FROM SMART CITY TO SMART FACADES

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SOLAR WINDOW BLINDS WITH PASSIVE COOLING COATING AND SMART CONTROLLERS

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In the recent design of solar window blinds, the flexible solar films are attached to one side of the window blinds, making use of the building facades. As solar films absorb the heat from sunlight, a significant decrease in energy conversion efficiency becomes one obstacle for widespread commercial application. In order to tackle the difficulty, this project yields an improvement, where a passive cooling coating (PCC) is applied to another side of the window blinds. The PCC makes the temperature of window blinds lower than the ambient temperature effectively, by emitting the long-wave infrared to the outer environment. With the aid of PCC, the lower in-room temperature is attained, resulting in less energy required for air conditioners during summers. The solar window blinds involve two work states: (I) solar films are orientated towards the sunlight to harvest energy; (II) PCCs are orientated towards the sunlight to cool down the surrounding temperature. The switch of work states between (I) and (II) is achieved by smart controllers based on temperature data acquired from sensors. A prototype is fabricated to demonstrated how much energy conversion efficiency is promoted with PCCs.

SELF-POWERED WIRELESS SENSING FOR SMART INFRASTRUCTURE

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Key Words: Wireless Sensing, Smart Infrastructure, Self-Powered Sensors

Effective sensing of environmental parameters or conditions rely on wireless connectivity of spatially distributed autonomous sensors to acquire and transmit data to a main location. To date, the majority of sensing and wireless transmission devices rely on wired connections or batteries that require periodic replacement, which is not entirely true to the concept of an autonomous embedded sensing network. Advances made towards the development of low-power microcontrollers, sensing devices and ultra low-power wireless technologies open the opportunity for substituting depletable batteries with low levels of locally-harvested kinetic, light, or thermal energy to power the sensing and transmission functions of a network.

The predominant approach to using locally-harvested power has been to use an auxiliary harvester, solar or mechanical power, to operate vibration or ow sensing and transmission devices. In contrast, it would be more advantageous, in terms of size or volume of sensing element or in terms of availability of power, to use the same device to sense a physical quantity over a specific time period and to harvest energy that can be used to operate itself as a sensor and to power the transmission of the acquired signal over other periods. In this work, we will present examples of self-powered wireless sensors of air speed, water flow and vibrations.

DESIGN AND DEMONSTRATION OF A THERMOELECTRIC-POWERED WIRELESS SENSOR PLATFORM IN WINDOW FRAMES FOR THE SMART BUILDING ENVELOPE

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SOLAR THERMAL SYSTEMS - PAST, PRESENT AND FUTURE

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FIRE AND ICE: LESSONS LEARNED FROM SUPERSTORM SANDY, AND THE CALIFORNIA WILD FIRES

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Seven years ago last month, Superstorm Sandy ravaged the Northeast generally and coastal CT-NY-NJ particularly. Hospitals were inundated with rising storm waters forcing the displacement of elderly and infirmed. Under-street wiring shorted then corroded from seawater intrusion. Near ground level generators supporting emergency operations similarly failed. So what power technology worked per specification for the whole of Sandy? More importantly, what “lessons learned” can be applied to future challenges, such as California’s fight with wild fires, and the just-announced use rolling blackouts (PSPS: Public Safety Power Shutoff) for the next fifty years?

MATERIALS AND DESIGN FOR HEAT HARVESTING AND THERMAL MANAGEMENT OF ASPHALT PAVEMENTS

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Key Words: thermal management, asphalt pavement, carbon nanotube, graphene, thermal conductivity

Asphalt pavements are subjected to annual, seasonal, and daily temperature fluctuations, which can lead to cracks and even failure of the pavements. Additionally, snow removal in winter on highways and parking lots in the cold-climate region is often challenging and the current snow removal approaches (salt and plowing) are neither efficient enough nor environmental-friendly. Here we propose a multifunctional system that utilizes solar and geothermal energy for heat harvesting and temperature regulation of the pavements, which allows self-deicing in winter, cooling in summer, reduced maintenance cost, and extended life span. This new pavement technology consists of an underground heat exchanger, circulation pumps, thermal tubes, a photovoltaic system, and thermally conductive pavement overly. This presentation will focus on investigation of the thermal, electrical, and mechanical performance of the asphalt materials modified with conductive additives including carbon nanotubes and graphene nanoplatelets. Using sonication combined with an oil bath and a mechanical shear mixer, we can achieve a homogenous dispersion of the conductive modifiers in asphalt binders, which is verified by a digital microscope. Our results show that the combination of carbon nanotubes and graphene nanoplates can enhance the thermal conductivity of the asphalt binders more than any of the single-phase addition. More work on the electrical conductivity improvement in using these modifiers are underway. These modified asphalt binders are expected to increase asphalt pavements' overall thermal conductivity, which is an integral part of the multifunctional pavement system.

DESIGN OF A GEOTHERMAL WELL FILLED WITH PHASE CHANGE MATERIALS FOR DAILY AND SEASONAL HEAT STORAGE AND SUPPLY

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Key Words: Geothermal, heat exchange, phase change materials, system integration.

Geothermal use can be dated back thousands of years. From primitive geothermal direct use to more sophisticated ways of using the resource, now geothermal energy has been utilized in households, farms, buildings and industrial processes. There are typically three geothermal energy systems including direct use and district heating systems, electricity generation power plants and geothermal heat pumps. Besides, geothermal heat pumps have almost no negative effects on the environment, and even have positive effects as they reduce the usage of other environmentally unfriendly energy sources. This project aims at designing a geothermal well for daily and seasonal heat storage and supply for energy efficient buildings as well as other geothermal applications. Coupling with heating, ventilation, and air conditioning (HVAC) systems and building integrated photovoltaic thermal (BIPVT) systems, it can not only significantly boost the efficiency of HVAC and BIPVT systems, but also be used for inter-seasonal heat exchange of heating (winter) and cooling (summer) for energy efficient buildings. The system can be further expanded by integrating with greenhouses on farms.

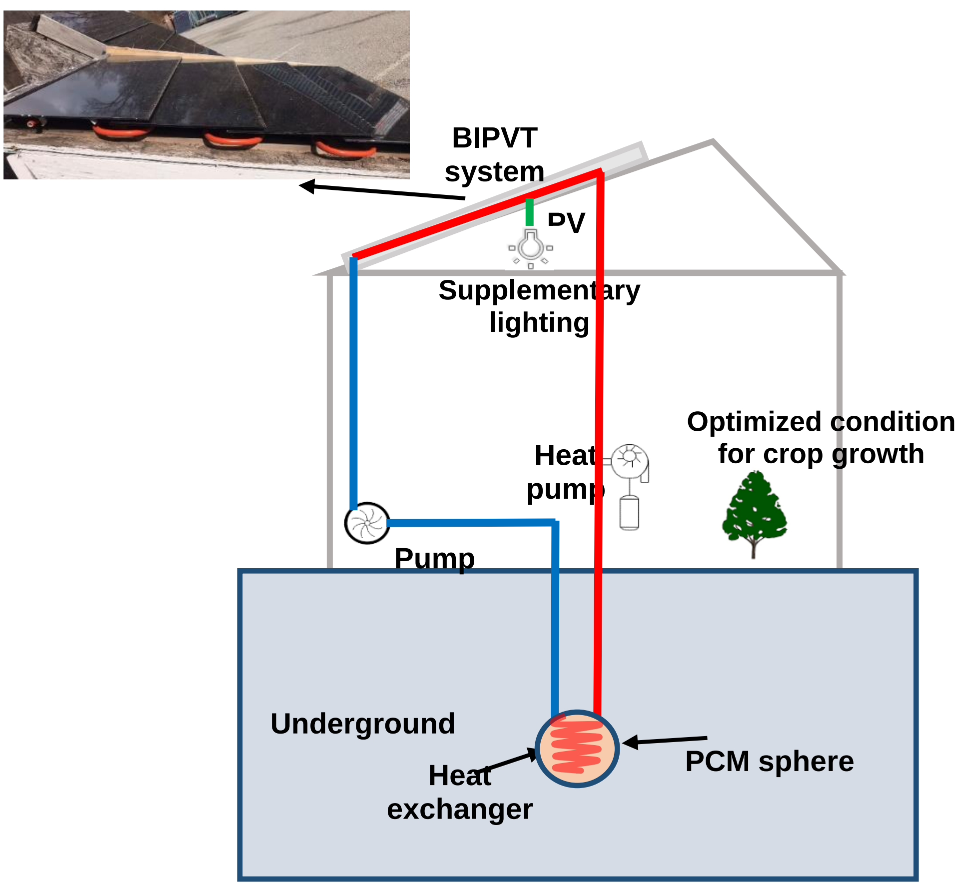

Figure 1 – Demonstration of the closed-loop system

THORNTON TOMASETTI CLIMATE MOBILIZATION FOR FACADES

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EMERGING TECHNOLOGIES IN BUILDING ENERGY EFFICIENCY

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Key Words: Emerging technologies; Building energy consumption; Building envelop; Advanced control

The U.S. building stock are under continuous aging and deterioration with deferred maintenance that hinders their operation. Existing buildings account for more than 86% of the annual construction cost in the U.S. and often suffer from lack of acceptable level of thermal comfort, indoor air quality (IAQ) as well as high energy use and costs. Considering future energy constraints (e.g. global warming and energy resources) and cost (e.g. capital cost and operational cost) suggest a need for a paradigm shift in our current understanding of energy efficiency and indoor environmental quality (IEQ) of the older existing building stock. Major technological advances beyond our current knowledge are much needed to design energy efficient buildings and retrofit large numbers of buildings at scale. Our technologies advances should be converged on high performance building enclosure materials, advanced building controls, intelligent building mechanical systems, efficient building lighting fixtures, and smart building plug-load management. For example, currently, majority of the residential buildings and a significant number of commercial buildings in the U.S. do not have any building automation systems, suggesting an emerging need to develop low-cost building automation systems specifically for residential buildings. This presentation covers a wide range of much needed technological advances on different building components and systems in order to design energy efficient buildings or retrofit large numbers of buildings. The aim of this presentation is not only to provide opportunities to reduce energy consumption in older existing buildings but also to shed light on new solutions to harvest energy through buildings.

POROUS RADIATIVE COOLING PAINT FOR BUILDING THERMAL MANAGEMENT

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Surface coating with high solar reflectance and high thermal emittance are attractive for saving energy in buildings. Conventional paints typically have a solar reflactance < 93% due to UV and near infrared absorption. Here we demonstrate a porous PVdF copolymer surface coating that shows high solar reflectance of over 96% and high thermal emittance of 0.97. When it is placed under sunlight, it can be 6 oC cooler than the environment without any electricity.

DEVELOPMENT OF FOAMED CONCRETE FOR BIPVT PANELS

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Transforming a building roof into a solar generator has not been easy due to high installation costs and tedious roof-solar integration. As a pioneering in U.S. residential and commercial building-integrated photovoltaic (BIPV) business, SPDLabs has developed hybrid solar/thermal solutions to favorably balance the cost of BIPV roof panels over solar modules. Our building integrated thermal electric roofing system (BITERS) enables efficiency increase by 40% when thermal is included in the solar harvest, while the highly durable Sunslates ensures long-term material integrity and performance. To further develop a lightweight yet higher-efficiency Roofing panel, we have applied a well-controlled foaming process to produce foamed concrete for the support substrate of BIPVT roofing panels. The thermal and mechanical performance of the foamed concrete composite is evaluated to ensure its strength and ability to reduce energy consumption in buildings.

INNOVATIVE ENERGY STORAGE SOLUTIONS

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ENERGY HARVESTING FOR MICROMOBILITY SYSTEMS

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RECOVERY OF ENERGY AND FUELS FROM WASTE MATERIALS IN A CIRCULAR ECONOMY SOCIETY

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Key Words: Circular economy, waste to energy, waste to fuels, urban development

Circular economy and bioeconomy are the policies adopted as a response to the unsustainable use of natural resources. It is argued that implementation of these concepts in tandem, through a systemic approach including design principles and process integration, would ensure resource efficiency and sustainability. Thermal treatment of waste materials for the recovery of energy or fuels (waste to energy or WTE), could stand as a strong link between these policy agendas that present common objectives and areas of intervention. Thermal treatment technologies can be included in a circular economy concept either as a final disposal step or as the core process unit able to produce a spectrum of marketable products. However, arguments against thermal treatment of wastes by environmental and other groups, are often creating obstacles on the deployment of such technologies in communities, e.g. Dublin, or even in few cases are cancelling the projects, e.g. Mexico City. The aim of this presentation is to provide evidence on the benefits of the recovery of energy and fuels from waste materials within the context of a circular economy. A review of the thermal treatment technologies is presented, evaluating their potential significance. An analysis of various types of thermal treatment technologies has been developed, including both pilot and large-scale applications. Future directions are highlighted.

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ENGINEERING VERTICAL CRYSTAL ARRTAYS FOR EFFICIENT SOLAR ENERGY HARVESTING

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Key Words: Organic solar cells, crystal engineering, nanoconfinement, continuous processing

Solution-processable organic semiconductors promise to drive down the cost of optoelectronic devices by affording the large-scale, high-throughput manufacturing of photo- and electrically-active layers. Achieving optimal morphologies during rapid deposition from solution, however, has proven exceedingly difficult and has thus far limited the performance of these materials. A novel method is presented to control the earliest stages of nucleation and crystallization during solution-phase deposition of small-molecule organic semiconductors. Nanoporous scaffolds were introduced to the surface of device platforms that confine organic semiconductor nucleation at the air-solution-surface interface during a continuous dip coating process. These nuclei were found to preferentially orient with their fast growth direction aligned parallel to the long axis of the pores. Subsequent crystallization proceeded beyond the scaffold to form arrays of high-density, vertical crystals with large exposed surface area. X-ray diffraction analysis revealed that the vertical crystals oriented with the π-stack direction perpendicular to the substrate surface, the optimal orientation for light absorption and charge transport in organic solar cells and other devices with a sandwich electrode configuration. The height, diameter, and spacing of these crystals were tunable by varying the scaffold geometry and deposition conditions.[1] Critically, this generalizable method is compatible with continuous processing methods that will enable the large-scale manufacturing of such materials.[2]

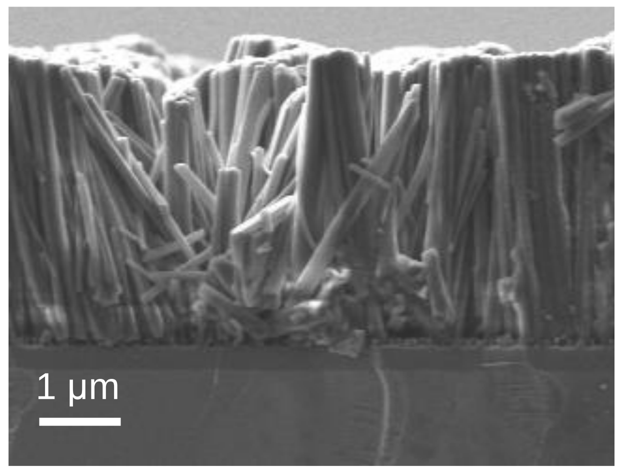

Figure 1 **-** *Cross-sectional scanning electron micrograph of a vertical organic semiconductor crystal array deposited from solution onto a nanoporous scaffold.*

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HARVESTING ENERGY FROM LOW-LEVEL VIBRATION USING ALTERNATE CONTACTS BETWEEN WATER DROP AND TWO DIELECTRIC MATERIALS

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Key Words: Electrostatic energy harvesting, contact electrification, water drop, PTFE, CYTOP.

Advances in low-power electronics and distributed systems have stimulated significant interests in small-scale power supply systems that generate electricity from ambient environmental energy sources. Recently, the rich electrostatic phenomena at liquid-solid interfaces have spurred renewed interest in harvesting mechanical energy through electrostatics.

Here we report an electrostatic harvesting approach which takes advantage of water moving across dielectric materials that possess significantly different surface charge densities. Such difference enables strong electrostatic induction and thus, leads to a high harvesting efficiency. Because CYTOP and PTFE respond to contact electrification very differently, a hydrophobic surface created with them will be electrified at different levels if brought into contact with water as shown in Fig. 1 [1]. Using prototype devices, we demonstrate the effectiveness of this approach in scavenging energy from low-level and low-frequency ambient vibrations. Each device was fabricated on a doped silicon substrate with one side coated by a thin, dielectric oxide layer. CYTOP and PTFE were used to create the two-region hydrophobic surface on which a 400 µL water drop was free to move. Under a 0.25 Hz vibration, the device in which the CYTOP and PTFE regions were fabricated with similar thicknesses could generate a peak open-circuit voltage of 42 V. When the CYTOP and PTFE regions were fabricated with significantly different thicknesses, the device could generate a peak open-circuit voltage of 115 V under an 8 V external bias when the device was driven under a 2.5 Hz vibration.

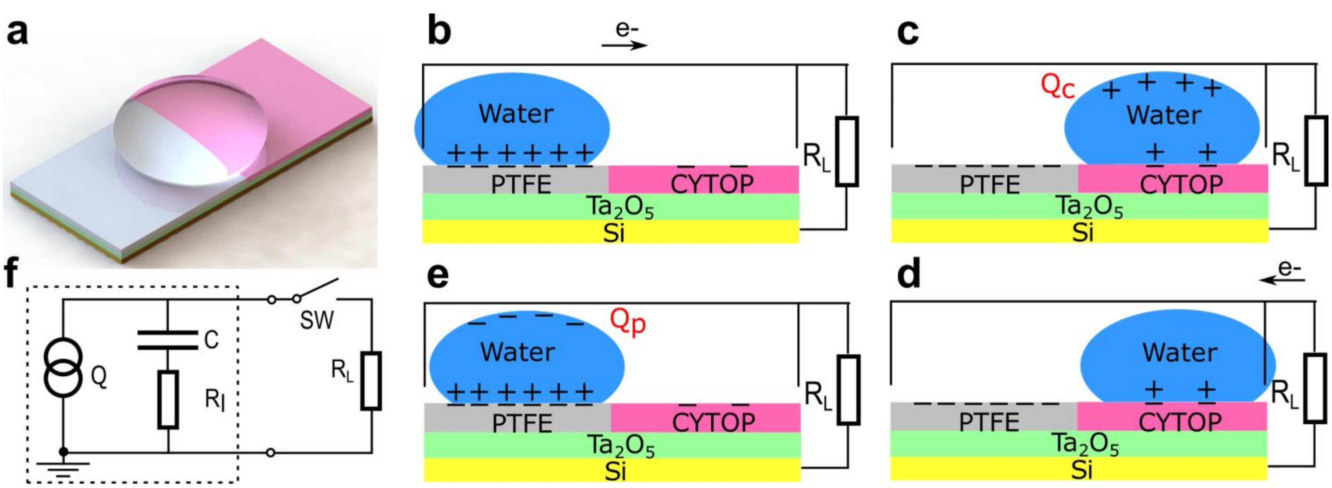

Figure 1 – Working principle of the prototype harvester.

Reference:
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OPTICAL THERMAL INSULATION VIA SOLAR-ENERGY HARVESTING PHOTOTHERMAL NANO COATINGS

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Key Words: Solar Energy, Green Window, Photothermal, Thermal Energy Loss, Nano Coating.

The current technological advancement has enabled glass-based building facades with double- or triple-glazed transparent panels. However, the conventional glazing technologies cannot effectively reduce building thermal energy loss especially for large area transparent building skin. According to a report by the U.S. Department of Energy, building heating, ventilation, and air conditioning (HVAC) accounted for 14.0 % of primary energy consumption in the United States. Heat loss through windows in cold weather consumes about 3.9 quads, which is estimated to encompass 28.7 % of total HVAC energy consumption. [1] We have developed a novel concept of Optical Thermal Insulation (OTI) without any intervening medium (Fig. 1). Instead of applying a thermal insulator, a transparent photothermal (PT) film can selectively absorb photons near the UV and NIR regions and efficiently convert them to heat, therefore raising the window surface temperature (via free energy). As the inner surface temperature is raised relative to room temperature, the heat transfer at the window inner surface can be effectively reduced via the so-called OTI, especially in winter. It must be noted that the PT films are spectral selective with high absorptions near UV and IR, while allowing high visible transmittance, therefore transparent and ideal for façade engineering. Based on this concept, a so-called “Green Window” has been designed for single-pane applications that meet the U-factor specifications of Department of Energy for colder regions of the United Sates. The “Green Window” is composed of chlorophyll (Chl) retrieved from natural greens (by which the name “Green Window” is derived). [2] A thin film window coating of naturally occurring chlorophyll exhibits strong near UV and NIR absorptions and pronounced photothermal effect, while remaining highly transparent (Fig. 2). Upon collecting solar light, considerable heat is created, effectively raising the window surface temperature, leading to a reduced U-factor less than 1.7 W m^{-2} K^{-1}, even below the values of double-panes. Based on these experimental results, we demonstrate of a new concept of “optical thermal insulation” that lifts the dependence on insulating materials making single-pane window highly possible. Fig. 2 shows the change in temperature (ΔTg) induced by simulated solar light as a function of time for the multilayer samples of chlorophyll. Consistently, thicker films (each layer is ~ 2 mm) gave greater ΔTg as expected. Conversely, the thicker films exhibit lower visible transmittance (VT). As shown in this figure, the temperature plateaus can be observed after 2 min.-irradiation by solar simulator. Fig. 2b shows $\Delta T_{g,max}$ vs. VT for thin films of different layers (a maximum of 6 layers). $\Delta T_{g,max}$ vs. VT displays a linear relationship extending to the point where no Chl film was applied (highest VT).

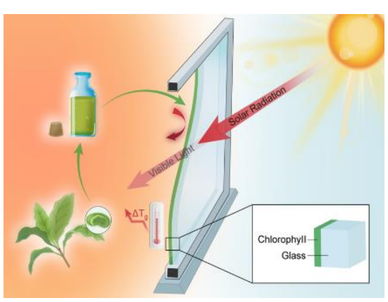

Figure 2 –Chlorophyll-coated “Green Window” for “optical thermal insulation.”

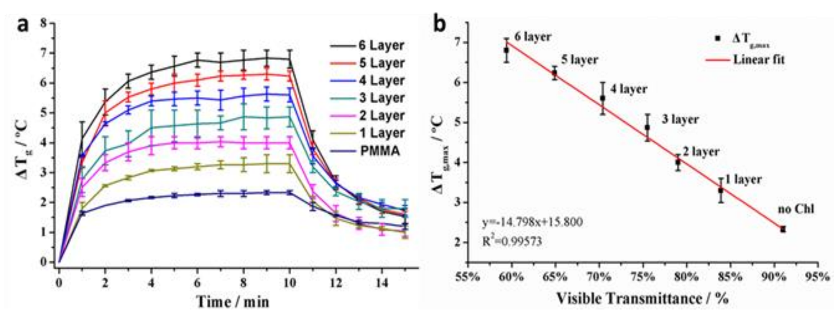

Figure 2 (a) ΔTg vs. Time for Chl-coated glass.
(b) ΔTg vs. VT for Chl-coated glass

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THE WATER POWER TECHNOLOGIES OFFICE AND POWERING THE BLUE ECONOMY

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AN ENERGY HARVESTING UNDERWATER ACOUSTIC TRANSMITTER FOR AQUATIC ANIMALS

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Autonomous electronic devices, especially micro devices, are limited by the finite energy capacities of their batteries. For an underwater acoustic transmitter, the weight and volume associated with the battery are the limiting factors in transmitter operational life, which subsequently affects the length of time the tagged animal can be studied. In this work, for the first time, we successfully developed and demonstrated a self-powered acoustic transmitter that used a piezoelectric composite beam to harvest the mechanical energy from the swimming motion of a live juvenile sturgeon, in which the transmitter was implanted subdermally. The self-powered transmitter did not contain a primary battery and was able to consistently send transmissions when the implanted fish swam in a natural manner. The prototype transmitter is 77 mm long, 5.3 mm wide, only 1 mm thick for the most part of its body. It weighs no more than 1 gram. This is the first implantable self-powered device that has been successfully demonstrated in a live fish. The successful development of this transmitter has potential to significantly expand our capabilities in long-term aquatic animal tracking and their migration behavior studies.

Bio

Dr. Deng is a Lab Fellow in the Energy and Environment Directorate at the Pacific Northwest National Laboratory and an adjunct professor of Mechanical Engineering of Virginia Tech. He directs the PNNL Bio-Acoustics & Flow Laboratory, an accredited multi-disciplinary R&D laboratory, addressing a broad range of engineering and ecological issues, with an emphasis on environmental monitoring and risk assessment for hydropower, wind, marine, and hydrokinetic energy systems. He has authored or coauthored 120 peer-reviewed journal articles. He has developed several licensed technologies related to renewable energy and acoustic sensors. He has six patents and seven pending patent applications. He received his PhD in Theoretical & Applied Mechanics from University of Illinois at Urbana-Champaign in 2003.

MULTI-FIDELITY MODELING AND SIMULATION OF WAVE ENERGY CONVERTERS

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Key Words: Wave Energy Converters, Modeling and Simulation, Scaling, Reduced-order models

Equations governing the response of wave energy converters (WECs) consist of partial differential equations and nonlinear boundary conditions that model the wave absorption, which is commonly used for classification of WECs, wave radiation and diffraction as required for prediction of wave energy generation by WEC farms, the converter's response and the transduction mechanism.

To date, the modeling and simulation of WECs or WEC arrays are based on linear wave theory, which assumes irrotational flow and limits the analysis for design to small wave amplitudes. In contrast, it is desirable to operate WECs in large waves under resonance conditions that would lead to large amplitude motions for effective energy conversion. With large amplitude waves and motions or responses, the linear and irrotational flow assumptions would not be valid. In this talk, we present a review and examples of (1) physics-based multi-fidelity modeling and simulation procedures that could be performed to develop effective control and optimization strategies for different types of WECs, and (2) nonlinear phenomena that can be exploited to enhance the performance of WECs.

THE GLOBAL PARTNERSHIP FOR OCEAN WAVE ENERGY TECHNOLOGY:
How a Patent Developed at the Stevens Institute of Technology and United Nations Partnership Will Transform the Energy Supply of Small Island Developing States and Other Coastal Communities

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Key Words: SurfWEC • Renewable Energy • Wave Energy Conversion • Marine Hydrokinetic • Sustainable Energy

The Global Partnership for Ocean Wave Energy Technology is a sustainable development multi-stakeholder partnership (MSP) that aims to identify the stakeholders, mechanisms, and funding sources required to develop a zero-emissions technology capable of utility-level electrical power generation from ocean waves. Should deployment of the underlying technology be realized, it has the potential to transform the energy supply of small island developing states (SIDS) and other coastal communities. With the cooperation of SIDS governments to train local people in the skills needed to support the technology, the jobs, and marketable energy products that would result offer the potential for the societal challenge envisioned in the United Nation's 2030 Agenda for Sustainable Development, supporting resilient societies and economies that can adapt to climate change.

The technology underpinning the partnership is known as the Surf-making Wave Energy Converter (SurfWEC) concept. It utilizes United States patent no. US 8,093,736 B2, established January 10, 2012, by its inventor Michael Raftery M.E. and with the Trustees of The Stevens Institute as the assignee. SurfWEC is a hydrokinetic device having a water surface float tethered to a submerged buoyant housing, provided with mechanisms for optimizing the amount of wave energy extracted from the waves by the device. Based on wave conditions, the optimization functionalities include controlling the depth of the housing to produce wave shoaling or storm avoidance, as well as to perform continuous phase control and load control for the purpose of matching the response frequency of the device to the frequency of the incident waves.

While Wave Energy Conversion (WEC) systems have been in development since the first patent in 1799, and there have been WEC development efforts as long as there have been industrial solar and wind efforts, the industry is still in its infancy globally and large commercial deployments have still not taken place. A key challenge for the commercial viability of WEC systems is effective extraction of the kinetic energy in waves by the power takeoff systems. Since the waveform and motion are critical factors influencing the kinetic energy input to WEC power takeoff systems, increasing the wave steepness acting on the WEC body can significantly enhance the velocities of water particles impacting prime movers and increase power takeoff performance. The use of variable-depth platforms to enhance wave steepness and increase power takeoff performance through increased kinetic energy input to prime movers is a novel idea that provides promise for increasing the capacity factor for WEC systems. The application of a variable-depth platform to wave energy conversion is discussed and quantified based on wave tank testing, wave theory, and the kinetic energy equation.

In addition to being a scalable utility-level power generation source to meet many needs, SurfWEC can be utilized for other applications to solve additional sustainability problems, such as (a) desalination of seawater onshore, or at sea with an offshore platform; (b) production of hydrogen onshore, or at sea with an offshore platform from seawater rather than by the conventional method of converting fossil fuels (methane); (c) diversification of the power grid to reduce outages, and a continuous source of electricity for small island states and coastal communities struck by hurricane or cyclone; (d) a reef-like environment with potential to improve ocean health and biodiversity; (e) smart technology that can 'learn' over time, becoming a data source for severe weather early warning systems; and (f) In the most severe storm conditions, the SurfWEC platform can be retracted on-site, autonomously, and remain fully operational.

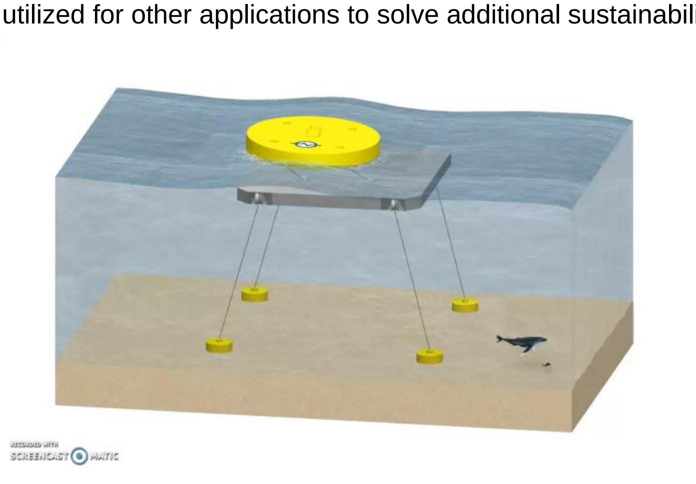

Figure 3 – Surf-making Wave Energy Converter – SurfWEC

TOWARDS BLUE ENERGY: THE DESIGN, DYNAMICS, AND CONTROL OF AN INNOVATIVE POWER TAKE OFF FOR OCEAN WAVE ENERGY HARVESTING

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Abstract: The ocean wave energy potential along US coastline is 64% of the electricity generated from all sources in the US. Over 53% of the population live with 50 miles off the coasts, so ocean waves offer ready opportunity to provide electricity without long-distance electricity transmission. However, the ocean wave energy harvesting is still in its infant stage worldwide. The power takeoff (PTO), the machinery to convert the mechanical energy into electricity, is widely considered as the single most important element in wave energy technology, and underlies many of the failures to date (A. Falcao 2010). Revolutionary power takeoff beyond the direct and indirect drives is urgently needed in order to realize the vast blue energy potential from the ocean. This talk will present the design, dynamics modelling, power electronics control, lab test, wave tank test, and ocean trial of a "mechanical motion rectifier" based power takeoff, which converts the irregular oscillatory wave motion into regular unidirectional rotation of the generator. Lab tests show that up to 80% mechanical energy conversion efficiency was achieved with reduced force in the PTO motion system. The rotatory inertia and two-body system design can further increase the power output in a large frequency range. Wave tank test and ocean trail also validated the high efficiency and reliability.

Bio Sketch: Lei Zuo completed his PhD in Mechanical Engineering from MIT in 2004. After working on industry for four years, he joined in State University of New York in 2008 as an assistant professor and was promoted to associate professor in 2013. He moved to Virginia Tech in 2014 and was promoted to full professor rank in 2017. He currently serves the Director of NSF Industry-University Collaborative Research Center for Energy Harvesting Materials and System. Lei Zuo's research interests include marine and hydrokinetic energy, mechatronics design, energy harvesting, vibration control, advanced manufacturing, and thermoelectricity. Since 2018 he has secured over 14 million US dollars of research funding ($11M as the PI), including ten projects from US Department of Energy, National Science Foundation, Energy Protection Agency, National Academy of Sciences, New York and Virginia States on the design, dynamics, control, and applications of ocean wave energy conversion. Lei Zuo has published 110 journal papers and over 150 conference papers, including 6 with best paper awards and 2 with best student paper awards. He graduated 10 PhD and 19 MS students and is currently advising 12 PhD and 7 MS students. The ASME recognized him as “a pioneering researcher in energy harvesting, especially at larger energy scale” with its 2015 Thar Energy Design Award. Zuo is also the sole recipient of the 2017 ASME Leonardo Da Vinci Award/Medal, for his “eminent achievement in the design or invention of a product which is universally recognized as an important advance in machine design”. He won R&D Awards twice (2015 and 2011) from R&D Magazine, which recognizes the top 100 technology innovations in the word of the year. He currently serves as a technical editor for IEEE/ASME Transactions on Mechatronics and associate editor for ASME Journal of Vibration and Acoustics and IFAC journal Mechatronics.

DESIGN AND SIMULATION OF A NOVEL SUBMERGED PRESSURE DIFFERENTIAL WAVE ENERGY CONVERTER FOR OPTIMIZED ENERGY HARVESTING EFFICIENCY AND PERFORMANCE

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Key Words: wave energy converter, energy harvesting optimization, hydrodynamic analysis, linear wave theory

A novel submerged pressure differential wave energy converter (SPDWEC) has been designed and simulated for energy harvesting under both regular waves and irregular ocean waves. As the waves pass by, the oscillating water pressure on the flexible surface of the SPDWEC moves the pistons of the power take-off (PTO) system, in such a way the wave energy is converted into electricity. Hydrodynamic responses of the SPDWEC are simulated by a numerical model calculating both the linear wave forces and the nonlinear effect of wave height reduction caused by energy extraction. The results show that the SPDWEC can reach a high power capture ratio through system optimization of the stiffness and damping of the PTO system. This innovative SPDWEC exhibits improved lifetime and maintainability by enclosing the PTO inside the WaveHouse, where the overall air pressure keeps nearly constant. As shown in Figure 1, the optimal power capture ratio of the SPDWEC ranges from 0.21 to 0.32, which means the PTO system can extract 20-30% of the incident wave energy. The ideal power capture ratio, which does not consider the nonlinear effect caused by energy extraction, is much larger than the optimal power capture ratio and is larger than one for wave periods larger than 9 s.

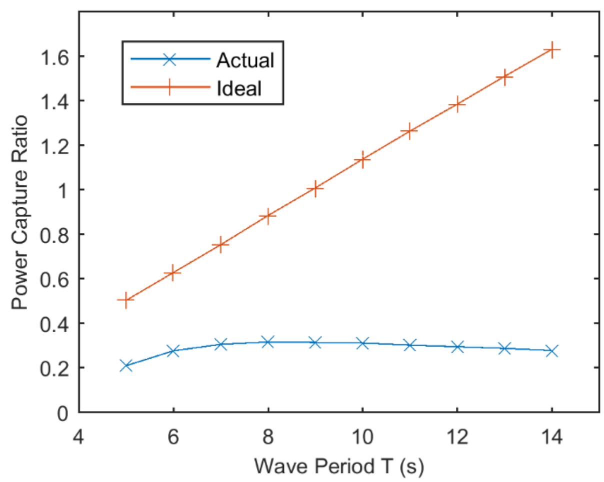

Figure 1. Power capture ratio with respect to wave period

WAVE-POWERED DESALINATION SYSTEMS FOR DEVELOPING COUNTRIES AND ISLAND NATIONS. CABO VERDE CASE STUDY

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A PUSH-PULL TRANSDUCER FOR OCEAN WAVE ENERGY HARVESTING

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Key Words: Ocean-wave, energy-harvesting, electrostatic, electret, low-frequency

Ocean wave energy is one of the primary energy sources, which is available during day and night, in various weather conditions. It was previously proven that energy harvesting from ocean waves could be used to generate electric power to supply sensors or small electronic devices located in buoys. Using a combination of various energy harvesters would enable more remote and unmanned future offshore sensor applications that can facilitate more effective monitoring and control. In this study, we successfully demonstrated a simple, low-cost and environmentally friendly energy harvester which can be optimally used as an Ocean Wave Energy Harvester (OWEH).

The primary purpose of this study is to design, built, and characterize a push-pull electret-based electrostatic energy harvester device (see Figure 1) for low-frequency applications. Experimental data was obtained and analyzed to determine the factors, such as vibration frequency, acceleration, and surface charge, which influence the performance of such a system. Also, a custom vibration shaker that is capable of testing such a system at low-frequencies is developed and utilized as a mechanical excitation source. Teflon FEP film was chosen as the electret material and being charged using corona triode method. Different surface potentials on electret films (300-1800 V), vibration frequencies (1-45 Hz), and accelerations (0.1-1.0 g) were analyzed to evaluate their effect on voltage, energy, and power outputs of the energy harvester (see Figure 2). Peak-peak voltage outputs of 300 V were observed. Besides, an output power of ~15 µW and energy of ~1 mJ were obtained over less than a minute harvesting at 18 Hz. These quantities can be easily enhanced through design optimization. It was successfully proven that our electrostatic energy harvester could be used to power small electronics by harvesting energy from low-frequency mechanical vibrations. Besides, our EH device can be easily mounted to a structure such as a floating buoy and replaceable if any problem occurs during the long term of use. Considering the irregular vibrations, environmental- friendliness, and harsh environmental conditions of oceans and offshore, our EH device could be one of the most appropriate solutions for small-scale ocean wave energy harvesting applications.

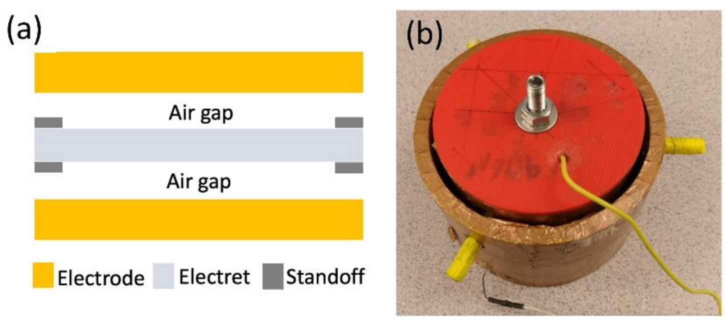

Figure 4 – Prototype device (a) illustration and (b) assembly

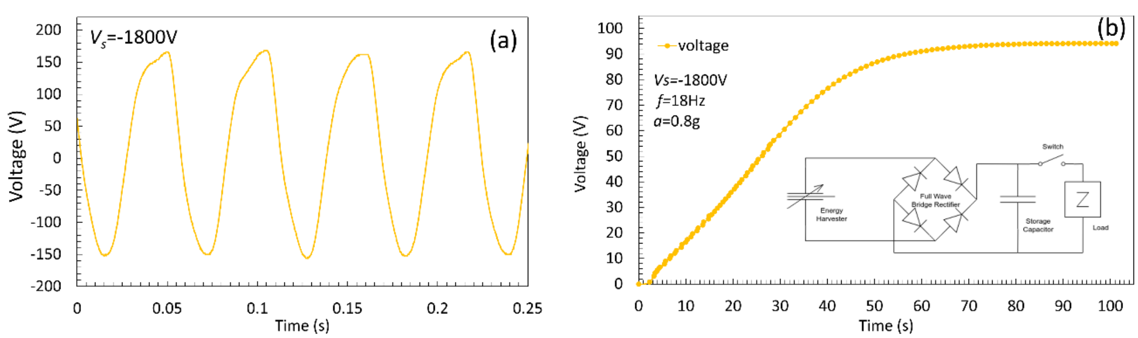

Figure 2 – Voltage measurements of our EH device (a) open-circuit and (b) charging a capacitor

PERFORMANCE OF A HYBRID WAVE-CURRENT ENERGY CONVERTER AND TANK TEST VALIDATION

NEEDS AND CHALLENGES IN MODEL TESTING OF WAVE AND TIDAL ENERGY DEVICES

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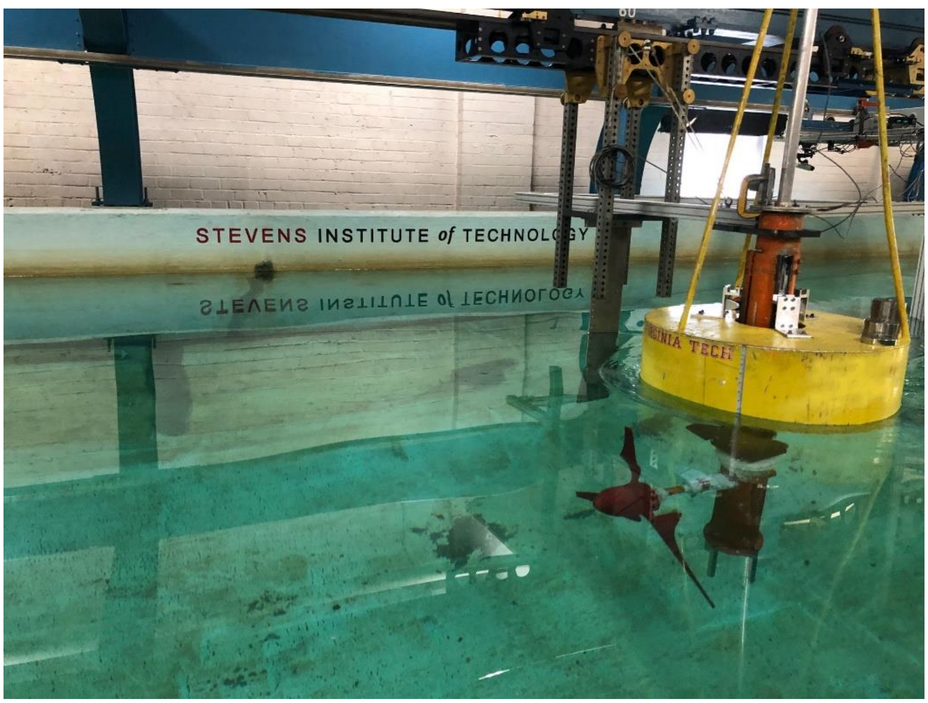
Key Words: Wave Energy Converters; Model Testing; Scaling Laws; Power Take Off

Evaluation of the viability of wave and tidal energy converters represent the main challenge for marine energy developers and government agencies. Although the concept of wave energy conversion is very intuitive, its performance evaluation is complicated by different factors including evaluation of efficiency, components performance and maintenance costs. These factors do not scale up directly from lab experiments. Testing at 1/100 or smaller ratios cannot resolve critical details or satisfy required dynamic similarities. Full-scale testing is expensive. Additionally, varying the designs may not be an option. This implies a need for testing at larger scales. In controlled tests at 1/50 or larger scales, WEC responses can be determined to the point where they can be scaled up and modes of failure can be assessed. This presentation discusses dynamic similarity, scaling laws and how these can be applied to wave and tidal energy devices. Test methodologies, standards and specialized instrumentation, understanding and interpretation of results will also be discussed. The presentation is based on knowledge gained from tests conducted on numerous scale model hull forms and marine platforms in the towing/wave tank of the Davidson Laboratory that have resulted in military full-scale prototypes and commercial systems.



FROM OIL TO INGENUITY, DIGITIZING SOLAR-POWERED MOBILITY

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ENERGY HARVESTING FROM AUTOMOBILES, TRAINS, AND ROADS

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DEVELOPMENT OF A NEW PIEZOELECTRIC-BASED ENERGY HARVESTING PAVEMENT SYSTEM

PIEZOELECTRIC NANOFIBERS AND THEIR APPLICATIONS IN ENERGY HARVESTING

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One dimensional nano structures such as nano-tubes, nano-wires and nano-fibers have great potential as either building blocks for micro/nano devices or as functional materials for micro-scale sensing and actuation applications. They provide more design flexibility and better performance which may not be achievable before. Piezoelectric materials such as PZT is a very good example which was commonly used in bulk or thin film forms. In this talk, the fabrication and characterization of piezoelectric (PZT) nanofibers will be discussed. We demonstrated the piezoelectric properties of polycrystalline PZT nanofibers through electro-mechanical coupling tests such as dynamic loading, mechanical vibration and electric field application using AFM. PZT nanofibers were fabricated by electrospinning process. Diameters of PZT nanofibers could be tuned from about 40 nm up to 200 nm. Titanium substrate with ZrO_2 as diffusion barrier was used to collect the PZT nanofibers for the tests. The largest output voltage from the dynamic test is 170mV under 0.5% strain, which suggest that PZT nanofibers have great potentials for energy harvesting from environments. A potable piezoelectric nanogenerator based on PZT nanofiber will be discussed. It consists of PZT nanofibers aligned on interdigitated electrodes and packaged using a soft polymer on a silicon substrate. The measured output voltage under periodic stress application to the soft polymer was 1.63 V.

IT'S BETTER WHEN YOU HELP

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RENEWABLE ENERGY AND ITS IMPACT ON FOOD-ENERGY-WATER (FEW) NEXUS

AMBIENT ENERGY HARVESTING: AN ELECTROSTATIC APPROACH BASED ON DROPLET CAPACITORS

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Scavenging mechanical energy from the environment has been considered as a potential game- changing technology, especially for applications that require long-term, unattended operations of distributed devices, such as wireless sensors, wearable electronics, medical implants, etc. Because of the advantages such as high voltage output, low cost, and high electromechanical coupling, etc., electrostatic devices have been studied extensively. However, the efficiencies and energy densities of these devices are limited due to the small amount of charge involved as compared to the ultimate capacity of the material as determined by its dielectric strength. Here we report a method in which a positive feedback mechanism is intentionally introduced through reconfigurations of a scavenger fabricated with capacitors. Such mechanism creates instability on the charge in the scavenger so that any arbitrarily small amount of initial charge will grow exponentially. We fabricated prototype devices based on droplet capacitors. The results from low-frequency excitations confirm the exponential growth of the charge and the scavenged energy until the threshold of dielectric breakdown has been reached. The obtained efficiency was orders of magnitude higher than existing devices of similar dimensions. Under a 2.5 Hz vibration, a scavenger with three liquid metal drops can illuminate 60 commercial LEDs and with three water drops, it can illuminate 20 LEDs. Unlike the traditional methods, our method is not domain specific. We demonstrate that it can be generalized to other domains of energy.

RENEW INFRASTRUCTURE BY SURFACE ENGINEERING: TOWARD ENERGY HARVESTING, INFRASTRUCTURE PROTECTION, AND SMART SYSTEMS

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Due to rapid urbanization and population expansion worldwide, addition of new construction in a built environment is not trivial while the existing infrastructure is constantly subjected to increasing demand. Any major disruption, caused by either natural or man-made actions, could have a strong impact on a large part of our nation. Therefore, protection of existing infrastructure, including building, roads, highways, bridges, etc., and enhancement of their performance and lifetime becomes of extreme importance from the viewpoint of security and economy. Inspired by human skin, emerging innovations and technologies are introduced to protect and rejuvenate our aging infrastructure by surface engineering technologies, smart sensing and control, and information management. Specifically, recent advances in energy efficient building, sun powered transportation system, and temperature regulated pavements will be introduced for improved durability and extended lifetime. Multifunctional materials and structures will be developed through physical and virtual experiments. The main approach is to design and develop bioinspired durable, smart skins to protect infrastructure with self-healing, temperature regulation, self-powered sensing and control. The fundamental understanding has been integrated into computer-aided design and manufacture for technology advancement and innovations. Finally, Dr. Yin will introduce his vision on energy in sustainable infrastructure and share some ongoing research at Columbia University.