

Alternative Energy Symposium 2009

Abstracts

Fuel Cells

Activity and Electronic Structure of Palladium-Copper Oxygen Reduction Electrocatalysts

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The high cost of the platinum-based cathode catalysts is a major challenge that limits the widespread application of polymer electrolyte fuel cell power systems. Many efforts have focused on the development of less expensive alternatives to platinum with comparable or enhanced oxygen reduction reaction (ORR) catalytic activity. One approach is to replace Pt with other catalytically-active noble metals and to alloy the noble metals with base metals to both enhance their activity, through modification of their electronic structure, and to reduce the overall catalyst cost.

Alloys of palladium with base metals such as iron and cobalt have exhibited enhanced ORR activities compared to palladium alone and, in some cases, even better mass activities than Pt. Our recent study showed that copper also enhances the ORR activity of palladium and that the extent of enhancement is composition-dependent, with Pd:Cu atomic ratios of 1:3 and 1:1 showing the highest activities. These two compositions were studied further by preparing them using a colloidal technique. They showed enhanced ORR mass activities, normalized to the mass of Pd, compared to Pd alone. The 1:1 Pd:Cu catalyst shows both higher ORR area specific activity and stability than the 1:3 catalyst.

The electronic structure of Pd-Cu nano-particle electrocatalysts and reference systems of bulk alloys, metal foils, and thin Pd films on Cu substrates have been studied using monochromatized x-ray photoelectron spectroscopy (XPS) and density functional theory calculations. A comparison of the valence band structure of the systems indicated that the total density of states (DOS) of the valence bands of Pd-Cu alloys, near the Fermi energy, is dominated by contributions from Pd and shows a shift of spectral weight to higher binding energies compared to Pd alone. A similar downward shift was previously observed for a variety of Pt alloys, and may be correlated with the activity by decreasing the overlap of Pd and oxygen orbitals/bands, thus potentially reducing the binding energy of site-blocking oxygenated intermediates Pd surface. The differences between the valence band structure of the nano-particles and the foils and correlation with ORR activity will be discussed.

The above observations can provide guidance to the design of low-cost, active, and durable catalyst structures for the Pd-Cu system. From this perspective, the current and future synthesis strategies for the formation of core-shell structured catalysts will also be discussed.

Circuital Modeling for Solid Oxide Fuel Cells Including Diffusion Currents

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Solid oxide fuel cells are particularly important because they can operate with conventional hydrocarbons. A complete model of their electrical behavior is still lacking in spite of previous efforts. Here we present a circuital model corresponding to the electrolyte section of a solid oxide fuel cell. We consider that the current in this region has conduction, diffusion and displacement components. The model is solved using a proper eigenvalue procedure and the solution is checked by numerical integration. Current step responses are obtained as well as sinusoidal responses at different frequencies - EIS electrochemical impedance spectroscopy. The approach is based on previous work on metal-insulator-metal structures.

We compare the results of our approach with other modeling procedures and we also discuss the requirements of a model that would include both electronic and ionic charge transfer mechanisms and analyze the numerical model derived by Iwai et al where the diffusion was not taken into account.

Preparation of Multicomponent Nanoparticles Using Microwave Irradiation

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Recently, this laboratory has focused on the relevance of microwave irradiation in nanoparticle synthesis, namely to develop multicomponent catalysts to be used in fuel cells. Various multicomponent nanoparticles of Group 8 – 10 transition metals were prepared using a microwave reactor. The size, structure, and composition of the resultant nanoparticles were characterized by transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD) and light microscopy. We are in the process of confirming the presence of metals in the various nanoparticles; even so, it appears possible to utilize microwave irradiation to prepare mixed multicomponent phases of various compositions. The electrocatalytic properties of the nanoparticles for use in fuel cells will be assessed in the near future.

Fuel Cell Integration in a Hybrid Electric Vehicle

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Fuel cells have potential for fuel economy, efficiency and reduced emissions in vehicles. The concept of electric vehicle with supplemental fuel cell power is fundamentally different from gasoline powered conventional vehicle. The hybrid electric vehicle power is supplemented by a fuel cell system which is used for charging the battery pack. The motor gets its power through a DC controller which takes power from the battery pack. The accelerator is connected to a potentiometer which provides the signal to the controller regarding how much power transmission is required. When driver pushes the accelerator, the voltage delivered by the controller to the motor increases, thus boosting output power to the vehicle. The controller can deliver any power output (from zero to full) depending on the position of accelerator pedal. These vehicles enjoy a longer driving range than typical electric vehicle without a long battery charging time. Several types of fuel cells will be discussed in this paper with an in-depth focus on polymer electrolyte/proton exchange membrane (PEM) fuel cells. These fuel cells use hydrogen and air to produce electricity which completely eliminates carbon dioxide onboard the vehicle. They offer high power densities, quick response time to load changes and durability. This paper discusses fundamentals of fuel cell systems, LTPEMFC and HTPEMFC, system integration, hydrogen storage, power electronics and power management. The conversion of an internal combustion engine vehicle into electric vehicle and integration of fuel cell is discussed.

Organic / Inorganic Hybrid Membranes Based on Dendrimers / Oligosilsesquioxane for Fuel Cell Application

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Proton exchange membrane fuel cell (PEMFC) is regarded as the critical technology for renewable energy systems. Since the membrane is considered to be the key element for more efficient PEMFC, a new class of polymer electrolytes has been investigated. In this paper, the synthesis of a new class of organic/inorganic hybrid membranes will be highlighted. The membranes, based on polyhydroxy-functional dendrimers and sulfonated oligosilsesquioxane, are evaluated as candidate materials for proton exchange membrane in direct methanol fuel cell (DMFC) application. The presence of inorganic particles can potentially provide physical barrier against methanol crossover while improving the mechanical and thermal stability. The chemical structure and thermal stability of the hybrid, characterized by FTIR, TGA and DSC will be highlighted. In addition, the physical properties and membrane performance, evaluated by the titration, gravimetric techniques, and proton conductivity measurements will be reported.

Microprocessor based Control of a Portable High Temperature PEM Fuel Cell

Kourosh Sedghisigarchi, Asad Davari

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This paper presents a microprocessor based control system design for a portable high temperature Polymer Exchange Membrane (PEM) fuel cell unit. A proper control results in a fuel cell which is more efficient and has longer start-up and shut down process than the conventional ones. This controller enables the fuel cell unit to be capable of managing start-up, production and shut-down conditions as well as monitoring critical fuel cell parameters such as cell voltages, air inlet, hydrogen inlet temperatures and pressures, stack temperature, stack current, and air inlet pressure. The control and monitoring functions are developed using a standalone system which contains a 16 bit microchip processor, an interface I/O board, a LCD and a keyboard. This portable unit automatically controls air blower, heater, air, hydrogen and nitrogen valves of the fuel cell system to ensure proper operation of the fuel cell during normal and transient conditions such as shut down and start-up.

EnerFuel's Technical Approach for the Impending Fuel Cell Market

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Diversification will be critical in the future for successful development and use of energy. Fuel cells will play a key role in that diversified energy future. Through its Extended Range Electric Vehicle Program EnerFuel has demonstrated a simplified approach to fuel cell development and integration, that minimizes the challenges which have hampered more widespread adoption of fuel cells.

Wind Energy

Optimizing Wind Energy through Analysis of Temporal Wind Patterns

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Despite the rapid growth of wind energy as an alternative energy source, little has been done to study the wind recourses themselves. Existing maps and databases provide only a general overview of wind energy and speed distribution. This paper will look at the highly time spatial variability of wind in any natural setting in an effort to provide practitioners in this rapidly expanding industry with information for planning, managing, and marketing wind energy and wind turbine and tower design.

The study will use a data analysis technique on one site (Brookings, SD; 3 m height) for annual data of hourly wind speed and gust, which will provide wind characteristics for three seasons (two of five months and one of two months). The mean speed and gust per hour during the day changes nearly doubles for some hours from season to season; the hourly range in speed also varies significantly as the seasons change. Results will describe the correlated variability of hourly wind speeds and gusts as a unique structure with seasonal and daily levels. The interannual variability for this site will then provide a template for similar analyses of spatial variability on different heights and on neighboring sites.

Natural time spatial variability of wind has to be studied on data from coop metrological and airport stations with additional existing data, as these results will help unveil a methodology for multilevel studies of wind energy. Systematic observation and data analysis of natural wind variability will provide a basis for comparing wind energy flow with manufactured electrical power for improving management and design of different size facilities.

Solar Energy

Towards Understanding Electron-Transfer Processes in Dye Sensitized Solar Cells

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The dye sensitized solar cell (DSSCs) is believed to have potential as a next-generation solar cell, providing flexibility (both mechanical and photophysical), cost reduction, and application-specific benefits over currently available solid state devices. However, as of yet no solar cell based on dye sensitization principles has matched the efficiency of silicon-based solar cells. Our research focuses on studying the electron-transfer interactions in a DSSC that are beneficial and detrimental to the efficiency of the device. This talk will describe how electrochemical techniques can be used to characterize a DSSC based on alizarin, an anthraquinone derivative that photosensitizes titanium dioxide. Traditional electrochemical techniques will be used to characterize the oxidation potential of alizarin, and helps to explain differences in the electron-transfer behavior of alizarin in solution and attached to a titanium dioxide surface. Scanning Electrochemical Microscopy (SECM) is used to characterize the interaction of surface bound alizarin with a dissolved redox mediator both in the dark and under illumination. These studies provide insight into the effects of heterogeneous electron transfer rates and mass transport on the efficiency of the DSSC.

Conformational Effects on Electron Transfer: Combining Solution-Phase X-ray Scattering and Molecular Dynamics Simulations

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Understanding electron transfer events are crucial for a wide range of processes including photosynthesis, respiration, and designing new solar energy devices. This understanding requires the development and application of methods that can investigate solution-phase conformational changes. Recent advances combining x-ray scattering measurement with coordinate-based modeling methods have created opportunities for enhancing our understanding of structural dynamics of supramolecular assemblies in solution. This talk will highlight correlations between solution x-ray scattering results and ensembles of molecules created through molecular dynamic simulations. Examples will include interactions between solvent molecules and zinc-porphyrin hexamers; the ability to distinguish conformational changes in cytochrome c7 proteins upon oxidation; and hydrogen bonding interactions in primary alcohols. The combination of atomic-scale molecular ensembles created through molecular dynamics simulations and solution-phase x-ray scattering offer possibilities for resolving the structure of dynamic supramolecular assemblies that can not be fully addressed by crystallographic techniques. In addition, this approach addresses the need to determine fundamental mechanisms for solar energy conversion by mapping out structures under conditions necessary for electron transfer.

Development of the I-V Measurement System for Solar Cell with Pulsed Flash Light Source at AST

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In this paper, the current measurement techniques with pulsed flash light source for solar cells are briefly reviewed, and the measurement system developed by AST is introduced. A several milliseconds pulsed flash light source, an electronic load, a high-speed oscilloscope and remote control technology were integrated into this measurement system. The crystalline silicon solar cell and the a-Si solar cell, which are available commercially, were applied to the development of the measurement system and to the characterization of pulsed flash light source. The measure results were compared to the specifications of the crystalline silicon solar cell sample and the a-Si solar cell sample. The result showed that the system developed by AST is effective in the I-V measurement of solar cells. The system can be applied to characterize the performance of solar cells in photovoltaic industry and scaled up to measure solar cells with larger size in the future. It will promote the development of a-Si solar cells in AST.

A Feasibility Study for a Solar Power Plant at a WV Coal Mine

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Underground coal mines consume large amounts of energy per year. A typical mine complex operates 24 hours a day, 365 days a year. The mine sites require electricity to operate underground lights, air circulating fans, miles of belt systems, buggies, and above ground processing plants. There is no surprise that Massey Energy, West Virginia's largest coal company, ranks second in energy consumption from AEP. Massey Energy has several mine complexes spread across the state, however, majority of the mine complexes are grouped together in central West Virginia. Central West Virginia also has the highest solar radiation region in the state.

In this paper, a solar power plant is proposed to be implemented on a West Virginia surface mine site. The energy produced could then be used to power, in whole or in part, an adjacent underground mine complex. Solar radiance maps are used to determine the solar potential in various areas of West Virginia. The proper photovoltaic system is selected to meet the needs of West Virginia based on the following: an efficiency to cost ratio, the ability and ease to install on a previously mined location, and

the ability to offset energy costs at current, local mine complexes. The location of the each solar plant is determined based on solar radiance and proximity to mine sites. The overall energy costs of an installed photovoltaic system are calculated with various offset percentages for a 20 year operational time frame. Also, It is compared to the energy costs of purchasing 100 percent of a mines power from an outside supplier such as AEP. These objectives will be discussed in detail along with the cyclical economics of coal mines and electricity companies.

Organic Molecules as Dyes for Dye-Sensitized Solar Cells

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Dye-Sensitized Solar Cells (DSSCs) have attracted considerable attention from the scientific community due to their potential to become viable sources of power generation. The dye in DSSCs is an organic or organometallic molecule which will provide electrons via sunlight excitation. The electron from the dye goes to the semiconductor material for current generation in DSSCs. Much effort has been devoted to the improvement of the solar cells output by molecular changes to the dyes. The search for such dyes has resulted in the investigation of a large number of molecules that can function as dyes in DSSCs. This presentation will review the current literature in organic and organometallic molecules that have been used as dyes in DSSCs. Their structures, physical, and photophysical properties will be presented. General trends and future potential molecules will also be discussed.

Development and Application of Amorphous Silicon Solar Cells Based on Different Substrates

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Due to the advance of technologies, the shortage of energy source and little impact on the environment, the amorphous silicon solar cell as alternative energy has been one of hot topics in the high-tech photovoltaic industry. This paper focuses on the development and the application of amorphous silicon solar cells. The amorphous silicon solar cell and its derivative based on glass substrate, plastic substrate and stainless steel substrate are reviewed. The typical process technologies of amorphous silicon solar cells based on different substrates are introduced. The influence of the substrate choice on the development of amorphous silicon solar cells is analyzed. Besides, the state of the art on the application of amorphous silicon solar cells based on different substrates is described. The future trend of amorphous silicon solar cells is discussed.

Synthesis of Anthocyanin Derivatives as Potential Dyes for Dye-Sensitized Solar Cells

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Anthocyanins are responsible for the red-orange color found in red coloring plants and fruits. Fruit extracts, which are rich in anthocyanins, have been used to generate dye-sensitized solar cells. Anthocyanins have a flavylium ion as chromophore. The C ring contains hydroxyl groups that are believed to function as the anchor groups that attach the flavylium ion to the titanium dioxide semiconductor in DSSCs. Although fruit extracts are easy to use, they provide low power output in DSSCs.

Furthermore, a systematic study of how anthocyanins molecular structure affects the output in DSSCs is hindered by the uncertainty in the amount and variety of anthocyanins present in fruit extracts. To investigate the use of anthocyanins as dyes for DSSCs in a systematic way we have decided to develop practical synthetic approaches to anthocyanins derivatives. This presentation will discuss one of such practical approaches which utilize the alkylation of acetophenone derivatives followed by flavylium ion formation. Our synthetic efforts in this two-step synthetic approach will be presented.

Bio-Fuels

Biocatalyst development for the Production of Bio-JP8

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As the fossil fuel supplies of the world are dwindling, the race for harnessing the alternate energy sources is skyrocketing. Biomass is one such source with huge potential and technologies for the production of biofuels (Biodiesel, Bio -JP8) are fast emerging. While biodiesel may be used directly, aviation fuels (JP8) require stringent composition to maintain fluidity at high altitude frigid temperatures. Chain length, degree of unsaturation and branching are critical determinants of fluidity, stability and combustion value.

Biological systems have evolved ingenious ways to meet their energy demands by developing enzymatic pathways that release energy from the available nutrients. Our objective is to explore and exploit these pathways to develop biocatalysts (enzymes and/or whole cells) that are suitable for the production of Bio-JP8 with desired properties from vegetable oils. Biocatalysts have the added advantage over conventional catalysts as they typically operate under mild conditions of pH and temperature leading to the formation of products of high purity and specificity. Our primary goal is to focus on developing biocatalysts to release fatty acid (FA) from vegetable oil and subsequently remove two carbons at a time to get optimum chain length.

Utilization of Refining Technology for BioJP-8 Production

Donghua Zuo, Amir Fattahian, Nader Enayati and Ali Manesh
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There has been an increasing interest in renewable fuels as replacements for conventional fossil fuels due to the depletion in fossil fuel reserves. Biodiesel is produced from a transesterification reaction between triglycerides with a short chain alcohol and is usually referred to as fatty acid methyl esters (FAME). While biodiesel can be used directly or as a blend in diesel engines, it will not work as a replacement for an aviation turbine due to limitations in its cold flow properties, heat value and stability. It is believed that in order to meet the specification requirements of JP-8 fuel, refining technologies such as deoxygenation (decarboxylation, decarbonylation and hydrogenation/dehydration), cracking (catalytic cracking and hydrocracking) and isomerization can be utilized to convert vegetable oils, specifically soybean oil into jet fuel range hydrocarbons.

Our catalyst development will be focused on the above mentioned three processes. The utmost goal is to develop a catalyst with combined multifunctional behaviors so that bio-jet fuels can be produced in one single step. The methodology followed would be 1) determine that the catalyst has appropriate functionalities in different model compounds such as methyl-esters and straight long chain hydrocarbons; 2) select an appropriate acidic support; 3) optimize metal content for the catalyst; 4) evaluate the performance of the research prototype catalyst in real feed stocks.

Creating a Bio-Refinery Based on Pulping Technology

Don Guay

University of Wisconsin, Stevens Point, WI

We have identified a novel solvent system, which when blended with dilute acid solutions, fractionates biomass into a cellulose pulp, an aqueous hemicelluloses solution, and a lignin-containing solvent fraction. The solvent system is actually generated by fermenting the sugars following saccharification.

Thus by using the biomass itself to produce the solvent, our process eliminates the biggest limitation of prior fractionation processes – the cost of solvents. The solvents (n-butanol and methyl butenol) we are producing are suitable for liquid transportation fuels and superior to ethanol. Another advantage is that after

separation from the solvent, the lignin is very pure, containing little or no sulfur. This increases its value as a feedstock for production of refined chemicals and polymers, instead of using it to just produce process energy.

Pressurized Steam Reforming of Bio-Derived Ethanol for Distributed Hydrogen Production

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In this paper we will present the results of our system analysis and experimental study of the steam reforming of bio-derived ethanol at elevated pressures using a hydrogen separation membrane for distributed production of hydrogen. Ethanol is an attractive renewable fuel because it has a high energy density, it is easy to transport, and it is environmentally more benign than petroleum-derived fuels. Hydrogen is normally stored and transported at high pressures, and compressing hydrogen is energy intensive and can consume a significant fraction of the fuel's heating value. Producing hydrogen from steam-reforming a bio-derived liquid at an elevated pressure offers a promising option for cost saving in hydrogen compression, since injecting liquid feeds (ethanol and water) into a pressurized reactor requires very little energy. Also, a pressurized hydrogen production process offers flexibility in choosing an appropriate hydrogen purification/separation technology. However, process challenges exist in the pressurized reforming of ethanol. These include lower hydrogen and higher methane yields. These challenges may be overcome through a combination of preferred catalysts, higher temperatures and S/C molar ratios, and hydrogen separating membranes, etc. The objective of this work is to examine these options for the pressurized steam reforming of hydrated ethanol for distributed hydrogen production. The benefits of pressurized steam reforming of ethanol have also been studied from a system perspective. The relative merits of one or more promising scenarios will be presented with respect to their potential for meeting efficiency targets.

In this work, a laboratory-scale Pd membrane reactor test facility has been used to study the membrane's ability to improve hydrogen yields of high-pressure steam reforming of ethanol. Experimental tests were conducted with and without in-situ H₂ membrane extraction under test conditions: an ethanol/water mixture feed of S/C = 6, the catalyst bed temperature ranging from 600°C to 700°C, the system pressure of 1000 psig, and the GHSV ranging from 9,000 h⁻¹ to 24,400 h⁻¹. Test results showed that the Rh catalyst used in this study effectively suppresses ethane and ethylene yields. We observed that higher catalyst temperatures increase yields of H₂, CO₂, and CO, but decrease CH₄ yield, and that lower GHSV increases CO_x selectivity and yields of H₂, CO₂, CO, and CH₄. In agreement with thermodynamic predictions, increasing reforming pressure decreases the yields of H₂ and CO, and increases the CH₄ yield. Under the H₂ extraction mode, higher H₂ yields and CO_x selectivities were obtained than in the reforming mode without H₂ extraction, confirming that H₂ removal through a membrane drives the reforming reaction to the right: $C_2H_5OH + 3 H_2O = 6 H_2 + 2 CO_2$. The experimental data trend agrees well with a mathematical model of the reactor. Systems analyses show the Pd-membrane reactor system can surpass the efficiencies of current technologies (i.e. steam reforming coupled with pressure-swing-adsorption) when combined with a turbo-compressor system.

Crystallization and Melting Behavior Of Unsaturated Methyl Esters Contained in Bio-Fuels

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Some of the low-temperature properties of biofuels may be improved if the fraction of esters of unsaturated fatty acids there is increased. In this presentation, we will describe crystallization and melting behavior of these esters which we probed by means of differential scanning calorimetry (DSC). These results will be briefly analyzed in light of the previous findings of other groups.

Control Strategy for a Biodiesel System

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The most common way of producing biodiesel is by transesterification reaction. The chemistry of transesterification reaction consists of a number of consecutive and reversible reactions. The sequences of these reactions are: conversion of triglycerides to diglycerides followed by conversion of diglycerides to monoglycerides and then conversion of monoglycerides to glycerol. The overall reaction yields one methyl ester molecule from each glyceride at each step. Each reaction is associated with few side reactions, which if not controlled properly, severely hampers product quality. Safety is the first concern for such a process which can be achieved by controlling temperature of the reaction, agitation speed, level, pressure, and pH of reactors as well as pH and agitation speed of purification vessel.

This paper investigates two control strategies: PC based and PLC based controllers. Advantages, disadvantages, capabilities, as well as flexibilities of both strategies are presented.

Engineering Microbes for Increased Hemiterpenoid Production

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Isoprene is a hemiterpenoid produced in large quantities by a number of plant species. In addition to the thermoprotective role it has in plants, it has potential use in industry in the synthesis of synthetic rubber. Methyl butenol is another hemiterpenoid made by pine trees that may be used as a bio-fuel. The focus of our laboratory is to genetically engineer microbes to produce these products in large quantities. We have made a synthetic operon containing the genes involved in hemiterpenoid synthesis from the methylerythritol 4-phosphate (MEP) pathway. We are combining this operon with genes for isoprene (IspS) and methyl butenol synthase (MboS) enzymes in different combinations to optimize the expression of this metabolic pathway. This work will result in the development of microbial strains that can be fed carbon from hydrolyzed wood sugars in a biorefinery and quantitatively convert them into isoprene and methyl butenol for commercial use.

Sustainable and Renewable Energy

The New Sustainable Standard for Higher Education

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HOK, Chicago, IL

The pressing demand for sustainable design, construction and operations has resulted in a significant market shift in many sectors. This shift has become very apparent among higher education institutions as universities and colleges strive to expand curriculums and building design criteria to include sustainable thought and methodologies. There is no better place for this change in culture to occur than in institutions that are producing the next generation of innovative thought leaders.

HOK has experienced this shift first-hand through its higher education project work. Both abroad and within the United States, HOK's higher education clients are requesting a higher degree of sustainable integration for building projects and campus operations. HOK will discuss their experience with multiple higher education institutions and the driving forces behind their requests for sustainable integration. The discussion will focus on recent project work, both abroad and within the United States. On-site renewable energy integration for these projects will be highlighted as an effective strategy to reduce operating costs and meet client goals. Driving forces such as the recent American College and University President's Climate Commitment (ACU PCC), cap and trade legislation and student demands will also be discussed in conjunction with the project examples.

The audience will leave with a better understanding of the "New Sustainable Standard" for higher education institutions. They will learn about the extent of this sustainable movement in higher education and the strategies that are currently being implemented on campuses around the world.

Challenges for Meeting 2030 Projections for Green Energy

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As Americans, we generate more than 85% of the energy we consume by combusting fossil fuels, i.e., petroleum, natural gas, and coal. Historically, the relative abundance and ease of recovery of these fuels has provided us with low-cost energy. However, with the increasing worldwide demand for energy leading to higher costs, dwindling petroleum reserves, and growing environmental concerns related to the combustion of fossil fuels, there is a growing awareness of the need to develop alternative energy sources to complement and, perhaps ultimately, replace fossil fuels. There are considerable efforts underway to increase our use of renewable energy sources, often referred to as "green energies," such as biomass, wind, solar, geothermal, hydroelectric, and ocean waves for meeting our energy needs. Currently, renewable energies account for about 7% of the energy consumed in the U.S., with about 30% of that total being generated by hydroelectric plants and 50% being generated by biomass. Currently, solar and wind account for <0.1 and 1 percent, respectively, of the energy consumed in the U.S. The U.S. Department of Energy's Energy Information Administration (EIA) projects that solar power generation will increase from 1.3 billion kilowatt hours in 2007 to 22.4 billion kilowatt hours in 2030, an increase of more than 1600%. Similar EIA projections for wind power generation indicate an increase from 32.2 billion kilowatt hours in 2007 to 130.6 billion kilowatt hours in 2030, an increase of more than 300%. With regards to biomass, the Energy Independence and Security Act will increase the use of renewable fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022. The presentation will discuss the barriers and challenges, as well as the potential, for solar and wind power and biomass-derived fuels to meet the projected and mandated contributions of renewable energies to the overall U. S. energy requirements.

Heating and Cooling Residential Buildings using Geothermal System

Fereidoon Delfanian

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The increased incentives and push to utilize renewable energy sources has made the use of geothermal heating and cooling systems more appealing than ever. Though the initial costs of the system in some cases are more than 50 percent higher than conventional heating/cooling options, the long term savings can make it worth the investment. Even in cold climates like the Upper Midwest, a properly designed and sized geothermal system can save the homeowner 30 to 50 percent on his heating and cooling costs. This presentation will look at the initial cost of installing a geothermal system in a newly constructed home and the cost savings realized over a three-year period. It will point out some of the factors that consumers need to consider in selecting a contractor with sufficient experience and understanding the complexity of the system. Additionally, incentives available through the state and federal government make this a viable alternative to conventional HVAC systems.

Leading in the Greentech/Cleantech Industry: Insights into Effective Leadership and Strategy

Dave Ancel

Emergent Solutions, Palo Alto, CA

Technological innovation, sufficient funding, and market penetration alone will not enable companies to thrive in the emerging and chaotic greentech/cleantech environment. Organizations must also possess solid leadership, a strong strategic focus, and the nimbleness to engage in rapid business transformation.

Right now, the greentech/cleantech industry is experiencing explosive growth and tremendous change. The need exists to create an industry snapshot from a leadership and strategy perspective, which will help executives make more informed bets about the future. In turn, Emergent Solutions, in partnership with Mariposa Leadership, is conducting the first-ever study focused on leadership and strategy in greentech/cleantech – “Leading in Greentech/Cleantech.”

Commenced in early 2009, this study aims to outline the current strategic environment and identify key leadership challenges, opportunities, and strategic imperatives faced by executives in greentech/cleantech. Specifically, it sets out to understand how leaders are navigating through issues such as impending industry consolidation, new government regulations, and escalating pressure to develop profitable business models while simultaneously maintaining a culture of innovation. This study will provide insights into these complex issues through conversations with C-level through VP-level executives in both veteran and start-up greentech/cleantech firms across a variety of sectors – including solar, wind, bio-fuels, fuel cells, and sustainable architecture.

Preliminary findings will be published in September, and The Alternative Energy Symposium is an excellent forum to share these findings and engage leaders in a rich dialogue around what will it take to thrive in this industry from a leadership and strategy standpoint.

Design of a Novel Energy Scavenging Power Supply for Small Electronic Systems

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Michael Ropp

South Dakota State University, Brookings, SD

The ability to reduce dependence on conventional batteries is becoming more essential as the world continues to investigate more environmentally reasonable sources of power. Some of the disadvantages of batteries are that they: are large and heavy, have a very low power (and energy) density, and are difficult to dispose of. To address this challenge, a novel Energy Scavenging Power Supply (ESPS) has been designed to harvest energy from the surrounding environment while the load is in operation. The device will collect solar, thermo, vibrational, and electric-mechanical energy using a host of transducers and store

that energy until the load requires it. An intelligent charging system using both electrolytic- and super-capacitors to achieve fast charging times and long term storage. This ESPS was optimized for a specific Non-Destructive Testing sensor-system and, therefore, the exact component values and system specification were dictated by the requirements of that sensor-system, but could be easily adapted to other systems. Topics investigated in this paper include: Design of the charging and storage systems, System characterization, and Initial test results.

The lowEx Building: Maximizing System Performance and Geothermal Utilization with Low Exergy Concepts

Forrest Meggers*, Luca Baldini, and Hansjürg Leibundgut

Swiss Federal Institute of Technology, Zurich

Low exergy buildings exploit the concept of exergy to more effectively extract both quality and quantity from energy. Exergy is a concept that considers entropy generation along with energy utilization as defined by the 1st and 2nd laws of thermodynamics. As entropy is generated, for example by heat transfer processes, exergy is destroyed. Because heat transfers with higher temperature gradients create more entropy, more exergy is destroyed. Therefore exergy analysis quantifies the value of relative temperatures and demonstrates the waste in unnecessarily large differences in buildings.

A low exergy building is designed to minimize the losses in quantity and quality. This is achieved by recognizing that a building indoor environment contains only relatively low quality energy, which demonstrates that it does not make sense to provide this energy with very high quality sources such as 500 °C combustion sources. Low quality geothermal heat can be extracted with heat pumps that currently move up to 5 units of heat for each unit of electricity. This heat can be provided to a building at low temperatures using large surfaces such as activated thermal mass. Conversely cooling can be provided using relatively high temperatures. Low temperature heating and high temperature cooling are key aspects of low exergy buildings. The low temperature difference leads to an even greater potential to improve the heat pump performance, which is inversely proportional to this difference.

The potential of exergy analysis for improving buildings has led to the expansion of research in this field. International research projects have formed such as the IEA ECBCS 's completed Annex 37 and ongoing Annex 49 (www.annex49.com) as well as the COSTeXergy program and lowEx.net research network. Also, exergy is being considered in new building codes and energy evaluations as has been done in Geneva, Switzerland. This paper will present the concept of low exergy buildings as well as systems and technology that are being developed and researched at the ETH in Zurich. These include new heat recovery systems that maximize the temperature of the heat recovery as well as a new active insulation system that uses the low temperature ground as source to directly reduce heat losses in an innovative external façade layer.

Fatigue Odometer System Powered by an Energy Scavenging Power Supply

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There are many cylindrical components in mechanical systems which undergo tremendous amounts of fatigue during their lifetime. Traditional methods of inspecting these components are costly and have often proven inefficient. To improve on these methods, a new device, the Fatigue Odometer System (FOS), counts and logs data after each fatigue event and the information is then downloaded to a database for analysis. The specific focus of this project was analyzing the remaining life of gun barrels on large weapon systems; however this technique applies to any thick-walled cylindrical component. Often different types of fatigue events affect the remaining life of the component differently; therefore, an added feature of the FOS is analyzing the data to determine which family of round-type was fired. Based on this determination, the fatigue produced by each round can be used to more accurately calculate the remaining life of the gun barrel, resulting in improved weapon maintenance. To maintain life-long, accurate records of a particular component, it is desired for the FOS to be permanently mounted to the component and require little or no maintenance. This poses a significant power constraint in that a battery will not be replaced throughout the long life of the mechanical component. The basic FOS design has been designed and tested on small caliber weapons. Aspects

investigated in this paper are system improvement, incorporation of an Energy Scavenging Power Supply (ESPS) which scavenges energy from the operational environment to extend the life of the FOS system, and results of large caliber testing.

High Frequency Electromagnetic Stimulation of Methane Hydrate Deposits and Pipe Plugs

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In the present work we analyze the low (60Hz) and high frequency (GHz) electromagnetic response of methane hydrate deposits at depths of the order of 1000 meters below the sea surface. In the low frequency case the source is connected to a conventional heater by cable, while in the high frequency case the source is connected by circular metallic pipes to the reservoir. In order to determine the high frequency response, we used published values for the real and imaginary permittivity of ice determined at high frequency as well as values extrapolated from recent low frequency results for methane hydrates. The Stefan problem representing the melting of the methane hydrate is solved under steady state conditions.

The results obtained in the simulations indicate the feasibility of the methods analyzed - using electromagnetic energy - both for methane hydrates deposits stimulation, as well as for the removal of pipeline methane hydrate obstructions.