THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

“Solar Cell Design and Processing”

Student Patent Presentations

8 December 2005

THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

Outline of Patent Presentations

- 6,897,085 – AR Coatings on Si Spheres
- 6,946,597 – PV using Porous Template
- 6,963,120 – Three-Layer PIN Junction Stacked Cell
- Application Number: 20050218467 – Dye Sensitized Cell with Light Scattering Particles
- 6,653,551 – PV Concentrator System with 4-Junction Cell
- 6,964,486 – Micro-mirrors for Solar Concentrator
- 6,410,362 – Flex Cell with Emissive Overlayer for Space Apps
- Application Number: 20050164474 – Plasma deposition with dilutant
- 6,689,950 – Solar Paint with MultiGap Mixtures
- 6,958,868 – Non-moving Solar Tracker/Concentrator
- 6,971,756 – Solar Concentrator with Curved Reflectors
- 6,880,553 – Solar Air Conditioning System
- 6,900,382 – Gel Electrolytes for Dye Sensitized Cells

Patent Summary Presentation

Igor Tikhonov

Solar Cell Design

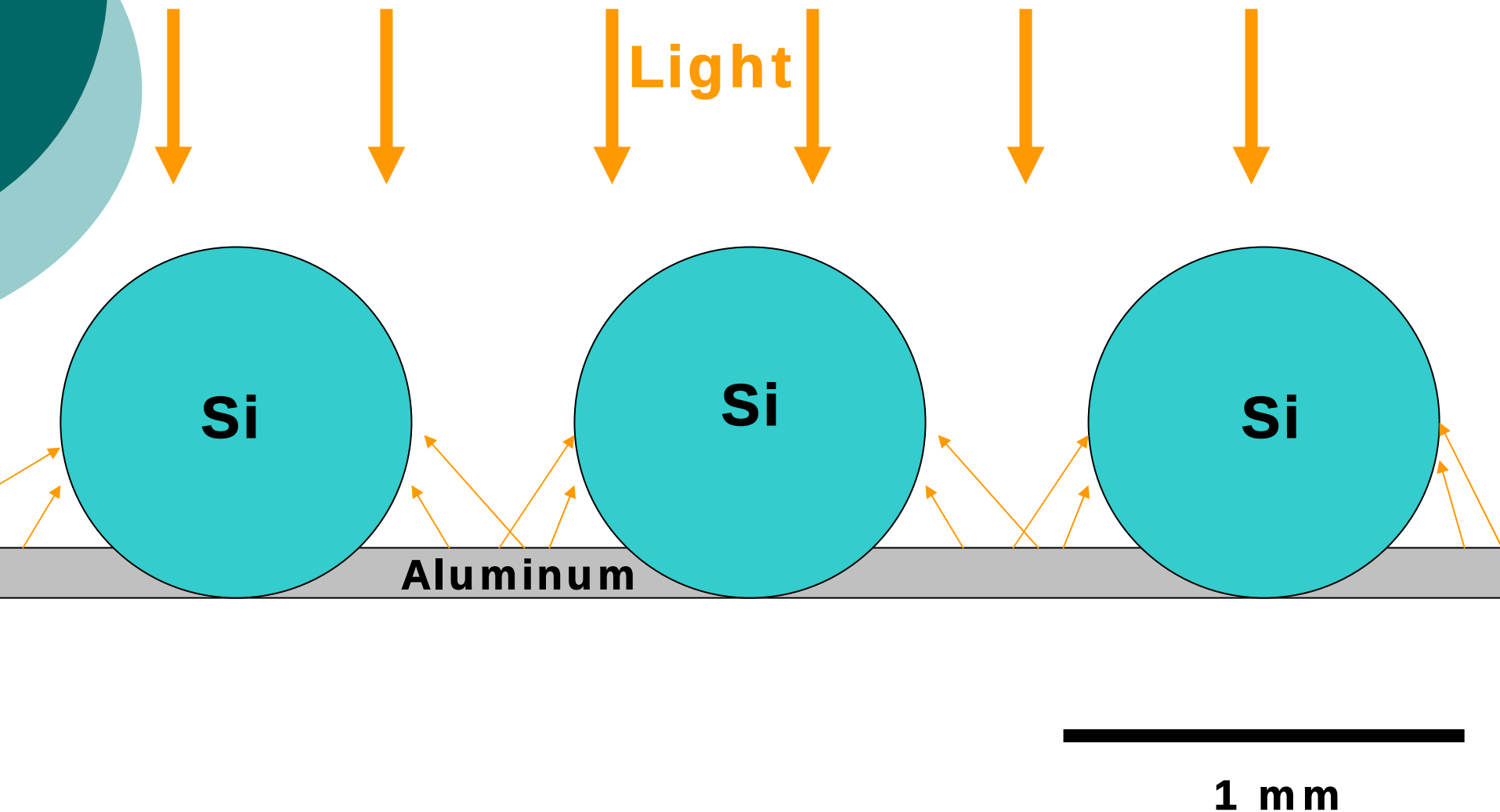
Fall ’05

Professor Birnie

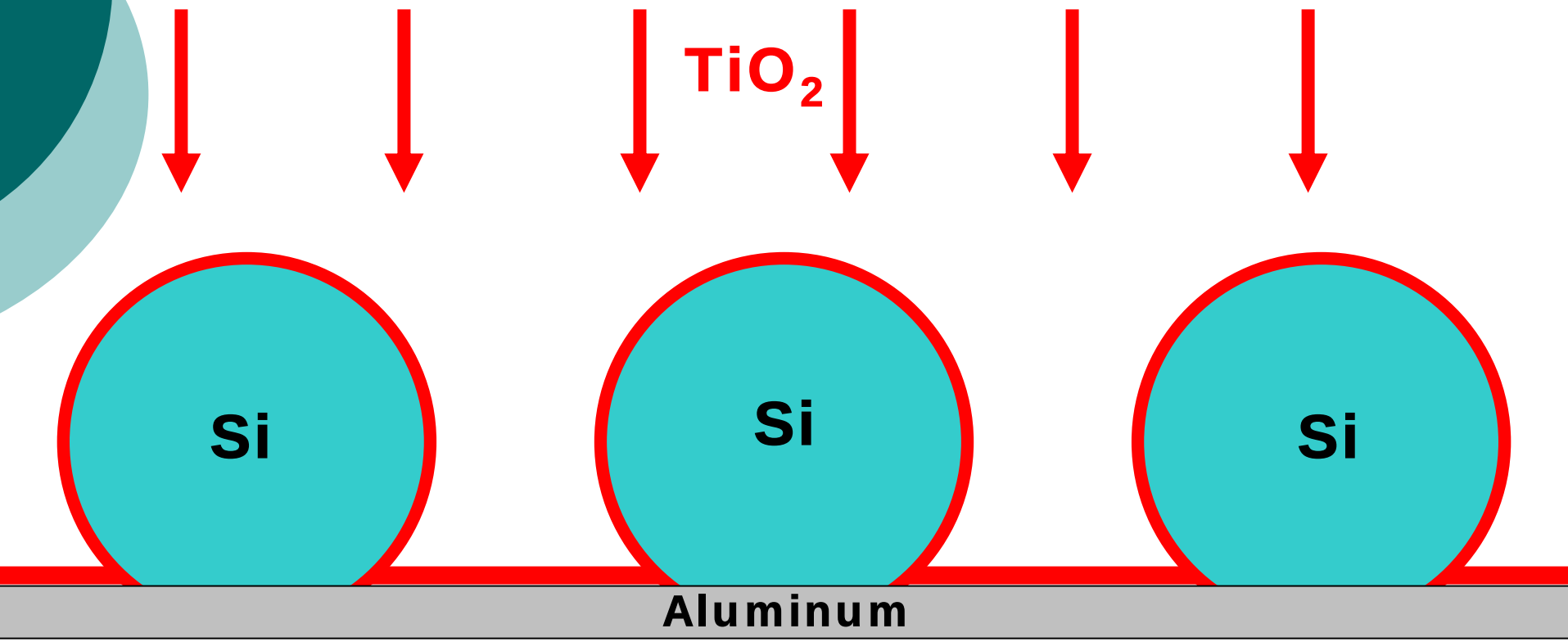
U.S. Patent #6,897,085

- Hammerbacher et al.
- Method of fabricating an optical concentrator for a photovoltaic solar cell
- Assignee: Spherical Solar Power, Inc.
- Date of Patent: May 24, 2005
- Filed : January 21, 2003

Reflection from aluminum



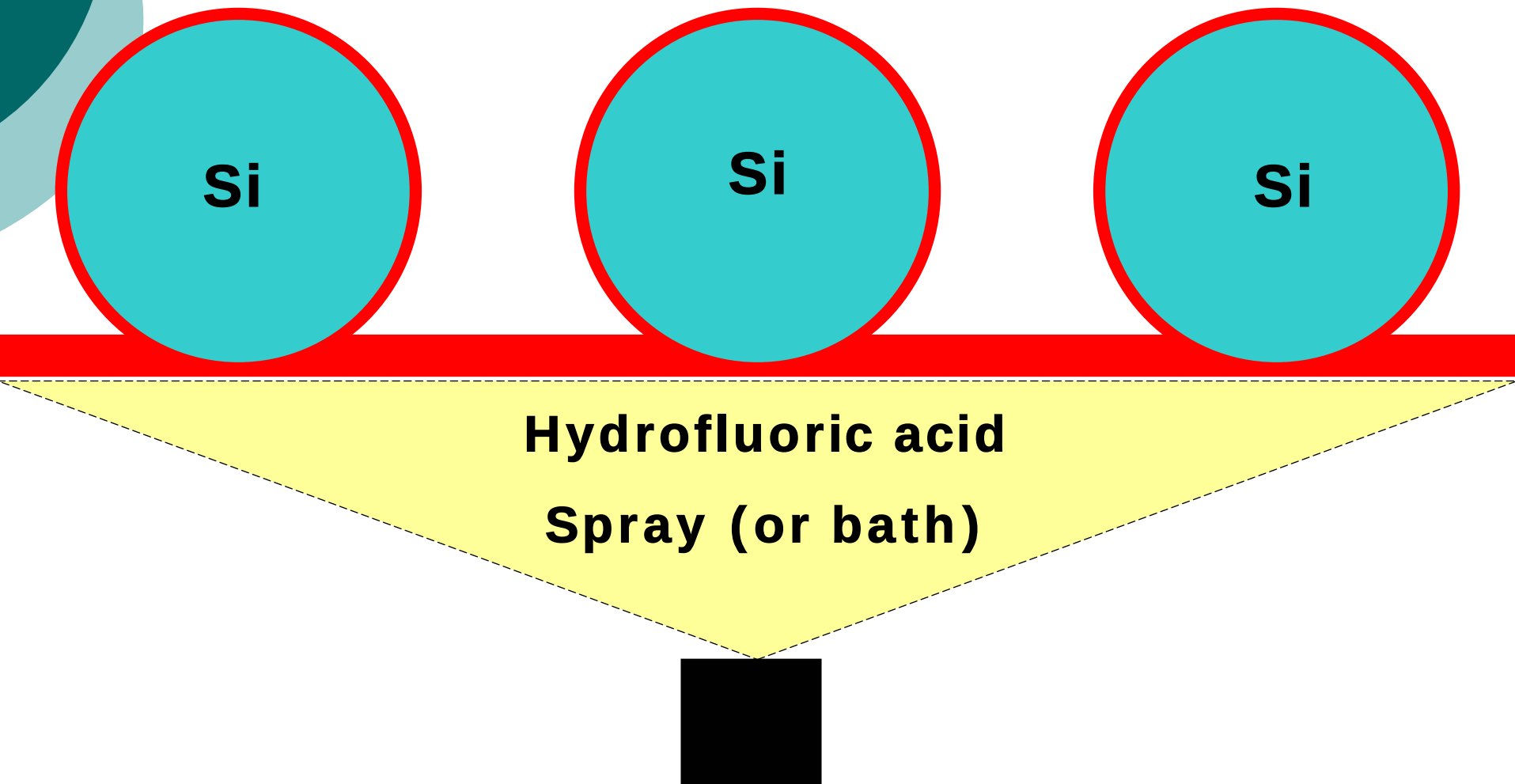
Anti-reflection coating deposition



Done by CVD process

1 mm

Chemical Etching removes TiO_2



Photovoltaic Devices Fabricated by Growth from Porous Template

Patent #: 6,946,597

Assignee: Nanosolar Inc.

Inventor: Brian M. Sager

By: Bill Coffin

Patent Description

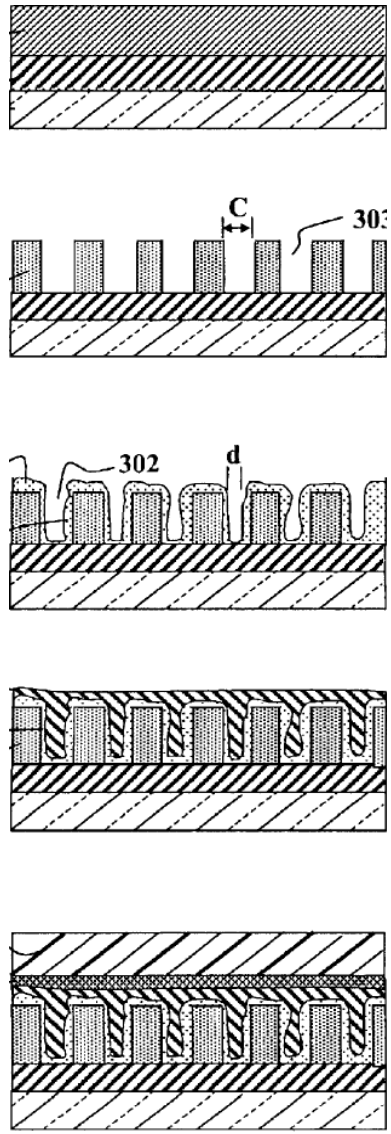
ANODIZE A LAYER OF METAL TO FORM A POROUS TEMPLATE HAVING AN ARRAY OF TEMPLATE PORES DISTRIBUTED IN A SUBSTANTIALLY UNIFORM FASHION

FILL TEMPLATE PORES WITH A FIRST CHARGE-TRANSFER MATERIAL

FILL ADDITIONAL SPACE WITH SECOND (COMPLEMENTARY) CHARGE-TRANSFER MATERIAL

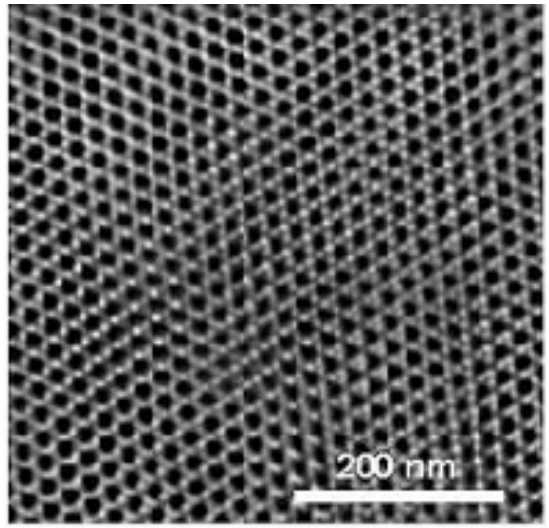
ADD ELECTRODES (OPTIONAL)

ENCAPSULATE (OPTIONAL)

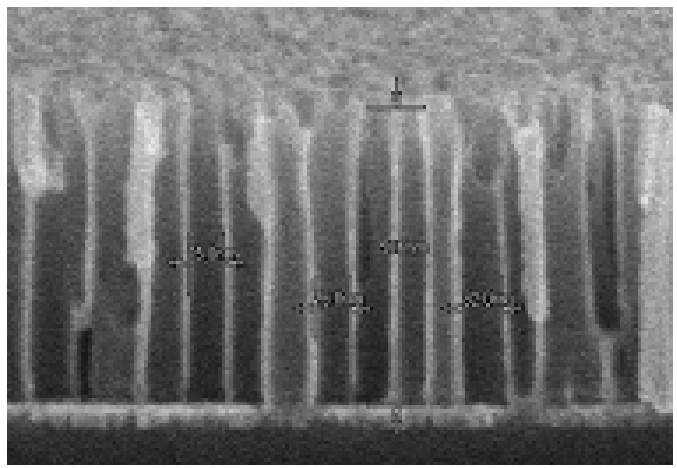


Benefits of Process

- Very uniform substrate
- Between 1-100 nm separation
- Control over thickness
- n-type coated by p-type
- High aspect ratio

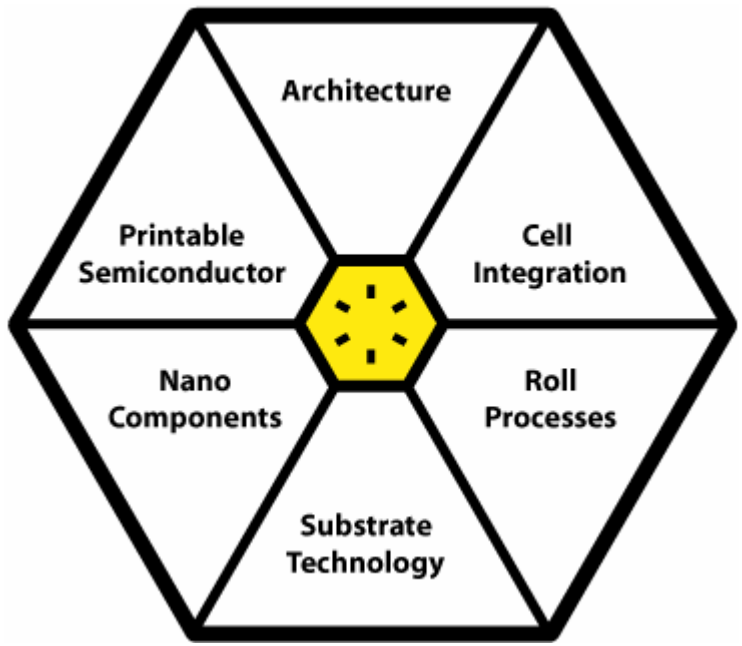


SEM images of solar array



nanosolar

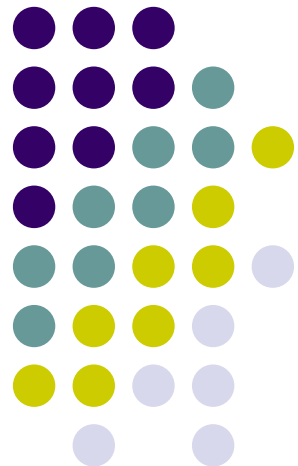
- Investments in excess of $48M
- Multiple types of solar cells
- Roll Processes
- Screen Printing
- Self Assembled arrays



http://www.nanosolar.com/index.html

Photovoltaic Element

Rob Hamill



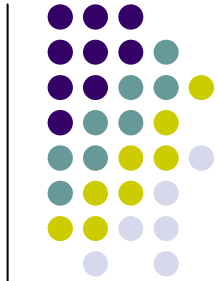
Photovoltaic Element

- **US Patent Number**: 6,963,120
- **Inventors**
  - *Shiozaki; Atsushi*
  - *Sugiyama; Shuichiro*
- **Application Number**: 704642
- **Date Filed**: November 12, 2003

Abstract

- Photovoltaic Element
  - High conversion efficiency
  - Low-cost producibility
  - Light Weight
  - Transparent protective member
- Comprised Of
  - 1st PIN junction – i-type amorphous semiconductor
  - 2nd PIN junction – i-type microcrystalline semiconductor
  - 3rd PIN junction – i-type microcrystalline semiconductor

PIN Junction



- 1st PIN Junction
  - Light Incidence Side
    - Transparent protective member
    - Transparent electrode layer
- 3rd PIN Junction
  - Smallest Photocurrent Generated

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Images

United States Patent 6,963,120

Shiozaki , et al. November 8, 2005

Photovoltaic element

Abstract

A photovoltaic element is provided which has a high conversion efficiency, a low-cost producibility, a light weight and good overall characteristics in a final product form with a transparent protective member. The photovoltaic element comprises a first pin junction comprising an i-type amorphous semiconductor, a second pin junction comprising an i-type microcrystalline semiconductor, and a third pin junction comprising an i-type microcrystalline semiconductor provided in the mentioned order from a light incidence side, wherein at least a transparent protective member and a transparent electrode layer are provided on the light incidence side of the first pin junction, and wherein of the photocurrents generated at the plurality of pin junctions, the photocurrent generated at the third pin junction is the smallest.

Dye–Sensitized Solar Cell

Zixi Huang
Solar Cell Design and Processing
Rutgers University
12/08/05

Patent Information

- “Dye–Sensitized Solar Cell”
- Patent number: 20050218467
- Inventors: Takashi Tomita (Kanagawa, JP)
- Assignee: Sony Corporation, Tokyo, JP
- Filed: May 20, 2005

Claims

- A solar cell comprised of following components: an electrode on a transparent substrate, a counter electrode, light–absorbing particles carrying dye, light–scattering particles that have a different size from the light–absorbing particles, and an electrolyte
- Particle size of the light–scattering particles is larger than the particle size of the light–absorbing particles
- The light–scattering particles and the light–absorbing particles are TiO_2 particles
- Substrate of the claimed solar cell is transparent

Schematic of the Claimed Cell

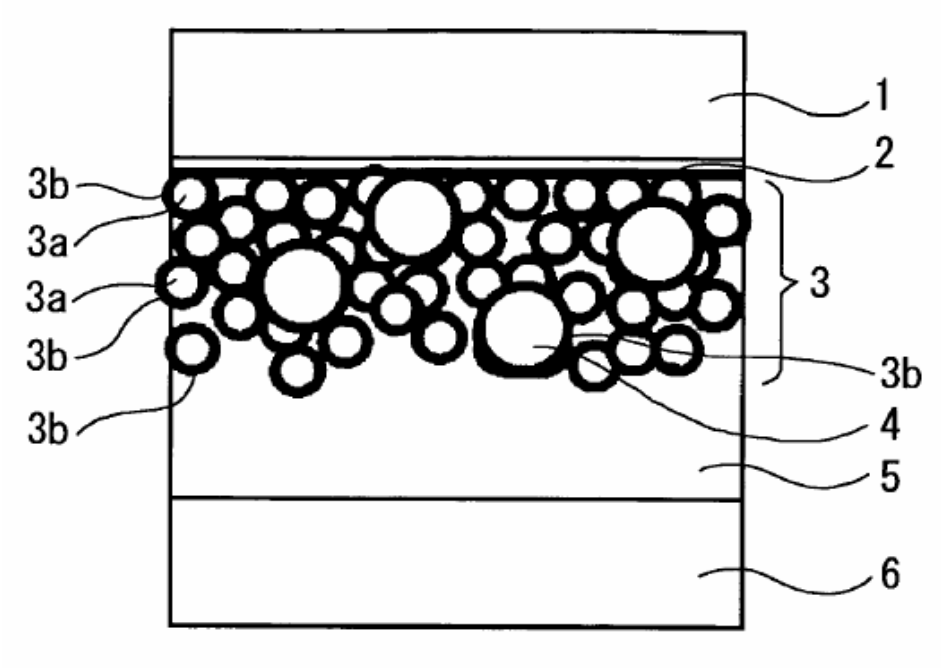


Figure adopted from patent 20050218467

Legend:

- Transparent substrate
- Electrode
- Light –absorbing layer

3a Light–absorbing particle
3b Dye
4 Light–scattering particle
5 Electrolyte
6 Counter electrode

Advantage:
1) Increase optical path length
2) Increase light absorption
3) No thicker absorbing–layer
4) Increase conversion efficiency

References

- US Patent & Trademark Office
- “Dye–sensitized solar cell,” patent number 20050218467, Takashi Tomita, Sony Corporation, Tokyo, JP

Stationary photovoltaic array module design for solar electric power generation systems

Patent Number: 6653551
Inventor: Chen, Leon L. C.
Issue Date: 11/25/2003
Patent Publication Date: 11/25/2003
Publishing Authority: US

Josh ding
12/8/05

Background

- “In 1999, Spectrolab broke the world record when it produced new triple-junction solar cells with a known commercial efficiency of up to 34%.”[3]
- The new triple-junction solar cells cost $$$$.
- A low-cost, high-efficiency, concentrator with point focus was designed
  - a much smaller area of expensive solar cell.

Introduction



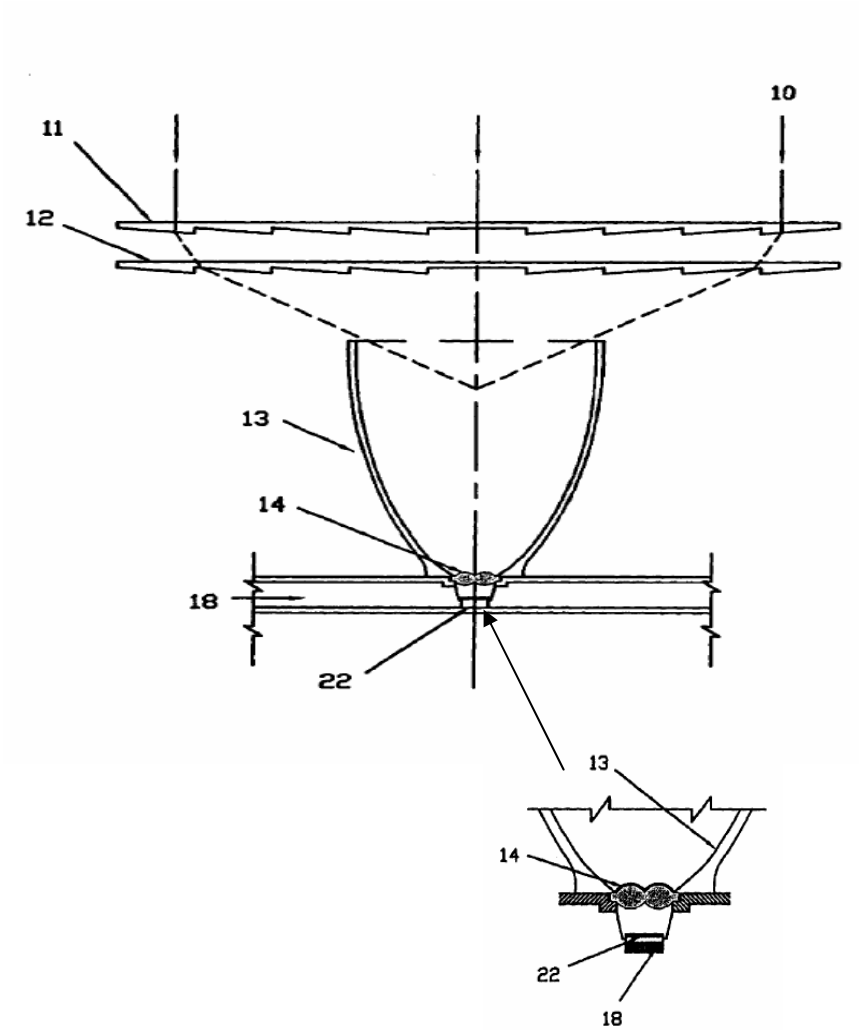
Solar power generation plant[2]

The concentrator design:

- Two optical concentrating fresnel lenses
- A compound parabolic concentrator (CPC)
  - High reflectance mirrors
  - Light concentrates significant times
  - A bottom concentration lens with anti-reflection coating

Schematic

- Four-junction concentrator solar cell with intensity concentration of 1000 times.
- 11 & 12 are the first & second optical fresnel lenses
  - concentrate sun rays five to ten times each.
- 13 is the parabolic mirror
- 14 is a specially shaped glass lens which focuses the rays up to 1000 times.
- 22 is the concentrator solar cell
  - 45% conversion efficiency with four-junction solar cell.
- Fluid heated by solar cells 22 & transfers heat to dissipater 18.



Summary

- A thin film multi-junction photovoltaic array module of solar electric concentrator power systems.
- It is a combination of fresnel lens and optical reflectors
  - concentrate solar intensity 300 to 1000 times within a six-inch distance.
- It can be made from low cost, conventional material, and replaces large portions of a module's surface area
- The total cost reduction up to 30%.
  - “commercially possible to install the low-cost, high-efficiency stationary concentration photovoltaic solar electric generation systems on the roof of a building or a fixed frame, and connect it to the power grid on a utility scale.”[1]

References

- http://www.uspto.gov
- www.fepc.or.jp/english/info/energyandenv/image/p39a.jpg
- http://www.freepatentsonline.com/6653551.pdf
- http://patents.globalspec.com/engineering-search/patents/abstract/154947527905/

Alignment of solar concentrator micro-mirrors US Patent #: 6,964,486

Student: Brett Ellerbrock

Professor: Dr. Birnie

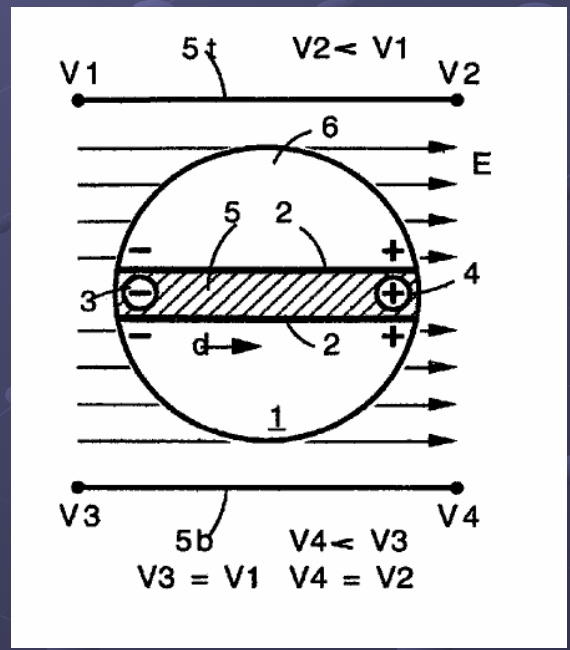
Class: Solar Cell Design

Patent facts

- Abstract
  - Stress the need for solar energy
  - Directing incident light
    - Solar propulsion assist
    - Illumination and projection of light
    - Optical switching
  - Compete solar cells with conventional energy sources

More patent info

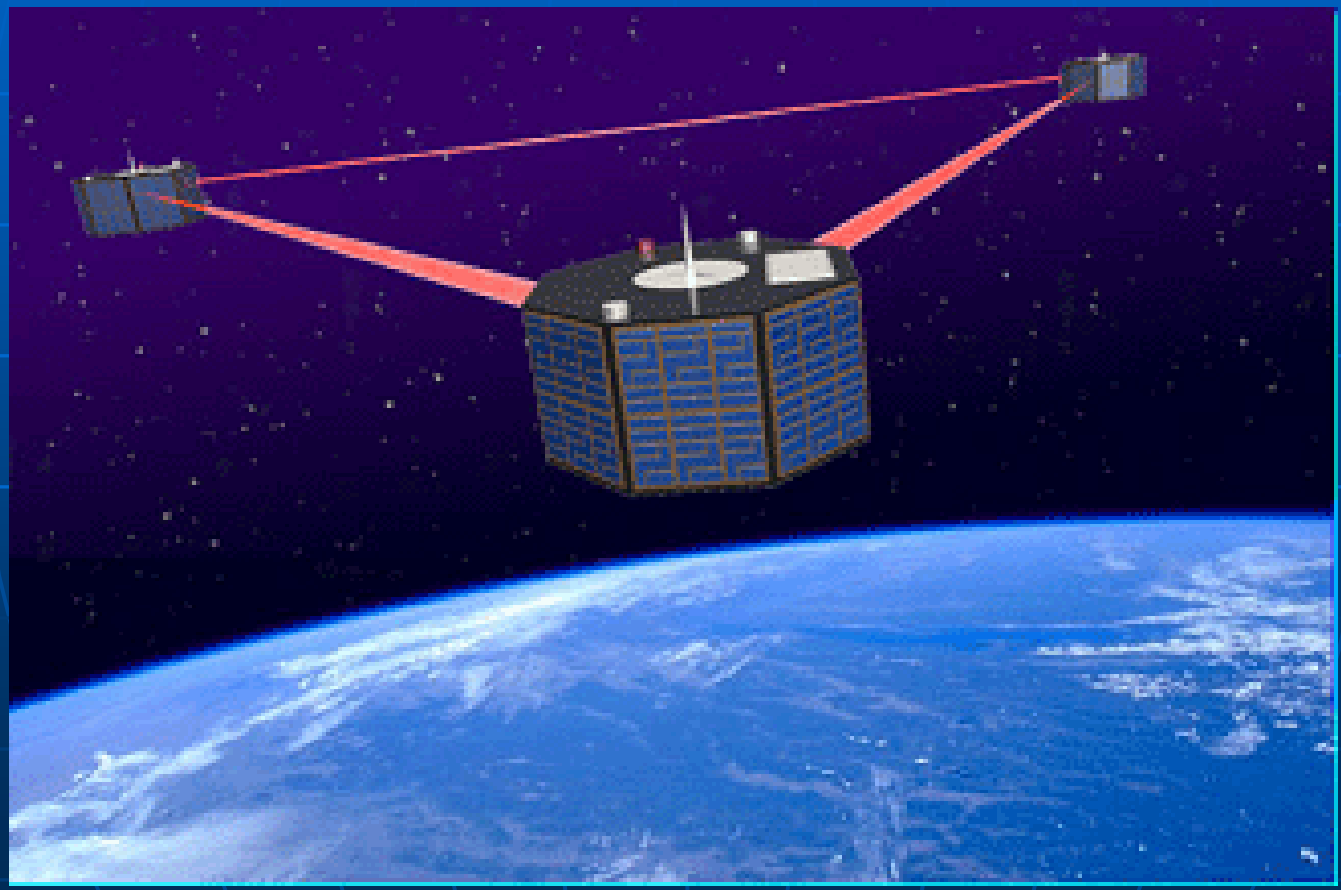
- Background
  - Energy converters (expensive) vs. micro-optics (inexpensive)
    - Shrink large panels shrunk with micro-optics
  - Zeta Potential
    - Electric dipole
    - Vector angle misfired
  - Micro mirrors
    - Balls and cylinders
    - Dipole fields being perpendicular to the axis of symmetry



Applications

- Primarily
  - Alignment of solar concentrator micro-mirrors
- Also….
  - Solar propulsion assist
    - Spacecrafts
  - Optical switching
    - Fiber optics
  - Illumination and projection of light

United States Patent 6410362
Flexible thin film solar cell



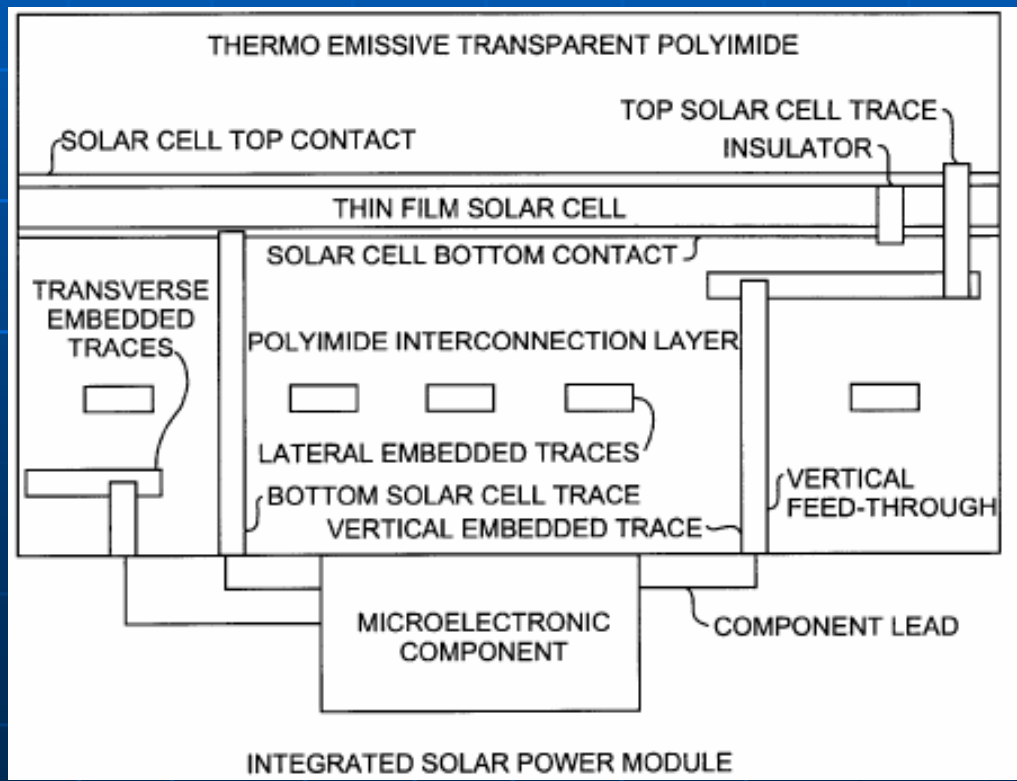
For use with micro and nanosatellites

Patent Description

- A clear thermal emissive polyimide is deposited directly on a thin film solar cell for flexibility and heat ejection purposes
- Suitable for forming a solar cell array over a curved surface such as a power sphere nanosatellite with thermal regulation



THERMAL EMMISIVE THIN FILM SOLAR CELL



INTEGRATED SOLAR POWER MODULE

Product Description

Roll-To-Roll Manufacturing

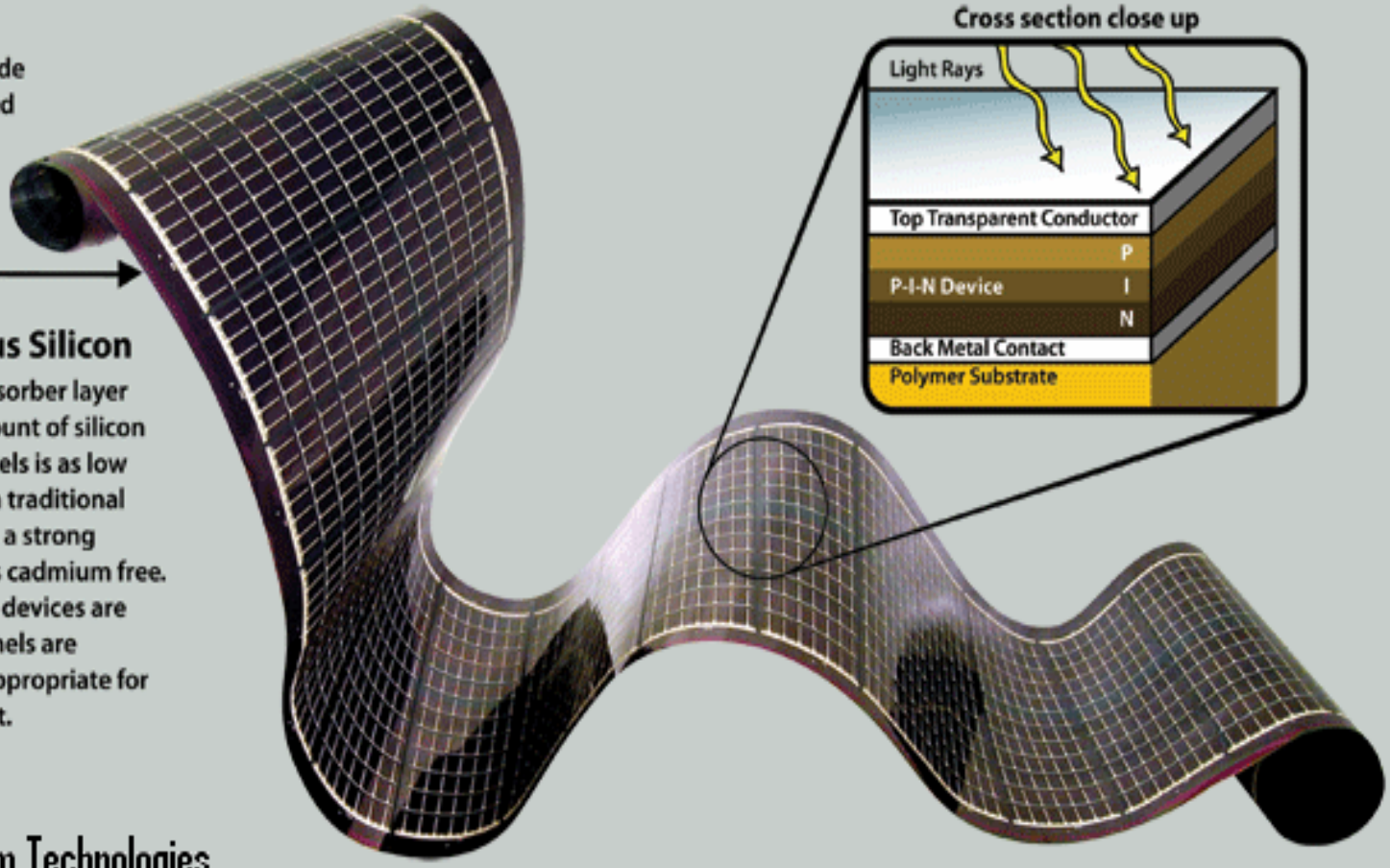
Roll-to-roll manufacturing significantly reduces manufacturing costs. Our company was the first and remains the only company in the world that manufactures and sells monolithically-integrated solar panels on plastic using a true roll-to-roll manufacturing process.

Polymer Substrate

Flexible yet durable polyimide substrate results in enhanced flexibility, paper thinness, and lighter weight. The substrate is as thin as 1 mil (0.025mm) thick.

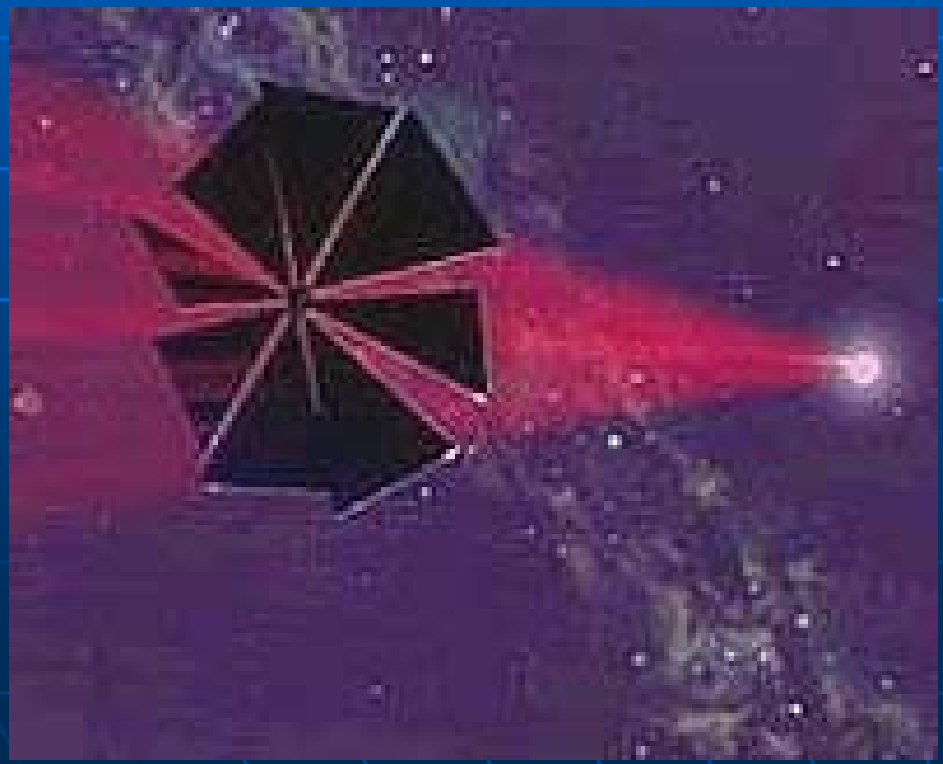
Thin Film Amorphous Silicon

Amorphous silicon is the absorber layer in the solar panels. The amount of silicon used in PowerFilm solar panels is as low as 1% of the amount used in traditional solar panels. PowerFilm has a strong environmental profile and is cadmium free. Single and tandem junction devices are manufactured. Finished panels are encapsulated in materials appropriate for the application environment.



Iowa Thin Film Technologies





Uses

- Extraterrestrial applications include micro and nanosatellites and solar sails.

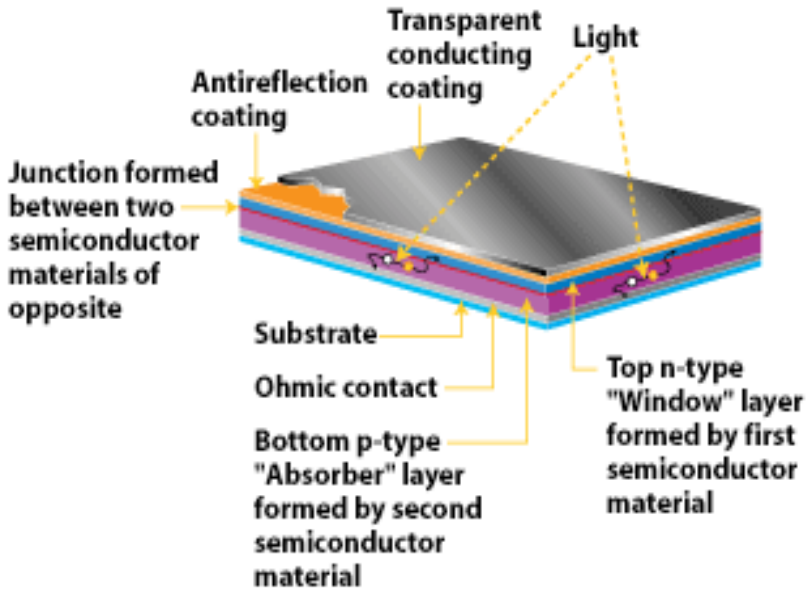
Patent: Polycrystalline Thin Film Solar Cells

John Matthew Rooney

December 8, 2005

Polycrystalline thin film

- Film application method
  - Deposited layers of molecules
    - Physical or chemical vapor
    - Electrochemical
    - Plasma deposition (new patent)
- Polycrystalline cell
  - Uses transparent conducting layer (ITO) instead of metal
  - Use semiconducting grains
  - Heterojunction structure
- Junction formed between layers
  - p-type and n-type semiconductor materials
  - Copper Indium Diselenide (CIS)
  - Cadmium Telluride (CdTe)
    - Band gap = 1.44 eV



http://www.eere.energy.gov/solar/tf_polycrystalline.html

Patent Details

- “Method for depositing high-quality microcrystalline semiconductor materials”
  - Guha, Subhendu ; et al. July 28, 2005
- Plasma deposition of microcrystalline semiconductor material layer
  - Energized gas with semiconductor precursor and dilutent
  - Deposited onto substrate
  - Concentration of dilutent controls thickness of layer

Fabrication of Solar Cells by paint.

United States Patent *6,689,950*
Cordaro
February 10, 2004
Paint solar cell and its fabrication

SUMMARY OF THE INVENTION

- The present invention provides a solar (photovoltaic) cell and a method for its fabrication. The voltage-generating components of the solar cell are paints, which may be formulated and then applied using p
- Painting techniques rather than the complex semiconductor deposition techniques. The preparation of solar cells of arbitrarily large size is therefore straightforward and inexpensive, and the amount of frame-like support structure is minimal.

Design

- The first paint layer structure 24 includes a plurality of p-type pigment particles 40 made of an operable p-type semiconductor material. Mixtures of different compositions of p-type semiconductor particles may also be used as the p-type pigment particles 40. The use of mixtures of p-type semiconductor particles 40 with different semiconducting band gaps allows the individual particles to respond to different wavelengths of the incident light 34, to maximize the conversion efficiency of solar energy to electrical energy.
- The second paint layer structure 26 includes a plurality of n-type pigment particles 46 made of an operable n-type semiconductor material. Mixtures of different compositions of n-type semiconductor particles may also be used as the n-type pigment particles 46. The use of mixtures of n-type semiconductor particles 46 with different semiconducting band gaps allows the individual particles to respond to different wavelengths of the incident light 34, to maximize the conversion efficiency of solar energy to electrical energy.
- Generally equiaxed particles from about 0.1 to about 10 micrometers in dimension

FIG. 1

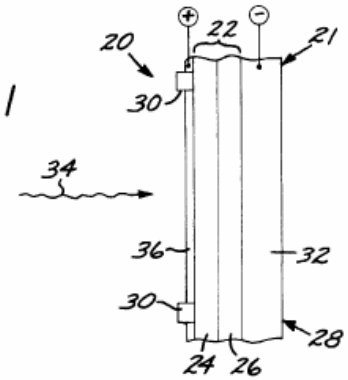
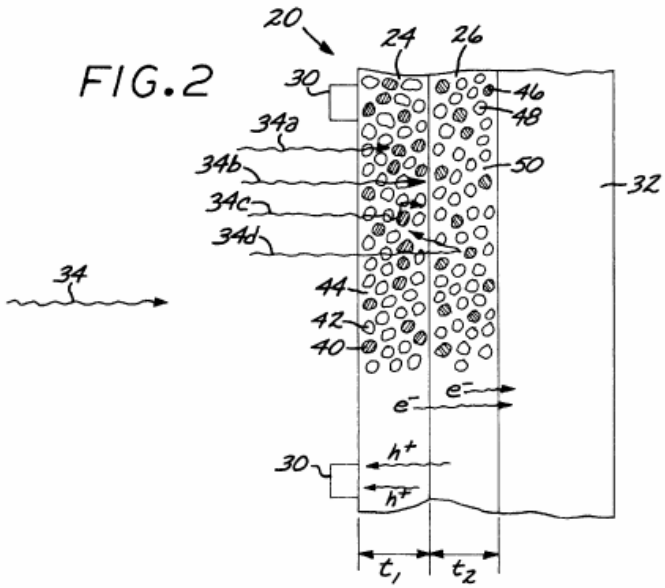
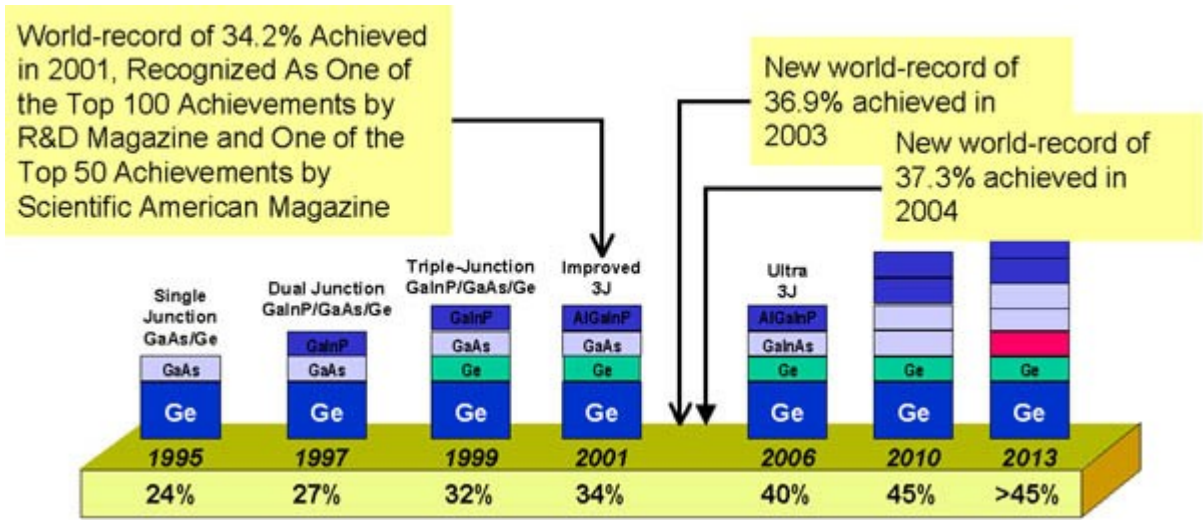


FIG. 2



Spectrolab

A Boeing owned solar cell fabrication and research company.



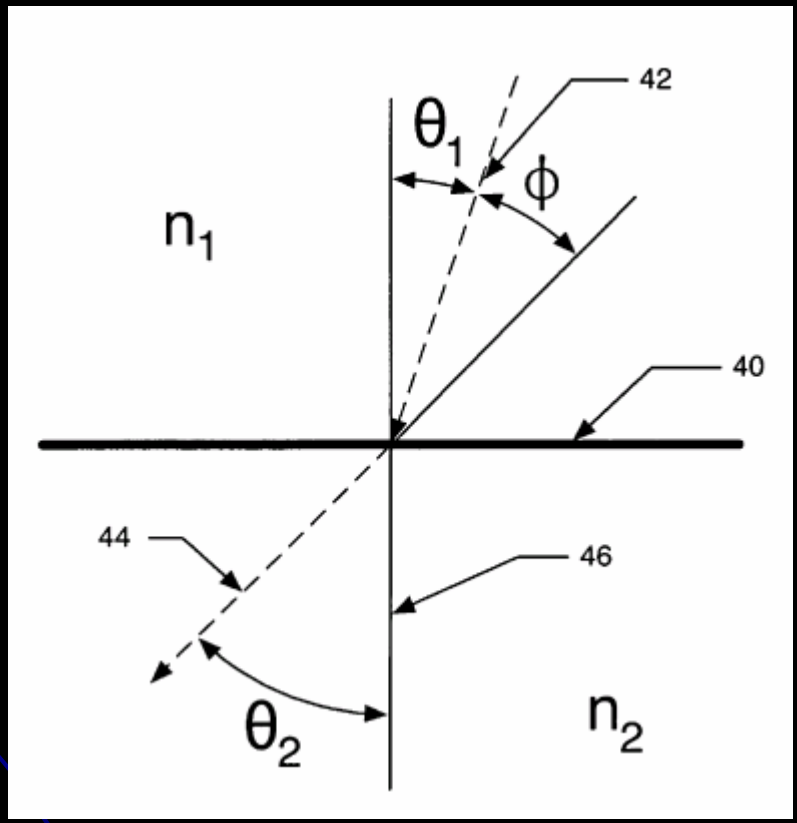
Motion-Free Tracking Solar Concentrator

Inventors: **Pender; John George**

Patent #: **6,958,868**

Filed: **March 29, 2004**

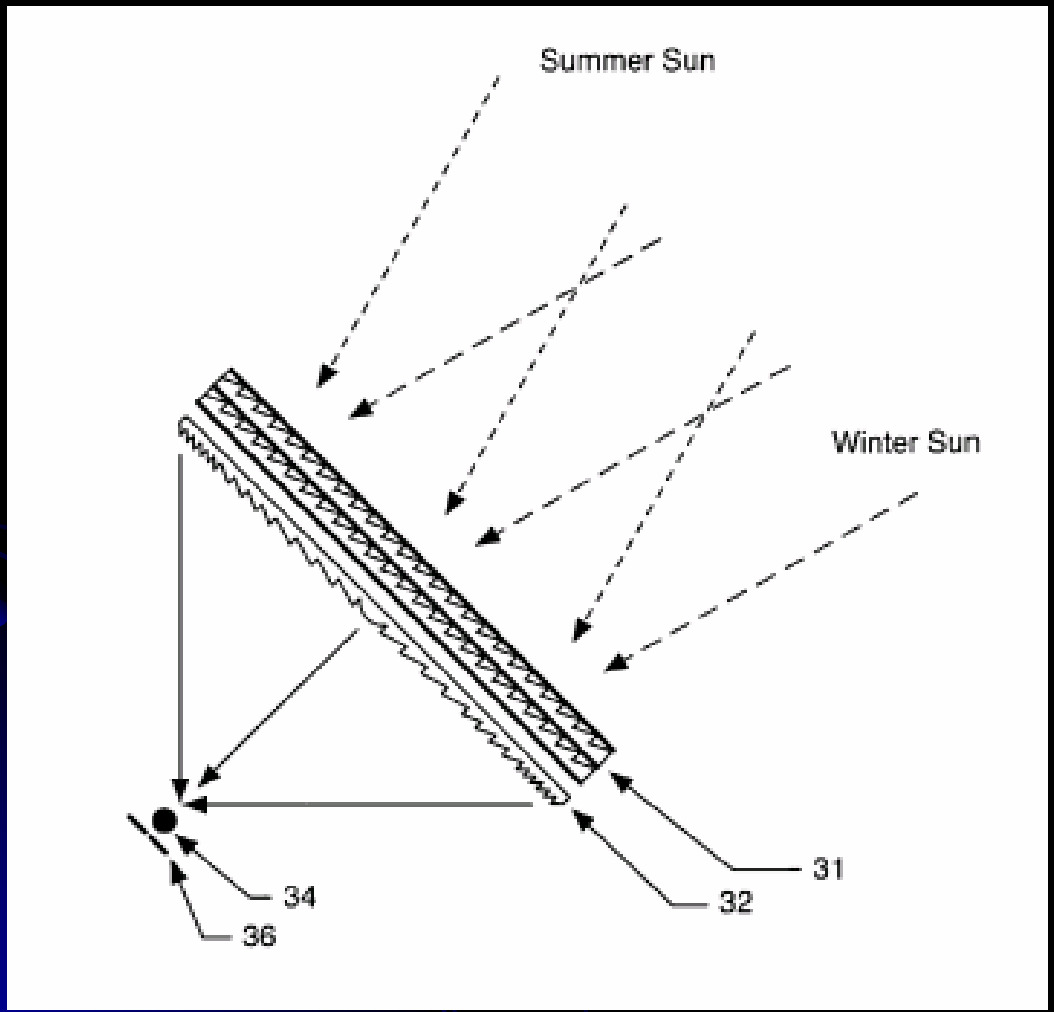
Snells Law ($n1\sin\theta_1 = n2\sin\theta_2$)



Brief Summary

- Solar Collector using a Fresnel Lens and liquid crystal prismatic cells, whose refractive index can be changed by applying an electromagnetic field. As the sun's angle changes, the voltage through the prisms change keeping the reflected light at a specific angle for the Fresnel Lens, thus keeping the light at a focus.

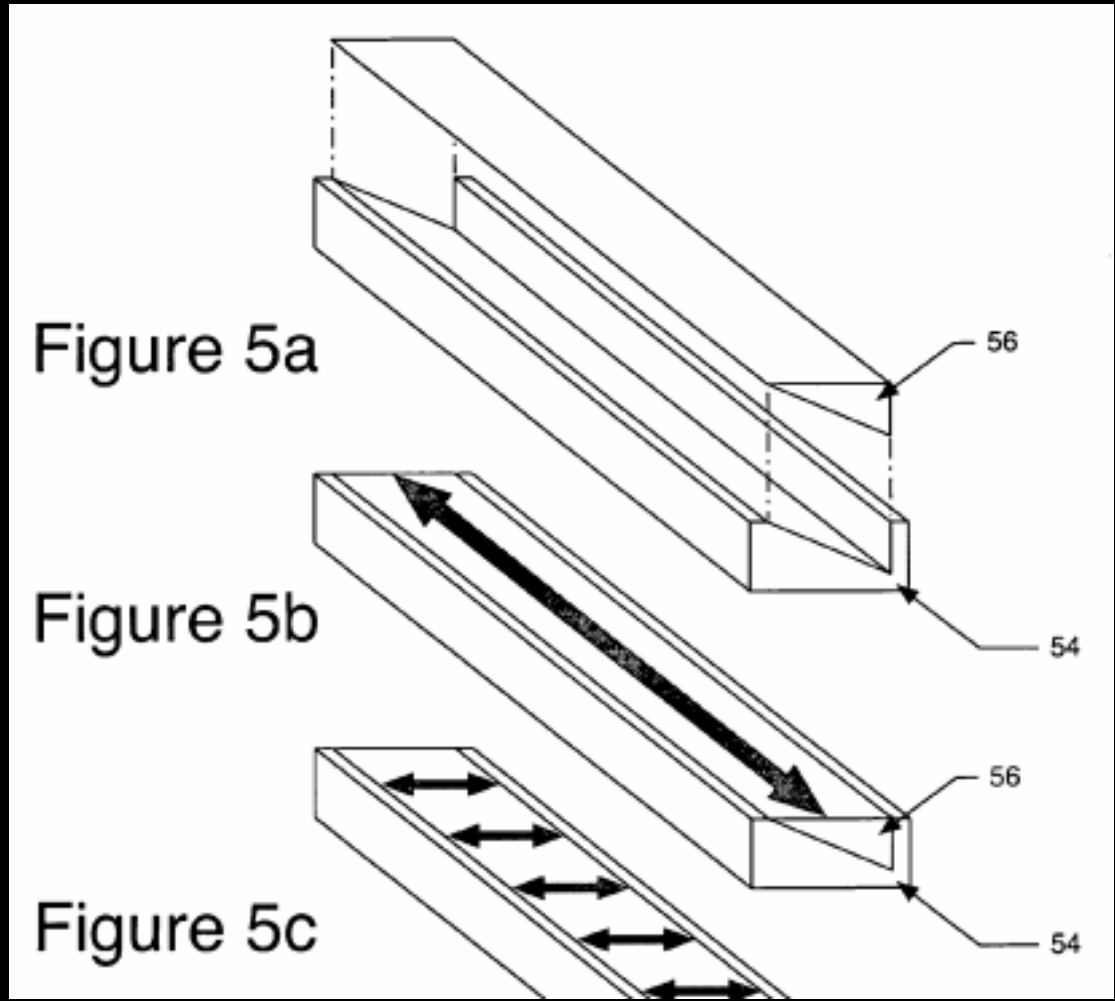
The Idea



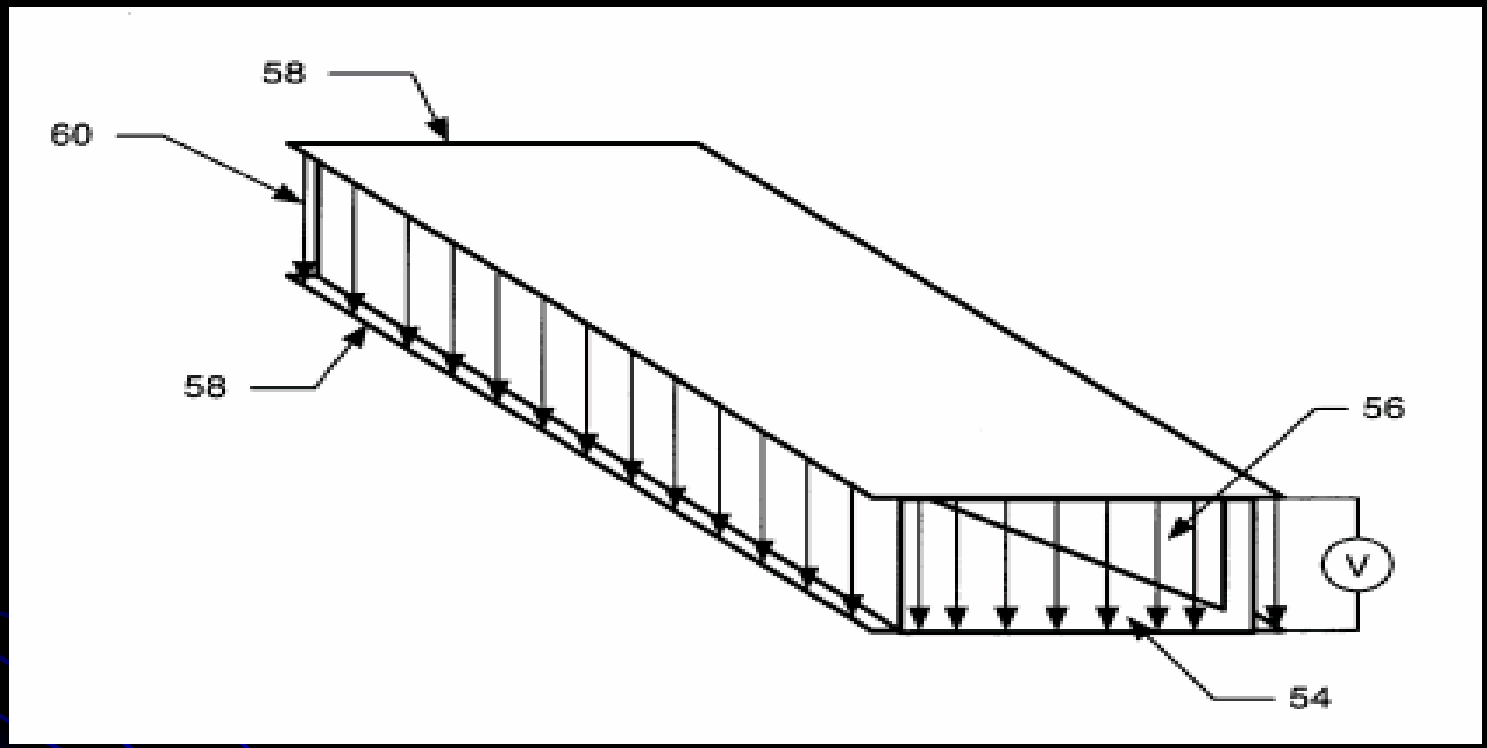
- 31 Beam Deflector – Electomagnetic field changes refractive index of prism shaped cells of liquid crystal.
- 32 Optical Condenser – Incoming light through prisms stay at specific angle.
- 34 Piping

Prism Design

- 54 Transparent material with a prism shaped groove carved out.
- 56 The liquid crystal material with the property of changing refractive index with EM field.

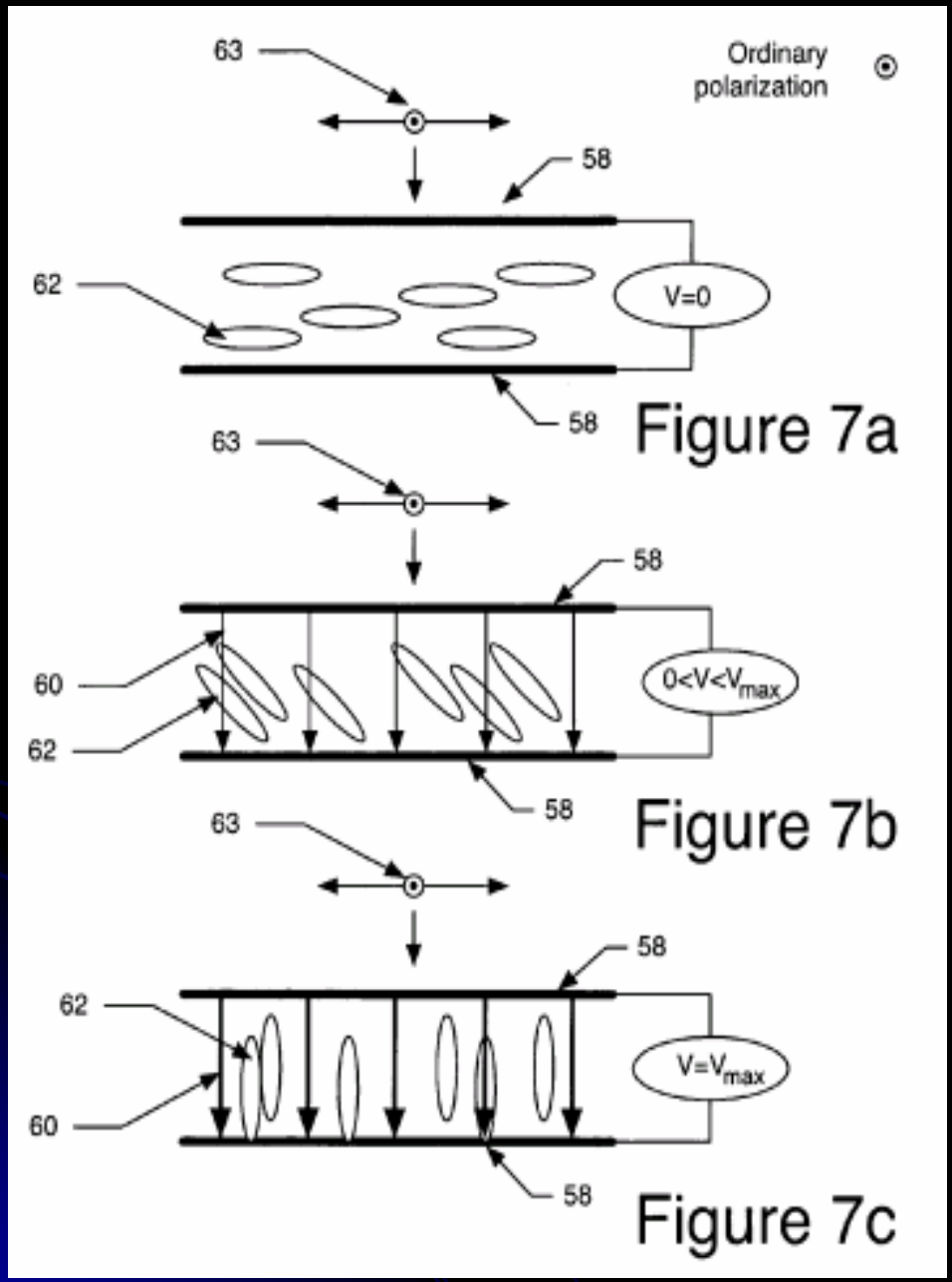


Production



- 58 A thing coating which is nearly transparent of conducting on top and bottom.
- 60 Voltage applied in perpendicular direction.

Liquid Crystal at Work



- 62 Crystal Molecules in a liquid crystal material with no EM field.
- 58 Conducting surface
- 62 EM field orients crystal up to at a max voltage. More voltage will not change the refractive index.

Advantages

- No Moving Parts makes it durable against wind and vibration.
- Less maintenance
- Over all weight is lighter then tracking machinery.

Appartus for Collecting and Converting Radiant Energy

Inventors

- Sergiy Victorovich Vasylyev(Davis, CA)
- Viktor Petrovych Vasylyev(Kharvkov, UA)

Their company was SVV Technology Innovations, Inc.(Elk Grove, CA)

- Filed December 17, 2001

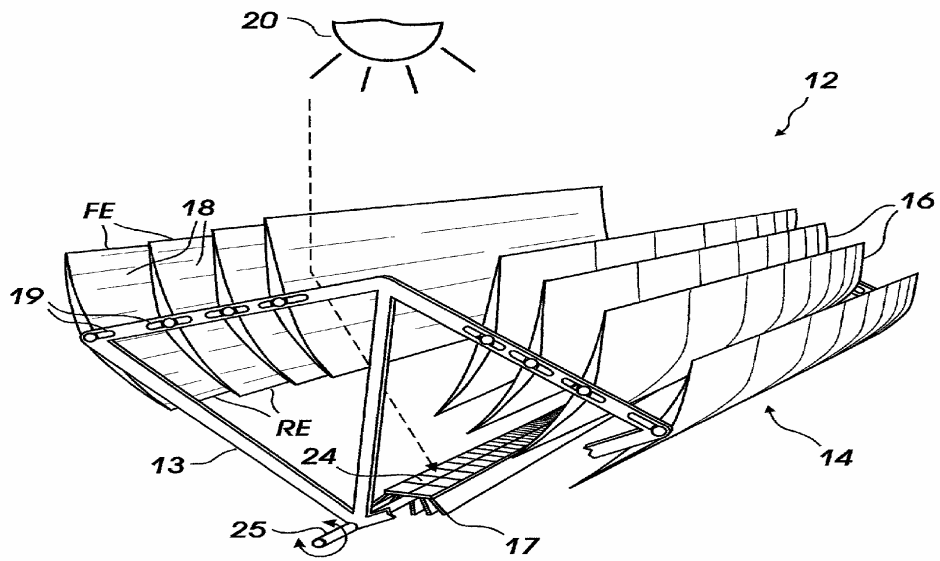


FIG. 1

FIG. 5

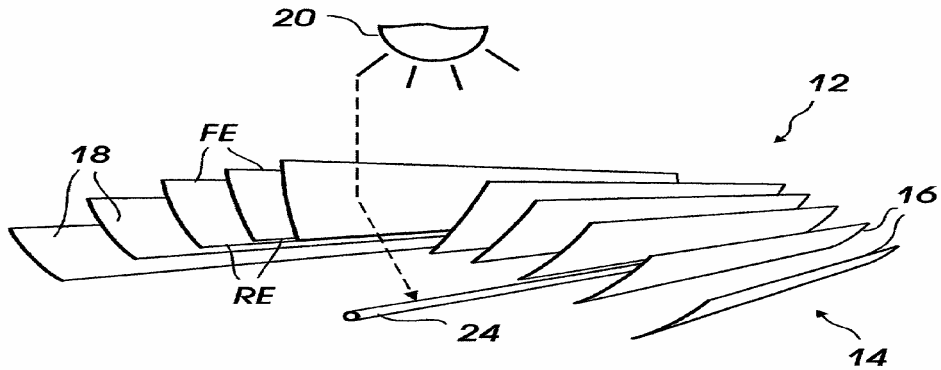


FIG. 6

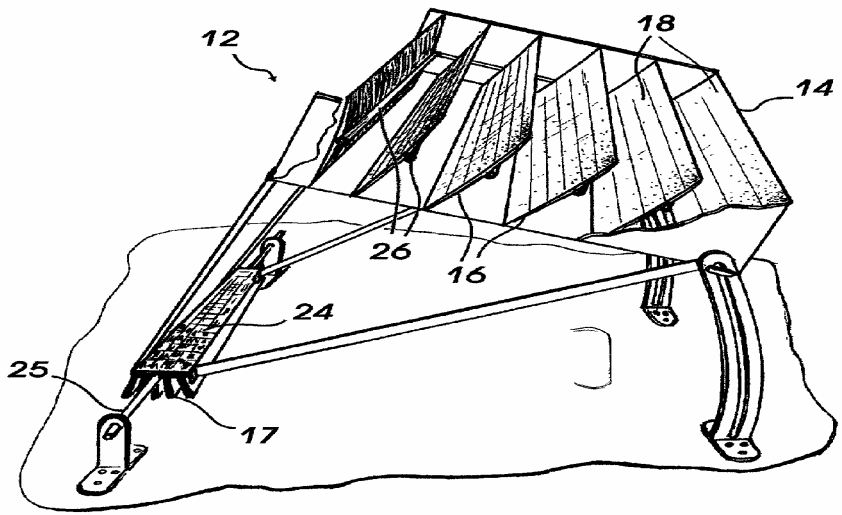


FIG. 2A

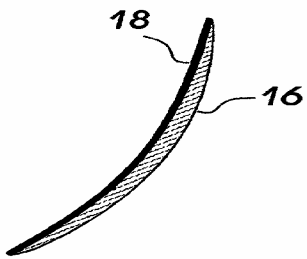


FIG. 2B

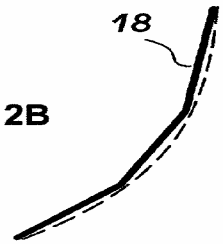


FIG. 3

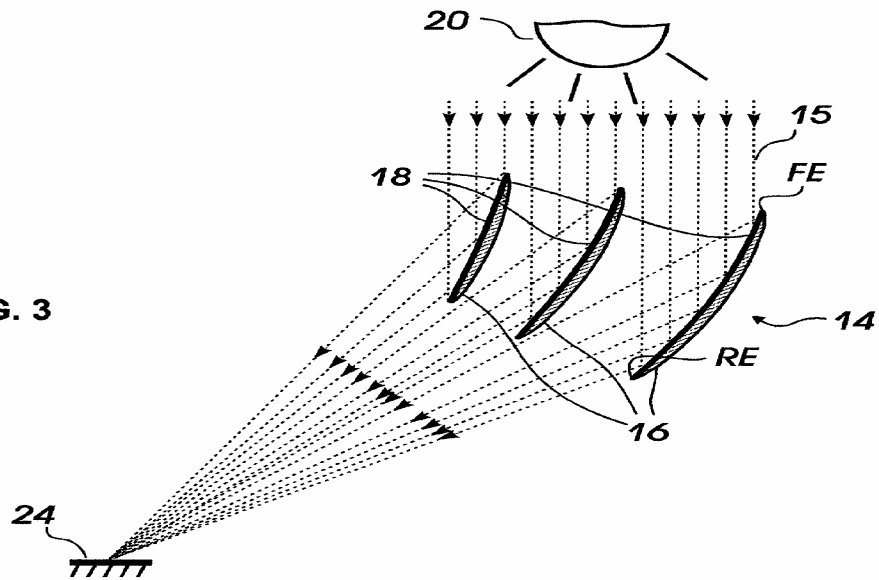
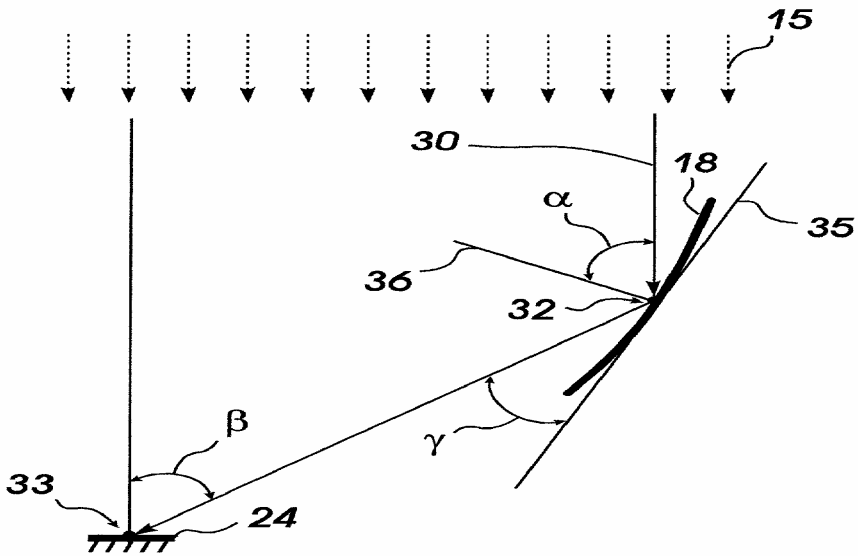


FIG. 4



Solar Air Conditioning System

Patent Presentation

Urmila Wadnerkar

Dec 8, 2005

General Description

- This air conditioning system uses solar energy for the purpose of heating air.
- It consists of:
  - A solar collector assembly
  - An inlet assembly and,
  - An outlet assembly

Schematic Diagrams of Assembly

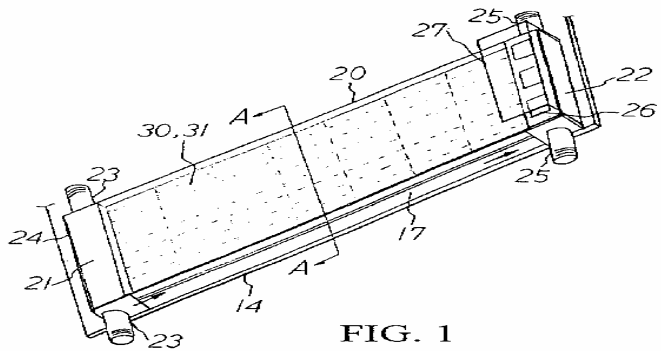


FIG. 1

Solar collector, inlet, and outlet assembly

References

- Patent for Solar Air Conditioning System
  by **Liu; Tay-Jian** and **Lee; Chien-Hsiung**, April 19th, 2005
  (from www.uspto.gov)

Schematic Diagrams of Assembly (cont.)

Fig.5 Inlet Assembly

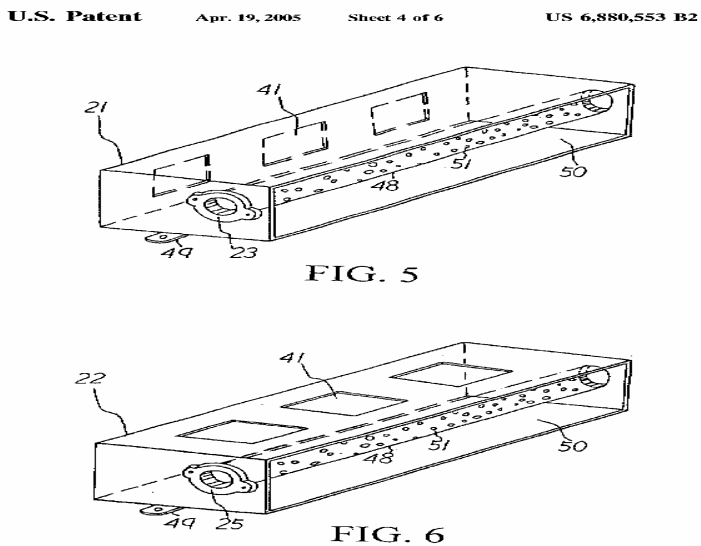


Fig. 6 Outlet Assembly

Significance of Invention

- This invention is significant in the fact that it is versatile according to the users needs. The inlet and outlet assemblies can be switched. This will allow the heated air to flow in the opposite direction.
- This enables the unit to intake hot air in the winter and expel it in the summer.
- This will greatly alleviate air conditioning and heating costs.

Gel Electrolytes for Dye Sensitized Solar Cells

Hana Lee

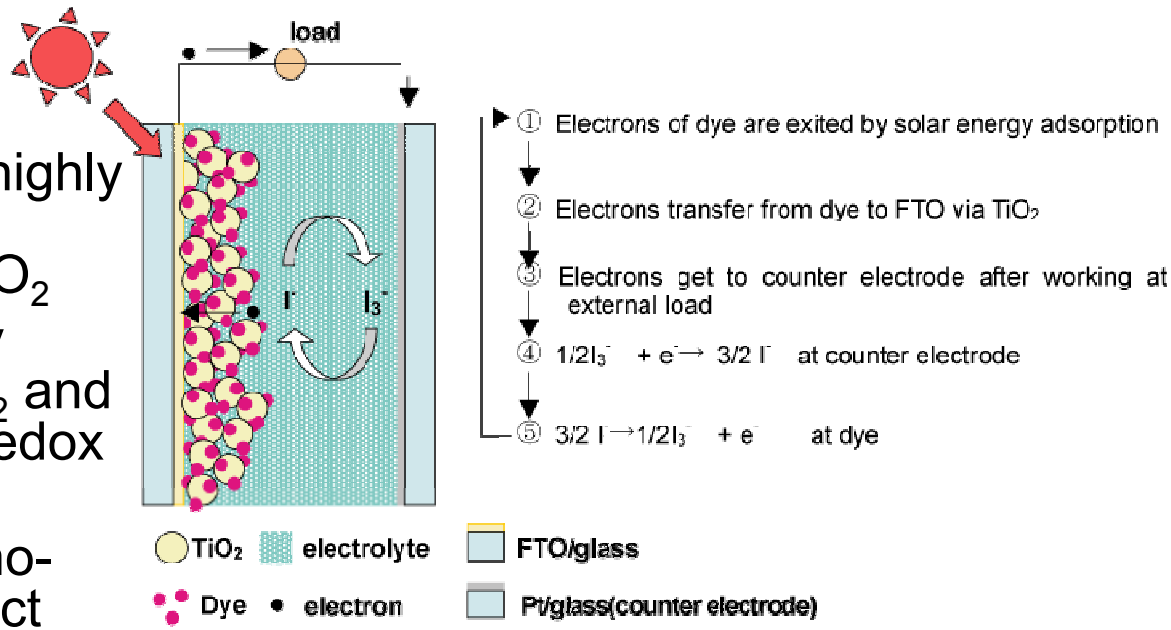
Solar Cell Design & Processing

Dr. Dunbar P. Birnie

December 8, 2005

Dye Sensitized Solar Cells ("DSSCs")

- Thin film solar cells composed of liquid electrolyte and dye-coated sintered titanium dioxide
- Absorption occurs in dye molecules absorbed at a highly porous structure of nano-particles of transparent TiO_2
- Dye excitation followed by electron injection into TiO_2 and by dye re-charging via a redox electrolyte.
- E- transported in TiO_2 nano-particles to the front contact (consists of transparent conductive oxide layer, TCO)
- High temp sintering process (>400C)



http://www.rite.or.jp/English/lab/chemical/uragami/uragami.html

Gel Electrolytes for DSSCs (US Patent: 6,900,382)

- Replacing liquid electrolytes with solid or quasi-solid elecrolytes
  - To produce flexible photovoltaic cells
  - Roll-to-roll or web processes
- Gel electrolytes contribute
  - less electrolyte leakage
  - help long-term stability problems with DSSCs
- Low temperature sintering
  - < 300^{o}C or room temperature
  - Easier to make flexible photovoltaic cells

Gel Electrolytes for DSSCs (US Patent: 6,900,382) cont.

- How?
  - Gel electrolyte compositions include redox acitve components and small amts of multiple ligand-polymeric and non-polymeric molecules gelled by metal ion
  - Method of gelling an electrolyte solution is presented
  - Method for reducing electron transfer to species within the electrolyte of a solar cell
  - Provides an electrolyte composition adapted for use in a solar cell

References

- www.uspto.gov
  - United States Patent: 6,900,382
- http://lpi.epfl.ch/solarcellE.html
- http://www.eifer.uni-karlsruhe.de/162.php