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The University of California, Merced is a research university built on the rich traditions of the world’s preeminent public university system.

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As America’s newest research university, UC Merced is uniquely able to rapidly transfer its innovations into competitive advantages.

This document describes more than 40 technologies invented at UC Merced in the fields of natural sciences, engineering and medicine.

UC Merced builds relationships with environment-friendly industries that complement its teaching, research and public service mission.

For more details, contact UC Merced’s Office of Research at ott@ucmerced.edu
Innovation begins at UC Merced

In 2005, the University of California, Merced opened its doors with an ambitious mission to become a modern, world-class university focused on teaching, research and public service in the heart of California’s rapidly growing San Joaquin Valley.

In that short time, we have grown into a community of more than 3,000 students and more than 110 faculty members with credentials from some of the world’s top-ranked universities. UC Merced currently consists of the School of Engineering, the School of Natural Sciences, and the School of Social Sciences, Humanities and Arts. In the decades ahead, these schools will be joined by a School of Management and a School of Medicine.

The power of the University of California has always been its people. As with all University of California campuses, there must be a strong dedication to research and scholarship. We are proud to report that, even in our brief period of existence, UC Merced’s talented researchers have used our state of the art laboratories and classrooms to produce dozens of inventions that have the potential to change lives, industries and communities. A by-product of these research activities is intellectual property that can be copyrighted or patented. A vital element of our public service obligation to the people of California is to ensure these research discoveries make the responsible transition from idea to application as products or services that benefit the community.

This report represents a major milestone in the continuing progress of UC Merced. It is with great pride that we share with you the fruits of the labor of several of our faculty. This document catalogues the inventions generated from January 2007 through June 2009 and acknowledges the faculty who developed these concepts. Forty-two inventions have been processed during this brief time, comparing favorably with the progress of larger, more established campuses, especially when considering that a disproportionate percentage of our faculty are young Assistant Professors.

Our deepest admiration and appreciation go to the faculty, staff and students identified in this document. Many thanks to Leslie Teixeira, Richard Cummings, Vincent Cook, John Shih, Byoung Rok Park and Richard Miller for the production of this report.
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Rapid Antimicrobial Susceptibility Assay

BACKGROUND

The rising incidence of infectious bacterial strains that are resistant to multiple broad-spectrum antibiotics poses serious complications to the treatment of infectious diseases.

Absent knowledge of a given infectious agent’s susceptibility to various antibiotics, physicians face the dilemma of prescribing an antibiotic that may prove to be ineffective, or prescribing an antibiotic capable of treating the most resistant strains but, if used unnecessarily, may accelerate the breeding of even more resistant strains.

In these circumstances, selection of the optimal antibiotic requires rapid profiling of a bacteria’s susceptibility to various antibiotics. However, current methods for assaying susceptibility of a purified bacterial culture, involving observations of the strain’s visible growth in antibiotic media, can take up to a full day. Thus, there is an urgent need for more rapid methods for assaying susceptibility that are suitable for use in clinical settings.

DESCRIPTION

Researchers at the University of California, Merced have developed a calorimetric technique that reduces the time needed for determination of a microbe’s susceptibility from 16–24 hours to as little as 2.5 hours.

In situations where purified strains can be obtained quickly (especially blood-borne diseases), the entire process from taking a sample to making a diagnosis can be reduced to 6 hours. At a minimum, the UC Merced invention is likely to reduce the time required for diagnosing bacterial antibiotic susceptibility (typically 3 to 4 days at present for most diseases) by a full day.

The basis for this invention was the discovery that antibiotics can have an almost immediate measurable effect on the thermal output of a growing culture in a suitable system.

Using the protocols and thermal measurement techniques of this invention, the efficacy of an antibiotic relative to a control is readily apparent long before visible colonies could be observed. There is a dramatic and unambiguous difference in the thermal signatures of normal growth versus antibiotic inhibition of non-resistant strains.

The UC Merced researchers have demonstrated the utility of this invention not only with E. coli, but also with K. pneumoniae, A. baumanii and P. mirabilis, and have also shown that thermal signatures can be used to characterize the effects of different antibiotic dosages.

APPLICATIONS

The UC Merced susceptibility assay may become the preferred system for clinical determinations of microbial susceptibility to antibiotics, and might also be found useful in research and public health laboratory settings when rapid assays are desired.

ADVANTAGES

As compared to existing disk diffusion tests and minimum inhibitory concentration tests, the UC Merced thermal test for antibiotic susceptibility offers:

• much more rapid results, often in as little as 2.5–4 hours,
• quantifiable data that is also useful for determining dosage effects, and
• simple protocols and devices that can be automated.

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A technique that reduces the time needed to diagnose microbial blood borne diseases from 4 days to 6 hours
Suppression of Hepatitis C Virus Replication

BACKGROUND
Hepatitis C is an infectious disease of the liver that afflicts approximately 200 million people worldwide, including 4 million Americans. The standard treatment for hepatitis C virus (HCV) infection is a combination of pegylated interferon α and ribavirin. This combination treatment is effective in only about 50% of the patients infected with HCV genotype 1 (which accounts for 80% of all HCV cases in the United States), about 75% of the patients infected with HCV genotypes 2 and 3, and about 65% of the patients infected with HCV genotype 4.

The problem of these low sustained cure rates is compounded by a lack of prophylactic vaccine. For those patients who do not respond to interferon/ribavirin therapy, there are currently no alternative treatments available for controlling the virus.

Moreover, interferon/ribavirin therapy is very expensive and often causes severe side effects, meaning that many patients are unable to afford or to complete the treatment. Thus, there is an urgent need for new hepatitis C therapies that are more effective across a broad spectrum of HCV genotypes and are less burdensome to patients in terms of cost and in terms of adverse secondary health consequences.

DESCRIPTION
Using an in vitro model of HCV replication, a researcher at the University of California, Merced discovered that intracellular hydrogen peroxide (H₂O₂), in concentrations low enough to be non-cytotoxic, can rapidly suppress HCV replication by inducing calcium ion release within an infected cell. The UC Merced researcher has shown that various indirect methods for stimulating intracellular H₂O₂ production inhibit HCV replication independently of the HCV genotype, and are therefore attractive candidates for a novel hepatitis C therapy.

These candidates identified by the UC Merced researcher include an FDA-approved class of pharmaceuticals, an inexpensive enzyme currently used as an in vivo biosensor, and various small polycyclic organic molecules that inhibit synthesis of antioxidant compounds. Initial studies in a human hepatoma cell line indicate that elevated intracellular H₂O₂ levels are as effective as interferon γ in decreasing HCV RNA levels. The suppression can occur as early as 15–30 minutes. The effects of H₂O₂ on HCV are also comparable to those of interferon α as well as interferon α plus ribavirin (see Frese et al., Guo et al., and Tanabe et al.).

APPLICATIONS
The UC Merced treatment may suppress HCV replication in the liver, offering a viable and potentially superior alternative to existing interferon/ribavirin-based HCV therapies.

ADVANTAGES
As compared to existing therapies, this invention is:
• readily available in several forms, including FDA approved compounds,
• likely to be effective across HCV genotypes,
• more affordable,
• likely to act rapidly, and
• not subject to severe side effects of the interferons.

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An affordable treatment technique that may suppress the ability of the Hepatitis C liver virus to replicate itself.
Suspended Carbon Nanotubes as Molecular Sensors

BACKGROUND
Relatively large surfaces areas and great sensitivity to environmental conditions make carbon nanotubes (CNTs) very promising candidates for sensing elements.

However, all existing CNT sensing methods based on electronic or acoustic techniques require complicated nanotube architectures involving multiple fabrication steps. Such complexity can increase the probability of material defects, and often requires CNTs of very high purity. Such problems have blocked the commercialization of CNT sensor systems.

DESCRIPTION
A researcher at the University of California, Merced has invented a molecular sensing system based on the optical properties of CNTs. Starting with CNTs suspended on a thin film substrate (described in the publication listed below), one can process the suspended CNTs (according to this invention to render CNT optical properties highly sensitive to the presence of biomolecules or other molecules of interest.

APPLICATIONS
This invention is generally useful for molecular sensing applications, particularly sensors for biomolecules. Given the thin film substrate used in the UC Merced CNT sensor system, it could be easily integrated into devices such as labs-on-chips.

ADVANTAGES
UC Merced CNT molecular sensors are:
- ultrasensitive,
- can be integrated into labs-on-chips,
- use a simple architecture with facile manufacturability,
- are more tolerant of CNT synthesis imperfections, and
- can employ any type of CNT with a diameter <2.0 mm.

PATENT STATUS
Patent Pending

PUBLICATION

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Efficient Syntheses Of Tetraketone Steroid Precursors

BACKGROUND

Steroids constitute an important class of pharmaceuticals, including compounds for treating andropause and menopause, for speeding the recovery in burn victims, for helping improve the quality of life in AIDS patients, for fighting breast cancer, and for staving off osteoporosis.

At the heart of steroid molecules are steranes, which consist of four fused rings of carbon atoms (three cyclohexane rings and one cyclopentane ring). There are also newer classes of important pharmaceuticals based on steroid-like scaffolds. In practical commercial-scale syntheses of steroids and other sterane-based compounds, it is desirable to start with single tetraketone rings, which can then be converted into fused bicyclic ketones, which in turn can be used as precursors of steroids.

The key to lowering the cost of such synthetic pathways is to lower the cost of the tetraketone reactants and to provide for stereoselective conversions of these tetraketones into fused bicyclic ketones. Such tetraketones would also lower the cost of synthesizing novel variants of the basic steroid structure.

DESCRIPTION

A University of California, Merced researcher has invented an efficient one-step synthesis of cyclopentane and cyclohexane tetraketones using low-cost reactants. These tetraketones in turn are suitable for facile stereoselective syntheses of fused bicyclic precursors of steroids and other sterane-based compounds using a simple amino acid catalyst and a low-cost solvent.

APPLICATIONS

The UC Merced tetraketones can be cyclized stereoselectively for use as reactants in the practical syntheses of steroids and other sterane-based bio-active molecules, especially in situations where costs and stereoselectivity are major concerns, as is the case with steroid pharmaceuticals and other sterane-based pharmaceuticals.

ADVANTAGES

The UC Merced tetraketones offer an additional synthetic handle as compared to conventional precursors of fused bicyclic structures, notably in enabling facile stereoselective cyclization. The syntheses of these tetraketones use low-cost reactants, offering a yield of approximately 90%. Also, these tetraketones offer an avenue into synthetic motifs of greater variability than has existed previously.

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Affinity Purification Scheme for PC-PLC

BACKGROUND
Phosphatidylcholine-specific phospholipase-C (PC-PLC) is an important enzyme in a number of signal transduction pathways, including pathways involving inflammation and apoptosis. It is thought that PC-PLC inhibitors might serve as a new class of anti-inflammatory compounds.

At present, only one inhibitor (D609) with poor specificity is known, so it would be highly desirable to fully characterize the structure of the PC-PLC protein so that novel, more efficacious inhibitors can be designed. However, purified PC-PLC protein has not been isolated yet nor its corresponding gene identified, so PC-PLC’s structure is unknown.

DESCRIPTION
Researchers at the University of California, Merced have invented an affinity purification scheme for PC-PLC.

Starting with a particular modification of D609, it should be possible to isolate PC-PLC and determine its sequence, which can then enable one using standard techniques to construct a genetic sequence to produce a purified form of PC-PLC that is suitable for detailed determination of its structure and for the design and testing of inhibitors.

APPLICATIONS
The UC Merced affinity purification scheme may facilitate the design and testing of a novel class of anti-inflammatory candidate pharmaceutical compounds.

ADVANTAGES
So far, PC-PLC has only been crudely characterized in terms of its molecular weight. This invention is the first process with a reasonable prospect of going beyond this to enable full characterization of PC-PLC, which in turn is necessary for generating candidate PC-PLC inhibitors via a structural design strategy.

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A purification method for a new class of potential anti-inflammatory drugs
Preventing HIV Infection with Bifunctional Griffithsin Analogs

BACKGROUND
Compounds for inhibiting viral entry into cells offer a promising component of microbiocidal creams or gels for prevention of HIV infections. The basis for such HIV entry inhibition is to block one or more of the interactions between HIV envelope glycoproteins (the gp120 cap and gp41 stem proteins) and surface proteins on the target immune system cells (the CD4 co-receptor and a chemokine receptor, usually CCR5 or CXCR4) that are necessary for HIV’s attachment and fusion to the target cell.

The protein Griffithsin and its derivatives are known to be a potent anti-HIV agents that function in this manner, binding to the sugar groups on the surface of gp120 and gp41. Griffithsin can also be cheaply produced in large quantities, and is therefore a strong candidate for use in microbiocidal formulations.

Notwithstanding Griffithsin’s advantages, it still suffers from some problems that also plague other potential HIV entry inhibitors, namely the greatly elevated concentrations required for efficacy in vivo and the potential for HIV mutations to create resistance to Griffithsin-based prophylactic compounds.

DESCRIPTION
A researcher at the University of California, Merced has invented a family of Griffithsin analogs, involving a cross-linkage of Griffithsin to other peptide sequences that add an additional prophylactic function to the protein. Not only do these bifunctional Griffithsin analogs bind the sugar groups of HIV envelope glycoproteins, they also bind certain amino acid sequences of gp41 and/or gp120. These analogs have been shown in cell fusion assays and in single round virus assays to be highly effective in blocking HIV infection.

APPLICATIONS
The UC Merced Griffithsin analogs are strong candidates for use as a component in microbiocidal creams and gels for preventing sexually-transmitted HIV infections.

ADVANTAGES
By binding at least two glycoprotein sites, the UC Merced Griffithsin analogs are even better than Griffithsin alone in blocking HIV entry (with a potential to lower the concentration required for microbiocidal formulations), and are less likely to be vulnerable to the development of drug resistance than Griffithsin alone.

PATENT STATUS
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A potential component for topical solutions to prevent the spread of HIV
Fast, Economical Cell Transfection using Unfunctionalized Nanoparticles

BACKGROUND

The introduction of foreign DNA or RNA into cells is a process of fundamental importance to modern genetics and biotechnology. There are many techniques for facilitating passage of nucleic acids through cell membranes, including viral transduction, transfection via chemical (such as cationic polymers and liposomes) or physical (such as electroporation) permeabilization of membranes, and transfection via mechanical penetration of membranes (such as microinjection and gene guns).

However, these techniques are constrained by serious tradeoffs, especially when dealing with cells that are relatively more fragile or less numerous, as is often the case with mammalian cell cultures. Generally speaking, the techniques that do the least harm to the cells while maintaining reasonable transfection efficiencies are also the most difficult techniques to use.

Gentler transfection techniques require time-consuming procedures such as conjugation reactions, nucleic acid encapsulation, or nanoparticle functionalization. Also, they require relatively expensive reagents that are often prone to being dissociated or digested without special storage and handling.

Thus, there is a need for new techniques that are more rapid and easier to use, while avoiding the damage to cells typically encountered with viral transduction and brute-force permeabilization techniques.

DESCRIPTION

Researchers at the University of California, Merced have discovered that unfunctionalized metal oxide nanoparticles, when mixed with nucleic acids in a suitable serum-free media, can transfect cells in a rapid, economical manner.

For example, when using titanium dioxide (TiO₂) nanoparticles in this procedure, one can transfect Chinese Hamster Ovary cells with efficiencies of ~0.5%–3.0% in less than 24 hours. Similar efficiencies have been obtained using this technique to transfect mouse embryonic stem cells and to transform E. coli cells. The preparation of the nanoparticle/nucleic acid solution and the cells is exceedingly simple and direct, so that very little labor is involved in setting up this transfection reaction. Since the nanoparticles are not chemically bound to the nucleic acids or any other compound, they are effective as permeabilizing agents without subsequently interfering with nucleic acids within transfected cells.

APPLICATIONS

This invention is generally applicable to introducing any kind of foreign nucleic acid into any kind of cell, though the benefits of this technique are particularly evident in transfection of cells that are relatively fragile and less numerous, especially mammalian cells. It could therefore achieve a significant market share for transfection reagents.

ADVANTAGES

As compared to existing techniques for transfection and transduction, the UC Merced transfection technique:

• avoids severe cytotoxicity and phenotype alterations in transfected cells while maintaining high transfection efficiencies,
• employs nanoparticles that are stable at room temperatures and relatively easy and inexpensive to make, and
• is rapid and easy to do, requiring relatively little labor.

PATENT STATUS

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A process that uses stable, room temperature nanoparticles to introduce nucleic acids through cell membranes
Neuron Regeneration Using Embryonic Stem Cells

BACKGROUND

Neural stem cells offer great potential for treatment of neurodegenerative disorders such as Alzheimer’s disease, Parkinson’s disease, Huntington’s disease; for treatment of neural dysfunctions such as dementia and epilepsy; and for repairing debilitating neural injuries such as brain traumas, spinal cord traumas, and strokes. However, adult stem cells for certain types of neural tissues are not available in sufficient quantities for commercial purposes. Embryonic stem cells may overcome this limitation, but growing neural cell types from them has been hampered by the difficulty in obtaining homogenous cell populations, in obtaining the glial cell subtype, and in obtaining a suitable culture media.

Moreover, the full regeneration of neuron tissue requires the correct geometric orientation of neural cells, not just the growth and differentiation of stem cells into the required neural cell types. On a normal culture surface, a neuron cell grown in vitro will extend its axons in all directions, thereby failing to replicate the parallel, cell-to-cell orientation of axons found in vivo. At present, there are no simple and economical methods available for growing, differentiating, and correctly orienting embryonic stem cells to regenerate functional neurons.

DESCRIPTION

A scientist at the University of California, Merced has invented a growth media supplement and a device for aligning cell growth, both of which facilitate quick, reliable, high yield production of neurons from embryonic stem cells.

The growth media supplement, consisting of a few simple and inexpensive compounds that are added to standard growth media, facilitates a much more rapid and reliable differentiation of stem cells into neural cell types than is currently available. The alignment device consists of a thermoplastic sheet with a specially-modified surface that acts as a substrate for orienting the cells, so that neurons will form in parallel on the surface during the process of stem cell differentiation.

APPLICATIONS

These UC Merced inventions could be commercially significant for enabling the manufacture of neuronal lineages useful for treating various neurological disorders and diseases and for repairing brain and spinal cord injuries, and for related medical research.

ADVANTAGES

These inventions eliminate the need for the slow, labor intensive methods currently used for growing and differentiating embryonic stem cells to produce neuronal lineages. The growth media supplement reduces the time needed for the differentiation process from two to three weeks to just a few days. The alignment device is the first practical technology for regenerating neurons from stem cells in vitro that feature the correct in vivo orientation.

PATENT STATUS

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An innovative process to facilitate the growth of stem cells that have the potential to cure neurological disorders
Improved Physical Methods for Increasing Stereoselectivity

BACKGROUND
Since 1988, the Food & Drug Administration has required that the enantiomeric composition of all drugs be known, making stereoselective reactions essential for the pharmaceuticals industry.

However, the reactions used to establish chirality at one or more stereocenters often are not sufficiently stereoselective to warrant asymmetric synthesis, thus necessitating the addition of costly stereoisomer resolution steps. Chiral pool resolution strategies have two significant limitations that are responsible for the growing popularity of stereoselective syntheses:

Isolation of a desired stereoisomer from the chiral pool imposes severe limitations on reaction yield; and resolution steps often entail the use of environmentally-damaging solvents, which increases costs associated with waste disposal.

A significant body of research has shown that it is often possible to increase stereoselectivity in asymmetric reactions using high pressure and thus bypass or minimize costly purification steps; however, high pressure apparatus is infeasible for syntheses on the kilogram scale and above.

DESCRIPTION
Researchers at the University of California, Merced have discovered an alternative physical method for increasing the stereoselectivity of reactions without the problems associated with methods involving a high pressure apparatus.

Like methods using high static pressures, the UC Merced method enhances stereoselectivity by favoring the transition state with the more negative volume of activation. So far, initial tests of the method with Alpine Borane reductions of various benzaldehydes and ynones have shown great promise, with excellent (>95%) selectivity being achieved after a few hours.

APPLICATIONS
This invention is generally useful for amplifying stereoselective reactions in pharmaceutical syntheses, including reductions, allylations, hydroaminations, hydroformylations, cyclizations, and cycloadditions.

Other syntheses requiring enantiomeric specificity, such as for producing speciality reagents and agricultural compounds, might also employ this invention.

ADVANTAGES
The apparatus required for the UC Merced method for increasing stereoselectivity:

- is inexpensive and commonly available,
- has a high throughput, and
- can be applied to a wide variety of stereoselective reactions.

PATENT STATUS
Patent Pending

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A faster and more efficient method to identify the purity of drugs, pharmaceuticals and agricultural compounds
Improved Fiber-based Optical Parametric Oscillators

BACKGROUND
Lasers used in conjunction with optical parametric oscillators (OPOs) are the state of the art for generating ultrafast wavelength-agile light pulses.

This agility property means that OPOs can greatly extend the range of wavelengths that a laser can generate and enables one to continuously change the wavelength of each laser pulse, making laser + OPO light outputs uniquely suited to a wide variety of industrial and scientific research applications.

Fiber-based optical parametric oscillators (FOPOs) are promising as a cost-effective alternative to currently-deployed OPO technologies, but are limited in most designs by their restricted wavelength tunability and pulse duration flexibility.

More advanced types of FOPOs, featuring four-wave mixing mediated by non-linear non-linearities in the glass, are able to overcome these shortcomings and achieve a useful level of wavelength agility, but they in turn have problems with low power outputs and narrow bandwidths.

DESCRIPTION
A University of California, Merced researcher has discovered that a simple modification of a particular parameter in FOPO fiber design leads to previously unexpected results.

Taking advantage of this insight, the researcher has designed advanced FOPOs capable of providing an output pulse energy >100 pJ with a bandwidth >100 Hz while preserving full wavelength agility.

The invention is compatible with different types of oscillator mechanisms, including mirror pairs and ring feedback loops, and with fibers incorporating photonic crystal fiber materials or other microstructure fiber materials.

APPLICATIONS
This invention may be the preferred approach for many OPO-based laser applications. OPOs are used in such fields as:

- spectroscopy, particularly for resolving fast chemical or biological reactions,
- pump-probe measurements of semiconductor properties,
- multi-photon excitations to induce fluorescence or photochemical reactions,
- micromachining/microfabrication, and
- imaging of biomaterials at wavelengths of increased transparency.

ADVANTAGES
The UC Merced FOPOs offer greater power and bandwidth over other advanced FOPO designs while retaining their wavelength agility.

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A new technique to increase the power of lasers without reducing their wavelength agility
Novel Enantiomeric Chiral Alcohols

DESCRIPTION
University of California, Merced researchers have synthesized novel enantiomeric chiral alcohols, derivatives of a phenyl isobutanol. These compounds feature a conformationally restrictive methyl group on the phenyl group adjacent to the alcohol functionality.

APPLICATIONS
The UC Merced chiral alcohols are potential candidates for chiral auxiliaries, chiral ligands, and alcohol precursors to other types of ligands, such as thiols or amines.

ADVANTAGES
The conformational restrictiveness of these compounds are highly advantageous for applications involving use as a chiral auxiliary or ligand, and could be beneficial in sterically occluding undesired reactions. The synthesis of these compounds involves a one-step procedure with enantiomeric yields >99%.

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A one step procedure to develop the chemical building block used in pharmaceuticals production
Nanochip Fabrication using Shrink Plastics

BACKGROUND
Many currently-used nanochip fabrication methods were originally derived from methods used for making semiconductor microchips.

The inherent difficulties in working with semiconductor materials such as silicon has prompted the development of numerous fabrication methods that require expensive equipment, labor-intensive procedures, complicated multi-step protocols for reducing new designs to small-scale structures, and ultra-clean working environments.

Having borrowed many of these techniques for its own use, the nanochip industry has also inherited many of their shortcomings, creating a pressing need for novel fabrication methods that are not as capital-intensive nor as complicated and time-consuming.

DESCRIPTION
Researchers at the University of California, Merced have developed nanochip fabrication methods using biodegradable plastics that enable complex structures to be manufactured on chips at a macro-scale and then shrunk to a much smaller scale by a simple heating procedure while retaining the original design.

Variations of these methods permit the fabrication of chips that incorporate metallized strips, quantum dots, and other nano-structural enhancements, so that the nanochips can be adapted to serve many different applications.

APPLICATIONS
A licensee of this invention is currently using this technology to develop a wide variety of nano-devices, including nanochips for advanced solar cells, microfluidics, nano-scale lighting systems, materials and biological materials processing (including novel stem cell research tools), and biosensors and other “lab on chip” applications.

ADVANTAGES
Nanochip devices made using the UC Merced method can be designed and protyped in a matter of a few hours without the costly equipment or labor intensive processes typically required by older nano-fabrication methods.

Design, manufacturing, and material costs are all substantially lower with this method, and the overall research and development cycle is greatly speeded up.

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LICENSING STATUS
This description represents several inventions. These inventions have been licensed.
Self-Tuning, Critical Branching Neural Computation

BACKGROUND
For computational tasks involving cognitive functions such as perception, classification, memory, and attention, the massively parallel circuitry and dynamic interconnection of nodes characteristic of neural networks have distinct advantages over conventional computer circuits. Accordingly, there is great commercial interest in developing nanoscale chips that simulate neural network computation, devices known as “liquid state machines” (LSMs).

One key requirement for LSMs is to mimic the processing of a signal (in neurons taking the form of a trans-membrane voltage spike, or “action potential”) at the interconnections between neurons (the synapses), which triggers an action potential spike in the adjacent neuron(s) while potentially giving rise to physical changes in the synaptic connections, thus dynamically altering signal processing over time.

DESCRIPTION
A University of California, Merced researcher has invented a mathematical model of LSM memory and computation suitable for simple implementations in conventional computer hardware and software. The UC Merced LSM model also goes beyond a simple biological analogy in its treatment of spike potentials, permitting signals that serve to stabilize network dynamics in an optimal state. Thus, this invention can be used to create a new class of LSMs that self-tune to attain critical branching, while retaining all the desired functionality of ordinary neural computation.

APPLICATIONS
This invention offers for the first time clear-cut dynamical rules for the design of LSM circuit architectures, greatly enhancing the feasibility of nanoscale LSM chips for next generation computing.

ADVANTAGES
In contrast to existing LSMs that require ad hoc tuning, LSM implementations of the UC Merced model can self-tune, achieving the full informational and computational potential of critically branched networks without manual adjustment of LSM parameters.

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A mathematical model that will spark a new class of liquid state machines inspired by neural networks
Efficient Fresnel Lens Concentrator for Solar Cells

BACKGROUND
Generating electricity from sunlight is currently not cost-effective in many situations because of the inherent limitations of photovoltaic (PV) cells and typical lighting conditions.

The production of commonly-used silicon PV cells demands expensive semiconductor fabrication methods and consumption of limited high-grade silicon feedstocks.

Newer thin-film cell technologies, while using cheaper fabrication methods, consume even scarcer exotic materials. Moreover, at typical sunlight intensities, PV cells are relatively inefficient, requiring large panels for a given peak power output.

To reduce costs, it is desirable to increase PV cell efficiencies while minimizing the use of costly materials and fabrication techniques. One promising way to accomplish this is with concentrator PV (CPV) systems, where an inexpensive optical element (usually made of glass) covering a large sun-lit area is used to greatly concentrate the light onto a small PV cell.

Higher light intensities enable higher efficiencies in converting sunlight to electricity while greatly reducing the size of the PV cell required. One important limitation of CPV, however, is the need to keep the concentrator surface aligned with the sun. For CPV to become cost-competitive with conventional PV technology, CPV designs must become less stringent in their alignment requirements (i.e. higher acceptance angles).

DESCRIPTION
Researchers at the University of California, Merced have invented a CPV design that features much wider acceptance angles than in other CPV systems while maintaining a high level of efficiency and a high concentration factor.

The UC Merced researchers had previously developed CPV systems featuring glass sheets with two reflective surfaces in a Cassegrain configuration and a non-imaging secondary element at the focal point that even distributes the concentrated light over a small PV cell.

In their new CPV invention, the UC Merced researchers retained the benefits of having the non-imaging secondary element, but improved on their older CPV design by changing the primary optics into a Fresnel lens configuration and by incorporating an additional design element for better regulating the PV cell environment. This Fresnel lens CPV can be used with both silicon PV cells and with multi-junction PV cells.

APPLICATIONS
This invention may become a preferred design for CPV systems, helping make CPV more competitive as compared to fixed panel arrays for solar electricity generation.

ADVANTAGES
This novel Fresnel lens concentrator design offers a number of potential benefits over previous concentrator technologies, including:

- simple design with few parts,
- relatively low material costs,
- high optical efficiency,
- high angular tolerance to ameliorate tracking requirements,
- uniform light distribution over photovoltaic cells, and
- suitability for use with advanced cell technologies.

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A solar cell boasting simple design, increased efficiencies and high angular tolerance
Improved Fresnel Lens Concentrator for Solar Cells

BACKGROUND
The generation of electricity from sunlight is currently not cost-effective in many situations because of the inherent limitations of photovoltaic (PV) cells and typical lighting conditions. The production of commonly-used silicon PV cells demands expensive semiconductor fabrication methods and consumption of limited high-grade silicon feedstocks. Newer thin-film cell technologies, while using cheaper fabrication methods, consume even scarcer exotic materials. Moreover, at typical sunlight intensities, PV cells are relatively inefficient, requiring large panels for a given peak power output.

To reduce costs, it is desirable to increase PV cell efficiencies while minimizing the use of costly materials and fabrication techniques. One promising way to accomplish this is with concentrator PV (CPV) systems, where an inexpensive optical element (usually made of glass) covering a large sun-lit area is used to greatly concentrate the light onto a small PV cell. Higher light intensities enable higher efficiencies in converting sunlight to electricity while greatly reducing the size of the PV cell required. One important limitation of CPV, however, is the need to keep the concentrator surface aligned with the sun. For CPV to become cost-competitive with conventional PV technology, CPV designs must become less stringent in their alignment requirements (i.e. higher acceptance angles).

DESCRIPTION
A researcher at the University of California, Merced has invented a CPV design that features much wider acceptance angles than in other CPV systems while maintaining a high level of efficiency, a high concentration factor, and more uniform illumination.

The UC Merced researchers had previously developed CPV systems featuring glass sheets functioning in a Cassegrain reflective or a Fresnel lens configuration, and a non-imaging secondary element at the focal point that even distributes the concentrated light over a small PV cell. In their new CPV invention, the secondary element was replaced with an element that has a reflective inner surface. This new type of secondary element uses specular reflections and (optionally) total internal reflections to achieve more uniform illumination of the small PV cell at wide acceptance angles. As with their previous designs, this CPV can be used with both silicon PV cells and with multi-junction PV cells.

APPLICATIONS
This invention may become a preferred design for CPV systems, helping make CPV more competitive as compared to fixed panel arrays for solar electricity generation.

ADVANTAGES
This novel Fresnel lens concentrator design offers a number of potential benefits over previous concentrator technologies, including:

• simple design with few parts,
• relatively low material costs,
• high optical efficiency,
• high angular tolerance to ameliorate tracking requirements,
• uniform light distribution over photovoltaic cells, and
• suitability for use with advanced cell technologies.

As compared to their previous Fresnel lens concentrator design, this invention, with its novel secondary element offers more uniform illumination at wide acceptance angles.

PATENT STATUS
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Improved Aplanatic Solar Concentrator

BACKGROUND
The generation of electricity from sunlight is currently not cost-effective in many situations because of the inherent limitations of photovoltaic (PV) cells and typical lighting conditions. To reduce costs, it is desirable to increase PV cell efficiencies while minimizing the use of costly materials and fabrication techniques.

One promising way to accomplish this is with concentrator PV (CPV) systems, where an inexpensive optical element (usually made of glass) covering a large sun-lit area is used to greatly concentrate the light onto a small PV cell. Higher light intensities enable higher efficiencies in converting sunlight to electricity while greatly reducing the size of the PV cell required. Optimization of solar concentrator design depends on maximizing light concentration and optical efficiency while enabling facile alignment of the system with the sun.

DESCRIPTION
A University of California, Merced (UC Merced) researcher has invented a CPV design that features higher light concentrations than in other CPV systems coupled with high efficiency and a generous acceptance angle for easy solar tracking. In this CPV design, a glass element with two aspherical surfaces (a small portion of one surface being metallized) achieves high light concentrations by refracting the incident light and generating a pair of internal reflections. The emergent light beam yields an aplanatic image focused on a PV cell mounted on one of the surfaces.

APPLICATIONS
This invention may become a preferred design for CPV systems, helping make CPV become more competitive as compared to fixed panel arrays for solar electricity generation. The concentrator optical element might also be used in reverse to provide a highly collimated light beam from light emitting diodes.

ADVANTAGES
This UC Merced solar concentrator design offers a number of potential benefits over previous concentrator technologies, including:

- higher light concentration (1,200x),
- high optical efficiency (81% on axis),
- large acceptance angle (±3° at 90% intensity), and
- compact size (~20:1 ratio of optical element thickness to PV cell width).

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Design Methods for Solar Concentrator Photovoltaic Systems

BACKGROUND

The high cost of photovoltaic (PV) cells poses a serious obstacle to cost-effective generation of solar electricity. To reduce costs, it is desirable to increase PV cell efficiencies while minimizing the use of costly materials and fabrication techniques.

One promising way to accomplish this is with concentrator PV (CPV) systems, where an inexpensive optical element (usually made of glass) covering a large sun-lit area is used to greatly concentrate the light onto a small PV cell. Higher light intensities enable higher efficiencies in converting sunlight to electricity while greatly reducing the size of the PV cell required.

This has been a difficult goal to attain, however, since conversion efficiency and other key cost factors in CPV design are governed by multiple variables, including the degree of light concentration, the efficiency of light transmission to the PV cell, the acceptance angle of the primary optical element, and the compactness of the optical elements. To achieve such gains in conversion efficiency, there is a pressing need for novel design methods that meet the unique optical requirements of solar concentrators.

DESCRIPTION

A researcher at the University of California, Merced has developed a general method for designing optical systems incorporating reflective and/or refractive elements that uniformly illuminate an exit aperture, which in turn can be a suitable location for a PV cell or for an entry aperture of an additional non-imaging concentrator.

Since the Sun is an extended light source that might be slightly off-axis, there are stringent requirements for the design of the reflective and refractive elements, specifically to homogenize light to achieve Köhler illumination of the exit aperture.

The UC Merced researcher has specified a general mathematical representation of these requirements that can be used to optimize a wide variety of CPV designs.

APPLICATIONS

This CPV design method is of general application in this field, including commonly-used configurations of optical elements such as Cassegrain and Fresnel designs. It has already been used as the basis for a number of other recent UC Merced CPV inventions, including a CPV that is in commercial production.

ADVANTAGES

Because of the importance of optimizing multiple parameters in practical CPV systems, design methods of this type are indispensable for realizing the full potential of CPV for reducing the costs of generating solar electricity.

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A low-cost method to concentrate the efficiency of photovoltaic cells
Improved Non-Tracking Solar Photovoltaic Concentrators

BACKGROUND
The generation of electricity from sunlight is currently not cost-effective in many situations because of the inherent limitations of photovoltaic (PV) cells and typical lighting conditions. To reduce costs, it is desirable to increase PV cell efficiencies while minimizing the use of costly materials and fabrication techniques. One promising way to accomplish this is to raise light intensities at the PV cell surface with concentrator PV (CPV) systems, where an inexpensive optical element covering a large sun-lit area is used to greatly concentrate the light onto a small PV cell.

However, a critical problem with many CPV systems is the expense of mounting and moving a CPV array to track the Sun. Fixed concentrator arrays do not concentrate light as effectively as tracking arrays, thereby dissipating much of the efficiency gains associated with using concentrators in conjunction with PV cells.

DESCRIPTION
A University of California, Merced researcher has invented a fixed CPV system that can achieve higher light concentrations and therefore greater PV efficiency than existing fixed concentrator designs.

The UC Merced fixed CPV system is similar to conventional trough-shaped reflector concentrators, but features an unusual geometric arrangement of PV cells that significantly increases the average light intensity at the PV cell surface.

Overall, there is a five-fold concentration of light and ten-fold increase in power output relative to fixed PV panels without any concentrator, and a large enough acceptance angle (65 degrees east/west, and 15 degrees north/south) that only rough seasonal adjustments of the concentrator are required. Because it relies on reflective elements, the optical efficiency of this CPV system is on the order of 90%, substantially better than many tracking CPV systems.

APPLICATIONS
The UC Merced fixed CPV system may become an preferred design for CPV systems, helping make fixed CPVs more competitive relative to fixed non-concentrator PV arrays and relative to tracking CPV arrays.

ADVANTAGES
This invention eliminates the need for costly tracking systems, while achieving a useful increases in light concentration for increasing PV efficiencies and high optical efficiencies.

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Inlet-Outlet Manifolds For Mini-Channel Evacuated-Tube Solar Collectors

BACKGROUND
Evacuated-tube solar collectors, in conjunction with non-tracking, non-imaging parabolic concentrators, can heat working fluids to 200°C at efficiencies near 50%, providing a relatively economical means for capturing and transferring solar energy for use in cooling, heating, and power generation applications.

However, the transfer of heat from the solar energy-absorbing element to the working fluid within such collectors poses a significant challenge to the feasibility of these systems. It is a critical limitation of existing evacuated-tube collector designs because of trade-offs between resistance to heat transfer, cost, and safety.

A scientist at the University of California, Merced has recently invented an improved evacuated-tube solar collector design that incorporates mini-channels for circulating the working fluid in the absorber element.

While mini-channel technology helps overcome the limitation described above, a serious engineering problem remains in optimizing the coupling between the absorber mini-channels and the connecting manifolds. These manifolds, which enable the flow of the working fluid to and from the mini-channels, must connect to pipes that are much larger and possibly a very different shape than the mini-channels. At present, inlet-outlet manifolds that are suitable for this application are not commercially available.

DESCRIPTION
A UC Merced scientist has invented several manifold designs for mini-channel-based absorbers, including absorbers containing flat-plate and semi-circular arrays of mini-channels. Variations of these manifold designs include manifolds with separate inlet and outlet sections, and also featuring an end cap where the fluids from different mini-channels can mix and flow back to the manifold through a separate tube or a shallow slit on the surface of a mini-channel-containing pipe. The manifold can also assume several different forms, including drums or semi-circular tube arrays.

APPLICATIONS
The UC Merced input-output manifolds are necessary for implementing evacuated tube solar collector designs based on mini-channels, which could help realize the great potential of mini-channels for making such solar collectors commercially feasible.

ADVANTAGES
At present, this invention is the only technology that addresses the specific need for enabling the flow of working fluids into and out of mini-channels in solar collector absorber elements.

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**Bi-Solar Concentrator**

**BACKGROUND**
One of the major design goals in tracking solar concentrators is to capture light from a source that is extended in angular extent (the Sun subtending approximately half a degree) and perhaps slightly off-axis (a few degrees being typical in solar concentrators intended for concentrator photovoltaic (CPV) applications), and deliver it to an exit aperture such that the exit aperture is uniformly illuminated by the source (Köhler illumination).

It is also desirable to reduce the volume and mass of the concentrator relative to its surface area, meaning that the light concentrating optical elements should be as thin as possible.

**DESCRIPTION**
A University of California, Merced researcher has developed a novel solar concentrator design involving two layers in the optical element, where the first layer employs a Fresnel-like arrangement of parabolic air gaps to reflect the incident light beam to a greater angle from the central axis as it passes to the second layer (effectively trapping the light within the second layer), while the second layer employs a series of internal reflections within the layer to concentrate the light at a central exit aperture. The two layers can be constructed as a single piece of any transparent material, such as glass or acrylic.

**APPLICATIONS**
The principal use for non-imaging concentrators is for generating electricity from photovoltaic cells at higher light concentrations (and thus smaller and less costly cells) than is the case without concentrators.

**ADVANTAGES**
This solar concentrator design combines light trapping and total internal reflection for light concentration with radial symmetry and skew invariance of the light pathways so that a highly concentrated, uniform illumination of the central exit aperture is achieved. The separation of light trapping and light concentration in two separate layers offers greater control over critical solar concentrator design parameters than other designs.

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A new invention that uses concentrated sunlight to generate electricity from photovoltaic cells
High Temperature Dewar-Type Evacuated-Tube Solar Collectors

BACKGROUND
Non-tracking solar collectors for heating working fluids are potentially valuable in a wide range of applications, including heating, cooling, and power generation via organic Rankine cycles (ORCs). However, conventional collector designs work at relatively low temperatures, usually heating the working fluids to no more than 120°C. For most applications, higher temperatures would be much more useful.

DESCRIPTION
A research team that includes a University of California, Merced scientist has invented a novel approach to solar collector technologies based on absorption of sunlight on a surface, such as a copper fin with a selective coating, contained within an evacuated glass tube. The evacuated tube works like a Dewar flask to prevent the loss of longer-wavelength heat from the absorptive surface, making it possible to efficiently heat the system to higher temperatures, with 180°C being feasible in some designs. Various methods can be used to transfer heat from the absorptive surface to the working fluid, including radiative transfer via heat pipes and conductive transfer via circulation of the working fluid in U-tubes or counter-flow tubes within the absorber element.

APPLICATIONS
A licensee of these inventions is currently commercializing these technologies for various uses, potentially including any application requiring working fluids heated up to 180°C where the use of glass materials in fixed locations is acceptable. This might include thermally-driven engines (especially ORCs), absorption chillers, steam plants, and water heating facilities.

ADVANTAGES
By overcoming the temperature limitation of previous non-tracking collector designs, the Dewar-type solar collectors enable one to achieve high temperatures without resorting to costly tracking systems.

PATENT STATUS
This description represents several inventions. These inventions have been licensed.

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Efficient Combined Heating, Cooling, And Power Generation Cycle

BACKGROUND

The combined effects of climate change, increasing energy consumption, and higher fuel prices are challenging universities and industry to develop more efficient ways to produce power, heating, and cooling for commercial and residential applications. The utilization of renewable energy sources is receiving considerable attention as a non-resource-depleting approach that reduces the emissions of pollutants and green-house gases to the atmosphere.

In this respect, solar thermal systems provide the capability of generating heat, electric power, and/or cooling in a sustainable way and for a variety of applications due to the relatively large range of temperatures that different collector configurations can provide.

DESCRIPTION

A University of California, Merced (UC Merced) researcher has invented a combined thermodynamic cycle for simultaneous refrigeration, water heating, and power generation using CO2 as a working fluid. This cycle employs multiple heat exchangers and loops for the working fluid (including a transcritical refrigeration loop), so that systems employing this cycle offer a number of important gains in efficiency and utility over existing systems. It can also accept heat inputs from other sources to generate even more power and hot water.

The proposed system achieves a 15% improvement in coefficient of performance (COP) with respect to a standard air conditioning system operating under the same conditions. The power/hot water generating loop can operate at much higher temperatures depending on the availability and quality of the additional heat. Energy obtained from solar collectors or from waste heat can be readily utilized for this purpose.

APPLICATIONS

Systems incorporating the UC Merced combined cycle would be particularly useful in settings where refrigeration (e.g. air conditioning), water heating, and power generation are simultaneously required.

ADVANTAGES

The advantages of the UC Merced combined cycle include:

• higher efficiency as compared to separate heating, cooling, and power generation system, particularly with its higher COP for the transcritical refrigeration loop at ambient temperatures,

• production of power and hot water using energy from the refrigeration cycle that is wasted otherwise,

• production of power and hot water from other waste heat or renewable energy sources, and

• usage of an environmentally-friendly working fluid.

PATENT STATUS

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Practical Carbon Nanotube Photovoltaic Materials

BACKGROUND
A key limit on the light-to-electricity conversion efficiency of existing photovoltaic (PV) materials is the fixed band gap energy needed to create electron/hole pairs.

Sufficiently energetic photons will waste whatever excess they have over the band gap level, while less energetic photons will not be converted at all. Crystal lattice vibrations (as in silicon PVs) can also squander the energy available in photons.

Carbon nanotubes (CNTs) are a promising alternative as a PV material. CNTs with different diameters and chiralities offer a plethora of bandgap energies that can cover a very wide range of light energies, thus significantly boosting the production of electron/hole pairs from incident sunlight.

One can optimize CNTs to match the solar spectrum, enhancing optical absorption and reducing carrier scattering. However, a remaining obstacle to realizing high efficiencies in CNT PVs is that interactions between thin film CNTs and substrate materials give rise to nonradiative recombination with low fill factors, resulting in low energy conversion efficiency.

DESCRIPTION
A University of California, Merced researcher has invented a three-dimensional CNT PV membrane that increases the fill factor of the CNT membrane via increased thickness without creating a problem with electronic screening. The CNT membranes of this invention eliminate nonradiative recombination, so that the potential of CNTs as a charge generation material can be fully realized.

APPLICATIONS
The UC Merced CNT membrane may become widely employed as a solar photovoltaic material.

ADVANTAGES
The UC Merced CNT PV membrane offers a number of cost advantages, as it:

- is an inexpensive, non-toxic material with great thermal and chemical stability,
- can be fabricated using conventional semiconductor fabrication technologies, and
- does not require materials like indium tin oxide.

It also offers a number of advantages in terms of increasing PV conversion efficiency, as it:

- is a direct bandgap material with a broad range of bandgaps,
- eliminates the nonradiative recombination typical of CNT thin film PVs, and
- offers graded photoabsorption.

PATENT STATUS
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An inexpensive, nontoxic carbon nanotube membrane to collect solar power
Efficient Solar Concentrator With A Low-Cost Tracking Mechanism

BACKGROUND
Solar concentrators used for heating a working gas or fluid have serious trade-offs in terms of the concentration factor attainable (high light concentrations being desirable for achieving high temperatures and, in power generation applications, high thermodynamic efficiencies) versus the cost of mounting and moving relatively large reflective or refractive surfaces and their associated light-absorbing elements in order to track the Sun’s movements across the sky.

DESCRIPTION
A University of California, Merced researcher has invented a new type of solar concentrator that enables one to greatly reduce the cost of the tracking mechanism while employing a reflective surface with a very large area in relation to the size of the light-absorbing element.

In this new UC Merced concentrator, only the light absorbing element needs to be moved in order to track the Sun, while the reflective surface remains fixed. The geometry of the concentrator design guarantees that high efficiencies can be maintained.

Moreover, the reflective surface can be formed using simple inflated balloon-type structures, further reducing the cost of the concentrator. Low-cost technologies can also be used for the light-absorbing element.

APPLICATIONS
This UC Merced solar concentrator may find widespread use in any application where a working gas or fluid needs to be heated by the Sun, particularly in applications where high efficiencies and/or high temperatures are desirable.

ADVANTAGES
This solar concentrator design enables higher temperatures and efficiencies as compared to fixed concentrators, while greatly reducing the cost of the tracking mechanism by keeping the reflective surface in a fixed configuration. Also, this design permits the use of low cost fabrication techniques for both the reflector and the absorber components.

PATENT STATUS
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Higher Efficiency Evacuated-Tube Solar Collectors

BACKGROUND
Evacuated-tube solar collectors, in conjunction with non-tracking, non-imaging parabolic concentrators, can heat working fluids to 200°C at efficiencies near 50%, providing a relatively economical means for capturing and transferring solar energy for use in cooling, heating, and power generation applications.

However, the transfer of heat from the solar energy-absorbing element to the working fluid within such collectors poses a significant challenge to the feasibility of these systems.

It is a critical limitation of existing evacuated-tube collector designs because of trade-offs between resistance to heat transfer, cost, and safety.

DESCRIPTION
A Researcher at the University of California, Merced has invented a new class of evacuated tube solar collectors that incorporate mini-channel technology.

Previously, mini-channel heat exchangers have been employed successfully in air conditioning and electronics cooling applications to achieve high performance and compact designs. The new UC Merced invention uses them to increase the amount of heat transferred from an evacuated-tube solar collector’s energy-absorbing element to the working fluid. Based on numerical simulations efficiency gains of nearly 5% can be obtained at inlet temperatures of ~180°C can be achieved using the mini-channel solar collectors.

APPLICATIONS
This invention may become a preferred design for evacuated-tube solar collectors, heating working fluids in non-tracking arrays to provide energy for heating, for solar cooling, or for power generation via organic Rankine cycles (ORCs).

ADVANTAGES
This mini-channel solar collector has the potential to significantly increase heat transfer efficiency in compact evacuated-tube systems without compromising safety (unlike Dewar-based collector designs where glass tube breakage is possible) or adding to fabrication costs (unlike collector designs that require multiple glass-to-metal seals or more substantial condensers).

Mini-channel technology has already been proven to be cost effective in other heat transfer applications.

PATENT STATUS
Patent Pending

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About UC Merced’s Inventions Program

One significant aspect of UC Merced’s public service mission is to ensure that the results of its research are made available for public use and benefit.

This “technology transfer” is accomplished in many ways through educating students, publishing results of research and ensuring that inventions are developed into useful products in the commercial marketplace for public use.

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• to disseminate new and useful knowledge resulting from University research through the use of the patent system,

• to license patents to industry in order to promote the development of inventions toward practical application for use by the general public,

• to provide income for use in supporting further research and education, with a share of the income going to the inventor, and

• to assure that patent-related obligation to sponsors of research are met.

The role of partnerships

UC Merced does not have the resources to develop products, but by pursuing patent protection for its technology, the University can offer a commercial company the exclusive rights to the technology and the incentive to invest in product development.

What is covered by the Program

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For more information, visit: www.ucop.edu/ott
More than 40 transformative, ready for market technologies have been invented at the University of California, Merced in the fields of natural sciences, engineering and medicine.

For licensing details, contact UC Merced’s Office of Research at ott@ucmerced.edu

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