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A Hybrid Energy Harvester Based on Piezoelectric and Electromagnetic mechanisms

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Energy Harvesting and Energy Efficiency Nicu Bizon, Naser Mahdavi Tabatabaei, Frede Blaabjerg, Erol Kurt, 2017-03-09 This book presents basic and advanced concepts for energy harvesting and energy efficiency as well as related technologies methods and their applications The book provides up to date knowledge and discusses the state of the art equipment and methods used for energy harvesting and energy efficiency combining theory and practical applications Containing over 200 illustrations and problems and solutions the book begins with overview chapters on the status quo in this field Subsequent chapters introduce readers to advanced concepts and methods In turn the final part of the book is dedicated to technical strategies efficient methods and applications in the field of energy efficiency which also makes it of interest to technicians in industry The book tackles problems commonly encountered using basic methods of energy harvesting and energy efficiency and proposes advanced methods to resolve these issues All the methods proposed have been validated through simulation and experimental results These hot topics will continue to be of interest to scientists and engineers in future decades and will provide challenges to researchers around the globe as issues of climate change and changing energy policies become more pressing Here readers will find all the basic and advanced concepts they need As such it offers a valuable comprehensive guide for all students and practicing engineers who wishing to learn about and work in these fields

Micro and Nano Energy Harvesting Technologies Bin Yang, Huicong Liu, Jingquan Liu, Chengkuo Lee, 2014-12-01 Seeking renewable and clean energies is essential for releasing the heavy reliance on mineral based energy and remedying the threat of global warming to our environment In the last decade explosive growth in research and development efforts devoted to microelectromechanical systems MEMS technology and nanowires related nanotechnology have paved a great foundation for new mechanisms of harvesting mechanical energy at the micro nano meter scale MEMS based inertial sensors have been the enabler for numerous applications associated with smart phones tablets and mobile electronics This is a valuable reference for all those faced with the challenging problems created by the ever increasing interest in MEMS and nanotechnology based energy harvesters and their applications This book presents fundamental physics theoretical design and method of modeling for four mainstream energy harvesting mechanisms piezoelectric electromagnetic electrostatic and triboelectric Readers are provided with a comprehensive technical review and historical view of each mechanism The authors also present current challenges in energy harvesting technology technical reviews design requirements case studies along with unique and representative examples of energy harvester applications

Advances in Industrial Engineering in the Industry 4.0 Era Kaushik Kumar, 2024-06-17 At the core of this book are several application areas where Industry 4.0 has been or can be applied This book introduces the Fourth Industrial Revolution with discussions and reflections that will lead the reader into a deeper understanding of the nature of the concept This book also reveals various facets that can be applied and utilized for implementation of the concept in various sectors

This book Comprehensively discusses skills for Industry 4 0 Provides insights into the application of Industry 4 0 in the healthcare sector Presents involvement of Industry 4 0 in current concepts such as supply chain and blockchain Showcases innovative additive manufacturing to enhance human machine co working Includes virtualization and simulation techniques for decision making in manufacturing and assembly processes This book is primarily written for graduate students and academic researchers in the fields of industrial engineering manufacturing engineering mechanical engineering production engineering and aerospace engineering

Hybrid Materials for Piezoelectric Energy Harvesting and Conversion S. Wazed Ali, Satyaranjan Bairagi, Shahid Ul Islam, 2024-05-14 Power small devices more efficiently and practically with these essential materials Piezoelectric energy harvesting is an increasingly widely deployed technique to generate electricity from mechanical energy Reliability ease of use and cleanliness make piezoelectric energy harvesting in small electronic devices a potentially valuable alternative to the practical challenges and waste production of disposable or even reusable batteries However piezoelectric materials have their own challenges advantages and limitations and choosing between them is a difficult engineering problem in itself hybrid piezoelectric materials which can be used to compensate the weaknesses of individual piezoelectric materials like ceramic or polymer are the emerging solution Hybrid Materials for Piezoelectric Energy Harvesting and Conversion offers a systematic analysis of these hybrid piezoelectric materials and their applications Each hybrid piezoelectric material is analyzed for its fundamentals structural requirements and applications and the result is a significant contribution to materials science and electronic engineering Hybrid Materials for Piezoelectric Energy Harvesting and Conversion readers will also find Comprehensive coverage of piezoelectric materials to provide the best fit for any set of engineering needs Detailed discussion of inorganic organic and hybrid piezoelectric materials Surface modification of piezoelectric filler in composite based piezoelectric materials Importance of semiconductive and conductive materials in enhancing piezoelectric response of hybrid piezoelectric materials In depth analysis of bio based hybrid piezoelectric materials Hybrid Materials for Piezoelectric Energy Harvesting and Conversion is ideal for researchers in materials sciences polymers textiles green and renewable energy and all related fields

Organic Ferroelectric Materials and Applications Kamal Asadi, 2021-10-27 Organic Ferroelectric Materials and Applications aims to bring an up to date account of the field with discussion of recent findings This book presents an interdisciplinary resource for scientists from both academia and industry on the science and applications of molecular organic piezo and ferroelectric materials The book addresses the fundamental science of ferroelectric polymers molecular crystals supramolecular networks and other key and emerging organic materials systems It touches on important processing and characterization methods and provides an overview of current and emerging applications of organic piezoelectrics and ferroelectrics for electronics sensors energy harvesting and biomedical technologies Organic Ferroelectric Materials and Applications will be of special interest to those in academia or industry working in materials science engineering chemistry and physics Provides an overview of key physical

properties of the emerging piezoelectric and ferroelectric molecular and supramolecular systems Discusses best practices of processing patterning and characterization methods and techniques Addresses current and emerging applications for electronics materials development sensors energy harvesting and biomedical technologies Flexible Piezoelectric Energy Harvesters and Sensors Bin Yang,Zhiran Yi,Chengkuo Lee,2022-09-19 Flexible Piezoelectric Energy Harvesters and Sensors A systematic and complete discussion of the latest progress in flexible piezoelectric energy harvesting and sensing technologies In Flexible Piezoelectric Energy Harvesters and Sensors a team of distinguished researchers delivers a comprehensive exploration of the design methods working mechanisms microfabrication processes and applications of flexible energy harvesters for wearable and implantable devices The book discusses the monitoring of normal force shear force strain and displacement in flexible sensors as well as relevant artificial intelligence algorithms Readers will also find an overview of design and research challenges facing professionals in the field as well as a variety of perspectives on flexible energy harvesters and sensors With an extensive focus on the use of flexible piezoelectric material technologies for medical applications Flexible Piezoelectric Energy Harvesters and Sensors also includes A thorough introduction to the working principles of piezoelectric devices including discussions of flexible PEH and piezoelectric sensors Comprehensive treatments of the design of flexible piezoelectric energy harvesters including the challenges associated with their structural design Fulsome explanations of the fabrication of flexible piezoelectric energy harvesters including piezoelectric ceramic thin and think films In depth treatments of cantilever piezoelectric energy harvesters including optimized cantilever bimorph and optimized bimorph PEH Perfect for materials scientists electronics engineers and solid state physicists Flexible Piezoelectric Energy Harvesters and Sensors will also earn a place in the libraries of sensor developers and surface physicists **Design, Modelling and Fabrication of a Hybrid Energy Harvester** Mohammed Ibrahim,University of Waterloo,2014 As sources of energy are becoming more scarce and expensive energy harvesting is receiving more global interest and is currently a growing field Energy harvesting is the process of converting ambient energy such as vibration to electrical energy that can power a multitude of applications Vibration energy is the by product of everyday life it is generated from any perceivable activity While typically viewed as noise there is a strong potential for harvesting this energy and deploying it to useful applications The focus of this thesis will be using vibration as the ambient source of energy Hybrid energy harvesters employ more than one of the harvesting technologies In this thesis two hybrid harvesters that utilize piezoelectric magnetostrictive and electromagnetic technologies are designed modelled and tested Both of these harvesters have beams that are spiral in shape The use of the spiral geometry allows the system to have a lower natural frequency as opposed to the traditional cantilever beam while still maintaining a high volume of active material The first harvester that is discussed is the P MSM harvester It utilizes piezoelectric and magnetostrictive material Both materials are configured in a spiral beam geometry and allowed to resonate independently The resonance frequency of these two materials is designed to create wideband energy

harvesting This allows the harvester to be operating efficiently even if the ambient vibration shifts a small amount The second harvester that is discussed is the P MAG harvester It utilizes piezoelectric and electromagnetic technologies It also incorporates a spiral geometry for the piezoelectric layers and includes a magnet attached at the centre The magnet is placed in the centre of the spiral to reduce the natural frequency of the system and to also actively contribute to the harvesting This harvester has two sources operating at the same resonant frequency which allows it to have a larger power output than if the sources were separated Finally finite element analysis was used to model both harvesters ANSYS was used for the piezoelectric material and COMSOL was used for the electromagnetic material The results are compared to the experimental and are in good agreement

Hybrid Piezo-pyroelectric Energy Harvesting from Pavement Jie Hu (Civil engineer), 2016 In the U S there are over 4 million miles 6 million km of roadways and more than 250 million registered vehicles The energy lost in the pavement system due to traffic induced vibration and deformation is enormous If effectively harvested such waste energy can serve as an alternative sustainable energy source that can be easily integrated to the transportation system To harness this forms of energy the common approach is to utilize a piezoelectric module which generates electricity when strained In this thesis literature review based on different energy harvesting methods has been made The potential of PVDF which is a piezoelectric as well as pyroelectric polymer material is investigated as a potential piezoelectric energy harvester integrated in pavement systems However the potential of PVDF as a hybrid piezo pyroelectric energy harvester has been seldom studied Through series of well controlled experiments it is found that there exists interesting coupling phenomenon between piezoelectric and pyroelectric effects of PVDF the voltage generated by simultaneous mechanical and thermal stimulations is the sum of voltages generated by separate stimulations In addition an estimation of power generation through piezoelectric and pyroelectric effect is conducted The overall effects of temperature on hybrid piezo pyroelectric energy harvesting piezo and pyro constant varies with temperature are discussed in the end

Assessment of Piezoelectric Materials for Roadway Energy Harvesting : Cost of Energy and Demonstration Roadmap Davion Hill, Arun Agarwal, Nellie Tong, DNV KEMA Energy & Sustainability (Firm), 2014

Piezoelectric Energy Harvesting Mohammad Adnan Ilyas, 2018-03-22 Environmental pollution has been one of the main challenges for sustainable development Piezoelectric materials can be used as a means of transforming ambient vibrations into electrical energy to power devices The focus is on an alternative approach to scavenge energy from the environment This book presents harvesting methodologies to evaluate the potential effectiveness of different techniques and provides an overview of the methods and challenges of harvesting energy using piezoelectric materials Piezoelectric energy harvesters have many applications including sensor nodes wireless communication microelectromechanical systems handheld devices and mobile devices The book also presents a new approach within piezoelectric energy harvesting using the impact of raindrops The energy harvesting model presented is further analyzed for single unit harvester and an array of multiple harvesters to

maximize the efficiency of the device Nonlinear Aspects and Performance of Hybrid Aeroelastic Energy Harvesters Umer Javed, 2017 The recent advent of micro electro mechanical systems has increased the demand for localized energy harvesting The autonomous gadgets structural health monitoring sensors wireless sensors and pacemakers are all paving their ways in our lives These electronic devices demand innovative ways of powering them effectively and efficiently Various ambient excitations can be used from the environment like base or aeroelastic For converting this wasted mechanical energy several transduction mechanisms are employed like piezoelectric electromagnetic and electrostatic This dissertation is a step forward in meeting the localized energy demand for operating low power electronic devices by using a hybrid formation of piezoelectric material and electromagnet coil arrangement for harnessing aeroelastic oscillations Therefore in the first part of this dissertation this hybrid configuration is utilized to discuss energy harvesting by a cantilever beam and prismatic shaped cylinder subjected to wind flow from transverse direction by using a special class of aeroelastic oscillations known as galloping After establishing the importance of accurate modeling of aeroelastic galloping force we proceed on to discuss about hybrid energy harvesting The inclined square section cylinders are investigated to harvest aeroelastic energy offered by galloping oscillations using accurate modeling proposed in the first part again by using a hybrid configuration The last part of harvesting energy by galloping oscillation using a hybrid transduction mechanism deals with using the same cantilever based hybrid galloping harvester but this time by inclusion of a non rigid support exhibiting non zero slope The impact of such support on piezoelectric and electromagnetic energy harvesting is investigated in detail The second part of this dissertation deals with using the same hybrid configuration for harnessing aeroelastic energy by using another rather well known class named vortex induced vibrations The different tools of nonlinear dynamics and vibrations such as Galerkin discretization Normal form of Hopf bifurcation and shooting method are used to dissect the hybrid energy harvesters in length throughout the Dissertation It is concluded at the end that hybrid energy harvesters come with their own added shunt damping effects because of an additional transducer to a single functioning transducer whether an added piezoelectric layer or an electromagnet inductive coil At the same time careful selection of the electrical load resistances of respective piezoelectric and electromagnetic circuitries would interplay with each other can help bring the overall coupled damping of hybrid formation to acceptable reduced levels This careful selection can help replace a sole classical electromagnetic or piezoelectric harvester with a hybrid one which can power multiple electronic lower power gadgets **Supercapacitors** Stanislav Kolisnychenko, 2015-07-31 Aggregated Book *Energy Harvesting Autonomous Sensor Systems* Yen Kheng Tan, 2017-12-19 Energy Harvesting Autonomous Sensor Systems Design Analysis and Practical Implementation provides a wide range of coverage of various energy harvesting techniques to enable the development of a truly self autonomous and sustainable energy harvesting wireless sensor network EH WSN It supplies a practical overview of the entire EH WSN system from energy source all the way to energy usage by wireless sensor nodes network After an in depth review of existing

energy harvesting research thus far the book focuses on Outlines two wind energy harvesting WEH approaches one using a wind turbine generator and one a piezoelectric wind energy harvester Covers thermal energy harvesting TEH from ambient heat sources with low temperature differences Presents two types of piezoelectric based vibration energy harvesting systems to harvest impact or impulse forces from a human pressing a button or switch action Examines hybrid energy harvesting approaches that augment the reliability of the wireless sensor node s operation Discusses a hybrid wind and solar energy harvesting scheme to simultaneously use both energy sources and therefore extend the lifetime of the wireless sensor node Explores a hybrid of indoor ambient light and TEH scheme that uses only one power management circuit to condition the combined output power harvested from both energy sources Although the author focuses on small scale energy harvesting the systems discussed can be upsized to large scale renewable energy harvesting systems The book goes beyond theory to explore practical applications that not only solve real life energy issues but pave the way for future work in this area

Energy Harvesting for Wireless Sensing and Flexible Electronics Through Hybrid Technologies Brahim Aïssa, Muhammad Iqbal, Malik Muhammad Nauman, 2023-10 Harvesting biomechanical energy is a viable solution for sustainably powering wearable electronics for continuous medical health monitoring remote sensing and motion tracking This book discusses vibration based piezoelectric electromagnetic and hybrid energy harvesters and addresses their modelling fabrication and characterization

Power Maximization for Pyroelectric, Piezoelectric, and Hybrid Energy Harvesting Murtadha A. Shaheen, 2016 The goal of this dissertation consists of improving the efficiency of energy harvesting using pyroelectric and piezoelectric materials in a system by the proper characterization of electrical parameters widening frequency and coupling of both effects with the appropriate parameters A new simple stand alone method of characterizing the impedance of a pyroelectric cell has been demonstrated This method utilizes a Pyroelectric single pole low pass filter technique PSLPF Utilizing the properties of a PSLPF where a known input voltage is applied and capacitance C_p and resistance R_p can be calculated at a frequency of 1 mHz to 1 Hz This method demonstrates that for pyroelectric materials the impedance depends on two major factors average working temperature and the heating rate Design and implementation of a hybrid approach using multiple piezoelectric cantilevers is presented This is done to achieve mechanical and electrical tuning along with bandwidth widening In addition a hybrid tuning technique with an improved adjusting capacitor method was applied An toroid inductor of 700 mH is shunted in to the load resistance and shunt capacitance Results show an extended frequency range up to 12 resonance frequencies 300% improvement with improved power up to 197% Finally a hybrid piezoelectric and pyroelectric system is designed and tested Using a voltage doubler circuit for rectifying and collecting pyroelectric and piezoelectric voltages individually is proposed The investigation showed that the hybrid energy is possible using the voltage doubler circuit from two independent sources for pyroelectricity and piezoelectricity due to marked differences of optimal performance

Chemical Engineering Progress ,2004 *A Hybrid Piezoelectric and*

Electromagnetic Wind Energy Harvester Mahmood Rashid Al-Riyami,2022 **Micro Energy Harvesting** Danick Briand,Eric Yeatman,Shad Roundy,2015-06-22 With its inclusion of the fundamentals systems and applications this reference provides readers with the basics of micro energy conversion along with expert knowledge on system electronics and real life microdevices The authors address different aspects of energy harvesting at the micro scale with a focus on miniaturized and microfabricated devices Along the way they provide an overview of the field by compiling knowledge on the design materials development device realization and aspects of system integration covering emerging technologies as well as applications in power management energy storage medicine and low power system electronics In addition they survey the energy harvesting principles based on chemical thermal mechanical as well as hybrid and nanotechnology approaches In unparalleled detail this volume presents the complete picture and a peek into the future of micro powered microsystems **Materials, Technologies and Machines of Modern Manufacturing** Spiridon (Spiros) Koutsonas,Giovanni Minafò,Masaru Tanaka,Takashige Omatsu,Zongjin Li,Alexander M. Korsunsky,2022-09-28 Special topic volume with invited peer reviewed papers only **Broadband Hybrid Electromagnetic and Piezoelectric Energy Harvesting from Ambient Vibrations and Pneumatic Vortices Induced by Running Subway Trains** Ya Wang (Ph. D.),2017 The airfoil based electromagnetic energy harvester containing parallel array motion between moving coil and trajectory matching multi pole magnets was investigated The magnets were aligned in an alternatively magnetized formation of 6 magnets to explore enhanced power density In particular the magnet array was positioned in parallel to the trajectory of the tip coil within its tip deflection span The finite element simulations of the magnetic flux density and induced voltages at an open circuit condition were studied to find the maximum number of alternatively magnetized magnets that was required for the proposed energy harvester Experimental results showed that the energy harvester with a pair of 6 alternatively magnetized linear magnet arrays was able to generate an induced voltage V_o of 20 V with an open circuit condition and 475 mW under a 30 ohm optimal resistance load operating with the wind speed U at 7 m/s and a natural bending frequency of 3.54 Hz

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