Purdue Featured Technologies

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**Purdue Featured Technologies**

The following Purdue technologies are available for potential development, licensing or commercialization. Many of the technologies include a Technology Readiness Level (TRL) number (from 1-9) which indicates how close each technology is to the market. The higher the TRL number, the closer to marketplace ready functionality. For example, TRL 9 means the technology is fully proven in an operational environment; TRL 5 means full testing of prototype completed, and TRL 3 means proof of concept validated and active R&D has begun. See details in the diagram below:

**Definition of Technology Readiness Levels (source: NASA)**

<table>
<thead>
<tr>
<th>TRL</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL 9</td>
<td>Actual system &quot;mission proven&quot; through successful mission operations Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.</td>
</tr>
<tr>
<td>TRL 8</td>
<td>Actual system completed and &quot;mission qualified&quot; through test and demonstration in an operational environment: End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios.</td>
</tr>
<tr>
<td>TRL 7</td>
<td>System prototyping demonstration in an operational environment System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.</td>
</tr>
<tr>
<td>TRL 6</td>
<td>System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.</td>
</tr>
<tr>
<td>TRL 5</td>
<td>System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.</td>
</tr>
<tr>
<td>TRL 4</td>
<td>Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.</td>
</tr>
<tr>
<td>TRL 3</td>
<td>Analytical and experimental critical function and/or characteristic proof-of-concept: Proof of concept validation. Active Research and Development (R&amp;D) is initiated with analytical and laboratory studies.</td>
</tr>
<tr>
<td>TRL 2</td>
<td>Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.</td>
</tr>
<tr>
<td>TRL 1</td>
<td>Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.</td>
</tr>
</tbody>
</table>
High-end Equipment and Manufacturing

PRF No. 65018 Optical Automatic Transmission Range Sensor (OTRS)

Technology Readiness Level: 6

Currently, Transmission Range Sensors (TRS) used in automatic transmission controls for passenger vehicles and light trucks use contact type sensors to denote the gear shift's position. These contacts are realized by means of mechanical components, such as aligned pins loaded by coil springs or leaf springs; however, these systems are prone to failures due to plate wear, spring relaxation, rusted contacts, etc. Researchers at Purdue have invented a new system that uses a non-contact approach to overcome most, if not all, of the failures of current TRS technologies.

PRF No. 64631 Vessels with Integral Life-Sensing Capability

Technology Readiness Level: 5

Many devices are consistently subjected to harsh and unpredictable conditions. Because of this, they become particularly susceptible to external injury. Some damages are not easily detected or prevented, even with proper maintenance and inspection. Damages to laminated structures can be especially harmful. Damages to some products such as tires occur because of gap damage within the tread, over-deflection, cults, punctures, imbalance, impact, rubber hardening/degradation, or improper mounting/repair.

Purdue University researchers have developed a sensing method that can alert operators when a device's structural integrity has degraded. This can save time and effort in repairing or deciding to change the tire, and in some situations, prolong the operable life of a tire. This new sensor method can not only detect unsafe operating conditions, but also alert operators to damage that occurs in situ.

Advantages:

- Sensors detect both internal and external changing structural conditions
- Ability to sense multiple types of structural damage and pinpoint location of failure
- Low cost solution
- Readily incorporated into traditional manufacturing process
- Real time life evaluation
- Advanced detection allows safer operation and use of devices, eases repair efforts, and prolongs device life by allowing condition based maintenance

PRF No. 65006 Modular Heat Exchanger for Metal Hydride Hydrogen Storage
The ever increasing dependence on limited fossil fuel resources and resulting pollution have created an urgent need for cleaner fuel sources in pursuit of a more secure energy future. One alternate fuel source is hydrogen. Unlike fossil fuels, which produce energy by combustion and yield polluting byproducts, hydrogen is consumed by chemical reaction with oxygen forming only water as byproduct. Thus, hydrogen has enormous potential as a clean power source for future generation of automobiles.

There is great interest in developing hydrogen power devices, especially hydrogen powered automobiles. One prerequisite for this application is that there is enough hydrogen to give comparable driving ranges as conventionally fueled automobiles. However, hydrogen poses the problem of very low density. To overcome this obstacle, cryogenic storage containers filled with metal hydrides have been developed to store enough hydrogen in its liquid form to match its convention rival. However, with this technology, there is a requirement to heat the liquid hydrogen to make it available for use. Inventors a Purdue University have developed a unique modular heat exchanger for use in hydrogen fuel cells. The patent pending internal design optimizes both pellet contact area for increased heat transfer and hydride pellet capacity. Additionally, the modular design allows for easy replacement of defective or malfunctioning modules. These highly efficient heat exchangers can provide the necessary heat to evaporate the liquid hydrogen while remaining compact and durable enough for use over the broad range of temperatures and under the high environmental pressure of a hydrogen storage tank.

Domain:
- Mechanical Engineering

Advantages:
- Modular design makes repairs/replacements easy
- Durable design

**PRF No. 65366 Fabricating Absorber Films with Nanoparticle Inks**

Technology Readiness Level: 4

Semiconductor alloys based on copper, indium, gallium, sulfur, and selenium (CIGSSe) are some of the most promising candidates for photovoltaic applications due to their unique structural and electrical properties. The highest quality CIGSSe films have been traditionally fabricated using vacuum co-evaporation; however, production cost is high, which has limited its applicability for large scale fabrication. Recently, solar cells with CIGSSe absorber layers, fabricated by deposition of various alloys, have been developed using alternative approaches.
Among the various alternatives, coating technologies utilizing nanoparticle inks are a promising alternative for low cost and high throughput production of solar cells as compared to traditional vacuum-based deposition methods.

The optical and electrical properties of the CIGSSe absorber depend strongly on the composition. Thus, one of the major challenges to all deposition techniques is the ability to control and maintain the composition at the molecular level. To overcome this challenge, researchers at Purdue University have developed a method related to the fabrication and control of the composition profile along the depth Cu(In1-xGax(S1-ySey)2 absorber films where x and y are between 0 and 1, through the utilization of ink solutions containing Cu(In1-xGax(S1-ySey)2 nanoparticles where x and y are between 0 and 1. This method utilizes a precursor layer containing CIGSSe nanoparticles followed by selenization, which converts the nanoparticles into a densely packed absorber film that is fixed at the molecular level.

Advantages:
- Densely packed film where the composition is fixed
- More stable optoelectronic and electronic properties
- Cost-effective

**PRF No. 65583 Nanoscale Thermoelectric Conversion**

Technology Readiness Level: 4

Purdue University researchers have developed a solution phase method to synthesize three new dumbbell-like nanowire heterostructures. After obtaining the well-defined nanowires, precursor solutions are injected and octahedrals selectively grow at both ends of the nanowires to form the dumbbell structures.

The thermoelectric figures of merit are improved by reducing thermo conductivities due to a combination of the interface scattering effect and size confinement effect compared with the conventional nanowires.

This breakthrough could lead to significantly better thermoelectric materials in the future. This method can also be extended to other nanowire heterostructure synthesis by simply changing the precursor solution to create other thermoelectric materials.

Advantages:
- Lower thermal conductivity
- Facile synthesis
PRF No. 65584 Ultrathin Nanowire-Based Thermoelectric Conversion

Technology Readiness Level: 3

Researchers at Purdue University have developed a facile solution phase method for the synthesis of ultrathin PbTe and Bi2Te3 nanowires with diameters of 10 nm or less using the ultrathin Te nanowires as the in-situ templates. PbTe and Bi2Te3 are the best candidates for thermoelectric conversion at temperatures close to room temperature and at 500K, respectively.

By fabricating their nanowires with diameters less than 10 nm, the thermal conductivity can be significantly reduced to enhance the thermoelectric figures of merit. The solution phase synthesis is easily scalable and reproducible for large-scale deployment of thermoelectric conversion devices.

Advantages:
- Can produce ultra-thin wires
- Thermal conductivity can be reduced

PRF No. 65762 Thermoelectric Materials for High Temperature Applications

Technology Readiness Level: 3

Thermoelectric devices turn heat into electricity or vice versa. To work efficiently the particles that are used to construct the device need to be as one-dimensional as possible.

The best possible shape for these particles is a long, thin wire, which maximizes the electrical conductivity and minimizes the thermal conductivity of the device. Thermoelectric devices will allow waste heat to be captured and reused, greatly increasing efficiency. Purdue University researchers have developed several novel titanates for use in advanced thermoelectric devices. These new titanates could be used for harvesting electricity from the waste heat at high temperatures where a traditional Tellurium or Antimony-based compound will either oxidize or decompose. Alternative applications of this technology include use as energy storage devices such as in super capacitors.

Advantages:
- Can produce ultra-thin wires
- Thermal conductivity can be reduced
PRF No. 65763 Nanostructure-Based Thermoelectric Energy Conversion

Technology Readiness Level: 3

Thermoelectric materials directly convert temperature difference into electric voltage or vice versa. Therefore, thermoelectric materials can be used as an electric generator to recover waste heat into electricity or as a refrigerator.

Researchers at Purdue University have developed a new type of highly efficient, environmentally friendly thermoelectric material. These thermoelectric materials are based on a nanostructured Copper Zinc Tin Sulfide (CZTS), all of which are inexpensive, abundant, and non-toxic elements. In addition to being less costly and safer to produce, this technology works over a wider range of temperatures than most conventional thermoelectric materials.

Advantages:
- High efficiency
- Work over wide range of temperatures
- Non-toxic

PRF No. 65806 Flexible Polymer-Based Thermoelectric Materialson Fabrics for Use as Personal Cooling/Heating Clothes and Portable Power Source

Thermoelectric cooling uses a device that transfers heat through a cooling plate and releases the heat on the opposite, hot side of the device. Current thermoelectric devices use materials that limit the pliability so applications are limited.

This device is thinner and more flexible than current thermoelectric devices so it can be coated onto fabric used to make clothing. Having clothing that keeps the body cool will protect those in hot climates, such as battlefields in Iraq and Afghanistan, from heat related illnesses and can also reduce detection by infrared body heat detectors. This device can also be used to convert body heat into electricity and serve as a portable power source.

Domain:
- Electrical Engineering

Advantages:
- Thin and flexible
- Portable power sources
- Can use body heat for electricity
PRF No. 65257 Selenization of CIS Nanoparticles

Technology Readiness Level: 5

There are currently various challenges in the selenization of CuInS2 (CIS) films. There tends to be delamination of the film after selenization, where the film peels off from the substrates. Another method requires a high-temperature hydrogen reduction step to reduce the oxides, where substantial amounts of energy and time are necessary. This step is also potentially explosive and may require the use of highly toxic H2Se gas. Further, expensive, high-end equipment is needed for safety concerns when the gas is at high temperatures. The most challenging problem in previous art is the lack of control of the film composition. Because the electric properties of CIS depend strongly on its composition, there is a need where composition of the film can be controlled at the nanometer scale.

Researchers at Purdue University have developed a photovoltaic printing technology utilizing CuInS2 nanocrystal inks, allowing for the creation of CIGS at the molecular level. This is beneficial because smaller particles will lead to a more densely packed nanoparticle film, and it allows for the fabrication of the film with solely the CuInS2 nanoparticle or a mixture of the CuInS2 nanoparticle with other CIGS materials, such as CuIn(Sy,Se1-y)2, CuGaS2, CuGa(Sy,Se1-y)2, Cu(InGa1-x)S2, and Cu(InxGa1-x)(Sy,Se1-y)2. This process is also safe, less expensive, and has a high production yield.

Advantages:
- Safe
- Allows for creation of CIGS with the desired composition
- Inexpensive
- High production yields

PRF No. 65352 Hydraulic System with Integrated Common Rail Energy Recovery System

A new hydraulic system topology, developed by researchers at Purdue, offers improved efficiency, reliability, and performance. The fluid power system allows energy recovery from assistive actuator loads to be immediately used by other resistive loads in the system or stored in a common rail accumulator for later use.

In this hydraulic system, any port on any actuator can be connected to any other actuator via a common rail system. Because of this, the system controller can intelligently control each valve to recover the maximum possible energy from an actuator. The network of valves is configured in such a way that allows the hydraulic system to operate with characteristics of multi-level load-sensing, displacement control, independent metering, energy recovery, and energy storage (if an accumulator is
added). These operating modes can co-exist depending on which combination provides the best overall efficiency and effectiveness for a given application and load cycle. The system includes the capability to re-route power in the event of component failure, leading to increased reliability and the ability to bypass the failed components in order to safely complete the desired task.

Domain:
- Mechanical Engineering

Advantages:
- More efficient use of hydraulic energy
- Captures energy that would have previously been lost
- Ability to bypass failed components and still function
Agribusiness and Food

PRF No. 65828 FIBitz - Soy Fiber and Protein Food Additive Capsule

Childhood obesity has more than tripled in the past 30 years in the United States (Control, 2010). With this drastic increase, more children are susceptible to mental health disorders, bone and joint disorders, and juvenile diabetes. There has recently been a movement within society, especially among parents, to provide foods with nutritive value to their children in order to curb childhood obesity.

Researchers at Purdue University have developed a kid-friendly, multi-flavored fiber and protein supplement to pair with a consumer’s favorite breakfast food. FIBitz are comprised of tiny spheres which provide a unique mechanism to deliver fiber and protein to children, while enhancing the flavor of whatever it is added to. Use them right out of the container to add a crunch to yogurt or cereal, or rehydrate them for baking. FIBitz are available in mixed berry, blueberry, lemon, or maple flavors and are a colorful, unique and fun way to supplement a child’s fiber and protein intake.

Domain:
• Food and Nutrition

Advantages:
• Provides supplementary fiber and protein to child’s diet
• Many uses
• Great taste

PRF No. 65190 Greatwoods - Genetically Superior Hardwoods

Black walnut trees are highly desirable for use in veneers and as decorative hardwood, but the natural tendency of the walnut tree is to grow crooked and with variable growth rates. Both of these traits reduce the timber value of the tree and cause it to yield fewer pieces of lumber. Researchers have been trying to develop a better walnut tree since the early 1960s but with little success; the long growth time of the tree and a lack of genetic research in the past put making a better walnut tree out of reach until now.

Using various techniques researchers at Purdue University were able to develop several new walnut varieties that reduce variation in growth rate and tree form. These Greatwoods have higher growth rates, better timber quality, and a stronger resistance to disease than any clones currently available.

Black walnuts are not the only improved species being developed. The goal of the Hardwood Tree Improvement and Regeneration Center (HTIRC) at Purdue is to improve the genetic quality and regeneration of fine hardwoods, including black walnut, black cherry, butternut, northern red oak, white oak, and American chestnut through
application of classical breeding, genomics, molecular markers, genetic modification, advanced propagation and seed production technologies, and silviculture. Greatwoods are the product of decades of research and testing that have created trees that are more profitable and resilient than ever.

Domain:
- Agriculture

Advantages:
- Higher timber quality
- Higher growth rate
- Better disease resistance

PRF No. 65530 PCR Assay to Identify dw3 Stable Alleles

Technology Readiness Level: 9

Sorghum plant height is a quantitative trait controlled by four major genes. Nearly all of the grain sorghum grown in the developed world is produced using semi-dwarf cultivars. These cultivars commonly are called "3-dwarf" sorghums since they utilize the recessive dwarfing alleles at three of the major dwarfing genes. Dw3 is the only height gene that has been cloned in sorghum. The recessive dw3 allele used in nearly all commercial cultivars does not produce a functional protein, and, although it can produce a useful dwarf phenotype, the allele is unstable and reverts to dw3 or tall plants. Commercial seed producers do not like height mutants because considerable effort is required to rogue these plants from hybrid seed production fields, which raise costs and seed loss.

Purdue researchers have developed a PCR assay to screen for stable dw3 alleles. Using this assay, four natural variants of dw3 were identified. These new alleles represent a solution to the problem of height mutants in sorghum and have been termed "dw3 stable." Plants with the new alleles cannot be differentiated from plants with the unstable allele by visual inspection. PCR markers have also been developed for the gene to facilitate marker assisted introgression of these alleles into elite parent lines.

Advantages:
- Eliminates height mutants
- PCR markers developed to allow identification of four stable dw3 alleles
Biotechnology and Medicine

PRF No. 66061 Wireless Magnetic Tracking for Radiation Cancer Therapy

Technology Readiness Level: 5

A serious side effect of radiation therapy for cancer treatment is that it kills healthy cells as well as cancerous cells. To limit the damage to healthy tissue the radiation is directed only to the area around the tumor. This is not an easy task because of the movements of organs within the body, the motion of which must be tracked to minimize collateral damage. Wired and wireless tracking systems currently exist but both have drawbacks. Wired systems require wires to extend through the skin which increases the risk of infection and can be mentally distressing to a patient. Existing wireless systems use passive transponders and can only track one of them at a time. Researchers at Purdue University have developed a novel wireless tracking system using active transponders, allowing multiple transponders to be tracked quickly and accurately. The transponders can also function as dosimeters to measure the radiation intensities at various sites.

PRF No. 64892 Detecting DNA Markers in Live Cells

Technology Readiness Level: 3

According to the National Institute of Health, invasive breast cancer inflicts 1 in 8 women in the United States each year. Unfortunately, while medical advancements have been made in the field of breast cancer detection and treatment, the effect on mortality has been modest. The Susan G. Komen foundation and the American Cancer Society, have data suggesting that between 1990 and 2009, the mortality rate only decreased by 1% for women. The incidence rate of invasive breast cancer has been increasing since 1976 with an average of 2% increase from 1976 to 2009. There is no argument against the need for better treatments and earlier detection. Increased high throughput microscopic detection of diseases, such as breast cancer, could increase the chance of survival in patients.

Purdue researchers developed a new method and apparatus that allows biosensors comprised of various detectors to be visualized and identify receptors and DNA markers, giving the cell identity. The biosensors are mainly comprised of gold nanoparticles that can identify cells based on its phenotype and genotype. The gold nanoparticles attach to the receptors or gene locus to emit a signal when excited by the viewing apparatus at specific wavelengths. This information gives an understanding of the cell types making up a tumor for example, and the best course of treatment to combat those cell types. The information also gives evidence of polarity, and gene expression, and localization of cell membrane receptors in a cell by cell basis. The whole system is easily incorporated into a hospital or laboratory for clinical or research use.
Advantages:
- Convenient, bench top system
- Multiplex and sensitive detection

**PRF No. 63076 Forehead Vital Signs Monitor**

Technology Readiness Level: 4

When performing medical operations, patients are usually connected to monitors that are away from the patient's body. If an anesthesiologist is monitoring the patient, it is not convenient for him to look away from the patient and the gauges to check the patient's heart rate, blood pressure, or oxygen saturation levels of the blood.

Researchers at Purdue have developed a lightweight, noninvasive, optical sensor applied to the forehead that can acquire systolic, mean, and diastolic pressure, heart and respiratory rate and oxygen saturation. It is useful for monitoring during surgery and other procedures in conscious or anesthetized subjects. Placing the monitor on the patient allows the surgeon or anesthesiologist to concentrate on the patient without having to look away to obtain vital signs.

Advantages:
- Lightweight
- Non invasive
- Easy to use

**PRF No. 64714 Immunological Disease Control**

Technology Readiness Level: 3

Physicians currently use a broad range of immunosuppressants to combat inflammation and several autoimmune diseases. The lack of specificity of nearly all immunosuppressants leaves the body vulnerable to other infections and can often result in devastating side effects.

Purdue Researchers have developed a cell-based approach in which immunoregulatory T cells (reg-T cells) are generated ex vivo. The novel, newly-generated reg-T cells localize exclusively in mucosal tissues where they selectively render their effects. Using a common animal model for inflammatory disease (inflammatory bowel syndrome), Kim et. al. have demonstrated in vivo the ability of these novel T cells to block overactive immune response in mucosal tissues. As a result, patients suffering from various inflammatory conditions within mucosal tissues can potentially be treated by: removing the patient's own T-cells through common cell isolation techniques, generating novel
reg-T cells selective for mucosal tissues, and reintroducing new, yet familiar reg-T Cells back into the same patient.

Advantages:
- Targeted immunosuppressant treatment
- T cells selectively render their effects

PRF No. 65127 Aerosolized Sol-gel Tissue Encapsulation

Technology Readiness Level: 3

Researchers at Purdue University have devised a method to encapsulate living cells within a mistable matrix for use in sensors or as adaptive drug delivery devices. Prokaryotic or eukaryotic cells can be suspended in the silica sol gel material, and then loaded into a nebulizer to aerosolize it into a fine mist of liquid particles. The aerosol can be used to actively or passively coat surfaces. The cells are able to maintain their functionality, affixed under the sol gel layer. This method can allow for the implantation of foreign cellular material without global suppression of the immune system.

Advantages:
- Highly adaptable
- Can be utilized under normal laboratory conditions
- Possible to generate complex lamellar glasses with layers tailored to facilitate different processes
- Layer thickness can be easily controlled

PRF No. 65660 Touch Actuated Micropump for Transdermal Drug Delivery

Technology Readiness Level: 3

Transdermal delivery of medications and other compounds has been aggressively pursued for many decades. Although patches have been used to deliver small hydrophobic molecules such as nicotine and nitroglycerin, an external pressure source in conjunction with a direct subcutaneous access port are required to deliver the majority of therapeutically important drugs through the skin. Microfluidics has played an important role in this area by providing microneedle arrays and miniature pumps. Although microneedle arrays made of silicon, polymers, and metals have reached a high degree of maturity in the past decade, their application has been limited due to the lack of a suitable micropump with adequate flow rate and back pressure.

Purdue University researchers have developed a new type of pump for drug-delivery patches that would use arrays of "microneedles" to deliver a wider range of medications possible than with conventional patches. The pump contains a liquid that boils at body
temperature so that the heat from a finger's touch causes it to rapidly turn into a vapor, exerting enough pressure to dispense the drug through the microneedles. This technology's low-cost and battery-less operation make it the ideal single-use/disposable transdermal drug dispenser.

Advantages:
- Battery-less operation
- Low-cost and disposable

**PRF No. 65683 Vaccine Linkers to Attach Proteins to Aluminum Hydroxide Adjuvants**

Technology Readiness Level: 3

Vaccines typically work by exposing the body to an antigen, which is either a weakened form of a microorganism or a toxin that it creates. This exposure stimulates an immune system response that lets the body recognize the pathogen so that it can more easily recognize and destroy it in the future. Sometimes the proteins used in the vaccine are bound to an adjuvant (commonly aluminum hydroxide) which acts as an irritant to enhance the immune response to the antigen while reducing the amount of foreign material that must be injected. To attach the aluminum hydroxide to the protein a phosphate group is first attached to the protein; phosphate groups have a high electrostatic affinity for aluminum hydroxide so they readily bond to each other. However, current techniques for attaching the phosphate group to a protein have the unintended effect of changing the structure of the protein.

Purdue Researchers have developed a simple chemical reagent that attaches a phosphate group to specific sites on the protein that do not change the overall structure. This method can work with a wide variety of antigens and could lead to more effective vaccines for many different pathogens.

Domain:
- Pharmaceuticals
- Veterinary

Advantages:
- Does not modify protein structure
- Works with many varieties of antigens
- Uses adjuvant with excellent safety record
Energy

PRF No. 64920 Method for Generating Hydrogen from Ammonia Borane

Major challenges exist to the commercialization of hydrogen fuel cells for widespread commercial use. Current methods of generation and on board storage are not safe or efficient and when combined with the fact that hydrogen technology is still too costly to be widely implemented, it is obvious that there are many roadblocks in the path of hydrogen fuel cell development.

Researchers at Purdue University have developed an innovative, new process for releasing hydrogen from ammonia borane. Ammonia borane has a high percentage of hydrogen and is a promising hydrogen storage material for fuel cells. This technology does not require the use of a catalyst and enables an increase in the amount of hydrogen released at specific temperatures than with pure thermolysis. This technology has the promise of being a major breakthrough in the area of fuel cell storage and efficiency.

Domain:
- Chemical Engineering

Advantages:
- Releases more hydrogen than current methods
- Required pressure can be easily created
- Cost effective

PRF No. 64923 Multiuse Coke Plant for Synthetic Fuel Production

Technology Readiness Level: 6

Although coke is an absolute essential part of iron making from ore and foundry processes, recently there was a shortfall of 5.5 million tons of coke per year in the United States. This shortfall resulted in increased imports, drastic increases in coke prices, and market volatility.

Purdue University researchers have developed an optimization algorithm for coke that could reduce annual coal fuel costs by up to 10 percent all-the-while allowing consideration for overlooked by-products that now have revenue potential. This cost reduction is obtained through the use of cheaper, lower heat content, high-sulfur coal from sources such as the Illinois Basin. Previously, the high-sulfur content was a detriment for coal users and almost made this coal unusable due to its undesirable trait of forming hydrogen sulfide during the pyrolysis process. This technology can place a value on this sulfur content, too. With modern technology and the current economic drivers for alternative energy, pyrolysis gas has a multitude of uses including the
production of electricity, liquid transportation fuels, fertilizer, and hydrogen. The value of lower-grade coal alternatives can now be identified, and better yet, maximized.

Advantages:
- Reduced cost of coal through utilization of Illinois Basin coal
- Enhanced revenue streams

PRF No. 64940 Fast Hydropyrolysis for Hydrogen Bio-Oil

The transportation sector currently relies almost exclusively on liquid hydrocarbons as its energy source for good reasons. One of many reasons is that the high energy density of gasoline far exceeds that of proposed replacements like hydrogen or batteries. Additionally, the liquid hydrocarbon fuel distribution infrastructure is efficient and already in place. Production of liquid fuels from biomass can solve the problem of C02 emission from the transportation sector because C02 released from vehicle exhaust is captured during biomass growth.

Researchers from Purdue University have invented a process of “fast” pyrolysis, which is to be used on biomass. The process feeds H2 from a carbon-free source to a fluidized bed reactor. The H2 is mixed with a biomass in the reactor. The resulting mixture produces a biomass containing less oxygen atoms than normal due to the addition of the hydrogen. The mixture is then sent to a separator to remove the char, which is burned to create heat for the system, from the “bio-oil.” The bio-oil is further processed to create the hydrocarbon, which is then cooled to create the liquid hydrocarbon. The H2Bioil has all of the advantages of conventional Bio-Oil in addition to a greatly increased energy density all-the-while retaining compatibility with the conventional hydrocarbon fuel distribution, a truly carbon neutral solution to the Green transportation fuels concern.

Domain:
- Energy

Advantages:
- Dramatically lower fuel cost
- Increased bio-oil energy density

PRF No. 65621 Low Lignin Second Generation BioEnergy Crops

In the quest for energy independence, production of biofuels, such as corn ethanol, has exploded. There has been a rapid increase in biorefinery construction, and tax credits encourage further production efforts. The majority of ethanol produced for transportation purposes is from corn, but this form of biofuel production is unsustainable. Transition from corn ethanol to cellulosic ethanol (derived from wood, grasses, or the non-edible parts of plants) is necessary, and federal support for this
transition is evidenced by the substantial tax credits allotted for cellulosic-ethanol producers. Maximization of available biomass is necessary, however, to ensure the long-term success of cellulosic biofuels.

Researchers at Purdue University have developed a transgenic variety of poplar tree for use as feedstock for cellulosic-ethanol production. The transformed plant accumulates biomass faster than its non-transgenic counterpart. The biomass produced is more easily degradable, and the plant is sterile. These desirable traits are owed to multiple stem growth and low lignin production.

Domain:
- Energy

Advantages:
- Rapid accumulation of biomass (multi-stemmed)
- Biomass is easily degradable (low lignin)
- Sterility confines the altered genome and further increases biomass production

**PRF No. 66109 A Shade Tolerant Panel Design for Thin Film Photovoltaics**

Technology Readiness Level: 6

Solar cells are becoming increasingly efficient at converting light into electricity but they still suffer from some reliability issues. One such issue is that if a cell of the solar panel is in the shade it will shut down and start absorbing excessive energy from the connected cells. The excess energy causes heating in the cell that can cause damage or even start a fire. This problem has usually been addressed by connecting diodes between segments of cells to prevent the current from flowing into a shaded panel section, but this does not work unless a large area is shaded. Researchers at Purdue University have developed a new solution to this problem by designing a radial layout for a solar panel. This design assures that a shadow will shade many cells at once, allowing those cells to distribute the reverse voltage across them. The design avoids reverse breakdown without need for external bypass diodes, simplifying the manufacturing process and alleviating shadow degradation.
Environmental Sciences and Engineering

PRF No. 64353 Residential Heat Pump with Two-Stage Compression for Nordic Climates

Nordic climates necessitate larger heating requirements than more southern, temperate regions. Typical heat pump systems include single-stage and ground, i.e. geothermal, heat pumps. These traditional heat pump solutions have lower efficiencies and higher operating cost relative to multi-compressor heat pump systems.

Researchers at Purdue University have developed a heat pump system that both operates at a relatively higher efficiency and at lower cost. This multi-stage heat pump can utilize two separate methods of heat transfer. Four modes of operation ensure the pump is operating in the most efficient manner for the given set of environmental conditions. The indoor air coil is also designed to fit the target climate and minimizes unnecessary energy consumption. Oil is well managed by a novel technique in the heat pump system. This ensures the compressors are running with the required amount of lubrication and are highly reliable. In addition, the heat pump is designed for manufacturability and is thereby more suitable to produce and maintain. Finally, the whole system is enclosed in a casing meant to reduce sound. The compressors themselves are acoustically dampened, allowing the residents of the building to enjoy both proper climate control as well as a quiet atmosphere.

Domain:
- Mechanical Engineering

Advantages:
- Enables heat pump use in non-traditional northern, temperate regions
- Lower running cost
- Higher efficiency compared to traditional heat pumps
- Acoustically dampened
Information Technology

PRF No. 64948 Technology Assisted Dietary Assessment

Technology Readiness Level: 4

Purdue University researchers have developed a technology to help the health-conscious better gauge what's on their plates by using their cell phone cameras. This project expands on a technique already in use by adding a strong scientific grounding. Currently, dieters can subscribe to websites that monitor eating habits by critiquing photos they send on their meals. This offers busy people the chance to get nutritional feedback without spending time writing down all of their meals, drinks, and snacks. It is designed to help people better evaluate portion sizes and nutritional content.

This software integrates various image processing technologies to provide a reliable method for estimating the sizes of food in the photos, techniques to help identify the food in the pictures, and the nutritional knowledge base to enable food evaluations and help determine possible impacts on health.

Advantages:
- Increased convenience
- Health awareness

PRF No. 65245 ReadingMate for Active Treadmill Enthusiasts

Reading is an activity that many people cannot perform while they are moving, namely because they cannot keep focused on the words. However, many people desire to read as well as exercise and equipment manufacturers are pushing to do just that: place computer screens on treadmills to display text and video. Unfortunately the users are in motion challenging their eyes to remain focused on the content on screen.

Inventors at Purdue have developed a device they call “ReadingMate” to overcome this problem. It utilizes a head tracking device implemented with software that dynamically moves text and multimedia content on a screen. The text moves with the user’s head alleviating strain on the eyes to keep things in focus.

Domain:
- Computer Technology

Advantages:
- Technology alleviates strain on eyes allowing an enjoyable reading experience
- Applicable to other industries where turbulence is an issue, such as aviation or construction
PRF No. 65361 Privacy-Preserving Verification Software Framework

Purdue University researchers have developed a set of protocols and algorithms as part of software that allows users to prove their knowledge of attribute to a service provider. The main feature of the protocols and algorithms is that they assure privacy of user data and security and protect the user data from malicious parties which may try to steal financial information from users or determine information about the user. The software includes the actual core framework, efficiency testing, and specific applications implementations using the framework. The core framework includes zero knowledge proof of knowledge protocols, oblivious transfer protocols, aggregation of commitments and digital signatures, secret key splitting and sharing, and a database backend using oracle.

These protocols and algorithms make it possible to prove information from between devices by using Wi-Fi, Ethernet, and Bluetooth. The framework is modularized giving more flexibility to the developer working on an application. They have developed a health care demo that is specific application scenario that uses the core framework. It includes code for the Nokia 6131 phone using the zero knowledge proof of knowledge protocols to preserve a doctor’s identity during an electronic prescription scenario.

Domain:
- Information Technology

Advantages:
- Can run on multiple platforms
- Medium independent
- More flexibility
New Materials

**PRF No. 64025 Cross-Linkable Polymeric Materials for Adhesion**

Polymers currently available have a rigid structure that is not amenable to modification. It is beneficial to have access to materials whose physical properties can be changed to fit a given application. Researchers at Purdue University have developed a new class of modifiable polymers which supersedes those currently available. Such polymers can be used in industrial to medical adhesives, rust-proof coatings, and many other applications.

Purdue Researchers have developed a family of polymers in which cross-linking groups are incorporated. The polymers have varied properties (e.g., hardness, crystallinity) and varied degrees of incorporated cross-linking groups. The polymers are prepared such that they can be cross-linked with various metals. By combining flexibility in polymer design along with flexibility in cross-linking reactions, we present a new and versatile family of materials which include water soluble, UV-cure and solvent applications.

Consequently, new materials can be designed with, for example, various hardness, adhesive, electronic, and optical properties. These materials have been tested for strength on a polished aluminum surface, a traditionally difficult surface for bonding, and showed strong adhesion up to 5 MPa (~750 lb/in2). Bonding strength on par with super glue all without having been optimized. The polymer plus crosslink material is also stable in boiling water for up to 2 hours.

**Domain:**
- Materials Engineering

**Advantages:**
- Uniquely strong waterproof adhesive
- As strong as super glue without having been optimized

**PRF No. 64270 Integrated Laser Material Processing Cell**

A common manufacturing difficulty is the lack of exact knowledge of specific material properties at all dimensions. The process builds on assumed properties and laboratory characterizations via samplings when the end product, such as advanced/high technology or future products undefined as of yet, require knowing exact properties at all dimensions. There currently exists no product or service on the market where the properties at all dimensions are provided.

Researchers at Purdue University have developed an advanced laser manufacturing solution with primary applications on flat surfaces and secondarily on round surfaces. The process allows for the simultaneous construction of explicit material properties and
dimensions as the substrate is being generated. Furthermore, the process can provide specific properties in different sections of the material.

The primary application for this system is material deposition. In this application, a similar or dissimilar metal or ceramic can be added to the work piece in variable layer thickness and sequences, with the option to machine as needed (i.e. micro/ nano-channels, micro/nano-holes, etc.). This allows the construction of freeform structures and parts with varying composition, layer by layer. This solution can even utilize laser heat to assist material removal from a work piece as necessary.

The system can also be used to harden or anneal the substrate material. With laser hardening, a work piece can be heated to a precise temperature for a duration of time to change the physical properties of a substrate at specific places to obtain the desired crystalline structure.

Domain:
• Materials Engineering

Advantages:
• Enables creation of parts with complex internal geometries
• Enables construction of solid parts with varying compositions

PRF No. 64677 Generalized Intelligent Grinding Advisory System

Grinding processes in manufacturing are diverse and complex with many variables affecting the process. Optimizing these variables is no simple task. Traditional grinding techniques say a very fine grind in a slow fashion is the best way to obtain a smooth surface finish. Conventional optimization strategies, which aim to speed up this generally slow process, often involve the use of trial and error and are of limited effectiveness.

The Generalized Intelligent Grinding Advisory System (GIGAS) has been developed to optimize complex manufacturing processes using novel methodologies. The optimization allows grinding to be done as quickly as possible, while maintaining the desired surface finish. This software based technology incorporates mathematical models and experimental data to enable an automatic optimization of the grinding process. GIGAS consists of several software databases which contain information on grinding machines, processes, and optimizations. To optimize an installed grinding machine, a user inputs the type of machine, materials being ground, the desired outcome along with several other variables. The software then quickly performs an efficient optimization based on those specifications. The user can then set up the grinding machine appropriately and enjoy the reduced manufacturing times while maintaining or even improving upon the original finish quality. With this technology manufacturers could typically see a 10-15% reduction in grinding times, with reductions...
of up to 65% possible, along with a 10% reduction in cost. As this technology is software based it requires little to no capital investment and has a return on investment of under 1 year. The current market for this technology is $10 Billion.

The software’s capability to automatically and quickly understand a situation effectively removes the need for a large amount of training data and trial runs. The software currently supports surface, cylindrical plunge, and cylindrical traverse grinding processes, but can easily be expanded to other grinding processes such as center-less and internal grinding.

Domain:
- Materials Engineering

Advantages:
- Automated grinding optimization
- Supports multiple types of grinding optimizations

PRF No. 64699 Self-Cleaning Materials

It has been possible to separate small amounts of oil from water for quite some time. This was made possible through the use of nanoporous filters. Unfortunately the minute size of the holes in a nanoporous filter requires the filtering process to be highly pressurized in order to function. In some situations such as oil spill cleanup, this is not always practical.

Inventors at Purdue University have devised a method of separating the small amounts of oil from water through the use of an advanced membrane coated glass micro filter. Micro filters don’t have the same pressure requirements as nanoporous filters; therefore, water can flow freely through them. The membrane is composed of a patented hydrophilic layer of polyethylene glycol and each molecule is tipped with fluorine. The water is attracted by the polyethylene glycol and flows through both layers freely. The oil is stopped at the fluorine barrier where it beads and can be easily removed through the use of cross flow filtration. Typical filters collect oil and must be changed out frequently when they have been rendered ineffective. This technology saves money though extending the life of the filter by making the oil easy to remove instead of exchanging the filter itself; all without the need for high pressure parts, lowering system costs.

Domain:
- Materials Engineering

Advantages:
- High Pressure system is not necessary
- Longer life so filters do not need to be replaced as often