectively grown on $Sr_2Nb_3O_{10}$/ Pt/SiO_2/Si (SN-PSS) at 250 °C. A $Sr_2Nb_3O_{10}$ (SN) monolayer served as a template for the growth of crystalline NNO thin films at low temperatures. This NNO film showed a small ε_r of 115, along with good insulating properties with a low leakage-current density (4.5×10^{-6} A/cm^2 at 0.3 MV/cm). This NNO film displayed a large d_{33} of 123 pC/N, which is the largest d_{33} value for NNO films to date. Moreover, it shows a very large $d_{33} \times g_{33}$ (14.8×10^{-12} m^2/N), which is the figure of merit for the power of piezoelectric energy harvesters (PEHs). The NNO film grown on SN/Ni at 250 °C for the fabrication of PEH demonstrated similar dielectric and piezoelectric characteristics. The NNO PEH shows a high power density (2.1 μW/mm^3), indicating that the [001]-oriented NNO film grown on the SN seed layer is a good material for use in a PEH. Moreover, this NNO film can be deposited on a polymer substrate and utilized as a future flexible device owing to its very low growth temperature and good physical properties.

11:30 AM

(EHS-012-2022) Ferroelectric-enhanced triboelectricity enables efficient acoustic energy transfer through liquid and solid media

H. Kim*[1]; S. Hur[1]; C. Kang[1]; J. Jung[2]; H. Song[1]

1. Korea Institute of Science and Technology, Electronic Materials Research Center, Republic of Korea
2. Inha University, Republic of Korea

As demands for portable electronic devices grow, wireless energy transfer (WET) has started to become readily available. Until now, studies on WET have been mainly based on the electromagnetic (EM) induction method using EM waves. However, it is still challenging to utilize current EM wave mediated WET in those areas where it is most needed: underwater, body-implant, and EM-shielded cases (liquid/metals). Acoustic energy transfer (AET) can be an alternative to EM-wave based WET. Here, we present a simple but powerful triboelectric AET module by tuning the work function of the triboelectric layer via the large polarization of the embedded relaxor single crystal. Additionally, uniform displacement, a quasi-mode oscillation, across the flexible electrode surface in response to the square wave has improved energy transfer efficiency. A systematic investigation was conducted for energy transferring conditions of receiving angle and ferroelectric polarization. We successfully demonstrated the transmission of 8 mW electric power at a distance of 6 cm underwater, which is sufficient to use in most demanding but inaccessible areas. In addition, AET is demonstrated and discussed in both liquids (underwater and in-body), and solids (metal, wood, and plastic). We anticipate that our approach will enable current next-level AET technology to be utilized in the actual field.

S1: Piezoelectric and Mechano-Magneto-Electric Energy Harvesting - II

Room: Columbia/Frederick/Annapolis
Session Chair: Jungho Ryu, Yeungnam University

1:30 PM

(EHS-013-2022) Significantly Enhanced Power Generation from Extremely Low-Intensity Magnetic Field via a Clamped-Clamped Magneto-Mechano-Electric Generator (Invited)

Z. Chu*[1]; S. Dong[2]

1. Harbin Engineering University, Innovation and Development Center, China
2. Peking University, China

A magneto-mechano-electric (MME) generator that can harvest ambient magnetic noise plays a significant role in powering Internet of Things (IoT) sensor networks. However, it is still a challenge to capture sufficient energy and continuously drive IoT nodes from extremely low-intensity magnetic noise below 1 Oe. To circumvent the close dependence of the resonant frequency on the magnetic proof mass in conventional MME generators, a new clamped-clamped (C-C) MME generator is proposed, that allows a much heavier magnetic mass to be attached at the beam center. Under weak magnetic fields of 0.48 and 0.96 Oe at 50 Hz, optimized output powers of 370 and 970 μWRMS, respectively are achieved, which shows an enhancement of ≈120% over that of cantilevered MME generators. The underlying mechanics are theoretically revealed by comparing the lumped parameters with a cantilevered MME generator and by calculating their deflection gain. Finally, it is demonstrated that the harvested energy from the proposed C-C MME generator from a 0.48 Oe magnetic field at 50 Hz is sufficient to continuously drive an IoT sensor without any additional intervals for recharging. Some perspectives for further study and discussions about the current limitation will also be included in this presentation.

2:00 PM

(EHS-014-2022) Bifurcation analysis of magnetic separation for optimal design of tuned vibration energy harvesters

P. Sosna*[1]; Z. Hadas[1]

1. Brno University of Technology, Faculty of Mechanical Engineering, Czechia

In the past decade, stiffness nonlinearities have become a hot topic in vibration energy harvesting. Apart from their main purpose, which is the increase in frequency bandwidth, they also make tuning of the system possible by altering a given system parameter. In this work, we present an analysis of a tuneable energy harvesting systems. The work is concerned with both the piezoelectric and electromagnetic transduction principles. The first system is a composite cantilever beam with additional permanent magnets with magnetic separation, manipulation of which allows for monostable and bistable behaviour as well as multi-periodic and chaotic responses. Bifurcation diagrams with magnetic separation are used in order to find the conditions when the power output is maximized. This way, the optimal design configuration is found, which is the fundamental framework for tuning. The second analysed system is electromagnetic VEH for train applications with a bistable configuration of additional magnets which is actuated by piezoelectric components. The tuning of load resistance is also analyzed and compared with untuned case. The responses of the nonlinear optimized harvesters show a large increase in bandwidth compared to the linear case. The usability and applicability of such tuning is discussed.

2:20 PM

(EHS-015-2022) Dynamics of a nonlinear energy harvester with subharmonic responses

G. Litak*[1]

1. Lublin University of Technology, Department of Automation, Poland

A frequency transmission band of the nonlinear energy harvester shall be studied numerically. For the analysis, the nonlinear piezoelectric energy harvesting system based on a cantilever elastic beam has been applied to harvest the kinetic energy of the moving frame. We used a double-well potential induced by permanent magnets for a ferromagnetic beam resonator. A piezoelectric patch attached along the beam was used as a transducer of the mechanical into electrical energy. It occurred that the system could work in a wide interval of frequency beyond the linear resonance. Besides the response with a period of excitation, solutions with dominating sub-harmonics of the harmonic inertial force excitation have been found. Particular solutions were illustrated, classified, and discussed using phase portraits and Fourier spectra of the output signals.
Supported by the program of the Polish Ministry of Education and Science under the project DIALOG 0019/DLG/2019/10 in the years 2019-2022

2:40 PM

(EHS-016-2022) Hybrid Magneto-Mechano-Electric energy generator with 2nd harmonic bending mode

S. Lee*[1]; J. Ryu[1]; G. Hwang[2]

1. Yeungnam University, Material Science and Engineering, Republic of Korea
2. Pukyong National University, Materials Science and Engineering, Republic of Korea

Condition monitoring by sensor communication and big data analysis are essential technologies in Internet of Things (IoT) epoch. Since the number of sensor nodes are drastically increasing, the powering them is one of the issues. Especially, autonomous powering device with energy harvesting is beneficial in the place where difficult to access, because it does not require periodic replacement or maintenance of batteries. This study introduces magnetic energy harvesting based on the Magneto-Mechano-Electric (MME) generator with hybrid energy conversion mechanisms. The cantilever-structured MME generator can induce mechanical deformation converted into electrical energy output from piezoelectric material under the magnetic field oscillation. For 2nd harmonic bending mode vibration, the magnet proof mass can be shaken at fixed position. By attaching electromagnetic (EM) induction coil nearby the proof mass, EM power generation can be utilized simultaneously. To maximize the output power, Finite Elements Analysis is used for optimization of piezoelectric plate location. Under 10 Oe at 129 Hz, hybrid MME generate can harvest more than 30 mW which is sufficient for the driving of wireless multi-sensor module. This signifies hybrid energy harvesting technology can maximize the output performance of MME generator.

3:00 PM

(EHS-017-2022) Miniaturized magnetoelectric energy harvester based on $(Fe_{1-y}Ga_y)_{1-x}B_x$ thin films

S. Sharma*[1]; S. Karan[1]; Z. Luyao[1]; K. Wang[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

In recent years, multi-source energy harvesters, that can simultaneously harvest energy from various ambient sources including magnetic field and vibration, have attracted a great deal of attention. In this regard, magnetoelectric (ME) devices that consist of layered magnetostrictive/piezoelectric heterostructures provide a promising approach. ME effect arises due to the coupling of ferromagnetic

and piezoelectric effects and is expressed as a change in polarization with respect to the applied external electric field and vice versa. The present work reports a highly efficient miniaturized magnetoelectric energy harvester by utilizing magnetostrictive/piezoelectric $(Fe_{1-y}Ga_y)_{1-x}B_x$ /AlN) thin film heterostructure. The developed energy harvesters show enhanced net power density and hold promising applications in the development of Internet of Things (IOT) devices including sensors.

S7: Workshop in Devices, Materials and Structures for Energy Harvesting and Storage

Room: Pratt/Calvert
Session Chairs: Shashank Priya, Pennsylvania State University; Grzegorz Litak, Lublin University of Technology

1:30 PM

(EHS-018-2022) Development of ultrafast supercapacitors (Invited)

W. Kim*[1]

1. Korea University, Department of Material Science and Engineering, Republic of Korea

Supercapacitors (SCs) such as electrical double-layer capacitors (EDLCs) and pseudocapacitors are promising energy storage devices owing to their high-power characteristics, long-term cycling stabilities, and high energy densities. For the last decade, ultrafast SCs have been investigated with the possibility of replacing the conventional aluminum electrolytic capacitors (AECs) used for alternating current (AC) line filtering applications. Owing to the more compactness and higher energy density of the ultrafast SCs compared to the AECs, the successful replacement of the AECs with the SCs can lead to the miniaturization of electronic devices. In this presentation, the strategies taken for the development of ultrafast ELDCs in our group and interesting discoveries made during the process are going to be introduced.

2:00 PM

(EHS-019-2022) Bi-directional water-stream behavior on multifunctional membrane for simultaneous energy generation and water purification (Invited)

J. Jang*[1]

1. Korea Institute of Science and Technology, Electronic Materials Research Center, Republic of Korea

Energy generation from environmental sources provides the promise of clean power for self-sustainable systems. Simultaneously, the technology of environmental source cleaning has been seriously considered. Widely known technologies such as solar cells, thermoelectric devices, and environmental cleaning techniques (e.g. water and air purification systems) required specific environments and usually developed independently. Here, for the first time, we rationally assembled the conductive materials (e.g. CNTs and PEDOT:PSS) and commercialized filtration membrane to facilitate the energy generation as well as water purification simultaneously (Electricity Generation and Purification Membrane, EPM). By using the water flow directions (perpendicular or horizontal water flow on EPM), the water source purification with energy generation characteristics were successfully achieved. Also, by employing the PAA/CMC composite binder to EPM, energy generation properties of our EPM were remarkably improved with exceptional mechanical stability in the water. More importantly, our EPM showed water purification characteristics (>90% rejection to sub-10 nm pollutants, and potentiality of angstrom level cation rejection) with continuous energy generation simultaneously.

2:30 PM

(EHS-020-2022) Additives and Solvents Engineering of Perovskite Solar Cells (Invited)

S. Kim*[1]

1. Korea University, Department of Material Science and Engineering, Republic of Korea

Perovskite solar cells(PSCs) have been attracting attention for several years due to their excellent optoelectronic properties, low processing cost, easy manufacturing process. However, improving the efficiency and long-term stability of PSCs still remain a challenge. Interfacial engineering and additive adding are widely used to reduce the interfacial loss process caused by surface recombination, improve the crystallinity of the active absorption layer, the work function of the contact layer, and the intimacy of the contact at the interface, as well as help the long-term stability of the solar cell. In order to investigate the role of additive for improving efficiency, $Pb(SCN)_2$, NH_4SCN and NaSCN were added as an additive to confirm the effect of SCN ions on the PSCs. Formamidinium cesium lead triiodide ($FACsPbI_3$) was chosen in this experiment. Current-voltage curve, X-ray diffraction, field emission scanning electron microscope, and UV-vis were measured to confirm the effect of thiocyanate ion on $FACsPbI_3$. It seemed that SCN^- is partly substituted for I^-, resulting in a $FACsPb(SCN)_3I_{3-x}$ perovskite. From results, thiocyanate ion is expected to be useful for fabricating $FACsPbI_3$ PSCs with high efficiency.

3:30 PM

(EHS-021-2022) Transparent thin film lithium ion batteries (Invited)

J. Choi*[1]

1. Korea Institute of Science and Technology, Center for Electronic Materials, Republic of Korea

Development of next generation devices such as smart lenses, wearable displays, and transparent displays have exerted pressure on the demand for manufacturing of transparent, high-efficiency, and thinner power source. Thin-film batteries have the advantages of size, shape tunable, thermal stability due to solid electrolyte, low self-discharge rate, and high battery efficiency. Also, thin film batteries can be integrated in microelectronic devices. The first part of this presentation is aimed at fabrication of flexible thin-film batteries for smart lens applications. Here, we design and demonstrate the flexible thin film batteries applied to contact lens form-factor, with direct fabrication on polymer substrates and single step low-temperature annealing. The battery utilized $LiFePO_4$ thin film cathode, LiPON electrolyte, and lithium metal anodes, demonstrates the energy storage capacity of 35 μWh under wet condition. The second part of the presentation is dedicated to studies of the transparent thin film batteries. All of the transparent battery research reported so far has a structure using an opaque micro pattern which is below the human eye resolution. This method has limitations such as complicated process, low energy density, and packaging system occupying a large volume. We have developed a battery in which all materials are transparent by laminating transparent battery materials.

4:00 PM

(EHS-022-2022) Autonomous resonance tuning mechanism for environmental adaptive energy harvesting (Invited)

H. Song*[1]

1. Korea Institute of Science and Technology, Electronic Materials Research Center, Republic of Korea

Energy harvesting technology that captures unused ambient energy and converts it into useful electrical energy can provide the most feasible solution for this problem. The piezoelectric method has been the most extensively investigated for energy harvesting due to its high-energy conversion efficiency, high energy density, and simple

integration with vibrating platforms. To maximize the power generated from vibrations, the energy harvester must operate at resonance since the displacement significantly reduces in off-resonance. In this talk, I will introduce novel strategies to achieve broadband operation through autonomous resonance tuning (ART) mechanisms that can automatically adjust their resonance frequencies by adapting to environments. First of all, I will introduce an idea for the ART mechanism employing the moving proof mass on a doubly clamped beam structure. I will discuss how the moving mass can provide the ART function both theoretically and experimentally. Second, the ART mechanism using the adaptive clamping system will be introduced, and discussed its operation mechanism and experimental validation in detail. The ART mechanisms were implemented only with mechanical principles without any additional energy consumption or human intervention and demonstrated that they can operate even in an actual frequency variant environment.

4:30 PM

(EHS-023-2022) Epitaxial Piezoelectric Thin Films on Si for Ultrasound Transducers (Invited)

S. Baek*[1]

1. Korea Institute of Science and Technology, Center for Electronic Materials, Republic of Korea

Secure authentication of one's identity is a major challenge in a modern society due to the increasing popularity of mobile devices (e.g. smart phones) that can not only store the owner's personal information but also allow banking transactions. A biometrics-based authentication system has attracted a great attention owing to its relatively high-security level and convenience. Current fingerprint recognition systems do not meet the required security level, optical sensors are hard to miniaturize and easily deceived, and capacitive detectors often fail to recognize the patterns by contamination. The ultrasound technology with pMUT (piezoelectric micromachined ultrasound transducer) is one of the most promising technologies to realize such a highly-secure biometrics-based authentication system for mobile electronics. The performance of pMUT is directly determined with the electromechanical property of the piezoelectric layer. Using conventional piezoelectric materials such as AlN, ZnO, and PZT, it is difficult to generate high power ultrasound that can penetrate into the skin to see veins. Therefore, it is highly desirable to integrate single crystalline relaxor-ferroelectrics, so-called giant piezoelectric materials, on Si substrate. I will discuss the recent progress on the epitaxial integration of $Pb(Mg,Nb)O_3$-$Pb(Zr,Ti)O_3$ thin films on Si, and the imaging of fingerprints and fingervein by ultrasound.

5:00 PM

(EHS-024-2022) Coaxial Piezoelectric Energy Generator (C-PEG) Yarn of Cu/PVDF-TrFE/ PDMS/Nylon/Ag (Invited)

W. Choi*[1]

1. Korea Institute of Science and Technology, Center for Opto-Electronic Materials and Devices, Republic of Korea

Continuous electrospinning deposition system was self-designed to produce coaxial type piezoelectric energy generator (C-PEG) nanofiber. Piezoelectric PVDF-TrFE nanofiber as an electroactive material was electrospun at a discharge voltage of 9~12 kV onto a simultaneously rotating and transverse moving Cu metal wire at an angular velocity of w_g=60~120 RPM. The piezoelectric coefficient d_{33} of the PVDF-TrFE nanofiber was evaluated by a piezoelectric force microscopy (PFM) and approximately -20 pm/V. As the applied pressure (P) was varied from 30 kpa to 500 kpa, the generated output voltage (V_G) increased according to the relationship exp(-aP) (a=0.41~0.57). The V_G values for ten and twenty pieces of C-PEG were V_G=3.9 V and 9.5 V at P=100 kpa, respectively. Such a large V_G of the C-PEG is considered to originate from the fact that it can generate a fairly high voltage due to the increased number of voltage collection points compared to a conventional two dimensional (2-dim) capacitor type of piezoelectric film or fiber device. C-PEG yarn was also fabricated via the dip-coating in a PDMS polymer solution, followed by winding with Ag-coated nylon fiber as an outer electrode. The current and power density of ten pieces of C-PEG yarn were correspondingly 22 nA/cm^2 and 8.6 mW/cm^3 at V_G=1.97 V, higher than previously reported values of 5.54 mW/cm^3 and 6 mW/cm^3.

Poster Session

Room: Harborview

6:00 PM

(EHS-P001-2022) Double-beams energy harvester with different flexibility of the beams

P. Wolszczak*[1]

1. Lublin University of Tecchnology, Department of Automation, Poland

We present the study of a system of two flexible mechanically or magnetically coupled beams. Piezoelements are placed on the beams, which convert the kinetic energy of vibrations into electrical energy. The system is tested in order to develop an energy harvester. Beam coupling causes a nonlinearity phenomenon that extends the effective frequency range. Various beam coupling systems were investigated, and the records were statistically analyzed in the time and frequency domains.

(EHS-P002-2022) Xenon flash-light annealing of $Pb(Zr,Ti)O_3$/ Metglas Heterostructure for effective Magnetoelectric (ME) coupling

J. Ye*[1]; P. Jakkapally[1]; A. Kumar[1]; D. Patil[1]; J. Lee[1]; J. Ryu[1]

1. Yeungnam University, Material Science & Engineering, Republic of Korea

Magnetoelectric (ME) composites are using the product combination of ferroelectric and magnetostrictive properties in a combined form of each constituents. In this research, dense ferroelectric PZT thick film is deposited on magnetostrictive Metglas substrate be aerosol-deposition (AD) route. The microstructure of ferroelectric ceramic film deposited by AD are typically consisted of nano-sized crystallites and highly disordered matrix phase, thus it requires thermal treatment for proper ferroelectric or piezoelectric properties. Traditional thermal treatment involves several problems, for example, long time, high energy loss, chemical reaction between ferroelectric film and metallic substrate and crystallization of amorphous phase in Metglas. In order to overcome these constraints, we proceed with photothermal treatment; Xenon flash annealing (XFA). It is a method of selective and effective thermal treatment in a short time for oxide film. The AD-PZT thick film was selectively annealed by XFA for higher ME coupling without deleterious interfacial reaction between PZT and Metglas. The dielectric and ferroelectric properties of film are improved through Xenon flash light thermal treatment, which make the extreme properties of ME coupling. The enhanced properties by AD and XFA will allow the ME material to be deployed more widely in the potential applications.

(EHS-P003-2022) Optimization of Antireflective Layers of Silicon Solar Cells: Studies of the Efficiency between Single and Double Layer at the reference wavelength

A. Diaw*[1]

1. Cheikh Anta Diop University, Physics, Senegal

The deposition of an antireflection coating (ARC) on the front side of the solar cells allows a significant reduction of the losses by reflection. It thus allows an increase in the efficiency of the cells. Various materials are used as an antireflection layer. For our studies, we focused on the deposition of some materials as an antireflection layer on the solar cell such as SiO_2, Si_3N_4, TiO_2, Al_2O_3, MgF_2, and studied the efficiency of the latter. A theoretical study of antireflection layers has shown that a single antireflection layer does not have as low a reflectivity as a double antireflection layer over a large wavelength range. Thus, our interest was focused on double and multiple antireflection layers. The influence of parameters such as the thickness of the layer (s) as well as the associated refractive indexes on the optical properties of the antireflective structure has been studied. It was found that there are optimal thicknesses and refractive indices for which the reflectivity of the antireflective system is almost zero over a wider or shorter range of wavelengths. The same phenomena are noted in the study of the external quantum efficiency of the solar cell with these materials.

(EHS-P004-2022) Preliminary modeling and prototyping of a scaled semi-submersible wind platform using tuned inerter dampers for vibration reduction

L. Hall[1]; R. Okuda*[1]; D. Lambert[1]; L. Zuo[1]

1. Virginia Tech, Mechanical Engineering, USA

Floating platforms are the key to expanding offshore wind beyond current limits of nearshore fixed bottom farms. However, these platforms introduce more complexity in the form of increased susceptibility to wave-structure interactions. Platform stabilization will help reduce stresses on the turbine, particularly in the tower and connection to platform, which would improve the longevity of the structure and reduce future maintenance costs. This study describes ongoing work in determining whether internal tuned inerter dampers (TIDs) may be useful in improving semi-submersible platform stabilization. TIDs may also provide a secondary benefit of wave-based power production from internal generators, which could be used to power turbine equipment and sensors. The team designed and manufactured a 1/50th scale model of a 15 MW turbine and platform, as well as a TID frame. Through MATLAB optimization codes, initial values for stiffness, mass, and generator damping were chosen and appropriate springs, weights, and generators were sourced for initial testing. It is expected that this will be an iterative process, and additional work is being completed for further optimization before the entire system will be brought to a wave tank. Instron machine testing has begun, which will be used to determine the potential power increase from internal power generation.

Thursday, September 8, 2022

Plenary 2

Room: Columbia/Frederick/Annapolis
Session Chair: Shashank Priya, Pennsylvania State University

8:05 AM

(EHS-PLEN-003-2022) Piezoelectric materials for mechanical energy harvesting applications

S. Zhang*[1]

1. University of Wollongong, ISEM, Australia

Energy harvesting technology which converts the ambient energy, such as mechanical/kinetic, thermal, wind and magnetic energies into electrical energy, has become a key research topic in the last decades, because of the ever-increasing demand for self-powered systems. Perovskite ferroelectric materials are at the heart of electromechanical devices, including the mechanical energy harvesting applications. $Pb(Zr_xTi_{1-x})O_3$ (PZT) solid solution system with morphotropic phase boundary (MPB) is the mainstay piezoelectric materials in last 70 years because of their good dielectric/piezoelectric properties, while the relaxor-PT ferroelectrics show superior properties far outperforming PZT ceramics, which are inherently associated with their unique local structural heterogeneity. Based on the above concept, recent developments have experimentally confirmed that modest changes in the polarizability of local structure, which is induced by the A-site donor dopants, such as rare earth Sm^{3+}, can be regarded as "seeds" to further enhance the dielectric properties. The modified relaxor-PT ceramics exhibit ultrahigh dielectric and piezoelectric properties, being on the order of 13,000 and 1500pC/N, respectively. This presentation will also survey other piezoelectric materials and discuss the figure of merits for their applications in energy harvesting.

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - I

Room: Pratt/Calvert
Session Chair: Chris Bowen, University of Bath

9:00 AM

(EHS-025-2022) Reliability study of piezoelectric energy harvesters for stable powering of Internet of Things sensor (Invited)

J. Jang*[1]; W. Yoon[1]; J. Choi[1]

1. Korea Institute of Materials Science, Department of Functional Ceramics, Republic of Korea

Piezoelectric single-crystal macro fiber composites (SFCs) based on lead magnesium niobate-lead zirconate titanate (Pb(Mg1/3Nb2/3)O3-Pb(Zr, Ti)O3, PMN-PZT) have been applied to vibrational or magneto-mechano-electric (MME) energy harvesters due to their high electromechanical properties, mechanical flexibility, and damage tolerance. Despite growing attention to improving the output power of SFC-based piezoelectric energy harvesters (PEHs), few dedicated studies on reliability have been reported. In this talk, an accelerated life test is applied to d32-type hard SFC-based MME/vibrational PEHs to efficiently estimate usable lifetime in a short period of time. Each failure mode is also assessed to identify vulnerable points that reduce the lifespan of SFC-based PEHs. In addition, the energy harvesting performance of the SFC-based PEHs is investigated by varying the temperatures from –20 to 70 °C and the relative humidity from 10 to 90% for potential outdoor applications. This study provides insight for evaluating and enhancing the reliability of PEHs as a basis for future practical application.

9:30 AM

(EHS-026-2022) Structural and dielectric properties of Nb_2O_5 doped $BaTiO_3$-$Bi(Mg_{1/2}Ti_{1/2})O_3$ multilayer ceramics capacitor for the application to electric automobile

H. Yu*[1]; S. Chae[1]; J. Eum[1]; S. Nahm[1]

1. Korea University, Republic of Korea

Nb_2O_5 added (1-x)$BaTiO_3$-x$Bi(Mg_{1/2}Ti_{1/2})O_3$ [(1-x)BT-xBMT] ceramics were sintered at various temperatures to develop the X8R multilayer ceramic capacitors (MLCC) for the application to the electric automobile. The 0.96BT-0.04BMT with 1.25 wt% of Nb_2O_5 ceramic sintered at 1150ºC showed the dense microstructure with the average grain size of approximately 2.0 μm. This ceramic also shows the large dielectric constant of approximately 2100 with the low dielectric loss of 1.7 %. The temperature coefficient of the capacitance (TCC) of this ceramic is ranged between – 1.73 % and -14.4 % at the temperatures between – 55 ºC and 150 ºC. Hence, this ceramic satisfied the requirements of the Electronic Industries Alliance X8R specification. Moreover, the change of the dielectric constant of this ceramic is very small of approximately 2.0 % at 6 kV/cm, implying that it has good reliability. Hence, this ceramic can be used as the MLCC for the electric vehicle. The MLCC consisting of five layers of 40-μm-thick 0.96BT-0.04BMT thick-films and Ag/Pd electrodes were fabricated at 1150 °C. No diffusion occurred between the Ag/Pd electrode and 0.96BT-0.04BMT thick-film. In this study, the detailed dielectric properties of this MLCC will be also discussed.

9:50 AM

(EHS-027-2022) Self-Biased Core-Shell Multiferroic Hexagonal ferrite-Ferroelectirc Nanofibers for Sensors and Energy Harvesters

Y. Liu[1]; P. Zhou[1]; G. Srinivasan*[1]

1. Oakland University, Physics, USA

This report is on coaxial nanofibers of hexagonal ferrites and ferroelectrics with a large magnetic anisotropy field that with acts as a built-in bias field, thereby eliminating the need for an external bias magnetic field for applications in sensors and energy harvesting technologies. We synthesized coaxial nanofibers of M-, Y-, or W-type hexaferrites and ferroelectric PZT or barium titanate (BTO) by electrospinning. Fibers with a diameter of 150-500 nm that contained M-type strontium ferrite (SrM), Y-type ferrite (Ni2Y or Zn2Y), or W-type ferrite (Zn2W or Co2W) and PZT or BTO were made and annealed at temperatures 700-1000 C. The fibers imaged by a scanning microwave microscope (SMM) showed fibers of uniform diameter with the expected core and shell structure. The ferroic order parameters for the core-shell fibers were much smaller than the measured values for pure ferrite and ferroelectric fibers. Measurements on the strength of direct-magnetoelectric (ME) interactions were done by static magnetic field induced polarization and low-frequency ME voltage coefficient in discs and 2D- and 3-D films assembled in a magnetic field. A very large ME response was measured in all of the films, even in the absence of an external magnetic bias field. Films made of the fibers are of interest use as miniature magnetic field sensors and for energy harvesting.

10:10 AM

(EHS-028-2022) Self-contained multi-source-based hybrid energy harvester

S. Karan*[1]; S. Priya[1]

1. Pennsylvania State University, Materials Science and Engineering, USA

Harvesting multiple ambient energies and storage at the same time using hybrid energy harvesting units is of great concern for wireless power transfer applications. Here, we have designed self-contained multi-energy harvesting (MEH) device is shown to effectively convert magnetic fields, vibration, and light into electricity, and can be able to charge the battery simultaneously during energy harvesting. The architecture is composed of a perovskite solar cell and battery integrated onto a magnetoelectric composite cantilever beam. The efficiency of the large-area perovskite solar cell is shown to reach 10.15% by selecting PET/indium tin oxide (ITO) as the cathode that reduces the charge recombination. The magnetoelectric composite beam is designed to include the effect of the mass and volume of the solar cell/battery on power generation. The designed MEH can capable to harvest the vibration and magnetic energy simultaneously in presence of solar irradiation. The generated power reached up to 30mW at 20kΩ external load resistance under 1g acceleration and 3mT applied AC magnetic field. The total output power generated by the MEH, including vibration, magnetic field, and solar stimuli is 127mW from a total surface area of 16.2 cm2. The above results can open a new impact on the design of the power sources for Internet of Things sensors and wireless devices.

10:30 AM

(EHS-029-2022) Hybrid Thermo-Magneto-Electric Generator coupled with Tribo and Pyroelectric effect

G. Lee*[1]; H. Choi[1]; C. Baek[1]; J. Ryu[1]

1. Yeungnam University, Material Science and Engineering, Republic of Korea

Since 40-60% of energy is wasted in low grade heat in our daily life, It could be a useful energy source if we can convert it into usable electricity. In this study, we introduce the thermo-magneto-electric generator coupled with piezo-tribo-pyroelectric effects(PTP-TMEG) that can convert waste heat into electric outputs from piezo, tribo and pyroelectric elements coupled in. The PTP-TMEG is comprised of heat exchanger and actuating parts. The heat exchanger part consists of hot side Peltier plate combined with permanent magnet (NdFeB) and cold side Peltier plate. The actuating part is the composite of three energy conversion materials, i.e., piezoelectric cantilever (macro fiber composite) coupled with triboelectric materials (PFA and Aluminum) and soft magnetic material (Gd). The pyroelectric material (PMNZT single crystal) is embedded inside of Gd. It takes advantage of the cyclic magnetic forces of attraction and repulsion arising through ferromagnetic-to-paramagnetic phase transition of the soft magnet is repeated while the actuation part reciprocates between hot permanent magnet and cold side. During reciprocation of soft magnet, the mechanical energy, electron flow and temperature change are converted into electrical energy through piezoelectric cantilever, triboelectric and pyroelectric material. PTP-TMEG were shown to achieve high vibration frequency at small temperature gradients.

10:50 AM

(EHS-030-2022) Analysis of Smart Metamaterial Structure for Sensing and Energy Harvesting

F. Ksica*[1]; Z. Hadas[1]; L. Pincek[1]; P. Marcián[1]; M. Hrstka[1]

1. Brno University of Technology, Czechia

This contribution presents a complex analysis of an auxetic metamaterial structure that exhibits unique behaviour due to its negative Poisson's ratio and precise force transmission. The cellular composition of the structure allows for implementation of piezoelectric transducers that can be utilized for sensing and energy harvesting purposes. Such transducers are integrated in the form of PZT stacks, and their response and sensitivity enhanced by the inherent mechanical properties of the structure are essential for evaluation of the applied load. The key electrical and mechanical parameters are determined via comprehensive experimental testing, numerical simulations and analytical modelling, and potential technical applications in the respective fields are explored. The geometry and topology of the cells, as well as evaluation of most suitable manufacturing methods, are subjected to further optimization with respect to utilization as a building block in more complex spatial structures. Smart structures based on metamaterials represent a novel engineering philosophy and their proper design opens up various interesting possibilities for new generation of sensing and energy harvesting devices.

11:10 AM

(EHS-031-2022) Monitoring Hawkmoth Octopamine Levels During Flight with a Millimeter-Scale Luminiscense-Photodetector Implant

Z. Luyao*[1]; K. Wang[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

Monitoring of neuroamine levels is essential to understanding the manifestation of information flow across the neural networks, brain, and body. As one of the staple neuroamines for Hawkmoth, octopamine plays a significant role in life movement. Existing systems for monitoring octopamine levels are limited by the lack of in-situ measurement, the possibility of electrochemical damage, or the inability to provide real-time data. In this work, we developed an implantable millimeter-size sensor based on up conversion nanoparticle and polymer photodetector, in which the former has the luminescence intensity inversely proportional to the octopamine level, and the latter converts the luminescence into a closed-loop current signal spontaneously. The present sensor shows a response time of 1.6 seconds under a constant infrared laser excitation at 980

nanometer with a good log-linearity between octopamine level and current within 10 to 500 nanomole. The measured octopamine levels distinguish the flying or non-flying states of Hawkmoth during the flight. Our system provides a facilitate way for tracking the vivo octopamine levels and further investigation of octopamine-involved behaviors.

S4: Thermoelectric Energy Harvesting - I

Room: Columbia/Frederick/Annapolis
Session Chair: Bed Poudel, Pennsylvania State University

9:00 AM

(EHS-032-2022) Thermoelectric ceramics based on $Ca_3Co_{4-x}O_{9+\delta}$ and large plate-like oxides (Invited)

A. Feldhoff*[1]; Z. Zhao[1]; M. Wolf[1]; M. Jakob[2]; O. Oeckler[2]; R. Hinterding[1]
1. Leibniz University Hannover, Institute of Physical Chemistry and Electrochemistry, Germany
2. University of Leipzig, Institute of Mineralogy, Germany

Among thermoelectric oxides, p-type $Ca_3Co_{4-x}O_{9+\delta}$ (CCO) is well-known for its high power factor combined with a low thermal conductivity. To enhance the thermoelectric properties of CCO, we investigated the influence of individually adding perovskite-related oxides such as the mixed ionic-electronic conductor $La_2NiO_{4+\delta}$ or the large bandgap semiconductor $Na_2Ca_2Nb_4O_{13}$ to obtain sintered composite ceramics. All three oxides are characterized by layered structures and therefore anisotropic transport properties (thermal and electrical). To benefit from a preferred orientation in a textured green body, gained by uniaxially pressing, the added oxides were synthesized as large anisotropic plate-like crystals in the size of several microns using molten-flux synthesis. Extensive microstructural and functional analyses of the composite ceramics were performed, which showed the influence of the added phases on the thermoelectric properties and enabled the identification of reaction products between CCO and the added phases. As a result, multiphase composite ceramics with enhanced thermoelectric properties were obtained. Compared to pure CCO, in the temperature range of 373 to 1073 K, the average thermoelectric figure could be improved by 20% in case of $La_2NiO_{4+\delta}$ additive and by 28% in case of $Na_2Ca_2Nb_4O_{13}$ additive.

9:30 AM

(EHS-033-2022) Thermomagnetic energy conversion and refrigeration for low-temperature applications (Invited)

M. Zebarjadi*[1]; M. Akhanda[1]
1. University of Virginia, Electrical and Computer Eng., USA

An applied temperature gradient and a perpendicular magnetic field results in a Nernst voltage response normal to both. The Nernst voltage is analogous to the Seebeck voltage and is the base of thermomagnetic energy conversion. We studied a variety of samples to fundamentally understand what parameters affect the Nernst voltage response. Here, I will present a summary of our studies on different classes of materials. A to temperature-induced phase transition in, a type-II Weyl semimetal is studied using temperature-dependent X-ray diffraction, resistivity, and Seebeck coefficient measurements. The Nernst coefficient in exhibits a topologically induced enhancement at low temperatures. A relatively large phase-transition induced Thomson coefficient of 111 is measured at 254 K. The Nernst coefficient is not limited to inorganic samples and is observable even in organic ones. We measured a Nernst coefficient of 11.2 $\mu V.K^{-1}T^{-1}$ at 80 K in P3HT bar-shaped polymers doped with F4TCNQ, which constitutes the highest value for organic materials to date.

10:00 AM

(EHS-034-2022) Conformal High-power-density Half-Heusler Thermoelectric Modules: A Pathway towards Practical Power Generator

W. Li*[1]; A. Nozariasbmarz[1]; R. Kishore[2]; H. Kang[1]; H. Zhu[1]; B. Poudel[1]; S. Priya[1]
1. Pennsylvania State University, Materials Science and Engineering, USA
2. National Renewable Energy Laboratory, USA

Thermoelectric generators (TEGs) exploiting Seebeck effect, provide a promising solution for waste heat recovery. Among large number of thermoelectric (TE) materials, half-Heusler (hH) alloys are leading candidates for medium to high temperature power generation applications. However, the fundamental challenge in this field has been insufficient power output from the modules, and rigid form factor of TE modules, which restricted the transition of TEGs in practical applications for over three decades. Here, we successfully demonstrate high-temperature high power conformal hH TE modules and their direct integration on flue gas platforms to form large area flexible TEGs. This new conformal architecture design provides a breakthrough towards to medium/high temperature TEGs over the conventional flexible TEGs design. Variable fill factor and greater flexibility due to conformal design results in higher device performance as compared to conventional rigid TEG devices. Modules with 72-couple hH legs exhibit device high-power-density of 3.13 $W\text{-}cm^{-2}$ and a total output power of 56.6 W under temperature difference of 570 °C. These results provide a promising pathway towards widespread utilization of thermoelectric technology into the waste heat recovery application and will have significant impact on the development of practical thermal to electrical converters.

10:20 AM

(EHS-035-2022) Numerical modeling assisted thermoelectric device design optimization

G. Goyal*[1]; B. Poudel[1]; A. Nozariasbmarz[1]; W. Li[1]; Y. Zhang[1]; S. Singh[1]; S. Priya[1]
1. Pennsylvania State University, Materials Science and Engineering, USA

Multiphysics finite elemental analysis (FEA) tools (e.g., COMSOL) can be used to optimize a thermoelectric (TE) module's dimensions, fill factor, TE leg aspect ratio, relative dimensions of the n and p-legs, based on the application specific hot, and cold side temperatures, ambient atmospheric conditions etc. Such numerically modeled TE module parameters are expected to result in better power output and/or efficiency from the module. Depending upon the application, which may demand either higher power, or higher efficiency, the parameters may be estimated to be applied and tested experimentally.

10:40 AM

(EHS-036-2022) There is Plenty of Room for Higher Thermoelectric Performance in Half-Heusler Alloys (Invited)

M. Mitra[1]; A. Benton[4]; M. Akhanda[2]; M. Zebarjadi[2]; D. J. Singh[3]; J. Poon*[1]
1. University of Virginia, Physics, USA
2. University of Virginia, ECE, USA
3. University of Missouri, Physics, USA
4. Clemson University, Dept. of Physics & Astronomy, USA

Half-Heusler phases exhibit high thermoelectric (TE) power factor, good thermal stability, and scalability. Familiar Half-Heusler (HH) alloys that contain refractory metals Ti, Zr, and Hf, herein called "common HH alloys", have emerged as promising TE materials at intermediate temperatures ~400-800 °C. HH-based TEG composed of 49 n-p couples demonstrated a conversion efficiency of 9 % and delivered a power output of 50 W with a power density of 3.55 W/cm^2. Three-stage module was shown to have a power density ~10 W/m^2. To date, high TE performance represented by dimensionless figure of merit, ZT, in the range of 1-1.5 is achieved through alloying, nanostructuring, and band structure engineering to increase the power factor, while independently decreasing the thermal conductivity. Recently, we have employed conventional doping using small amounts of ordinary dopants to achieve ZT of 1.3 -1.5 in some common n-type and p-type alloys based on ZrNiSn and ZrCoSb, respectively. The discovery of high ZT in these seemingly exhausted alloys via conventional doping indicates that the potential for higher thermoelectric performance has yet to be uncovered in Half-Heusler alloys. Collaborators: Mousumi Mitra (Physics, UVA), Allen Benton (Physics, Clemson U.), Sabbir Akhanda (ECE, UVA), Ji Qi (Physics, UVA), Mona Zebarjadi (ECE & MSE, UVA), David Singh (Physics, U. Missouri), Joseph Poon (Physics & MSE, UVA)

11:10 AM

(EHS-037-2022) High Thermoelectric Performance Materials for Cooling Application

Y. Zhang*[1]; B. Poudel[1]

1. Pennsylvania State University, USA

Solid-state thermoelectric devices can directly convert electricity into cooling or enable heat pumping through the Peltier effect. The commercialization of thermoelectric cooling technology has been built on the Bi_2Te_3 alloys, which have had no rival for the past six decades around room temperature. With the discovery and development of more promising material science, it is possible to move thermoelectric cooling technology towards further stage.

11:30 AM

(EHS-038-2022) Recent Development of High-Performance Thermoelectric Silver Chalcogenides for Energy Harvesting

S. Singh*[1]; K. Hirata[2]; A. Nozariasbmarz[1]; T. Takeuchi[2]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA
2. Toyota Technological Institute, Energy Materials, Japan

The development of thermoelectric generators for alternate energy is currently a major focus for many applications such as sensors, electronic gadgets, and wearable devices that requires improvement of thermoelectric figure of merit, ZT. Besides, if these materials are flexible, the number of applications would be significantly enlarged. Recently, Ag_2S is found to be an interesting material, showing very low thermal conductivity and a large Seebeck coefficient. However, due to the large electrical resistivity, ZT is low. To improve ZT, partial substitutions of Se and/or Te are investigated. The ductile nature of Ag_2S was found to be excellent with Se substitutions at the sulfur site for $Ag_2S_{1-x}Se_x$ ($0 < x < 0.55$) compositions, and the ZT of ~0.6 at 300 K is achieved. Also, these materials show a large change in thermal conductivity across phase transition. Although the value of ZT is significantly improved, there are limited studies on compositional optimization of Ag_2S in order to tune the thermoelectric properties and phase transition temperature. In this study, the TE properties and the effect of annealing on ZT are studied. The magnitude of thermal conductivity and phase transition temperature both are tunable by changing the composition. Additionally, utilizing these properties enables highly efficient thermal diodes and rectifiers for future thermal management applications.

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - II

Room: Pratt/Calvert

Session Chair: Chris Bowen, University of Bath

1:30 PM

(EHS-039-2022) High-voltage management in triboelectric kinetic energy harvesters (Invited)

P. Basset*[1]

1. Univ Gustave Eiffel, CNRS, ESYCOM lab, France

Triboelectric contact is a simple way to charge the electret of an electrostatic kinetic energy harvester. Unlike traditional techniques such as the corona effect or soft x-rays, triboelectric charging does not need to be performed during the fabrication of the device. On the contrary, it allows a regular renewal of the charges trapped in the tribo-electret layer “at work”, which can compensate for the tendency of the electret charges to release over time. However, the resulting built-in voltage of the TENG (for Tribo-Electric-Nano-Generator), can be very high, up to several hundred, if not thousands, of volts. It may results in an even higher DC output voltage, depending on the rectifier chosen and the max/min capacitance ratio of the TENG, which may not be suitable for most applications that typically require a few volts to power a device. On the other hand, poor triboelectric materials, low friction or low variation in TENG capacitance can result in low output voltage generally associated with low energy conversion efficiency. In this presentation, we will discuss how to handle these different possibilities. In particular, we will show how an unstable charge pump can compensate for the low built-in voltages of (tribo)-electret layer and how plasma-switches can handle high output voltages in a DC-DC down converter.

2:00 PM

(EHS-040-2022) Search of Gd-based Alloys for Development of Thermomagnetic Devices for Energy Harvesting

S. Singh*[1]; N. Liu[1]; Y. Zhang[1]; S. Karan[1]; A. Nozariasbmarz[1]; W. Li[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

Power generation in the form of a clean source of energy is the most desirable need of human society for a wide range of applications. For the active operation of several electronic gadgets, typically a few mW is required, which can be generated from waste heat energy via thermomagnetic phenomenon. Gadolinium (Gd) is one of the best thermomagnetic materials which shows a large magnetic moment (7.29 mB) with magnetic phase transition near room temperature, and large thermal conductivity of 8 $Wm^{-1}K^{-1}$. With optimized geometric shape, thermomagnetic devices made of single crystal and polycrystalline Gd material have been earlier reported with h_{rel} (DT = 5 K) equal to 20.5 and 11.4%, respectively. For a wide range of applications, materials with a large magnetic moment, large thermal conductivity, and different phase transition temperatures are highly desirable. To find the best suitable materials, screening of materials with first principle-based calculations are performed. The effect of magnetic element doping on Gd and Gd (Si,Ge) based alloys is carried out using Korringa–Kohn–Rostoker (KKR), and Quantum espresso codes. The magnetic moment as a function of different doping levels and curie temperature is estimated. In this meeting, the results obtained from computational work and the practical applicability of a thermomagnetic device with the best performance will be presented.

2:20 PM

(EHS-041-2022) Templated Grain Growth of Mn-doped PYN-PMN-PT piezoelectric ceramic

D. Lee*[1]; C. Kang[1]; S. Nahm[2]; H. Song[1]

1. Korea Institute of Science and Technology, Electronic Materials Research Center, Republic of Korea
2. Korea University, Dept. of Materials Science & Engineering, Republic of Korea

Piezoelectric materials exhibit the best electrical properties when they are single crystals However, the single crystals have serious drawbacks of poor mechanical properties and high cost due to a long growth time. As the alternative to single crystals, grain-oriented polycrystal ceramics have been great attention through Templated Grain Growth (TGG). For high power applications, piezoelectric materials should have "hard" piezoelectric properties of high mechanical quality factor (Qm) and low dielectric loss (tan δ) as well as "soft" properties of high strain coefficient (d) and high electromechanical coupling coefficient (k). However, these two characteristics are difficult to achieve at the same time because they are a trade-off relationship. In this study, we tried to improve soft properties while maintaining high hard properties through TGG of hard piezoelectric ceramics. Mn-doped Pb(Yb1/2Nb1/2)O3–Pb1/3Nb2/3)O3–PbTiO3 (PYN-PMN-PT) ternary hard ceramics were oriented in the <001> direction employing BaTiO3 platelet templates. Through the TGG process, the d33 property improved while maintaining the high Qm properties of the matrix materials. Thus, we believe that the TGG method is an effective way to make high-power applications such as ultrasonic transducers by engineering the microstructure of hard piezoelectric ceramics.

2:40 PM

(EHS-042-2022) Developing Ti-Ni-Cu shape memory alloys for low-grade heat engine application

N. Liu*[1]; W. Li[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, USA

Shape memory alloys (SMAs) has become a good candidate to convert the low-grade thermal waste (<100 °C) to the mechanical energy/electrical energy as applied to heat engine. Such materials are predicted to outperform thermoelectric materials' conversion efficiency in temperatures below 100 °C. SMAs undergo shape memory characteristic accompanying with the transformation between martensite and austenite phases provoked by the heating-cooling cycle. The high rate of phase transformation, low hysteresis and high recoverable strain of SMAs are necessity conditions for manufacturing high-efficiency and low-fatigue heat engine. The drawbacks of commercially used Nitinol SMAs are the weak mechanical properties-fatigue resistance and their high thermal hysteresis. Hence, developing novel SMAs candidates for heat engine application turn to be increasingly significant. In this presentation, we discuss about the Ti-Ni-Cu SMAs systems which performed a phase transformation below 100 °C, high thermal cycles, and low thermal hysteresis by properly tuning the composition and thermal-mechanical treatments.

3:00 PM

(EHS-043-2022) Refractory high entropy alloy: A potential candidate for high temperature structural material

L. Raman*[1]; W. Li[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Material Science and Engineering, USA

The efficiency of a system can be improved if the operating temperature of the material can be increased. These high-temperature structural materials operate under conditions which are drastically and significantly different from those whose service conditions are at or near room temperature. The discovery of more promising compositions for high temperature applications resulted in a paradigm shift in the alloy design strategy, which gave birth to refractory high entropy alloys (RHEAs). RHEAs show considerable potential as ultra-high temperature materials due to their high melting point (> 2000 °C), and unique property of strength retention. However, high density, poor oxidation resistance and lack of adequate ductility at ambient temperature are the drawbacks of RHEAs. The high melting temperature and poor oxidation resistance of refractory alloys render casting practices involving vacuum or electron beam melting expensive. Hence, powder metallurgy (mechanical alloying followed by spark plasma sintering) processes must be resorted to, where the end powders' purity is a major concern. Here, we have tried to synthesis a RHEA through both routes to understand the influence of synthesis route on the microstructure and property.

S4: Thermoelectric Energy Harvesting - II

Room: Columbia/Frederick/Annapolis

Session Chair: Bed Poudel, Pennsylvania State University

1:30 PM

(EHS-044-2022) Towards efficient tuning of the thermoelectric properties in oxide materials (Invited)

A. Kovalevsky*[1]

1. CICECO - Aveiro Institute of Materials, University of Aveiro, Department of Materials and Ceramic Engineering, Portugal

Oxides attract considerable attention as a promising alternative to traditional thermoelectrics. These materials allow high-temperature operation and possess unique redox flexibility, offering the possibility to operate in various atmospheres. Although their conversion efficiency is considerably lower, their known structural and microstructural versatility can open new horizons for thermoelectric applications. This work reviews some representative cases of engineering the composition and microstructure of oxides towards high thermoelectric performance. The selected approaches will include laser processing, in-situ formed composites, defects tailoring and aluminothermy-boosted sintering, also taking into account the unique redox-tuning capabilities of oxides. Representative examples will include ceramic materials based on $SrTiO_3$, ZnO, $CaMnO_3$ and $Ca_3Co_4O_9$.

2:00 PM

(EHS-045-2022) Improved Thermoelectric Performance by using Distributed Transport Properties to Reduce the Detrimental Effects of Joule Heating (Invited)

D. Crane*[1]; B. Madigan[1]; L. Bell[1]

1. DTP Thermoelectrics, USA

With today's TE materials, optimal structuring of spatially distributed transport properties (DTP) within TE elements can produce TE systems with increased maximum temperature differentials, higher operating efficiencies, and increased heat pumping capacities. Introduction of position-dependent Thompson effect within the elements can partially offset detrimental distortion of the temperature profiles Joule heating produces. This, combined with locally optimized thermal and electrical transport properties, increases TE element efficiency and thermal power pumping capacity. We describe the unique behavior of DTP TE material systems in which TE elements incorporating available TE material with peak ZT at higher temperatures is used at the low temperature side in combination with material with peak ZT at colder temperatures is used at the high temperature side. We report on recent experimental results that quantify performance improvements in maximum temperature difference, coefficient of performance (COP), and cooling capacity. An update is provided on the development of materials specifically optimized for DTP purposes along with their projected further contributions to TE device performance.

2:30 PM

(EHS-046-2022) Introducing Perovskites as Capable Thermoelectric Materials

A. Nozariasbmarz*[1]; Z. Luyao[1]; B. Poudel[1]; K. Wang[1]; W. Li[1]; Y. Zhang[1]; S. Priya[1]

1. Pennsylvania State University, Materials Science and Engineering, USA

Halide perovskites have emerged as a new material class in multiple energy conversions research fields such as photovoltaics, photodetection, light emission/, memristor, ferroelectric, and photothermal conversion due to their exceptional combination of optoelectronic and charge carrier transport. However, thermoelectric properties of halide perovskites have received limited attention despite their capability. Halide perovskites are classified as having phonon glass, electron crystal. They have ultralow thermal conductivity and superior Seebeck coefficient coupled with decent mobility and charge carrier tunability. However, they suffer from instability, poor electrical conductivity, and small power factor. Among halide perovskites, Pb- and Sn-based materials have shown better thermoelectric properties to date. For future thermoelectric applications, reliable materials synthesis methods and thermoelectric property measurements are required. In this talk, we introduce perovskites as a new thermoelectric materials system and discuss research capabilities and future perspectives on these materials systems.

2:50 PM

(EHS-047-2022) Thermoelectric thin films fabricated using RF magnetron sputtering technique

S. Sharma*[1]; B. Poudel[1]; S. Priya[1]

1. Pennsylvania State University, Material Science and Engineering, USA

Thermoelectric (TE) thin films offer a wide range of applications in the fabrication of portable/wearable electronic devices owing to their small size and light-weight. Among the various semiconducting chalcogenides, Bismuth telluride (Bi_2Te_3) and Antimony Telluride (Sb_2Te_3) are well-known low-temperature thermoelectric materials that are used in a wide range of thermoelectric generators and coolers. Present work reports the growth and optimization of Bismuth telluride (Bi_2Te_3) and Antimony Telluride (Sb_2Te_3) thin films using the magnetron sputtering technique. The fabricated thin films possess a high Seebeck coefficient and larger Power factor, which indicates their potential application in high-performance thermoelectric devices.

3:10 PM

(EHS-048-2022) Development of high temperature and high performance thermoelectric devices for power generation

B. Poudel*[1]; W. Li[1]; A. Nozariasbmarz[1]; Y. Zhang[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

Thermoelectric generators (TEGs), which are solid state devices converting thermal energy into electrical energy, are promising solution for waste heat recovery. However, there are challenges to realize them in economically viable way such as low conversion efficiency, lack of reliable high temperature device fabrication process and long-term stability. In order to realize an efficient and reliable thermoelectric power generation, it is critical that in conjunction with high TE materials figure of merit, zT, there is also a reliable TE module fabrication process. In this presentation, I will discuss the important considerations and techniques that have been successfully applied in reliable and efficient module fabrication. We will discuss the TEG fabrication process that results in low thermal and electrical contact resistances between metal electrodes and TE legs that are compatible to high application temperatures, 600 C. The fabrication approach is demonstrated in Bismuth Tellurides and half-Heusler TE materials systems. High temperature brazing material is used as a filler that enables direct bonding of TE legs to the copper electrode without metallizing legs in half-Heusler TE materials. These results are highly promising for advancing the TE modules in waste heat recovery applications.

Friday, September 9, 2022

Plenary 3

Room: Columbia/Frederick/Annapolis
Session Chair: Shashank Priya, Pennsylvania State University

8:05 AM

(EHS-PLEN-002-2022) Materials-related Strategies for Highly Efficient Triboelectric Energy Generators

S. Kar-Narayan*[1]

1. University of Cambridge, Department of Materials Science, United Kingdom

Triboelectric energy harvesting technologies have received a substantial amount of attention as they constitute one of the most efficient ways of transforming vibrational and frictional energy into electrical energy, regardless of location and environmental conditions. One of the most significant advantages of this technology is in the suitability of a very wide range of materials that can be readily incorporated into devices. To achieve efficient energy harvesting performance, advances in materials science and nanotechnology have been applied to develop high-performance triboelectric nanogenerators. I will discuss materials-driven progress related to triboelectric energy harvesting, with emphasis on the study of materials-related operating mechanisms and emergent materials design strategies for highly efficient triboelectric devices. I will focus on the role of polymer crystallinity and surface polarization in determining the triboelectric energy harvesting properties of polymeric nanowires. As an example, the strong hydrogen bonding in α-phase nylon-11 serves to enhance the molecular ordering, resulting in exceptional intensity and thermal stability of surface potential, and consequently enhanced triboelectric performance compared to other polymorphs of nylon-11.

S6: Third generation Photovoltaic Technologies with emphasis on Perovskite Solar Cells and Modules

Room: Columbia/Frederick/Annapolis
Session Chair: Kai Wang, Pennsylvania State University

9:00 AM

(EHS-049-2022) Perovskite solar module: Efficiency and operational stability (Invited)

W. Nie*[1]

1. Los Alamos National Laboratory, USA

Solar to electricity conversion technology is one of the promising clean energy generation techniques to address the global energy consumption crisis. Lead halide perovskites-based photovoltaics have recently undergone an unprecedented surge in the power conversion efficiency improvements, and are at the edge for commercialization. In this talk, I will discuss our progress in perovskite photovoltaic module development using a additive assisted dip coating method. The additive greatly widens the processing time window allowing for a uniform perovskite film deposition over a large area. As a result, a mini module with power conversion efficiency of 16 % was demonstrated. Next, I will discuss the perovskite solar cell's operational lifetime under various gas environment. When exposing the solar cell under various gas mixture environment, we observed an interesting device degradation

behavior upon constant white light illumination. And the device performance can be restored once the light is removed. And we also discovered that the relative humidity plays a central role in accelerating the device degradation process and recovery effect. Finally, I will focus on the 2D perovskite materials for photovoltaics and talk about the carrier transport properties.

9:30 AM

(EHS-050-2022) Indoor/Outdoor Performance Tracking of Metal-Halide Perovskite Photovoltaic Modules (Invited)

N. Doumon*[1]; J. Berry[2]; L. Schelhas[2]

1. National Renewable Energy Laboratory, Chemistry & Nanoscience, USA
2. National Renewable Energy Laboratory, USA

The increasing global demand for energy and the challenge of reducing carbon emissions have prompted the development of numerous alternative energy technologies, emphasizing renewable sources. Metal-halide perovskite materials for photovoltaics (cells and modules) are viable in this direction. They offer many potentials due to their compatibility with flexible substrates, solution-processing, high efficiency, and thus, a promise of a low-cost renewable energy source. A little over a decade of intensive research into the enormous potential of these materials led to high record efficiencies of 25.7% at the single junction cell level with 29.8% for multijunction cells. However, to date the number of reported studies of devices in outdoor conditions is small relative to the large volume of work on these materials for photovoltaics. Additionally, upscaling of production will require faster techniques to monitor the quality and performance of the modules during the production and certification before hitting the market. This talk attempts to unveil works currently being carried out in two collaborative projects to understand these challenges, namely (i) development of accelerated indoor testing protocols for modules reliability, (ii) monitoring of modules' outdoor performance, (iii) reconciling indoor and outdoor data, and (iv) in-depth characterization of the perovskite films, cells, and modules.

10:00 AM

(EHS-051-2022) Development of perovskite solar cell architectures specific for efficient light harvesting under indoor illumination (Invited)

T. M. Brown*[1]

1. University of Rome Tor Vergata, Department of Electronic Engineering, Italy

The Internet of Things revolution requires a low-cost, stable and efficient power source to allow autonomous operation of smart objects and wireless sensors networks. These need to operate indoors, under artificial lighting with different spectra and power outputs compared to standard test conditions, i.e. under the sun. Here we show the progress achieved in our labs in developing perovskite solar cells for these conditions achieving 27% efficiency on rigid glass substrates under 200-1000lx white LED illumination via optimization of effective metal-oxide electron transport layers as well as band gap engineering of the perovskite semiconductor. Via low temperature fabrication of device architectures, including mesoporous scaffolds, we manufactured 13% efficient perovskite cells on transparent PET films as well as over 22% on curvable ultra-thin glass substrates which showed that the performance of perovskite photovoltaics surpassed all other PV flexible technologies for indoors. Key parameters and figure of merits necessary to achieve high efficiencies at these low light levels in indoor environments will be highlighted.

10:30 AM

(EHS-052-2022) Multi-Functional Conjugated Ligand Engineering for Stable and Efficient Perovskite Solar Cells (Invited)

L. Dou*[1]

1. Purdue University, Chemical Engineering, USA

Surface passivation is an effective way to boost the efficiency and stability of perovskite solar cells. However, a key challenge faced by most of the passivation strategies is reducing the interface charge recombination without imposing energy barriers to charge extraction. In this talk, I will present a novel multi-functional semiconducting organic ammonium cationic interface modifier inserted between the light-harvesting perovskite film and the hole transporting layer. For the first time, we show that the conjugated cations can directly extract holes from perovskite efficiently, and simultaneously reduce interface non-radiative recombination. Together with improved energy level alignment and stabilized interface in device, we demonstrate a triple-cation mixed-halide medium-bandgap perovskite solar cell with an excellent power conversion efficiency of 23.10 %, and the suppressed ion migration and halide phase segregation, which lead to a long-term operational stability over 1000 hours. Our strategy provides a new practical method of interface engineering in perovskite solar cells towards improved efficiency and stability.

11:00 AM

(EHS-053-2022) Nonlinear elastic design and analysis of large building integrated photovoltaic panels

H. Yin*[1]

1. Columbia University, Civil Engineering and Engineering Mechanics, USA

Large building integrated photovoltaic (BIPV) panels have been more frequently used in buildings for architectural and constructional advantages. Although the brittle materials of glass and solar cells are subjected to small deformation at local points exhibiting linear elastic behavior, the large thin layer of a panel commonly exhibits a nonlinear large deflection at the center under transverse loading with the increase of the span between the supports. The deflection of the panel becomes the control factor in panel design. To reduce the deflection, thick glass sheets are required to provide sufficient flexural rigidity, which increases the dead load thereby leading to inefficient design. In this study, another stiffening mechanism for BIPV panels is presented by imposing horizontal constraints on the supporting edges. For a large BIPV panel with simple supports on two opposite edges with a linear horizontal constraint, the deflection of the panel can be predicted by the nonlinear elastic theory, which is well validated by the experiments. The load transfer through different layers is analyzed, so as to optimize the material design of the BIPV panels. A new mounting frame is introduced to adaptively control the stiffness by horizontal constraint, so that a large lightweight panel can be designed for solar energy harvesting.

11:20 AM

(EHS-054-2022) Homogenization of Optical Field in Nanocrystal-Embedded Perovskite Composites

Y. Hou*[1]; J. Zhang[2]; X. Zheng[2]; Y. Lu[2]; J. Piper[2]

1. Pennsylvania State University, Department of Material Science and Engineering, USA
2. Macquarie University, Australia

Photonic upconversion of in-band light into shorter-wavelength light has been proposed as a protocol to overcome the Shockley–Queisser (SQ) limit of photovoltaics. Many research contributions have attempted the incorporation of upconversion materials to realize this strategy. However, devising a real device with an efficiency exceeding the SQ limit still remains technically unreachable. To understand this paradoxical question, herein we use a typical upconversion nanoparticle (UCNP) with halide perovskite as a platform to quantify the UC contribution to the efficiency improvement. Our results show that the UC-induced photocurrent gain is negligible; nevertheless, the incorporation of nanomaterials even without UC capability can still enhance the photocurrent, which is related to a redistribution of the optical field and consequently a homogenization of the optical field (HOF). This can lead to a reduced photocarrier loss and provide a noticeable photocurrent enhancement (ca. 7%), which explains the general photocurrent improvement in solar cells with nanomaterials.

11:40 AM

(EHS-055-2022) Cost-Effective High-Performance Charge-Carrier-Transport-Layer-Free Perovskite Solar Cells Achieved by Suppressing Ion Migration

Z. Luyao*[1]; T. Ye[1]; S. Priya[1]

1. Pennsylvania State University, Department of Materials Science and Engineering, USA

Perovskite solar cells (PSCs) without charge-carrier-transport layers (CTLs) are theoretically achievable due to the ambipolar charge-carrier-transfer characteristics presenting in perovskites. However, the power conversion efficiency (PCE) of the CTL-free PSCs needs further improvement. In this paper, we report a breakthrough in the fabrication of the cost-effective high-performance hole-transport-layer (HTL)-free PSC and trilayer PSC with device configurations of fluorine doped tin oxide (FTO)/SnO_2/perovskite/carbon and FTO/perovskite/carbon, respectively. We introduce perfluorotetradecanoic acid (PFTeDA) with a carbonyl unit and carbon fluorine bonds to suppress the ion migration and reduce the crystal defects in perovskites. The modified carbon-based HTL-free PSC shows a record PCE of 18.9%. Furthermore, the PFTeDA molecules are found existing at the grain boundaries between the perovskite crystals, resulting in enhanced environmental, thermal, and light stabilities for the resultant cost-effective high-performance CTL-free PSCs.

12:00 PM

(EHS-056-2022) Self-Assembly of 0D/3D Perovskite Bi-Layer from A Micro-Emulsion Ink

Y. Hou[1]; H. Wu*[1]; K. Wang[1]; S. Priya[1]

1. Pennsylvania State University, Department of Material Science and Engineering, USA

2D/3D bilayer perovskite synthesized using sequential deposition methods has shown effectiveness in enhancing the stability of perovskite solar devices. However, these approaches present several limitations such as uncontrolled chemical processes, disordered interfacial states, and microscale heterogeneities that can chemically, structurally, and electronically compromise the performance of solar modules. Here, we demonstrate an emulsion-based self-assembly approach using natural lipid biomolecules in a nonionic solution system to form an 0D/3D bilayer structure. The new capping layer is composed of 0D nanoparticles of perovskite encapsulated by a hydrophobic lipid membrane, analogous to a cell structure, formed through a molecular self-assembly process. This 0D layer provides a strong water repellent characteristic, optimum interface microstructure, and excellent homogeneity that drives significant enhancement in stability. Solar modules with a large active area of 70 cm^2 fabricated using films comprising of 0D/3D bilayer structure are found to show consistent efficiency of >19% for 2800 hr of continuous illumination in the air (60% relative humidity). This emulsion-based self-assembly approach will have a transformative impact on the design and development of stable perovskite-based devices.

12:20 PM

(EHS-057-2022) Halide perovskite: overcoming Shockley-Queisser limit of photovoltaics (Invited)

K. Wang*[1]

1. Pennsylvania State University, USA

Single-junction photovoltaics have a theoretical efficiency limit of 33.7%, with over 50% energy losses in thermalization and in-band transparency. Prior engineering at system levels has been developed to reduce these losses and break the Shockley-Queisser (SQ) limit; many require high-standard manufacturing but deliver mild efficiency enhancement. A breakthrough can be found from the materials perspective. Halide perovskites with various physical merits may provide the platform to overcome both thermalization and in-band transparency losses and thus elevate efficiency by two factors. For example, long-lived hot carriers in perovskite could boost the photovoltage to exceed its band gap or to execute a multi-exciton generation process to double the photocurrent. A delicately designed quantum structure could overcome the in-band losses by mechanisms such as intermediate band, multiple quantum well cascade, and photoferroic effect. Here, we discuss the oppor-tunity, feasibility, and challenges of overcoming the SQ limit by designing upon a perovskite platform.

LATE BREAKING ABSTRACTS

Wednesday, Sept. 7

S5: Piezoelectric and Triboelectric Energy Harvesting using Low-Dimensional Materials

Room: Pratt/Calvert

11:30 AM

(EHS-012-2022) Phase transformations driven by complex interatomic interactions in sodium transition metal oxides (Invited)

J.C. Kim*[1]

1. Stevens Institute of Technology, Department of Chemical Engineering & Materials Science

As an alternative to Li-based technology for large-scale applications, Na-ion batteries made of earth-abundant elements have attracted substantial research and industry interest. Na storage materials with a layered oxide framework are known to undergo reversible phase transformations upon Na intercalation. However, large desodiation often leads to an unclarified, irreversible phase transformation at high voltage due to complex interatomic interactions, hindering the full use of transition metal (TM) redox. In this talk, how TM chemistry affects the stability of desodiated sodium TM oxides will be discussed, and recent findings on a quaternary TM system including Ti and Fe will be underlined. A highly-desodiated phase that exhibits peculiar oxygen stacking to afford alternating octahedral and prismatic Na layers, namely OP2 stacking, will be demonstrated. The formation of OP2 is rationalized by distortion-tolerant Ti and Jahn-Teller-active Fe. This new phase participates in redox reaction reversibly, fundamentally distinct from inactive high-voltage phases in many Na-ion cathodes.

Thursday, Sept. 8

S3: Multi-functional Energy Conversion Materials and Devices for Energy Harvesting and/or Sensing - I

Room: Pratt/Calvert

11:30 AM

(EHS-058-2022) Phononic Crystals and Metamaterials for Sustainable Power Generation (Invited)

M. Kim*[1]

1. Sungkyunkwan University, School of Advanced Materials Science & Engineering, Korea

Beyond conventional energy harvesting research efforts on materials, devices, and circuits, a further disruptive approach for power enhancement in energy harvesting is required. Phononic crystals (PnCs) and metamaterials, artificially engineered structures, have proved useful for input mechanical energy manipulation, thus providing a new paradigm of solution to enhancing power generation in acoustic and vibration energy harvesting. The amplified input energy through PnCs and metamaterials is delivered to the piezoelectric device for energy conversion, thereby realizing a significantly amplified power output overall. Here, I will summarize a collection of advances that push the boundaries to achieve a new paradigm of energy harvesting systems using various metamaterial designs ranging from defected phononic crystals, elastic and acoustic gradient index (GRIN) metamaterials, locally-resonant acoustic materials, to elastic instability-based mechanical metamaterials. Two recent advances – 1) machine-learning-enabled GRIN PnC designs and 2) simultaneous vibration suppression and energy harvesting - will be part of this talk, introducing intriguing concepts in metamaterial-based energy harvesting.

Author Index

*** Denotes Presenter**

A

Achadu, O. J.* . . . 5
Akhanda, M. . . . 13

B

Baek, C. . . . 12
Baek, S.* . . . 10
Basset, P.* . . . 14
Bell, L. . . . 15
Benton, A. . . . 13
Berry, J. . . . 17
Brown, T. M.* . . . 17

C

Cao, J. . . . 7
Chae, S. . . . 5, 11
Chae, S.* . . . 6
Chae, Y.* . . . 5
Choi, H. . . . 12
Choi, J. . . . 11
Choi, J.* . . . 9
Choi, W.* . . . 10
Chu, Z.* . . . 8
Claus, R. . . . 6
Crane, D.* . . . 15

D

Deem, J. . . . 6
Diaw, A.* . . . 10
Dong, S. . . . 8
Dou, L.* . . . 17
Doumon, N.* . . . 17

E

Eum, J. . . . 5, 11

F

Fanton, M. . . . 6
Feldhoff, A.* . . . 13
Fox, J. . . . 6

G

Go, S. . . . 5
Gonzalez, C.* . . . 6
Goyal, G.* . . . 13
Grasberger, J.* . . . 7
Greeley, I. . . . 6

H

Hadas, Z. . . . 8, 12
Hall, L. . . . 11
Hinterding, R. . . . 13
Hirata, K. . . . 14
Hou, Y. . . . 18
Hou, Y.* . . . 17
Hrstka, M. . . . 12
Hur, S. . . . 7
Hwang, G. . . . 8

J

Jakkapally, P. . . . 10
Jakob, M. . . . 13
Jang, J.* . . . 9, 11
Jung, J. . . . 7

K

Kang, C. . . . 7, 15
Kang, C.* . . . 5
Kang, H. . . . 13
Kar-Narayan, S.* . . . 16
Karan, S. . . . 8, 14
Karan, S.* . . . 12
Kim, D. . . . 5
Kim, E. . . . 5
Kim, H. . . . 5
Kim, H.* . . . 7
Kim, I.* . . . 7
Kim, M. . . . 5
Kim, S.* . . . 5, 9
Kim, W.* . . . 9
Kishore, R. . . . 13
Kovalevsky, A.* . . . 15
Ksica, F.* . . . 12
Kumar, A. . . . 10

L

Lambert, D. . . . 11
Lee, D.* . . . 15
Lee, G.* . . . 12
Lee, H. . . . 5
Lee, J. . . . 10
Lee, S.* . . . 8
Li, W. . . . 13, 14, 15, 16
Li, W.* . . . 13
Litak, G.* . . . 8
Liu, N. . . . 14
Liu, N.* . . . 15
Liu, Y. . . . 12
Lu, Y. . . . 17
Luyao, Z. . . . 8, 16
Luyao, Z.* . . . 12, 18
Lyle, L. . . . 6

M

Madigan, B. . . . 15
Marcián, P. . . . 12
McKinney, D. . . . 6
Mitra, M. . . . 13

N

Nahm, S. . . . 5, 6, 7, 11, 15
Nahm, S.* . . . 5
Nie, W.* . . . 16
Nozariasbmarz, A. . . . 13, 14, 16
Nozariasbmarz, A.* . . . 16

O

Oeckler, O. . . . 13
Okuda, R.* . . . 11

P

Patil, D. . . . 10
Pincek, L. . . . 12
Piper, J. . . . 17
Poon, J.* . . . 13
Poudel, B. . . . 8, 13, 14, 15, 16
Poudel, B.* . . . 16
Priya, S. . . . 6, 8, 12, 13, 14, 15, 16, 18

R

Rajagopalan, R.* . . . 6
Raman, L.* . . . 15
Ryu, J. . . . 8, 10, 12
Ryu, J.* . . . 6

S

Schelhas, L. . . . 17
Seung, H. . . . 5
Sharma, S.* . . . 8, 16
Singh, D. J. . . . 13
Singh, S. . . . 13
Singh, S.* . . . 14
Snyder, D. . . . 6
Song, H. . . . 7, 15
Song, H.* . . . 9
Sosna, P.* . . . 8
Srinivasan, G.* . . . 12

T

Takeuchi, T. . . . 14
Trinh, A. . . . 6

W

Wang, K. . . . 8, 12, 16, 18
Wang, K.* . . . 18
Wolf, M. . . . 13
Wolszczak, P.* . . . 10
Wu, H.* . . . 18

Y

Ye, J.* . . . 10
Ye, T. . . . 18
Yin, H.* . . . 17
Yoon, W. . . . 11
Yu, H.* . . . 11

Z

Zebarjadi, M. . . . 13
Zebarjadi, M.* . . . 13
Zhang, J. . . . 17
Zhang, S.* . . . 11
Zhang, Y. . . . 13, 14, 16
Zhang, Y.* . . . 7, 14
Zhao, Z. . . . 13
Zheng, X. . . . 17
Zhou, P. . . . 12
Zhu, H. . . . 13
Zuo, L. . . . 11

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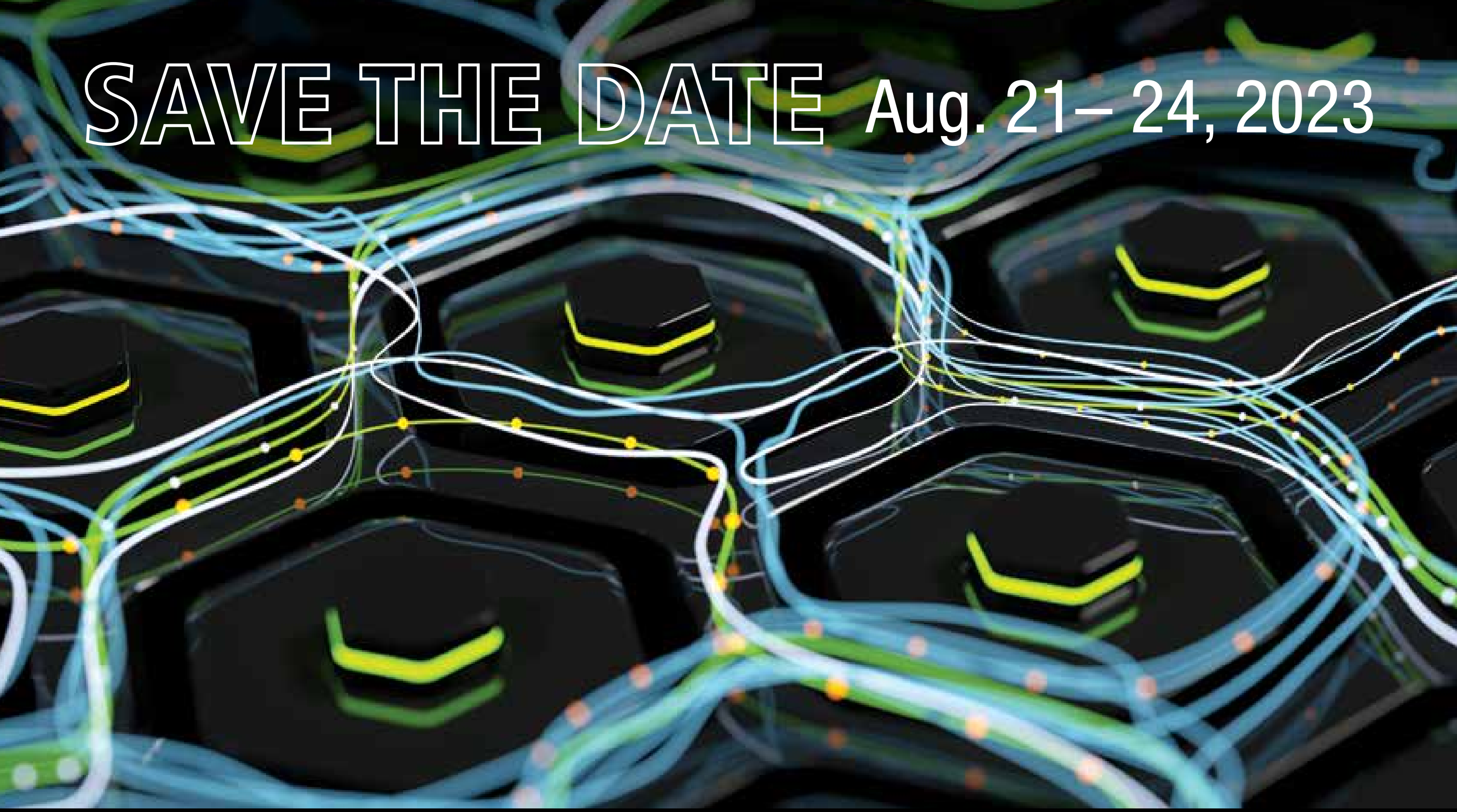

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