ADVANCED SOLAR TECHNOLOGY
SAMPLE TECHNOLOGY ACQUISITION REPORT

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For further information on the technologies contained in this report, please contact:
Richard R Matner, Ph. D., M.B.A.
Tekcapital Ltd.
New Road, Oxford OX1 1BY, United Kingdom
UK: +44 1861 261 445; US: +1 716 908 2946; rmatner@tekcapital.com
www.tekcapital.com

Disclaimer
Although all of the presented technologies are listed by their respective institutions as "available for license" or acquisition, that status can quickly change. Tekcapital continues to investigate and assess the current availability of all technologies contained in this report.

Search and Analysis Methodology Employed in this Report
The goal for this report is to provide relevant, new, solar technologies available for immediate acquisition. The next steps are to review the technology candidates to determine which might be of interest. Equally important is for us to understand why a technology might not be a good fit, as this will enable Tekcapital to refine our criteria to produce the most relevant results in subsequent reports. Further, for any of the technologies described in this report that you or your team have an interest in, we would be glad to immediately produce and provide an Invention Analysis report that describes the market opportunity for the technology.

The process employed to identify technology acquisition opportunities consisted of inputting specific parameters based on the relevant departmental technology acquisition interests into Tekcapital’s discovery search engine which is linked to the technology commercialization offices of approximately 3,300 research institutions in 160 countries. In addition Tekcapital selectively searched across nearly 1,000 technology companies that have been spun-off from these institutions. Further, Tekcapital contacted technology transfer officers at several institutions with a known expertise in advanced solar technology. Several hundred technologies have been screened to produce the technology acquisition candidates identified in this report. All of the acquisition candidates contained in this report have been reviewed by our Science Advisory Board for scientific merit and available for immediate acquisition as of the date the report was produced.
Technology 1: Microsystems Enabled Photovoltaics (MEPV) - Photovoltaic solar concentrator

From: Sandia National Laboratories

Overview
Microscale photovoltaic cells harness energy from a variety of light sources and power devices in flexible, moldable, or flat-plate formats. Microscale PV cells generate electricity through the photovoltaic effect. When light shines on the semiconductor, electrons are excited, drift and diffuse in the material, and then are collected at the terminals.

Just as lithium ion battery development for the laptop computer industry enabled the migration of this energy storage technology to electric vehicles, microscale PV products can provide the scale and necessary revenue stream to develop new microscale PV technologies for other nascent applications. If done right, the powering of almost anything could become as simple as exposing it to light.

Technology
Sandia’s MEPV team has developed microscale photovoltaic (PV) cells using microsystems tools and manufacturing techniques familiar to the semiconductor industry. With dimensions as small as 100-µm wide and 1-µm thick, these miniaturized PV cells convert photons from the sun or any other light source into electricity. As with microelectronic components, the small size of the PV cells enables the packaging and integration of the energy system into a variety of formats that conform to the shapes and contours. From 14 to 20 micrometers thick, they are 10 times thinner than conventional 6-inch-by-6-inch brick-sized cells, yet perform at about the same efficiency; 100 times less silicon generates same amount of electricity. They use 100 times less silicon to generate the same amount of electricity of the powered device and blend into the device’s look, feel, and functionality.

Three microscale PV cell designs have been developed:
1. A silicon back-contacted interdigitated finger pattern.
2. A silicon back-contacted radial pattern.
3. An ultrathin single-junction gallium arsenide (GaAs) cell with back contacts.
All of the enumerated microscale PV cell designs can be embedded into highly flexible PV modules, incorporated into low-cost microconcentrator modules, or built into consumer electronic products. And because there are no electrical contacts on the front side, these microscale PV cells can be integrated in aesthetically pleasing patterns that may not even reveal the cells’ electricity generation capability.
Inventor
Gregory N Nielson

Principal Member of Technical Staff
Sandia National Laboratories

Education
Mechanical engineering Utah State

Research Interest
Researchers at Sandia National Laboratories are pioneering solar photovoltaic (PV) technologies that are cheaper to produce and easier to install than traditional grid power and capable of producing clean, safe, and reliable electricity. These innovations can help accelerate the growth of PV as a mainstream power source in the United States and globally.

One such innovation under development at Sandia is microsystems enabled photovoltaics (MEPV). MEPV concepts use microdesign and microfabrication techniques to produce miniaturized solar cells that are released into a solution similar to printing ink. This solution is then placed or ‘printed’ onto a low-cost substrate with embedded contacts and microlenses for focusing sunlight onto the cells. Sandia’s approach uses cells that are tiny in both thickness and lateral dimensions – as small as 14 microns thick and 250 microns wide. The thinness of the cells reduces material costs while enhancing cell performance by improving carrier collection and potentially achieving higher open circuit voltages.

Sandia’s microsystems enabled PV advances combine mature technology and tools currently used in microsystem production with groundbreaking advances in photovoltaic cell design, decreasing production and system costs while improving energy conversion efficiency. The technology has potential applications in buildings, houses, clothing, portable electronics, vehicles, and other contoured structures.
Related Publication


Patent Status:

Technology 2: Method and apparatus for integrating an infrared (ir) photovoltaic cell on a thin film photovoltaic cell

From: University of Florida

Overview

Photovoltaic cells are considered an important source of renewable energy for helping to solve the world's energy shortage today. Various photovoltaic cell technologies have been developed, and thin film photovoltaic cells such as copper indium gallium selenide (CIGS) and CdTe have received attention because of their compatibility with large area manufacturing. While these thin film photovoltaic technologies have reported power conversion efficiencies of around 20% resulting from an external quantum efficiency of more than 90% at visible wavelengths, these thin film photovoltaic cells have no sensitivity for radiation with at a wavelength above 700 nm. There is a need for advanced solar panels that can advantageously capture and store solar energy from a wider spectrum of photons than conventional photovoltaic cells.

Technology

This invention relates to photovoltaic panels for harvesting a large portion of the solar spectrum by integrating an IR photovoltaic cell on a photovoltaic cell (such as a conventional thin film photovoltaic cell). In particular cases, a photovoltaic panel can harvest the entire solar spectrum. When an IR photovoltaic cell is integrated on a photovoltaic cell (such as a conventional thin film photovoltaic cell), a high efficiency photovoltaic panel is produced.

Therefore, a solar panel is described that includes: a first photovoltaic cell sensitive to photons in a first wavelength range; and a second photovoltaic cell, sensitive to photons having a second one or more wavelength range, such that at least one of the second one or more wavelengths is not in the first wavelength range, and at least one of the first one or more wavelengths is not in the second wavelength range. The second wavelengths can be greater than 700 nm. In addition method of fabricating the hybrid solar panel is described.

Many unique photocell structures are described by this invention. The following will serve as the most common example:
The solar panel can be configured such that light incident on an input surface of the photovoltaic cell, which passes through the photovoltaic cell and exits an output surface of the first photovoltaic cell, is incident on an input surface of the IR photovoltaic cell and enters the IR photovoltaic cell. The solar panel can be configured such that light incident on an input surface of the IR photovoltaic cell, which passes through the IR photovoltaic cell and exits an output surface of the IR photovoltaic cell, is incident on an input surface of the photovoltaic cell and enters the photovoltaic cell.

Inventor
Franky So

Principal Investigator
Organic Electronic Materials and Device Laboratory
University of Florida

Education
B.A., Physics, Hamilton College
M.S., Materials Science, Massachusetts Institute of Technology
Ph.D., Electrical Engineering, University of Southern California

Research Interest
Organic Solar Cells

In meeting the challenge of the energy crisis facing the world, harvesting energy from sunlight offers a viable solution. In this context, solar cells based on organic materials are considered a promising alternative to their inorganic counterparts for the generation of affordable, clean, renewable energy. Other than cost-effectiveness, these organic devices have several additional attributes including greater mechanical flexibility, light weight, aesthetically pleasing colors, and the potential for transparent embodiments which open up novel application possibilities. With steady improvement in efficiency this technology is nearing the benchmarks for commercialization. In our lab, we apply a three-pronged
approach in the research of organic based solar cells. In collaboration with our partners in chemistry, we employ new polymers and small organic molecules, with untapped functionalities, in fabricating high-performance solar cells. For example, we are studying color-tunable and broadly absorbing donor-acceptor polymer systems as viable photovoltaic polymers. At the same time, we implement new architectural modifications to maximize the performance of these devices. In this area, we are studying the role interfacial modifications on device efficiency. Finally, we study the device physics to investigate the fundamental operation mechanisms and the processes limiting their performance to enable further rational optimization.

-Nuclear Materials
-Optical and Optoelectronics
-Particle Science
-Sensors
-Energy and Environment

Related Publications

Record solar cell efficiency with dithienogermole-thienopyrrolodione donor-acceptor photoactive layer and novel ZnO/polymer composite electron extraction layer - Nature Photonics

"Dithieonogermole as a fused electron donor in bulk heterojunction solar cells" - Collaboration with Dr. John Reynolds's group for high efficiency solar cells - Journal of the American Chemical Society

"PbSe nanocrystal-based infrared-to-visible up-conversion device" - Nano Letters

"Low-voltage, low-power, organic light-emitting transistors for active matrix displays" - Science

"Degredation Mechanisms of Small Molecule and Polymer Organic Light Emitting Diodes" (Cover Story - Advanced Materials)

Patent Status:
Technology 3: Photovoltaic cells with quantum dots with built-in-charge and methods of making same

From: State University of New York

Overview
Quantum dot (QD) solar cells have been attractive for solar cell applications due to their ability to enhance light absorption via multiple energy levels introduced by the quantum dots and extend the absorption edge into the infrared range. Quantum dots are very promising candidates to create energy level structures for better use of the solar spectrum. In QDs the carriers are confined in all three dimensions with the allowed absorption bands being separated by the forbidden gaps. In such multiple energy level cells additional energy levels accommodate the mismatch between the solar spectrum and two-level electron transitions. In this way QD structures allow for minimizing so-called thermalization losses and the use of charged quantum dots increases QD solar cell conversion efficiency.

Technology
The increased conversion with quantum dots is due to effective harvesting and conversion of IR radiation and suppression of recombination losses.

This invention provides devices (e.g., photovoltaic devices) with quantum dots with built-in charge (Q-BIC) and methods of making such devices. The dot charging is realized by n-doping the semiconductor material in which the dots are disposed. This approach provides control of a potential relief in the QD solar cell, and allows management of the photoelectron processes. This device comprises a plurality of quantum dots disposed in an n-doped semiconductor material, such that the quantum dots have built-in charge. The charge in the quantum dots creates potential barriers which prevent photoelectron capture by the quantum dots, and the electrons in the charged dots provide coupling to infrared radiation.

The concept of QD solar cell is analogous to the concept of the impurity photovoltaic cell, which has been studied for many years. In the early sixties, Wolf proposed to use impurity levels to collect the long-wavelength radiation. In response, Shockley and Queisser argued that additional impurity levels drastically enhance the recombination processes (Shockley-Read-Hall recombination) and consequently deteriorate the device performance. Trade-off between IR energy harvesting and recombination losses due to impurity electron levels is a long-term problem studied without noticeable success in a number of
theoretical and experimental investigations. However, compared to the midgap impurities, quantum dots offer more flexibility for nanoengineering of electron processes via dot size and selective doping.

**Inventor**

Dr. Andrei Sergeyev

Senior Researcher
State University of New York
Department of Electrical Engineering

**Education**

Department of Quantum Electronics, Physics, Quantum Electronics, M.S. 1980

Moscow Institute for Physics and Technology, Moscow, Russia

Department of Physics, Theoretical Solid State Physics, Ph.D. 1987

Moscow Pedagogical University

**Research Interest**

Research interests are concentrated in the areas of quantum transport and solidstate electronics. Specific research topics include:

- Ultrasensitive superconducting and semiconducting detectors. Hot-electron nanosensors and nanocalorimeters.
- Electron-phonon interaction in disordered conductors, micro- and nanostructures.
**Related Publications**


**Patent Status:**

Patent application PCT/US2012/021847
Technology 4: Super-transparent electrodes for photovoltaic applications From: Boston College

Overview
A typical conventional solar cell contains a light absorber, such as amorphous or crystalline silicon, sandwiched between two electrodes. One of the electrodes is typically transparent. An incident light creates carriers in the absorber, which subsequently are collected through the electrodes. Because the top electrode (ITO in a-Si or a highly doped surface layer in c-Si) is usually insufficiently conductive, current collection fingers are typically placed on the light-absorbing surface of the absorber. The presence of collection fingers, however, reduces the active surface area of the absorber. There is a need for highly transparent electrodes collection fingers.

Technology
This invention provides new types of conductive coatings that can dramatically increase conductivity of a solar absorber surface, while preserving its high transparency and the efficiency of the anti-reflection coating. The coatings include a conductive metal layer in combination with an anti-reflective coating (ARC). The coatings can be applied to the surface through which light enters a solar absorber to act as a light entry (top) electrode.

Super-transparent electrodes for photovoltaic applications include a light entry electrode that includes an anti-reflective coating (ARC) layer; and a nanoscopically perforated metallic film. A photovoltaic cell includes an absorber material capable of absorbing solar energy and converting the absorbed energy into electrical current; a window electrode disposed on a light-entry surface of the absorber material, the window electrode comprising an anti-reflective coating (ARC) layer and a nanoscopically perforated metallic film; and a rear electrode disposed on a surface of the absorber material in opposing relation to the window electrode. The rear electrode in combination with the window electrode are configured to collect electrical current generated in the absorber material.

The coatings may be designed to be simultaneously highly conductive and transparent in a broad range of light spectrum when placed on a absorber material that has a large refractive index (i.e., silicon)
Inventor
Dr. Krzysztof Kempa

Professor of Physics
Boston College

Education
Ph.D., Theoretical Physics, University of Wroclaw, Poland
M.S., Electrical Engineering: Semiconductor Technology, Technical University of Wroclaw, Poland

Research Interest

Related Publications


Patent Status:
Patent application PCT/US2012/044346
Technology 5: Optical concentrator and associated photovoltaic devices

From: Heriot-Watt University, Edinburgh UK

Overview
Solar PV materials are struggling to increase their conversion efficiency and one potential route being taken to reduce the cost of generating electricity from PV systems is to use less PV material in the device itself, however using a smaller area of PV reduces the surface available to the solar energy and this can lead to a significant drop-off in PV device conversion efficiency and to counter this effect, solar concentrators have been used as a means to focus the sun's energy onto the smaller area of PV material.

Solar concentration is well known and there already exist a number of optical components that can be used to concentrate solar energy, including curved mirrors, patterned plastic sheets, curved metal reflectors, lens arrays and specialised lenses, such as Fresnel lenses. Incorporation of these optical components has given rise to a new class of PV systems known as "Concentrating Photovoltaic" or CPV devices. The fabrication of CPV devices offers advantages over flat plate, or non-concentrating PV devices. These advantages can include, but are not limited to: 1) concentrator PV devices can increase power output while at the same time reducing the number of solar cells needed; and 2) concentrator PV devices can utilize solar cells that are of a much smaller surface area, that are easier to mass-produce compared to large surface area solar cells.

Technology
This invention is a transmissive optical concentrator comprising an elliptical collector aperture and a non-elliptical exit aperture, the concentrator being operable to concentrate radiation incident on the collector aperture. The photovoltaic device comprises a concentrator and a photovoltaic cell arranged to receive collected radiation from the exit aperture. The invention also includes a photovoltaic building unit which is an array of optical transmissive concentrators, each having an elliptical collector aperture; and an array of photovoltaic cells, each aligned with an exit aperture of a concentrator; the area between adjacent collector apertures is transmissive to visible radiation. The array of transmissive concentrators may be a single piece with the transmissive areas between adjacent concentrators being formed from the same material as the concentrators. This one-piece array of optical transmissive concentrators can function as both a concentrator array and a cover glass.
Inventor
Dr. Tapas Kumar Mallick

Senior Lecturer
School of Engineering & Physical Sciences
Heriot-Watt University

Education

• 2003: PhD, "Optics and Heat Transfer for Asymmetric Compound Parabolic Photovoltaic Concentrators for Building Integrated Photovoltaics", Faculty of Engineering, University of Ulster, UK.

• 1999: Pre-PhD Course Work, CES, Indian Institute of Technology, New Delhi, India.

• 1998: MTech (Energy Science & Technology), SES, Jadavpur University, Kolkata, India

• 1996: MSc (Physics), Visva-Bharati University, Santiniketan, West Bengal, India

• 1994: BSc (Hons, Physics), Visva-Bharati University, Santiniketan, West Bengal, India

Research Interest

My group is researching on new devices and system for energy efficiency solar energy system such as novel concentrating system for building integrated photovoltaic applications. Such system has potential to feed electricity and adequate lighting into the building ensuring low cost energy tariff. Another area of research is developing non-tracking solar concentrators for water desalination applications. In addition, our group has developed integrated optical-thermal-electrical model for performance analysis of concentrating photovoltaic systems.

Related Publications


**Patent Status:**

Patent application PCT/GB2012/053221 WO2013093487 A2
Technology 6: Hybrid photovoltaic devices and applications thereof

From: Wake Forest University

Overview

A significant amount of the solar spectrum is not collected by current photovoltaic devices. Infrared radiation beyond 1150 nm, for example, is often converted to thermal energy within photovoltaic devices as opposed to electron-hole pairs. The generation of thermal energy within photosensitive regions of a photovoltaic device can produce negative consequences such as a reduction in $V_{oc}$ and permanent structural damage to the photovoltaic cell. Therefore a hybrid photovoltaic devices with electrical and thermal energy production capabilities is needed.

Technology

This photovoltaic apparatus comprises electrical and thermal production capabilities. The apparatus comprises a conduit core comprising at least one radiation transmissive surface, a fluid disposed in the conduit core and a photoactive assembly at least partially surrounding the conduit core, the photoactive assembly comprising a radiation transmissive first electrode, a photosensitive layer electrically connected to the first electrode, and a second electrode electrically connected to the photosensitive layer.

A fluid disposed in the conduit core absorbs radiation having one or more wavelengths falling in the infrared region of the electromagnetic spectrum. A fluid in the conduit core is radiation transmissive. Additionally, the photovoltaic apparatus is coupled to a heat exchanger or other apparatus operable to capture thermal energy generated in the fluid in the conduit core. The photovoltaic apparatus can comprise a plurality of photovoltaic cells, at least one of the photovoltaic cells comprise a conduit core with at least one radiation transmissive surface, a fluid in the conduit core and a photoactive assembly at least partially surrounding the conduit core, the photoactive assembly comprising a radiation transmissive first electrode, at least one photosensitive layer electrically connected to the first electrode, and a second electrode electrically connected to the photosensitive layer.
Inventor
Dr. David L. Carroll
Professor of Physics
Center for Nanotechnology and Molecular Materials
Department of Physics

Education
PhD: Physics
University: PhD- Wesleyan U. (CT/US)
BS- NCSU (NC/US)

Research Interest
Our research work focuses on “Quantum Matrix Composites.” These materials are based on spatially correlated arrays of quantum-functional nanomaterials, within an electroactive host. Local symmetries, degrees of freedom, and scale-invariant topologies lead to a rich assortment of interactions within the complex architecture. We specifically seek to understand the quantum-cooperative behavior that results.

Our group also explores how these materials might lead to the development of technologies in:
1) Power: advanced photovoltaic architectures and materials, PV/T hybrids, lighting and display systems, piezo/thermo-electrics.

Patent Status:
Technology 7: Methods of manufacturing photovoltaic electrodes

From: University College Dublin

Overview
Dye-sensitized solar cells (DSSCs) show considerable potential as a relatively low cost alternative to silicon based solar cells. These cells were developed by Gratzel and co-workers in 1991 [B. O'Regan, M. Gratzel, Nature, 353 (1991) 737-740] and there is currently a considerable focus on enhancing their light conversion efficiency and stability. The principal components of a DSSC electrode are a conducting substrate, which is usually a transparent conductive oxide coated on glass, a highly porous layer of semiconductor material, and a photosensitive dye absorbed into and coating the porous semiconductor. A disadvantage with current thermal sintering process of the electrodes is the processing time. When one adds the heat-up and cool-down times, it can take approximately 4 hours to process a substrate. This invention aims to address at least some of this shortcoming and to provide improvements in the manufacture of photovoltaic electrodes.

Technology
This invention involves a photovoltaic electrode made by the following steps: (a) depositing on a substrate a dispersion comprising powdered semiconductor particles in a dispersion medium; (b) removing the majority of the dispersion medium to leave the powdered semiconductor particles in a deposition layer on the substrate; (c) creating a plasma using microwave energy excitation; (d) exposing the deposition layer to said microwave-excited plasma for a sufficient time to sinter the nanoparticles thereby adhering them to the substrate; and (e) absorbing a dye into said sintered deposition layer. The electrode thus obtained exhibits improved performance relative to conventional sintered electrodes. The most widely used n-type electrode material is nanostructured titanium dioxide. For p-type electrodes, perhaps the most promising technology employs nickel oxide (NiOx) coatings, which has a considerable potential for use as a cathode in tandem cells. This is due to their p-type nature, excellent chemical stability, in addition to well defined optical and electrical properties. Moreover, NiOx is considered as a model semiconductor substrate due to its wide band-gap energy range from 3.6 to 4.0 eV depending on the amount of Ni(III) sites. NiOx films have been fabricated by various techniques which include spin coating, dipping, electrochemical deposition, magnetron sputtering and sol-gel. With the exception of the sputtering and electrochemical techniques, the other methods require a sintering step in order to obtain dense coatings. Thermal sintering also performs the function of removing the binder in the case of sol gel deposited coatings. Typically sintering conditions of 300-450° C. for 30 to 60 minutes are reported with
start up and cool down times, the sintering process takes approximately 4 hours. This invention describes an enhanced material and quicker process for electrode production.

**Inventor**
Dr. Denis Dowling

**Senior Lecturer**
School of Mechanical & Materials Eng
University College Dublin

**Education**
University College Dublin

**Research Interest**
My research work is focused on the engineering of surfaces to enhance their performance. Application areas include medical devices, solar energy and packaging. The research can be divided into three broad areas as follows:

* Functional coatings - evaluation of how nm thick coatings can influence a diverse range of surface properties including cell adhesion, polymer to polymer or metal adhesion (particularly composites) and coatings for photovoltaic applications. These coatings are deposited by both PVD and PECVD techniques. A particular research focus is on the deposition of coatings using atmospheric plasma systems.

* Tribological coatings - wear resistant and low friction coatings on tools and engineering components. These coatings are deposited by magnetron sputtering.

* Microblast coatings - Deposition of coatings from powder particles entrained in air jets using microblast and CoBlast™ techniques. A particular focus is the low temperature deposition of hydroxyapatite and Teflon coatings onto medical implants.
Related Publications


Patent Status:
Technology 8: Thin film photovoltaic cell structure, nanoantenna, and method for manufacturing

From: Aalto University - Finland

Overview
In a photovoltaic cell, before any energy conversion can take place, light has to enter the cell and penetrate to the active region. Thus, losses due to reflection, scattering, and absorption before the active region should be minimized. Moreover, having reached the active region, the light energy should be absorbed there as effectively as possible without passing through it or reflecting back out of the cell. This is an important issue in all photovoltaic cell configurations. In thin film cells where the active region typically is a layer having a thickness in a range of only tens of nanometers to some micrometers, effective capturing of light energy into the active region becomes a key factor for the overall efficiency of the cell.

In thin film photovoltaic cells the semiconductor layers of the device are realized as thin layers with a thickness in a range from a few nanometers to some tens of micrometers. Thin film cells can provide advantages in the energy conversion efficiency and in the manufacturing costs. Decreased layer thicknesses also mean lower weight of the cells and the solar panels formed of them. A thin overall structure enables also flexible device configurations.

Intensive effort is focused in the field of thin film photovoltaic cells on research and development of more and more efficient solutions to improved light capturing.

Technology

The object of this invention is to provide a thin film photovoltaic cell structure with improved light capturing efficiency and enabling cost-efficient industrial-scale manufacturing. Another object of this invention is to provide a nanoantenna which is suitable, for example, for use in such thin film photovoltaic cell structures. In addition, this invention provides a cost-efficient method for manufacturing such thin film photovoltaic cells.

Recently, one of the most active research areas has been the different forms of plasmonic light concentrators (LC) based on plasmonic nanoparticles arranged in an array on the surface of a photovoltaic cell on the side of the incident light. The operation of plasmonic nanoparticles (PNP) is based on resonant
excitation of surface plasmons by the incident light. With suitable configuration of the nanoparticles and proper structural connection between the nanoparticles and the active region of the cell, the plasmon resonance, i.e. resonant oscillation of the electrons in the nanoparticles, results in efficient coupling of incident light into the active region. In this coupling, the light energy in the incident plane wave is concentrated into a plurality of so called hot spots located at least partially within the active region of the cell. At the same time, reflection backwards from the active region as well as transmission through it is minimized.

The above objects are partially achieved by the invention. This invention is focused on a thin film photovoltaic cell structure comprising a substrate; a first dielectric layer on the substrate; an active layer on the first dielectric layer for generating free charge carriers via a photo-voltaic effect; and a plasmonic light concentrator arrangement on the active layer for coupling incident light at a first wavelength band into the active layer. By a thin film photovoltaic cell structure is meant a structure forming at least a part of a thin film photovoltaic cell. By a thin film photovoltaic cell, in turn, is meant a photovoltaic cell in which at least the active layer where the actual photovoltaic effect, i.e. the generation of free charge carriers via absorption of incident light energy, takes place is in the form of a layer having a thickness in the range from a few nanometers to some tens of micrometers, typically from tens of nanometers to a few micrometers. The active layer can be formed of any material and structure suitable in the form of a thin film for photovoltaic conversion. It can comprise e.g. p-doped amorphous silicon, or polycrystalline silicon or gallium arsenide.

Inventor
Dr. Constantin Simovski

Professor, Department of Radio Science and Engineering
**Education**

2000 Doctor of Sciences in Physics and Mathematics, St.-Petersburg Polytechnic University, Russia

1986 Ph.D. in Radio Physics, Leningrad Polytechnic Institute, USSR

1980 Diploma Eng.-Physicist in Radio Physics, Leningrad Polytechnic Institute, USSR

**Research Interest**

Thin-film solar cells enhanced by non-plasmonic metal nanoantennas. Idea: metal nanoantennas with some combination of design parameters can operate as if they were perfectly conducting elements. They can trap the light do to collective effects and do not exploit the plasmonic properties of the metal. This prevents the harmful dissipation of the solar light in metal elements and offers the broadband light trapping. For very thin photovoltaic layers the array of such nanoantennas combined with the dielectric superstrate operates better than other light-trapping structures and than the simple antireflecting coating. This work was supported by the Pre-seed project “Custom-design thin-film solar cells with light-trapping covering” of the Aalto Center of Entrepreneurship.


**Related Publications**


**Patent Status:**

Patent application PCT/FI2012/050250 WO201212364
Technology 9: Apparatuses, systems and methods for cleaning photovoltaic devices

From: King Abdullah University of Science and Technology - Saudi Arabia

Overview

The efficiency of a solar panel is measured by the ratio of the amount of sunlight it receives to the amount of electricity it generates. After a solar panel is installed, dust and other debris typically begins to accumulate on the solar panel surfaces. Dust accumulated on a solar panel often reduces the number of photons that the solar panel can convert to electric energy during a unit of time, and therefore may significantly reduce the efficiency of the solar panel.

As such, many systems comprise a solar panel cleaning system to improve the efficiency of solar panels. Typically, most solar panel cleaning systems use liquid cleaning solutions or water for cleaning the solar panels. Dust and other debris may also become moist from rain, dew, and other condensation on the panels. The moistened dust and debris may become sticky and adhere to the surfaces of the solar panel. This typically complicates the cleaning process, and is one reason that most cleaning systems use liquid cleaning solutions in the cleaning process. A non-liquid based cleaning method can solve many of these problems.

Technology

This invention involves solar panel cleaning apparatuses, solar panel cleaning systems, and solar panel cleaning methods. The solar panel cleaning apparatuses, systems and methods may not require any water or other cleaning liquids in the whole cleaning process, which makes them prominent well suited in for water-deficit environments such as deserts. The solar panel cleaning apparatus comprises one or more rotatable brushes each having a rotational axis and a drive configured to move each of the one or more rotatable brushes in a direction that is not perpendicular to the rotational axis. The solar panel cleaning apparatus may be configured such that the angle of the rotational axis of at least one of the one or more rotatable brushes is adjustable relative to the direction of travel.
NOMADD

Inventor
Georg Eitelhuber

Energy Conservation Specialist
King Abdullah of Saudi Arabia

Education
Master of Science (M.Sc.), Renewable Energy, 2009 – 2012 The University of Western Australia

Research Interest
Implementing energy saving initiatives across the community, fusing the knowledge and skills of multiple departments and interests to achieve leveraged value. No Water, Mechanical, Automated, Dusting Device for Photovoltaic installations (NOMADD). This technology is a system designed to remove dust that has collected on long banks of solar panels located in arid environments, where water is generally scarce and unavailable.

Patent Status:
Technology 10: Photovoltaic structures having a light scattering Interface layer and methods of making the same

From: University of Toledo

Current- Institute of Electrical Engineering, Chinese Academy of Science
Beijing City, China

Overview
It would be advantageous to fabricate a light diffusion layer in thin-film solar cells in order to improve the light absorption in extremely thin absorber layers. Thin-film solar cells made using such methods permit the use of much thinner absorber layers and thus facilitate faster manufacturing and less use of expensive absorber layers, thus lessening possible adverse environmental impacts.

Technology
This invention describes the process of fabricating a very thin light diffusion layer at the entrance to very thin semiconductor absorber layers that can produce very strong light diffusion. This strong light diffusion or scattering greatly enhances the light absorption in absorber layers that are otherwise too thin to absorb fully the incident light.

This invention also describes a method of fabricating a light diffusion (light scattering) layer in thin-film solar cells. A photovoltaic (PV) cell structure is described: a first layer comprised of a first semiconductor material adjacent to a second layer comprised of a second semiconductor material, the first semiconductor material having a first lattice constant, and the second semiconductor material having a second lattice constant which is different from the first lattice constant; and, at least one light scattering interface layer configured to diffuse or scatter light prior to entering one or more of the first and second layers. The light scattering interface layer has been formed at a boundary between the first and second layers of the semiconductor materials or within the first or second semiconductor material. Or the first and second semiconductor materials have a lattice mismatch between each semiconductor material's crystal lattice constant sufficient to cause the formation of the light scattering interface layer.

This invention provides further benefits by reducing the thickness of the absorber layers in thin-film solar cells. For example, the reduced thickness of the absorber layers provides a concurrent reduction in deposition time, less use of expensive materials, and less use of materials that may have environmental impacts. The invention method is particularly suited to thin-film solar cells. The inventors have
discovered a method that, in effect, can take advantage of the properties of the deposited layers and is readily scalable to large areas needed for thin-film solar cell manufacturing.

In addition this invention describes a method for making a very thin, yet strong, light scattering, or light diffusion, layer in an interior interface during the fabrication process of a solar cell. The thin diffusion layer is fabricated using magnetron sputtering of the layers and a subsequent heat treatment of the solar cell structure. For example, CdS/CdTe solar cells were fabricated on glass coated with a transparent conducting oxide (TCO) layer.

Most of the scattered light rays will be directed at large angles to the perpendicular to the interface layer. Consequently, even in a very thin layer these light rays can be nearly fully absorbed.

Inventor
Dr. Xiangxin Liu

Research Professor at Institute of Electrical Engineering, Chinese Academy of Science Beijing City, China | Semiconductors

Education
PhD University of Toledo
Received B.S. in 1999 from Xiamen University, China
**Research Interest**

Ion Implantation on CdTe:

We implant some elements into CdTe crystals and study their effect by photoluminescence. This will be good for higher efficiency solar cells.

**Related Publications**


**Patent Status:**

Technology 11: Rapid thermal activation of flexible photovoltaic cells and modules

From: University of Toledo

Overview
Cadmium telluride PV cells are built on glass in a superstrate configuration, which takes advantage of glass's transparency, mechanical rigidity and the opportunity to form the back contact last. However, glass is heavy and its rigidity and fragility are disadvantages for many applications. As an alternative material for superstrates, transparent polymers can be used instead of glass. Polymer materials, however, impose processing limitations because of certain material property changes due to, for example, temperature and chemical exposure. These processing parameters are known to darken or otherwise alter the transparent characteristic of the polymer front window. Such alterations prevent certain wavelengths of the solar spectrum from penetrating to the active layers and thus reduce the overall power efficiency of the PV cell.

The chloride activation step, employs one of the highest temperatures in the fabrication process, that may be on the order of 370-400° C. This contrasts with the sputter deposition process, used to form the active layers, which may be performed at 250-300° C. For example, present methods using glass substrates use typically 15 to 30 minutes of treatment due to the heat capacity of the glass and its tendency to fracture when heated or cooled very fast.

Shorter treatment times would be desirable in order to maintain the transparency and material integrity of polymer substrates and superstrates such as, for example, polyimide superstrates. It would also be advantageous to manufacture a flexible diode such as a PV cell that has a front window with high transparency and low light spectrum absorption and that can be assembled economically and in high volume.

Technology
This invention is a photovoltaic cell which includes a polymer window and at least one active semiconductor layer that is conditioned using a cadmium chloride treatment process. The photovoltaic cell is heated, during the cadmium chloride treatment process by a rapid thermal activation process to maintain polymer transparency. A method of producing a photovoltaic cell using the rapid thermal activation process and an apparatus to conduct rapid thermal activation processing are also disclosed.
Specifically, the invention is a PV cell that includes a polymer front window layer having an optical transparency characteristic that is not substantially degraded by the process used to form the PV cell. The PV cell comprises a flexible polymer-based superstrate layer having a first optical transparency characteristic prior to cell layer assembly. An active semiconductor layer is applied during cell layer assembly. The semiconductor layer is exposed to a CdCl2 vapor process and a rapid thermal activation process. The CdCl2 vapor process, in conjunction with the rapid thermal activation process, permit the polymer-based superstrate layer to take on a second optical transparency characteristic in the wavelength region for CdTe from 400 nm to 900 nm that is 95% of the first optical transparency characteristic.

**Inventor**
Dr. Alvin D Compaan

**Professor**
Director, Center for Materials Science and Engineering
Department of Physics and Astronomy
College of Arts and Sciences, The University of Toledo

**Education**
A.B., Calvin College, 1965
M.S., University of Chicago, 1966
Ph.D., University of Chicago, 1971

**Research Interest**
The principal research effort of Dr. Compaan, on the deposition of semiconductor thin films for solar cells, is supported by the National Renewable Energy Laboratory (NREL). Complete CdS/CdTe thin film solar cells are being fabricated at Toledo with the CdS, CdTe, and CdCl2 deposited by pulsed laser deposition and radio frequency (rf) planar magnetron sputtering. The research emphasizes techniques
scalable to large-area, thin-film modules for applications of photovoltaic power generation. Most of our research effort involves the use of glass substrates which are coated with fluorine-doped tin oxide which serves as the transparent conductor. However, some research is directed to the development of CdS/CdTe cells on flexible substrates such as molybdenum foil and high temperature polymers. There are currently two major projects supported by NREL. The first involves continuing research to improve the performance of the CdTe-based cells and to study defects and non-uniformities in the thin films which can lead to long term degradation of the cell performance. The second project involves next-generation devices such as developing CdTe alloys suitable for a top cell in a two-junction tandem configuration. This top cell needs to have a band gap of about 1.7 eV compared with the 1.5 eV band gap of CdTe. We are also working on the development of a transparent back contact (and/or tunnel junction) for the top cell so that sunlight (and current) can pass to the smaller-gap bottom cell. Other faculty collaborate in this work. These include Profs. Victor Karpov, Randy Bohn, Xunming Deng in Physics and Astronomy, and Dean Giolando of the Chemistry Department. Another related research effort of our group involves the development of improved thin films for flat-panel plasma display panel (PDP) technology and the study of vacuum-ultraviolet emission spectroscopy from PDP structures with time resolution of nanoseconds.

In our labs we use a wide variety of characterization and diagnostic techniques including Raman scattering, photoluminescence, x-ray diffraction, scanning electron microscopy (SEM) with energy dispersive x-ray analysis (EDS), laser-induced time-resolved fluorescence, photoreflectance and electroreflectance, spectral quantum efficiency, and I-V device measurements. We collaborate with other research groups in using atomic force microscopy (AFM), spectroscopic ellipsometry, Rutherford backscattering (RBS), and synchrotron-based x-ray studies (grazing incidence x-ray fluorescence, x-ray absorption near edge structure (XANES) and extended x-ray absorption fine structure (EXAFS).

**Related Publication**


**Patent Status:**