

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
4 December 2008 (04.12.2008)

PCT

(10) International Publication Number
WO 2008/144809 A1

(51) International Patent Classification:
C01B 3/32 (2006.01) *H01L 31/00* (2006.01)

(74) Agent: **GRIFFITH HACK**; Level 29, Northpoint, 100
Miller Street, North Sydney, New South Wales 2060 (AU).

(21) International Application Number:
PCT/AU2008/000736

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date: 26 May 2008 (26.05.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2007902813 25 May 2007 (25.05.2007) AU

(71) Applicant (*for all designated States except US*): **NEW-SOUTH INNOVATIONS PTY LTD** [AU/AU]; Rupert Myers Building, Gate 14, Barker Street, UNSW, Sydney, New South Wales 2052 (AU).

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

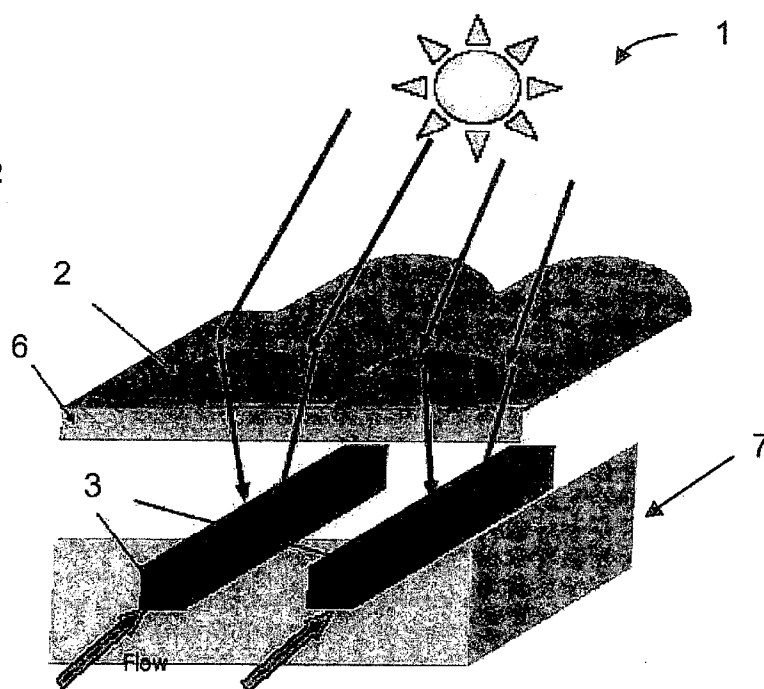
(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **ROSENGARTEN, Gary** [AU/AU]; NewSouth Innovations Pty Limited, Rupert Myers Building, Gate 14, Barker Street, UNSW, Sydney, New South Wales 2052 (AU). **ZIMMERMAN, Raul** [IL/AU]; NewSouth Innovations Pty Limited, Rupert Myers Building, Gate 14, Barker Street, UNSW, Sydney, New South Wales 2052 (AU).

Published:
— with international search report

(54) Title: A DEVICE FOR CONVERTING SOLAR ENERGY TO FACILITATE A PROCESS

Figure 2



(57) Abstract: A device for converting solar energy to facilitate a micro-process comprises a substrate comprising a micro-formation arranged to hold a medium requiring energy for facilitating the micro-process. An optical concentrator additionally provided by the device is arranged to focus solar energy at the micro-formation.

WO 2008/144809 A1

- 1 -

A DEVICE FOR CONVERTING SOLAR ENERGY TO FACILITATE A PROCESS

Field of the Invention

5

The present invention relates to a device for converting solar energy to facilitate a process requiring energy input and more particularly, but not exclusively, to a device with micro-components, for converting solar
10 energy to facilitate a process.

Background of the Invention

It is known that solar thermal power can be utilised
15 at the macro scale for applications such as solar heating. Large solar panels may, for example, be utilised to heat water for heating houses and for other energy requirements.

20 Much work is presently being carried out at the micro and nano levels in relation to numerous processes that can benefit from the different reactive properties of thin films, for example. Micro reactors have been developed, for example, being tiny chemical processing plants, that
25 may contain microscopic pumps, valves, channels, heat exchangers, separators, etc. They have been applied to processes ranging from gene research to continuous polymer bead production. There have also been proposals for portable micro-reactors for producing hydrogen in order to
30 provide fuel for micro fuel-cells. There are many other potential applications of micro-reactors.

Many processes, which may be carried out on a micro or nano level, require energy input in order to facilitate
35 the processes. At present, there are no sustainable power sources for providing the required energy for micro-reactors.

- 2 -

Further, some processes on the micro and nano level may require energy transfer to, for example, remove excess energy which may be being generated by the process. It
5 would be useful to have a satisfactory method of energy transfer in these circumstances.

Summary of the Invention

10 In accordance with a first aspect, the present invention provides a device for converting solar energy to facilitate a micro-process, comprising a substrate comprising a micro-formation arranged to hold a medium requiring energy for facilitating the micro-process, and
15 an optical concentrator arranged to focus solar energy at the micro-formation.

In at least an embodiment, the micro-process is provided with energy from the solar energy, in order to
20 facilitate the micro-process. Examples of processes which may be driven by embodiments of the present invention include the production of hydrogen in micro-reactors, purification of water and/or air using a catalyst, thermo-electric power generation, and many more applications.

25 In an embodiment, the optical concentrator comprises a micro-lens. On a macro scale, most solar concentration is carried out using mirrors, as large lenses are expensive, difficult to make and absorb significant amounts of solar
30 energy. At the micro level, however, micro-lenses may be made cheaply and accurately in batch mode, using micro fabrication photo-lithographic techniques. The lenses may comprise cylindrical lenses or spherical lenses.

35 In an alternative embodiment, micro-mirrors may be used to focus the solar energy.

- 3 -

In an embodiment, the micro formation comprises a plurality of micro-channels along which fluids may be driven, in order to facilitate a micro-reaction, for example. The channels may comprise a plurality of
5 parallel channels. The solar energy may be focussed at any point within the channel. In an embodiment, the solar energy is focussed on the walls of the channel, which are of a substance which heats up and may transfer the heat to the fluid to promote a reaction. The walls of the channel
10 may mount one or more layers of compounds or elements for promoting the process, such as catalysts, for example. The channels may be laid out in any convenient way for promotion of the process.

15 In an embodiment the micro-channels are thermally isolated from one another in the substrate. In such an embodiment the concentrator may focus the solar energy on either the substrate or micro-channels to achieve the desired micro-reaction. For example, the micro-channels
20 may be suspended in a vacuum within the substrate.

In an embodiment, the optical concentrator is mounted by a cover arranged over a substrate mounting the micro-formations. In an embodiment, in order to retain heat
25 within the micro-formations, a vacuum layer is formed between the cover and the substrate.

In an embodiment, the device may be a micro-reactor for producing hydrogen. In an embodiment, hydrogen is
30 produced by a methanol reforming reaction. In this embodiment, the micro-formations contain a catalyst for promoting methanol reforming.

In an embodiment, the micro-formations may mount
35 photo-sensitive electrodes arranged to facilitate photo-electro chemical water decomposition, to produce hydrogen.

- 4 -

In an embodiment, the micro-formations may contain a catalyst for promotion of water and/or air decontamination.

5 Photovoltaic cells for generating electricity can heat up to temperatures well above ambient, especially for concentrated systems. This is an unwanted by-product and the power output of photovoltaic cells decreases with increased temperatures.

10

 In an embodiment, the micro-converter comprises a micro-photovoltaic cell array. The micro-formations comprise micro channels along which water and other cooling fluid can be pumped, in order to remove waste heat from the photovoltaic cells. In an embodiment, this heat can then be used to drive a further process.

15

 In an embodiment, the micro-converter may be used for thermo-electric power generation, utilising thermo electric materials.

20

 In accordance with a second aspect, the present invention provides a method of producing hydrogen, comprising the steps of focussing solar energy on a substrate carrying a micro-flow of methanol and water, and providing a catalyst to promote methanol reformation. In an embodiment the solar energy is focused on individual micro-channels formed within the substrate which carry the micro-flow.

25
30

 In an embodiment, the method may utilise the device of the first aspect of the invention.

 In accordance with a third aspect, the present invention provides a method of promoting water decomposition, comprising the steps of focussing solar energy on photosensitive electrodes proximate a micro-flow

35

- 5 -

of water.

In an embodiment, the method may utilise the device of the first aspect of the invention.

5

In accordance with a fourth aspect, the present invention provides a method of water and/or air decontamination, comprising the steps of focussing solar energy on a substrate carrying a micro-flow of water and/or air associated with a catalyst. In an embodiment the solar energy is focused on individual micro-channels formed within the substrate which carry the micro-flow.

In an embodiment, the method may utilise the device of the first aspect of the invention.

In accordance with a fifth aspect, the present invention provides a method of generating electricity, comprising the steps of focussing solar energy on photovoltaic cells and removing heat generated by the photovoltaic cells by a micro-flow of cooling fluid proximate the photovoltaic cells.

In an embodiment, the method may utilise the device of the first aspect of the invention.

In accordance with a sixth aspect, the present invention provides a method of facilitating a micro-process, comprising the steps of focussing solar energy on a reactive medium for causing the micro-process.

In an embodiment, the method may utilise the device of the first aspect of the invention.

In accordance with a seventh aspect, the present invention provides a method of fabricating a device for converting solar energy to facilitate a micro-process,

- 6 -

comprising the steps of forming micro-formations in a substrate, and forming an optical concentrator in a cover arranged to cover the substrate.

- 5 In an embodiment, the optical concentrator is arranged to focus solar energy on the micro formations.

In an embodiment, the method comprises the further step of bonding the cover to the substrate.

10

In an embodiment, the method comprises the further step of forming a vacuum layer between the cover and the substrate.

- 15 Photolithographic techniques may be utilised to form layers in the substrate and cover to form the optical concentrator and micro-formations.

- 20 In accordance with an eighth aspect, the present invention provides a method of promoting a process, comprising the steps of focussing solar energy on a plurality of channels within a substrate, the channels being arranged to contain fluids for facilitating the process.

25

- In an embodiment, the fluids may comprise reactants for various reactions. These may include methanol reformation, water decomposition, and other reactions. In an embodiment, the channels may mount other elements for
30 facilitating a process, such as catalysts, for example, or devices such as electrodes, and other elements.

- In accordance with a ninth aspect, the present invention provides a device for converting solar energy to
35 facilitate a process, comprising a substrate comprising formations arranged to hold a medium requiring energy for facilitating the process, and an optical concentrator

- 7 -

arranged to focus solar energy at the formations.

In an embodiment, the formations are channels containing or arranged to contain reactants or other
5 elements for facilitating the process.

In accordance with a tenth aspect, the present invention provides a device for generating electric power, comprising a substrate mounting a thermo-electric material
10 and an optical concentrator for focussing solar energy on the thermo-electric material in order to cause the production of electricity.

In an embodiment, the substrate may be formed of the
15 thermo electric material.

In accordance with an eleventh aspect there is provided a device for converting solar energy to facilitate a micro-process, comprising a substrate
20 comprising a micro-formation arranged to hold a medium requiring energy for facilitating the micro-process, and a cover operable to pass incident solar energy onto the substrate for facilitating the micro-process.

25 In an embodiment, the cover comprises an infra-red filter. According to such an embodiment, the transmission of thermal infra-red wavelengths from the substrate can be kept to a minimum for keeping a suitable amount of heat within the device.

30

In an embodiment, the cover comprises high transmittance glass.

In an embodiment, the micro-formation comprises a
35 micro-channel.

In an embodiment, the micro-formation comprises a

- 8 -

plurality of micro-channels.

In an embodiment, the cover encases the substrate such that a vacuum layer is formed between the cover and
5 the micro-formation.

In an embodiment a coating having desired light emittance/absorptance characteristics may be applied on one or both sides of the micro-formation, substrate and/or
10 cover. For example, the coating may be a selective solar surface coating having a relatively high solar absorptance in comparison to solar emittance.

In an embodiment the side of the micro-formation
15 which is not in direct contact with the solar energy may be coated with a reflective coating to reduce heat losses within the device.

In an embodiment, the substrate comprises SU8 polymer
20 photo-resist material.

In an embodiment, the substrate comprises glass.

In an embodiment, micro-channels are thermally
25 isolated from one another. For example, the micro-channels may be suspended in a vacuum layer formed by wafer bonding.

In an embodiment, the device further comprises a
30 catalyst for promoting methanol reforming to facilitate a micro-process for hydrogen production.

In an embodiment, the catalyst is contained by the
micro-formation.

35

In an embodiment, the catalyst is Cu/ZnO.

- 9 -

In an embodiment, the device further comprises a plurality of photosensitive electrodes arranged to facilitate photo-electrochemical water decomposition within the micro formations.

5

In an embodiment, the device further comprises catalyst for promoting water and/or air decontamination.

10 In an embodiment, the micro-formations are coated with the catalyst.

In an embodiment, the device further comprises photovoltaic cells mounted within the micro-formations and arranged to facilitate the generation of electricity when
15 exposed to the incident solar energy.

In an embodiment, the micro-formations comprise micro-channels, and wherein the micro-channels are arranged to have a fluid flow through them to cool heat
20 generated in operation of the photo-voltaic cells.

In an embodiment, the micro-formation comprises a layer of thermo-electric material, arranged to generate electrical energy in response to the solar energy.
25

In accordance with a twelfth aspect there is provided a method of fabricating a device for converting solar energy to facilitate a micro-process, comprising the steps of forming micro-formations in a substrate, and forming a
30 cover over the substrate which is operable to pass sufficient incident solar energy thereon for achieving the micro-process.

In an embodiment, the method comprises the further
35 step of bonding the cover to the substrate.

In an embodiment, the method comprises the further

- 10 -

step of forming a vacuum layer between the substrate and the cover.

In accordance with a thirteenth aspect there is
5 provided a device fabricated by the method in accordance with the twelfth aspect.

In accordance with a fourteenth aspect there is
provided a device for utilising solar energy to facilitate
10 a process, comprising a substrate comprising formations holding a medium requiring energy for facilitating the process, and a cover operable to pass sufficient incident solar energy at the formations to achieve the process.

15 In an embodiment, the cover encases the substrate such that a vacuum layer is formed between the cover and the micro-formation.

In an embodiment a coating having desired light
20 emittance/absorptance characteristics may be applied on one or both sides of the formations, substrate and/or cover. For example, the coating may have a relatively high solar absorptance in comparison to solar emittance. For example, in one embodiment, a solar absorptance of
25 approx .9 and emittance of approx .05 at 900 microns is envisaged. A number of different material compositions may be employed for the coating. For example electroplated black chromium, nicked-pigmented anodiac (AI203), or the like may be utilised. Another appropriate
30 solar selective surface comprises a double cermet layer structure.

In an embodiment the side of the micro-formation which is not in direct contact with the solar energy may
35 be coated with a reflective coating to reduce heat losses within the device.

- 11 -

In accordance with a fifteenth aspect there is provided a device for generating electric power, comprising a substrate mounting a thermo electric material and a cover for directing solar energy on the thermo
5 electric material in order to cause the production of electricity.

In accordance with a sixteenth aspect there is provided a device for converting solar energy to
10 facilitate a micro-process, comprising an evacuated void comprising a suspended micro-formation arranged to hold a medium requiring energy for facilitating the micro-process, and a cover operable to direct sufficient incident solar energy onto the micro-formation to achieve
15 the micro-process.

In an embodiment the micro-formation comprises a plurality of micro-channels each independently suspended in the evacuated void. The evacuated void may comprise a
20 vacuum chamber formed, for example, by wafer bonding.

The term "micro" is used to indicate that a device in accordance with embodiments of the present invention has components which are small, in an embodiment less than a
25 few millimetres, and, in embodiments less than 1 millimetre. In an embodiment, the term "micro" may also indicate some kind of micro fabrication technique has been used in manufacture of the device. In this specification, the term "micro" also includes "nano" and
30 smaller dimensions.

Although embodiments of the invention are implemented on the micro-level, the invention is not limited to micro-dimensions for all embodiments. The process may be
35 performed on the macro level and the device may be of macro dimensions. For example, the above aspects which employ a non-directive lens arrangement (e.g. which

- 12 -

instead comprise a cover and a selective coating) may be particularly suited for achieving macro scale process due to their operability without need for lens arrangements. Where lenses are used as the optical concentrator, as size increases the use of lenses will become uneconomical, but they may still be economical at some macro level.

Brief Description of the Drawings

- Figure 1 is a diagram of a device in accordance with an embodiment of the present invention;
- Figure 2 is a detailed view of the device of Figure 1;
- Figure 3 is a diagram of a device in accordance with an embodiment of the present invention for cooling photovoltaic cells;
- Figure 4 is a detail view of the device of Figure 3;
- Figure 5 is a diagram of a device in accordance with an embodiment of the present invention for producing hydrogen from methanol reformation;
- Figures 6a and 6b are schematics of the device of Figure 5 according to alternative embodiments;
- Figure 6c is a schematic showing the different layers of the selective surface coating;
- Figure 7 is a 2D schematic of the micro-converter shown in Figure 6a;
- Figure 8 is a theoretical stagnation temperature graph;
- Figure 9 is a two-dimensional radiation model showing stagnation temperatures;
- Figure 10 is a theoretical stagnation temperature graph for the micro-converter;
- Figure 11 is a water/methanol graph;
- Figure 12 shows the thermal efficiency of the micro-converter;
- Figures 13(a) through (j) show steps in a process for fabrication in accordance with an embodiment of the present invention, and

- 13 -

Figure 14 is a diagram of a device in accordance with a further embodiment of the present invention.

Figures 16 and 17 shows process steps for fabrication in accordance with alternative embodiments.

5

Detailed description of embodiments

Referring to Figures 1 and 2, there is shown a device in accordance with an embodiment of the present invention, which is designated generally by reference numeral 1. In this embodiment, the device is in the form of a micro-converter 1 and comprises an optical concentrator, in this example comprising a plurality of micro-lenses 2, and micro-formations. In this example, the micro-formations comprise a plurality of parallel micro-fluid channels 3.

In more detail, the micro-converter 1 is formed from an array of micro-lenses 2 and micro-fluid channels 3. In operation, the micro-lenses 2 operate to concentrate solar energy on the channels 3. Fluid may be pumped through the channels 3 and the solar energy may be utilised to promote processes, such as, for example, chemical reactions. New processes benefiting from utilising the solar energy, may be implemented utilising the micro-converter 1 of this embodiment of the invention. The micro-converter may include other micro-scale components, such as valves, heat exchangers, pumps, etc.

Referring again to Figure 1, a fluid inlet 4 may be used to introduce fluid into the channels 3 and once the process has been implemented within the channels, further processing may occur elsewhere.

In the embodiment of the micro-converter described here, cylindrical lenses are utilised. Micro-lenses can be made with excellent precision and control in very small sizes, ranging from a few micrometres to millimetres.

- 14 -

In this embodiment, a parallel array of cylindrical micro-lenses operate to focus solar energy on to the array and micro-channels 3. As will be discussed in more detail later, the micro-channels 3 are made using photo lithography in SU8 which is a very robust polymer photo-resist material with low thermal conductivity that can withstand high temperatures. Note that in embodiments the array of micro-lenses need not be straight and parallel as shown, but could be arranged in different ways. Also, other types of micro-lenses than cylindrical micro-lenses may be utilised. For example, cylindrical micro-lenses are available. Any other type of micro-lens may also be used. Further, in embodiments other materials than SU8 may be utilised and other techniques may be used to form the micro-channels, such as bulk micro-machining in low grade silicon, for example.

A thin film of the selected solar absorbing material is provided by a sputtering (or deposition or other techniques) to coat the insides of the channels 3. The lenses 2 focus incoming solar energy onto the walls of the channel where the fluid is flowing. This increases the wall temperature and the heat is transferred from the wall to the flowing fluid. The fluid will rise to a temperature which depends on the flow rate and length of the channel.

In embodiment the channels may be suspended in insulating material to avoid any heat dissipation caused by thermal diffusion. In other words, the micro-channels may be thermally isolated from one another. This may be advantageous where the spacing between the micro-channels is relatively narrow and where high temperatures are required to be generated by the micro-converter 1. For example, the micro-channels may be suspended in a vacuum (see Figure 1a).

- 15 -

In the illustrated embodiment, the micro-lenses 2 are formed on a cover 6 which is mounted to the substrate 7 within which the micro-channels are formed. In one embodiment the cover 6 may be mounted directly to the substrate 7. In an alternative embodiment, in order to facilitate heat insulation, a space between the substrate 7 and cover 6 is evacuated to reduce heat loss (see later).

Many processes can be facilitated utilising this new micro-converter 1. The following description gives examples of just some of the processes that may be facilitated. The invention is not limited to these processes, and may be applied with many other processes.

It is well known to utilise photovoltaic cells to convert solar energy directly into electricity. One of the unwanted by-products of the photovoltaic process is the production of heat. The efficiency of photovoltaic cells decreases significantly with increased temperatures. It would therefore be very useful if a convenient and effective way of removing generated heat could be implemented.

Power Generation using Photovoltaic Cells

Figures 3 and 4 illustrate a further embodiment of the present invention which operates to both focus solar energy on photovoltaic cells and facilitate removal of unwanted heat.

The device of this embodiment is in the form of a micro-converter 10. Micro-channels 11 are formed in a substrate 12. The micro-channels have photovoltaic cells 13 along the base or sides of the channels 11. Micro-lenses 14 mounted by the cover 15 operate to focus

- 16 -

solar energy on the photovoltaic cells, so that they operate to produce electricity. Cooling fluid 16, such as cooling water, is pumped along the micro-channels 11 to remove the excess heat from the photovoltaic cells 13 and maintain them running efficiently. A pump 17 is used to pump the fluid along the channels 11.

In this embodiment, the water 16, which is heated, can then be used in a further process, either a heat exchanger or thermo-electric generator (reference numeral 18 of Figure 3). A thermo-electric generator may be formed as one or more modules to which the heated water 16 is introduced. The water heater could be utilised in any other process where the heat may be useful.

15

By use of the Peltier effect, thermo-electric materials may be utilised to cool and/or heat processes.

Hydrogen Production

20

An application of a further embodiment of this invention is hydrogen production using methanol reformation. The resultant hydrogen may be used to power a fuel cell, such as a proton exchange membrane (PEM) fuel cell which can in turn be used in turn to power an electrical/electronic device.

An example system implementation is illustrated in Figure 5. It can be seen that solar energy is advantageously utilised to supply the heat needed to reform methanol into hydrogen which is then fed into the fuel cell 29 to produce electricity. Further, as persons skilled in the art will appreciate, great care needs to ordinarily be taken when transporting hydrogen due to its high energy content per unit mass and low volumetric energy density. According to the illustrated embodiment the hydrogen source (i.e. micro-converter 20) can be

30

35

- 17 -

located at the actual delivery point (e.g. adjacent the PEM fuel cell) thereby avoiding such transportation issue.

The endothermic steam reforming reaction utilised in the illustrated embodiment is given by:



with the energy required for the reaction being 49kJ/mol.

10

This reaction is best suited for fuel cells as 75% of the product is hydrogen, no compressed gases are needed, and the peak reaction efficiency occurs at temperatures between 250-300°C, which is relatively easy to achieve utilising solar energy. For typical methanol flow rates of 0.1 mol/hr, for chip sizes in the order of 6x6cm, the power flux required is in the order of 1kW/m², which is equivalent to mean terrestrial solar energy power flux.

20 The micro-converter 20 of Figure 5 is shown in more detail in Figure 6a. It is noted that the micro-converter 20 in Figure 6a employs a different heating/concentrating arrangement to the micro-converters previously described, in so far as the micro lenses are substituted by a cover
25 employing a high quality selective surface and vacuum insulation which envelop the plurality of micro-channels 23 (formed in the substrate 24). The present inventor has found that such a configuration is sufficient to produce temperatures high enough to reform methanol and
30 concentration does not increase the temperature further due to thermal diffusion. Concentration may be used with suspended micro-channels that are thermally isolated from each other, which is explained in detail in subsequent paragraphs. Such an arrangement is referred to hereafter
35 as a "flat plate" micro-converter although it will be understood by persons skilled in the art that non-flat configurations are equally suitable.

- 18 -

In more detail, the cover 21 employed by the flat plate converter is in the form of two high transmittance glass sheets 21. Vacuum layers 22 separate the substrate 24 from the glass sheets 21 and act to suppress convection losses. The substrate 24 is coated with selective solar surface coating which acts to absorb most of the incident solar radiation while simultaneously suppressing emittance. In other words, the coating acts to allow short wavelength light to pass (so as to heat the micro-channels 23) while suppressing infra-red losses. In this embodiment the coating is in the form of a double cermet film as shown in Figure 6C and has a short wavelength ($<3\mu\text{m}$) absorbance higher than .9 and long wavelength ($>3\mu\text{m}$) thermal emittance of less than .1. The selective coating may, for example, be applied using DC sputtering techniques known to persons skilled in the art. Other equally suitable selective coatings which may be utilised comprise electroplated back chromium, nickel-pigmented anodiac Al_2O_3 and the like.

The combination of vacuum installation and selective coating may yield stagnation temperatures in excess of 300°C . Another advantage arising from the use of the flat plate arrangement is that the micro-converter 20 is not particularly sensitive to the incident angle of the solar energy.

A methanol/water mixture 25 is pumped through the micro-channels 23 by a pump 26.

In this embodiment, the micro-channels 23 are coated with a selective solar absorbing coating and catalyst to facilitate the methanol reformation (reference numeral 27). In this embodiment the catalyst is Cu/ZnO . Such a catalyst has excellent reactivity and selectivity and can be formed relatively easily in the micro-

- 19 -

channels 23. This may be done by flowing an aqueous solution of nano-particles that have been ground from commercial Cu/ZnO catalyst pellets through the channel and letting the particles precipitate. The precipitate is then dried and baked to immobilise it inside the channels. Note that other catalysts than Cu/ZnO may be used in other embodiments. For example a catalyst comprising Cu/ZnO/Al₂O₃ is also effective in achieving the desired reaction.

Following the reaction in the micro-converter 20, a gas separator 28 is utilised to separate out the waste gas and the hydrogen. The hydrogen may then be utilised to power the fuel cell 29. If required, hydrogen produced by the micro-converter 20 can be temporarily stored in a hydrogen reservoir 31 during excess production phases. A back-up heater 33 may take over to provide energy to the micro-converter 20 when solar energy is low or not available.

In an alternative embodiment to that described above, and with specific reference to Figure 6b, the micro-converter 20 may include a lens arrangement much the same as employed in the photovoltaic cell implementation (see Figure 4).

Thermal Modelling for Hydrogen Generation

Figure 7 is a two-dimensional schematic of the micro-converter which was utilised in the modelling processed described hereafter. In this model, the wall of the vacuum layer exposed to the sun is coated with the selective coating ($\epsilon_s = 0.06, \alpha_s = 0.92$) while in the other vacuum layer, a high reflective coating ($\epsilon_i = 0.02$) is used to reduce the losses. The base has a low emittance as well ($\epsilon_i = 0.2$). Neglecting the absorptance of the glass, the heat flux absorbed by the surface [3] is,

- 20 -

$$q_s'' = \frac{\tau_g \alpha_s}{1 - (1 - \alpha_s) \rho_g} q_{sun}''$$

In order to predict the water/methanol mixture temperature, the energy balance equations for the walls are formulated (Eqs. 2-4 below). The convective and conductive heat transfer was neglected in the vacuum insulation gap, Since the Biot number (Bi) based on the reactor length and for laminar flow is in the order of magnitude of 0.1, the temperature of the walls are expected to be uniform (this assumption was verified using a two dimensional CFD model), allowing one dimensional energy analysis. The liquid water and the methanol are expected to boil in the entrance to the collector, due to the low flow rates needed for the reformer. Therefore, the mixture will flow through the converter in a gaseous phase.

Glass energy balance:

$$\frac{\sigma(T_g^4 - T_s^4)}{\frac{1}{\epsilon_s} + \frac{1}{\epsilon_g} - 1} + \sigma \epsilon_g (T_g^4 - T_\infty^4) + h_e (T_g - T_\infty) = 0 \quad (2)$$

Middle walls energy balance:

$$\frac{\sigma(T_s^4 - T_g^4)}{\frac{1}{\epsilon_s} + \frac{1}{\epsilon_g} - 1} + \frac{\sigma(T_s^4 - T_b^4)}{\frac{2}{\epsilon_i} - 1} + h_i (T_s - T_i) = q_s'' \quad (3)$$

Base energy balance:

$$\frac{\sigma(T_b^4 - T_s^4)}{\frac{2}{\epsilon_i} - 1} + \sigma \epsilon_b (T_b^4 - T_\infty^4) + h_e (T_b - T_\infty) = 0 \quad (4)$$

- 21 -

From the energy equation of the flow through the channel we obtain,

$$h_1(T_l - T_s) - \dot{m} \int_{T_i}^{T_j} c_p dT = 0 \quad (5)$$

5

Where c_p is the temperature dependant specific heat of the water-methanol mixture and H_{fg} accounts for the enthalpy of vaporization of both fluids. As the pressure drop through the micro-converter is expected to be low (<1kPa), the methanol and the water will vaporize at 65°C and 100°C respectively.

The system of nonlinear equations (2-5) were solved for different values of ϵ_s and α_s , to predict the stagnation temperature (without flow, $m = 0$) of the micro-converter. A heat transfer coefficient $h_e = 10 \text{ W/m}^2\text{K}$ was assumed to account for low external air flow over the collector. The glass and coating properties were taken from existing materials datasheets. The results, presented in Figure 8, show that higher surface emittance characteristics are effective in order to obtain high temperatures in the non-concentrating collector.

Choosing the current selective coating technology values for emittance ($\epsilon_s = 0.06$) and absorptance ($\alpha_s = 0.92$), and with the combination of vacuum insulation, a stagnation temperature above 400°C is achievable.

In order to validate the results obtained, a two dimensional model was solved using the commercial software "FLUENT". The DTRM radiation model was used to account for the heat transfer through the vacuum gap. The stagnation temperatures obtained for $\epsilon_s = 0.06$ and $\alpha_s = 0.92$ (all the other parameters as in Figure 8) are shown in Figure 9. The results differed by 0.1 °C with those obtained solving

- 22 -

Eqs. 2-5 and therefore, the assumption of uniform temperature across the walls was also confirmed.

The sensitivity of the results to the external convective heat transfer coefficient for different solar heat fluxes was examined by solving equations (2-5) for different values of q''_{sun} and h_e .

Figure 9 shows the stagnation temperatures obtained as a function of q''_{sun} and h_e .

In the natural convection regime ($h_e < 5 \text{ W/m}^2\text{K}$) and for a constant solar heat flux, the stagnation temperature slightly decreases with an increasing external heat transfer coefficient. On the other hand, no variation in temperature is expected for forced convection as the temperature of the external walls of the collector is close to the surrounding temperature. The results also show that high stagnation temperatures can be reached for heat fluxes that are lower than the mean terrestrial solar energy power flux corresponding to lower latitudes, cloudy sky or in the morning or afternoon when the sun radiation is attenuated.

Finally, equations (2-5) were solved for different values of q''_{sun} and m to determine the mixture temperature for different flow rates and heat fluxes. The results are shown in Figure 8, as a function of volumetric feeding flow rate per exposed area to the sun (v'). The region where methanol and water are expected to boil are clearly seen (for $T_s=65^\circ\text{C}$ and $T_s=100^\circ\text{C}$). In order to obtain a temperature above 250° for a solar heat flux of 1000 W/m^2 (equivalent to the mean terrestrial solar energy power flux), a maximum flow rate of about 0.12 ml/h/cm^2 is allowed. The current investigations of methanol reforming in micro-reactors, present a feeding flow rate in the range between 0.07 ml/h/cm^2 and 0.9 ml/h/cm^2 (flow rate per

- 23 -

area of the reactor), however higher methanol conversion was achieved for the lower flow rates. For higher flow rates, a bigger solar collector can be built in order to collect the heat necessary to reach the appropriate
 5 temperatures of the mixture.

Once the gas mixture reaches the reacting temperature of 250°C to 300°C for a solar heat flux of 1000 W/m², and considering the heat losses and the enthalpy of the
 10 methanol reforming (Eq. 1), a maximum water/methanol feed flow rate of 0.1 ml/h/cm² (per area of the reactor exposed to the sun) will keep the temperature while the reaction takes place (assuming that the reaction rate is faster than the heat transfer mechanism). Otherwise the
 15 temperature will drop as a result of the enthalpy of the reaction. Therefore, the micro-converter proposed is able to supply the heat necessary to reach and maintain the temperature of this endothermic reaction.

20 In order to quantify the collector performance, its thermal efficiency was calculated as the ratio of the heat absorbed by the flow to the solar heat flux (Eq. 7). The calculated values are plotted in Figure 12. The horizontal lines correspond to the boiling regime, as heat losses are
 25 expected to be constant for a constant boiling temperature.

$$\eta = \frac{\dot{m} \left(\int_{T_i}^{T_f} c_p dT + H_{fg} \right)}{q'_{sun}} \times 100 \quad (7)$$

30 The region where the fluid temperature is between 250°C and 300°C is shown in the graph. The expected thermal efficiency for these temperatures and for a solar heat flux of 1000 W/m² is between 46% and 59%. As seen on the graph, this efficiency decreases for lower heat
 35 fluxes.

Other Applications

Other applications of the micro-converter in accordance with embodiments of the present invention include, but are not limited to, the following:

- Hydrogen production using propane reforming with high temperature steam. This process requires very high temperatures, but a device in accordance with an embodiment of the present invention may be used to save considerable energy by preheating the steam. The device may include a plurality of channels and optical concentrators for preheating the steam.
- Photo-electro chemical water decomposition using solar energy involves converting light energy into electricity in a cell with two photosensitive electrodes immersed in an aqueous solution. In this embodiment, the photosensitive electrodes may be manufactured from material such as TiO_2 , CaTi_3 and SrTiO_3 , which are coated inside the channels. This electricity is then used for water electrolysis which produces hydrogen and oxygen.
- TiO_2 can act as a photo catalyst for water and/or air decontamination. A device in accordance with an embodiment of the present invention, with channels coated with the catalyst, may be utilised as a solar water and/or air purification system.

There may be many other processes that a device in accordance with embodiments of the present invention may implement.

Referring to Figure 13, an example fabrication process for an embodiment of the present invention will now be described.

Referring to Figure 13(a) through (j), the channels may be formed by standard photolithographic techniques. SU8 polymer photo-resist is utilised (Figure 13(a) which has the advantage of being an excellent high temperature thermal insulator. For higher temperature applications,

- 25 -

such as hydrogen production, the channels may be fabricated directly into either glass or a ceramic to minimise conduction through the substrate or silicon.

In Figure 13(a), the SU8 photo-resist 30 is spun onto the substrate 31. A photolithographic mask 32 (Figure 13(b)) is utilised to form the pattern of micro-channels 33 (Figure 13(c)). Thin film deposition may be utilised to coat the micro-channels with a coating 34 (Figure 13(d)) which may include catalysts, other reactants, etc.

Referring to Figures 13(f) through (j), the lenses are formed using grey-scale lithography to directly pattern a photo-resist (reference numeral 35, Figure 13(f)) onto a substrate 36. A grey scale mask 37 (Figure 13(g)) is utilised to pattern the lenses 38 (Figure 13(h)) and then reactive ion etching is utilised to form the glass substrate 36 into lens shape (Figure 13(i), reference numeral 39 indicating the lenses). Another method may involve reflowing a patterned photoresist to form cylindrical lenses. These can be used as they are, or reactive ion etching may be used to form the channels in glass as mentioned previously in Figure 13.

Figure 13(e) shows block bonding of the lens cover 39 to a substrate 31 to form a microconverter, without any intervening vacuum.

Figure 13(j) illustrates a further step of forming a vacuum insulation layer 40 between the cover 39 and substrate 31.

Referring to Figure 14, a further embodiment of the present invention which utilises micro-mirrors instead of micro-lenses to optically concentrate solar energy, will now be described.

In this embodiment, micro-mirrors 50 are formed substrate 52, by appropriate micro-fabrication techniques and reflective coating deposition. A further substrate 53 is formed as a cover to be mounted over the mirror 50 substrate 51, as illustrated in Figure 14. The

- 26 -

substrate 53 has micro-channels 54 formed therein. Solar energy is reflected by the mirror upwardly to heat the material forming the channels 54 as indicated by notional light rays 55 in Figure 14. Substrate 53 may be
5 multilayer. Substrate 53 will be transparent, at least in part, to allow transmission of light. Channels 54 are coated with a heat absorbent material such as SU8. A vacuum layer may be formed between the mirror substrate 52 and the channel substrate 53 or between the channels 53
10 and the lid 54.

A flat plate micro-converter fabrication technique is shown in Figure 15. According to the illustrated embodiment integrated vacuum layers are incorporated into
15 the micro-converter 60 to minimise heat loss. The evacuated layers may be produced by a vacuum wafer bonder. In order to ensure a low vacuum (approx. 1mTorr) a "getter" may be utilised to absorb trace gasses. In a first step (step 1) a silicon substrate 62 is
20 provided. At step 2 a photo-resist 64 is spun onto the substrate 62. Micro-channels are then formed into the photo-resist (step 3). At step 4, a selective coating 66 is applied to the micro-channels using thin film deposition 66. The coating may include solar selective
25 surfaces, catalysts, other reactants, etc. A getter is also positioned to ensure a good vacuum. The micro-channels are then sealed with a lid by gluing or anodic bonding (step 5). Finally, at step 6, the top and bottom covers are connected to the substrate using anodic bonding
30 in a vacuum using a wafer bonder with vacuum facilities and the getter activated.

Figure 16 illustrates a technique for fabricating suspended (i.e. thermally isolated) micro-channels such as
35 those illustrated in Figure 1a. In this embodiment lens fabrication is achieved using a grey-scale mask that patterns the photo-resist in three-dimensions. Reactive

- 27 -

ion etching is then employed to form the correct channel shapes within the glass. A more detailed description of a method for fabricating suspended channels can be found in the following document which is incorporated herein by

5 reference: Arana, L.R., S.B. Schaevitz, A.J. Franz, K.F. Jensen, and M.A. Schmidt, A microfabricated suspended-tube chemical reactor for fuel processing, Journal of MicroElectroMechanical Systems 600-612 (2003).

10 In the above embodiments, where channels are incorporated in the substrate, the channels are shown as being parallel. In other embodiments, the channels may be formed in any manner. For example, the channels may be suspended in a vacuum layer or chamber by wafer bonding
15 techniques. In such a suspended arrangement incident solar energy may be directed onto each of the channels for achieving the desired micro-reaction. One potentially advantageous arrangement is a tree network of channels. This may reduce pressure drop of fluids flowing through
20 the channels and also increase heat transfer. Further, in embodiments, hydrophobic coatings may be used to coat the channels to allow for high flow rates of fluid. This may be particularly useful where high flow rates of water, for example, are required to keep temperatures down for
25 photovoltaics.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary
30 implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

- 28 -

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the
5 invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

- 29 -

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A device for converting solar energy to facilitate a micro-process, comprising a substrate comprising a micro-formation arranged to hold a medium requiring energy for facilitating the micro-process, and an optical concentrator arranged to focus solar energy at the micro-formation.
2. A device in accordance with Claim 1, wherein the optical concentrator comprises a micro-lens.
3. A device in accordance with Claim 2, wherein the optical concentrator comprises an array of micro-lenses.
4. A device in accordance with Claim 2 or Claim 3, wherein the micro-lens comprises a cylindrical lens.
5. A device in accordance with Claim 2 or Claim 3, wherein the micro-lens comprises a spherical lens.
6. A device in accordance with Claim 1, wherein the optical concentrator comprises one or more micro-mirrors.
7. A device in accordance with any one of the preceding claims, wherein the micro-formation comprises a micro-channel.
8. A device in accordance with Claim 7, wherein the micro-formation comprises a plurality of micro-channels.
9. A device in accordance with any one of the preceding claims, further comprising a vacuum layer formed between the micro-formation and optical concentrator.
10. A device in accordance with any one of the preceding claims, wherein the substrate comprises SU8 polymer

- 30 -

photoresist material.

11. A device in accordance with any one of Claims 1 to 9,
wherein the substrate comprises glass.

5

12. A device in accordance with any one of Claims 1 to 9,
wherein the substrate comprises ceramic.

13. A device in accordance with any one of the preceding
10 claims, further comprising a catalyst for promoting
methanol reforming to facilitate a micro-process for
hydrogen production.

14. A device in accordance with Claim 13, wherein the
15 catalyst is contained by the micro-formation.

15. A device in accordance with Claim 13 or Claim 14,
wherein the catalyst is Cu/ZnO.

20 16. A device in accordance with any one of Claims 1 to 12,
further comprising a plurality of photosensitive
electrodes arranged to facilitate photo-electrochemical
water decomposition within the micro formations.

25 17. A device in accordance with any one of Claims 1 to 13,
further comprising catalyst for promoting water and/or air
decontamination.

18. A device in accordance with Claim 14, wherein the
30 micro-formations are coated with the catalyst.

19. A device in accordance with any one of Claims 1 to 13,
further comprising photovoltaic cells mounted within the
micro-formations and arranged to facilitate the generating
35 of electricity when solar energy is focussed on them.

20. A device in accordance with Claim 19, wherein the

- 31 -

micro-formations comprise micro-channels, and wherein the micro-channels are arranged to have a fluid flow through them to cool heat generated in operation of the photo-voltaic cells.

5

21. A device in accordance with any one of Claims 1 to 6, wherein the micro-formation comprises a layer of thermoelectric material, arranged to generate electrical energy in response to the solar energy.

10

22. A method of producing hydrogen, comprising the steps of focussing solar energy on a substrate carrying a micro-flow of methanol and water, and providing a catalyst to promote methanol reformation.

15

23. A method in accordance with Claim 22, carried out utilising a device in accordance with any one of Claims 13 to 15 or 48 to 50.

20

24. A method of promoting water decomposition, comprising the steps of focussing solar energy on photosensitive electrodes adjacent a micro-flow of water.

25

25. A method in accordance with Claim 24, being carried out utilising a device in accordance with Claim 16 or Claim 51.

30

26. A method of water and/or air decontamination, comprising the steps of focussing solar energy on a substrate carrying a micro-flow of water and/or air associated with a catalyst.

35

27. A method in accordance with Claim 26, carried out utilising a device in accordance with Claim 17, Claim 18, Claim 52 or Claim 53.

28. A method of generating electricity, comprising the

- 32 -

steps of focussing solar energy on photovoltaic cells and removing heat generated by the photovoltaic cells by a micro-flow of cooling fluid adjacent the photovoltaic cells.

5

29. A method in accordance with Claim 28, carried out utilising the device of Claim 20 or Claim 49.

10 30. A method of facilitating a micro-process, comprising the steps of focussing solar energy on a reactive medium for causing the micro-process.

15 31. A method in accordance with Claim 30, carried out utilising the device of any one of Claims 1 to 20 or Claims 39 to 50.

20 32. A method of fabricating a device for converting solar energy to facilitate a micro-process, comprising the steps of forming micro-formations in a substrate, and forming an optical concentrator in a cover arranged to cover the substrate.

25 33. A method in accordance with Claim 32, comprising the further step of bonding the cover to the substrate.

34. A method in accordance with Claim 32 or Claim 33, comprising the further step of forming a vacuum layer between the substrate and the cover.

30 35. A device fabricated by the method by any one of Claims 32 to 34.

35 36. A method of promoting a process, comprising the steps of focussing solar energy on a plurality of channels within a substrate, the channels being arranged to contain fluids for facilitating the process.

- 33 -

37. A device for utilising solar energy to facilitate a process, comprising a substrate comprising formations holding a medium requiring energy for facilitating the process, and an optical concentrator arranged to focus
5 solar energy at the formations.

38. A device for generating electric power, comprising a substrate mounting a thermo electric material and an optical concentrator for focussing solar energy on the
10 thermo electric material in order to cause the production of electricity.

39. A device for converting solar energy to facilitate a micro-process, comprising a substrate comprising a micro-
15 formation arranged to hold a medium requiring energy for facilitating the micro-process, and a cover operable to pass incident solar energy onto the substrate to facilitate the micro-process.

20 40. A device in accordance with Claim 39, wherein the cover comprises high transmittance glass.

41. A device in accordance with any Claim 39 or 40, wherein the micro-formation comprises a micro-channel.
25

42. A device in accordance with Claim 41, wherein the micro-formation comprises a plurality of micro-channels.

43. A device in accordance with any one of the preceding
30 claims 39 to 42, further comprising a vacuum layer formed between the micro-formation and cover.

44. A device in accordance with any one of claims 29 to 42, wherein a coating is applied to a wall of at least one
35 of the substrate and cover for allowing transmission of a desired wavelength range of the incident solar energy.

- 34 -

45. A device in accordance with any one of the preceding claims 39 to 44, wherein the substrate comprises SU8 polymer photo-resist material.

5 46. A device in accordance with any one of Claims 39 to 45, wherein the substrate comprises glass.

47. A device in accordance with any one of Claims 39 to 46, wherein the micro-channels are thermally isolated from
10 one another.

48. A device in accordance with any one of the preceding claims 39 to 47, further comprising a catalyst for promoting methanol reforming to facilitate a micro-process
15 for hydrogen production.

49. A device in accordance with Claim 48, wherein the catalyst is contained by the micro-formation.

20 50. A device in accordance with Claim 48 or Claim 49, wherein the catalyst is Cu/ZnO.

51. A device in accordance with any one of Claims 39 to 47, further comprising a plurality of photosensitive
25 electrodes arranged to facilitate photo-electrochemical water decomposition within the micro formations.

52. A device in accordance with any one of Claims 39 to 47, further comprising catalyst for promoting water and/or
30 air decontamination.

53. A device in accordance with Claim 49, wherein the micro-formations are coated with the catalyst.

35 54. A device in accordance with any one of Claims 39 to 48, further comprising photovoltaic cells mounted within the micro-formations and arranged to facilitate the

- 35 -

generating of electricity when exposed to the incident solar energy.

55. A device in accordance with Claim 54, wherein the
5 micro-formations comprise micro-channels, and wherein the micro-channels are arranged to have a fluid flow through them to cool heat generated in operation of the photo-voltaic cells.

10 56. A device in accordance with any one of Claims 39 to 47, wherein the micro-formation comprises a layer of thermo-electric material, arranged to facilitate the generating of electrical energy in response to the solar energy.

15 57. A method of fabricating a device for converting solar energy to facilitate a micro-process, comprising the steps of forming micro-formations in a substrate, and forming a cover over the substrate which is operable to pass
20 sufficient incident solar energy thereon for achieving the micro-process.

58. A method in accordance with Claim 57, comprising the further step of bonding the cover to the substrate.

25 59. A method in accordance with Claim 57 or Claim 58, comprising the further step of forming a vacuum layer between the substrate and the cover.

30 60. A device fabricated by the method by any one of Claims 57 to 59.

61. A device for utilising solar energy to facilitate a process, comprising a substrate comprising formations
35 holding a medium requiring energy for facilitating the process, and transparent cover arranged to pass incident solar energy at the formations.

- 36 -

62. A device for generating electric power, comprising a substrate mounting a thermo electric material and a cover for focussing solar energy on the thermo electric material
5 in order to cause the production of electricity.

63. A device for converting solar energy to facilitate a micro-process, comprising an evacuated void comprising a suspended micro-formation arranged to hold a medium
10 requiring energy for facilitating the micro-process, and a cover operable to direct incident solar energy onto the micro-formation to facilitate the micro-process.

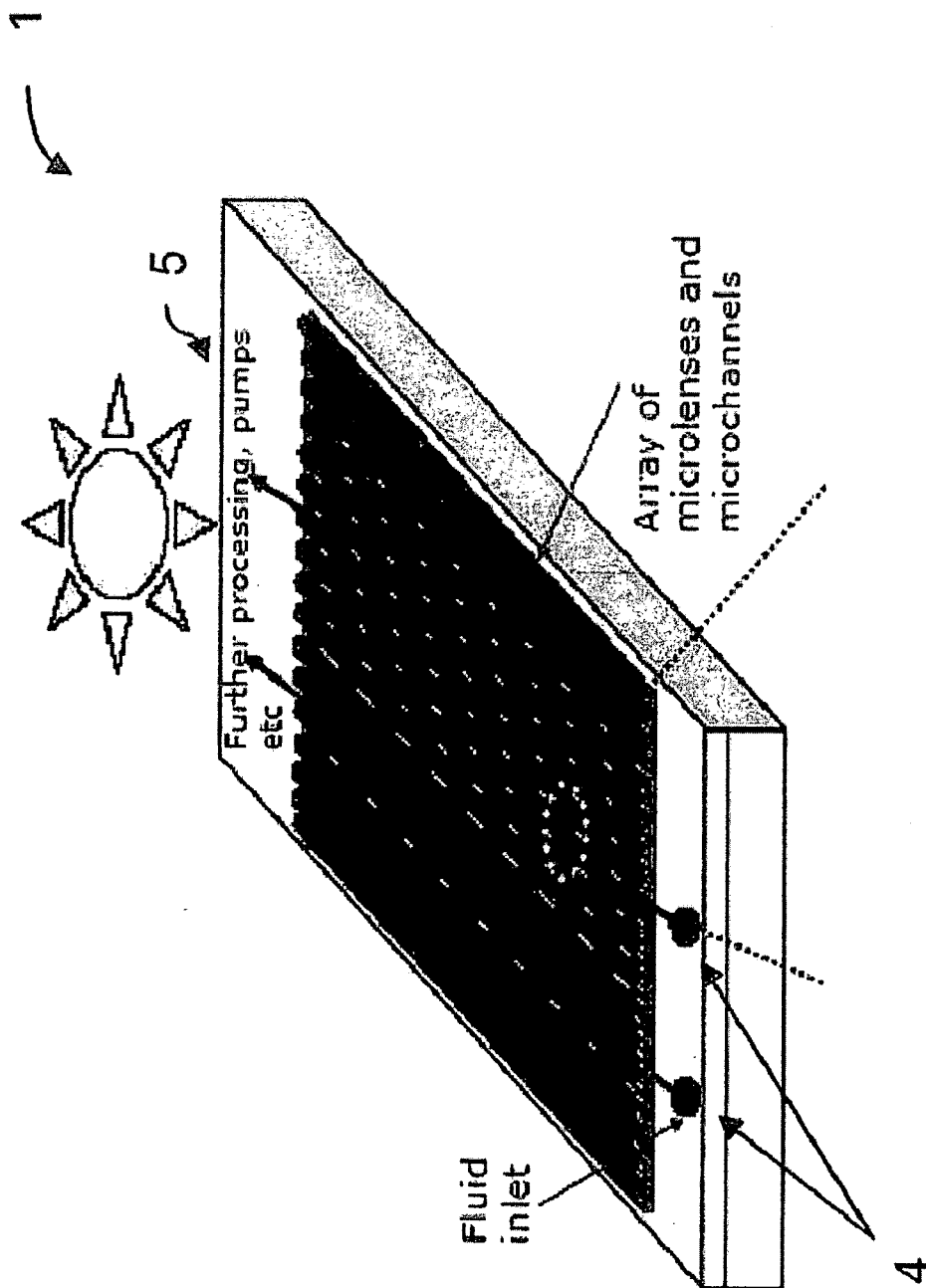


Figure 1

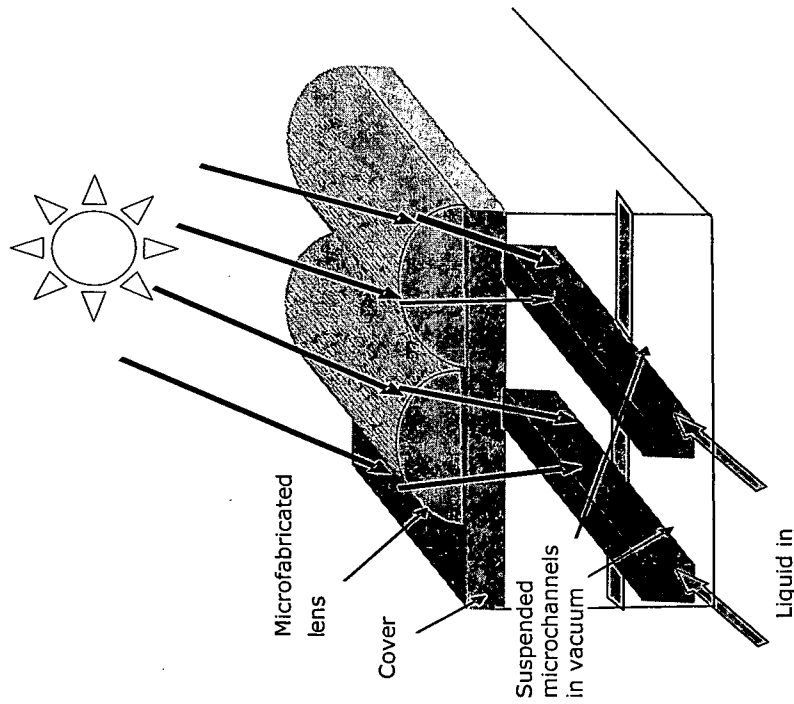


Figure 1a

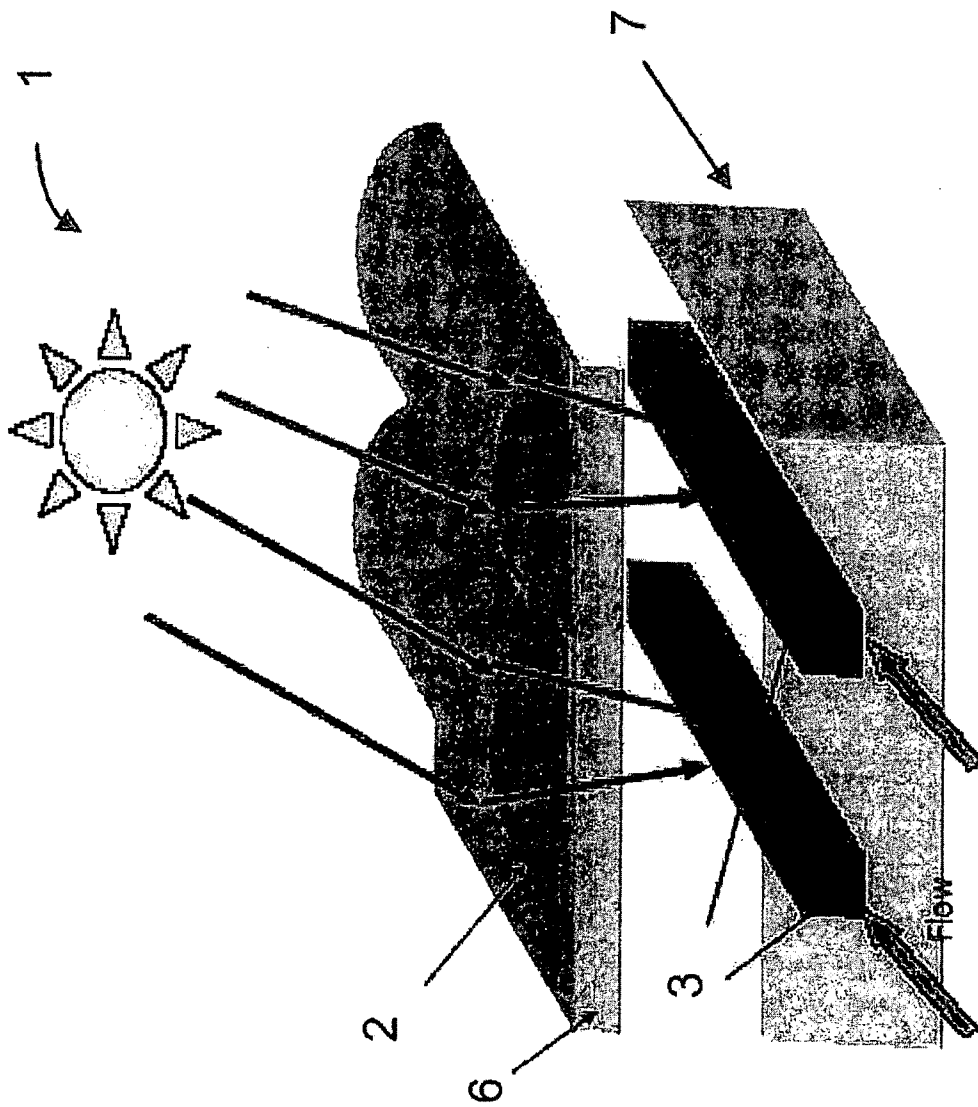


Figure 2

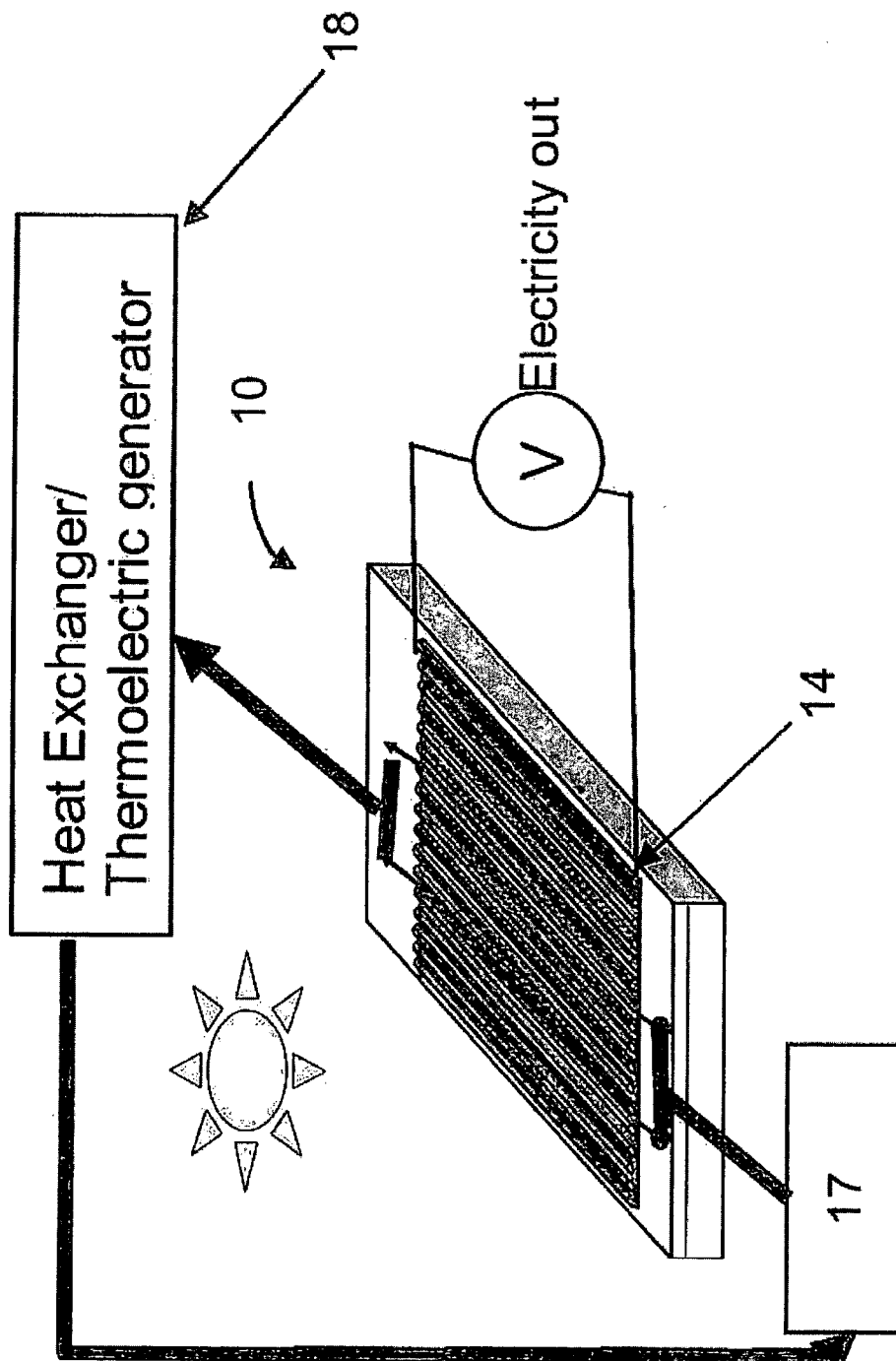


Figure 3

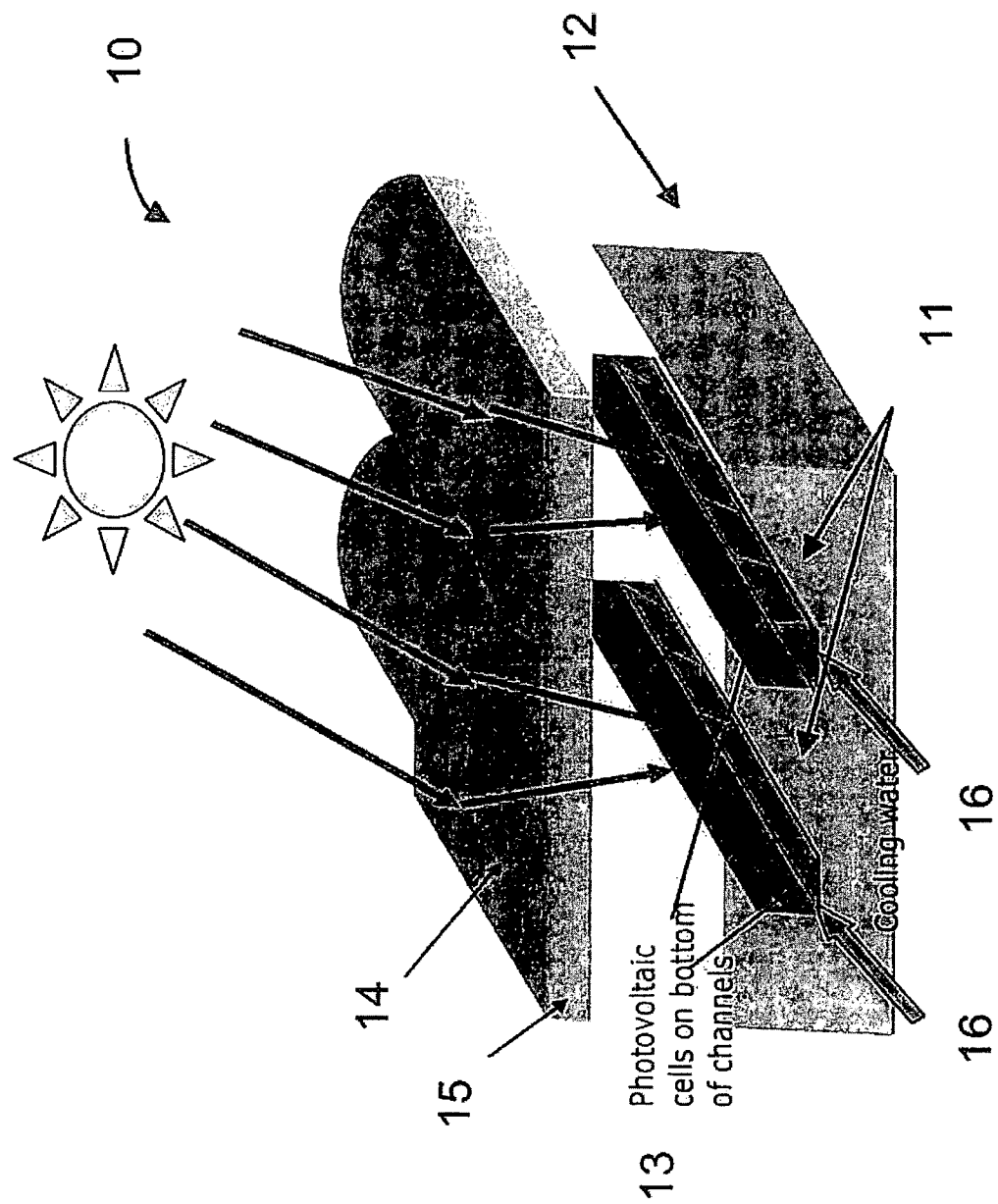


Figure 4

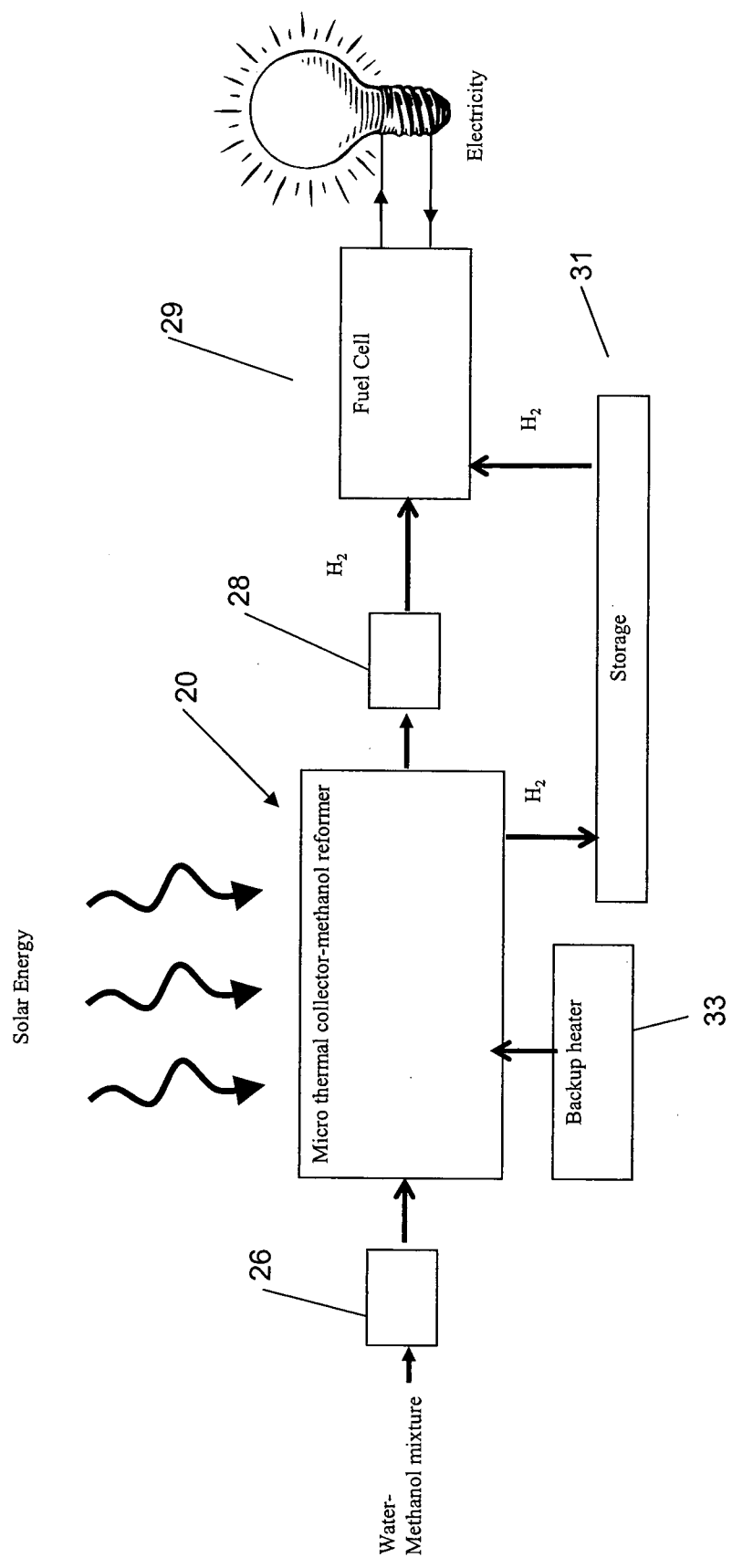


Figure 5

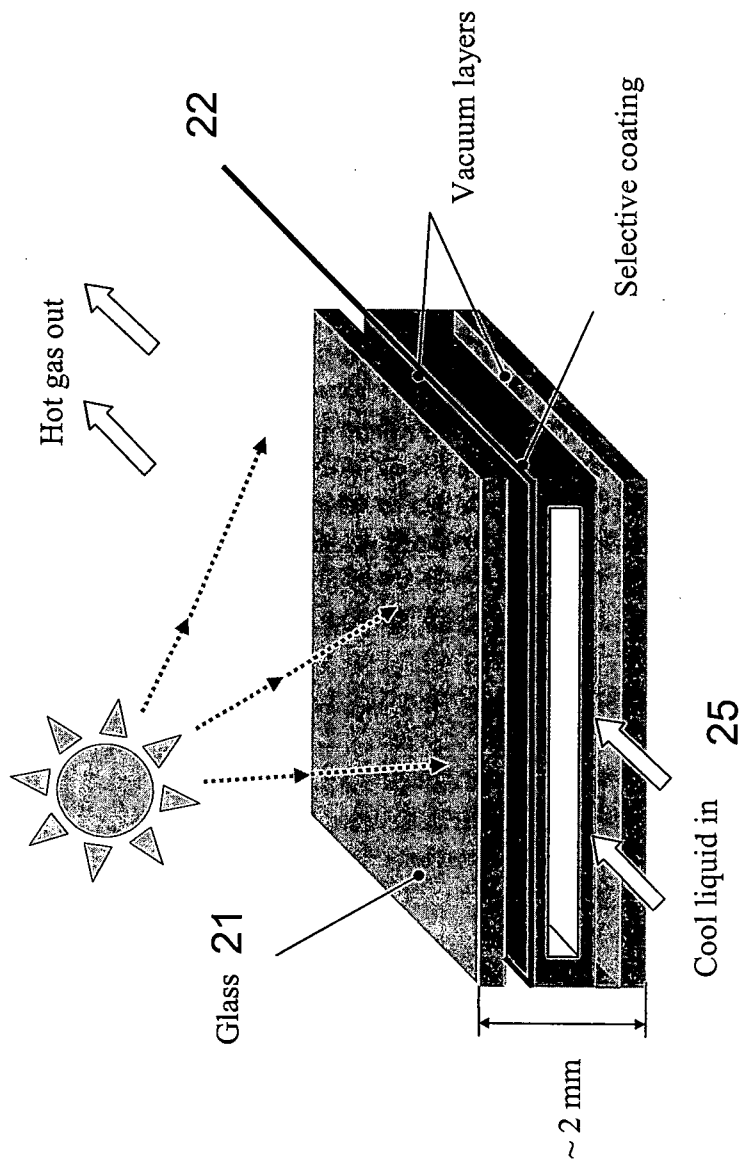


Figure 6a

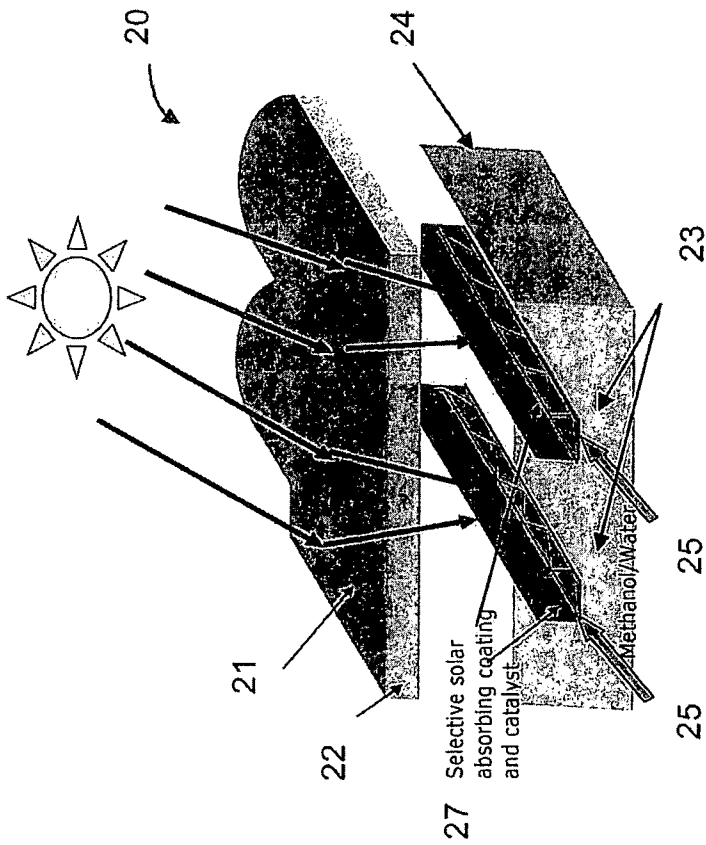
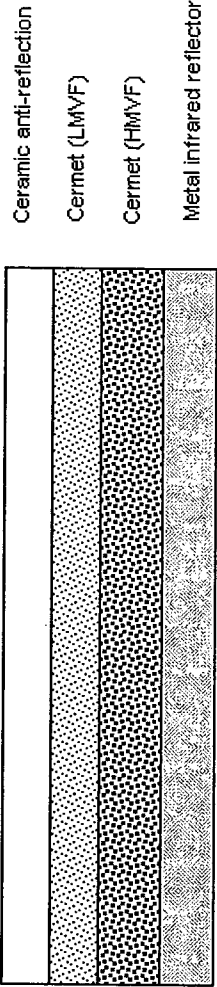


Figure 6b

Figure 6c



Ceramic anti-reflection
Cermet (LMVF)
Cermet (HMVF)
Metal infrared reflector

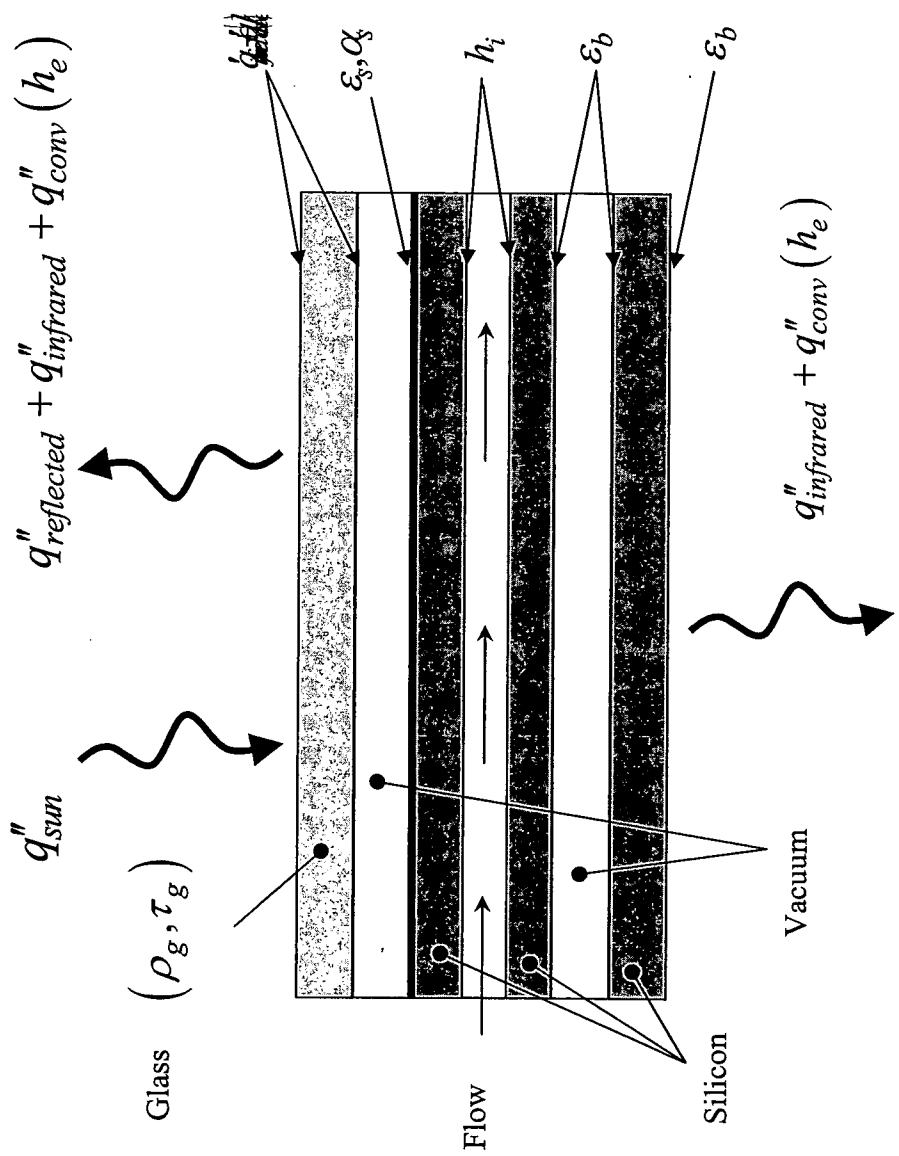


Figure 7

10/18

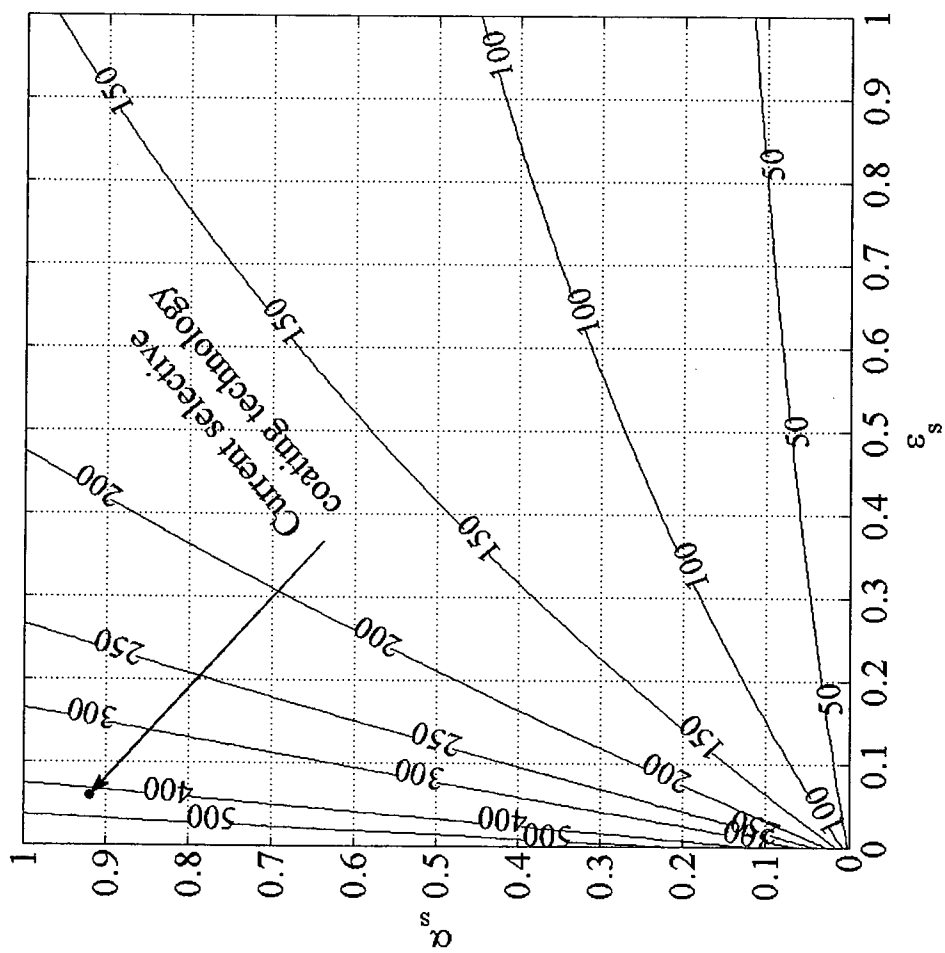


Figure 8

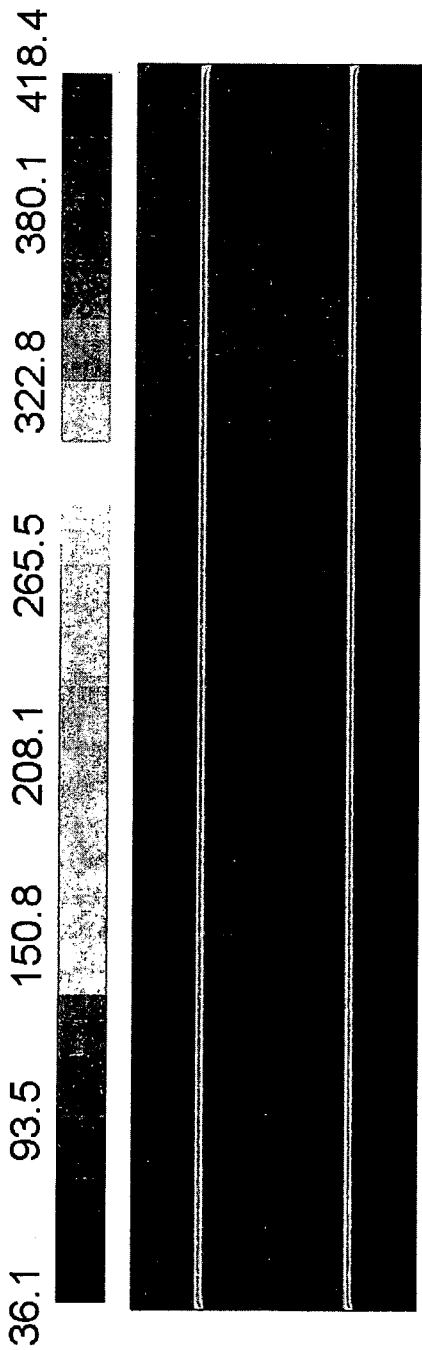


Figure 9

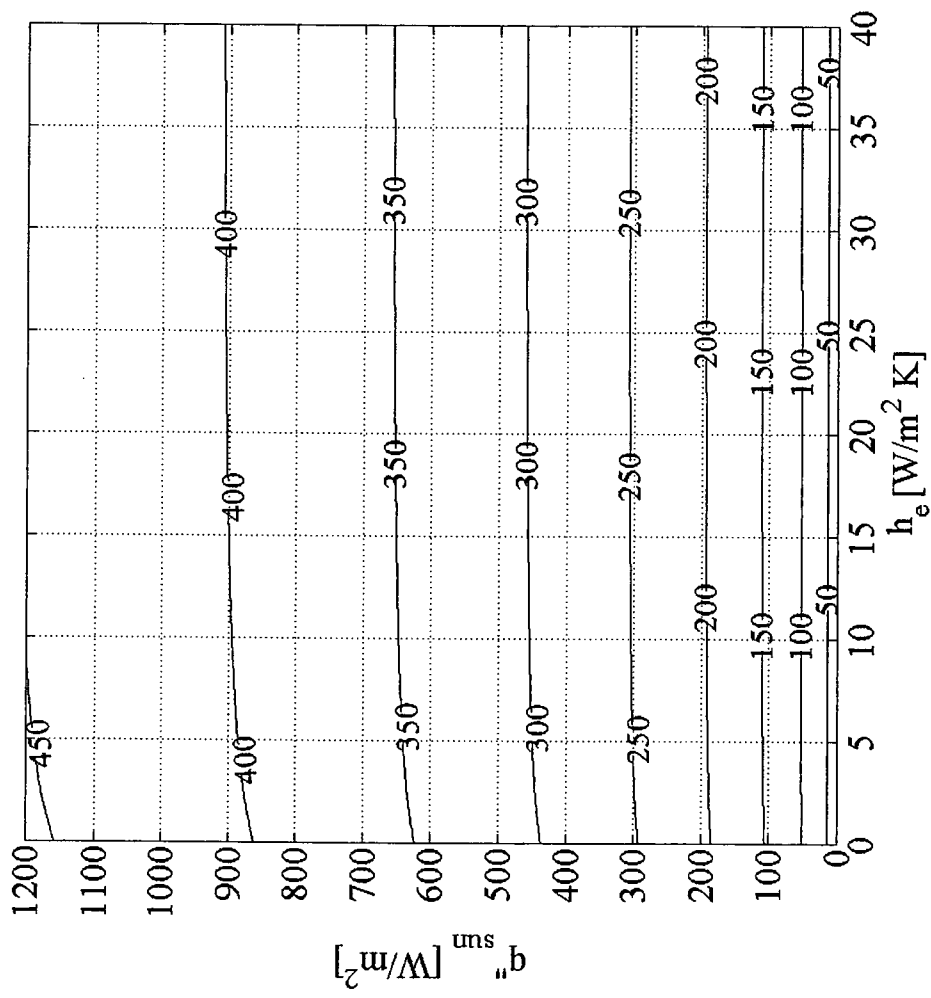


Figure 10

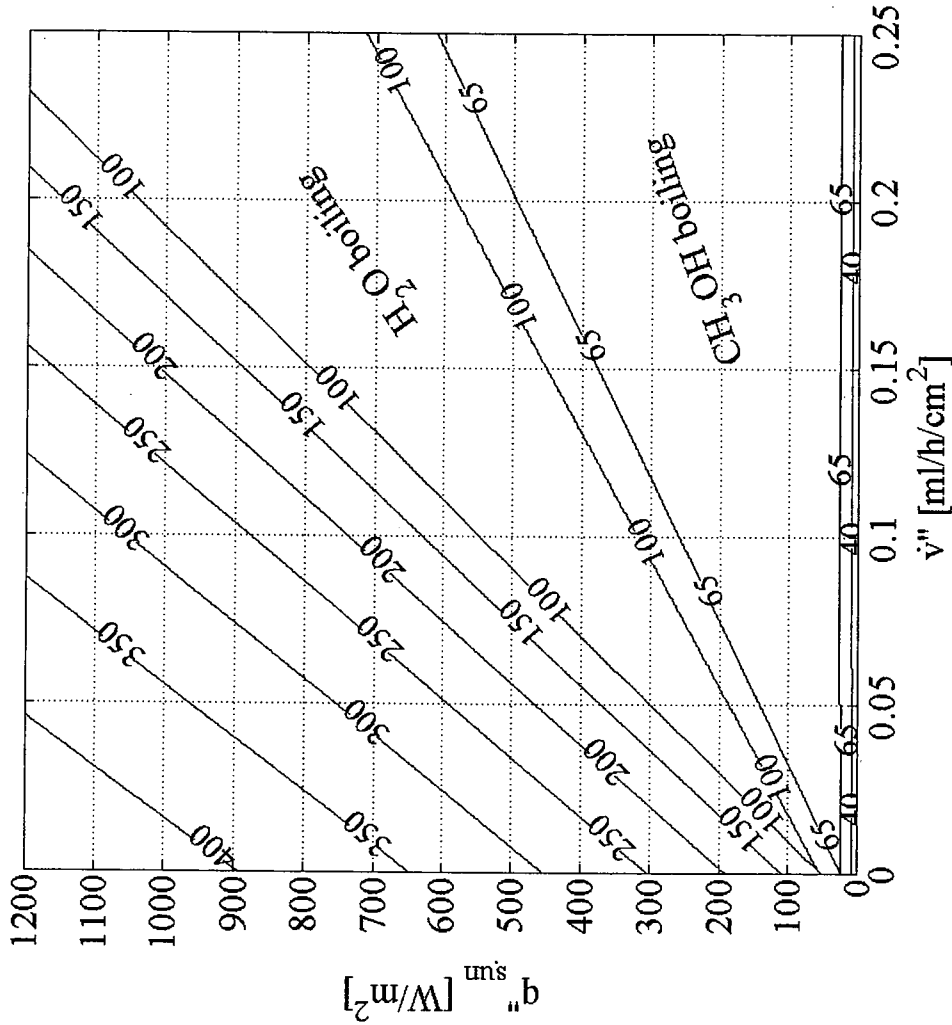


Figure 11

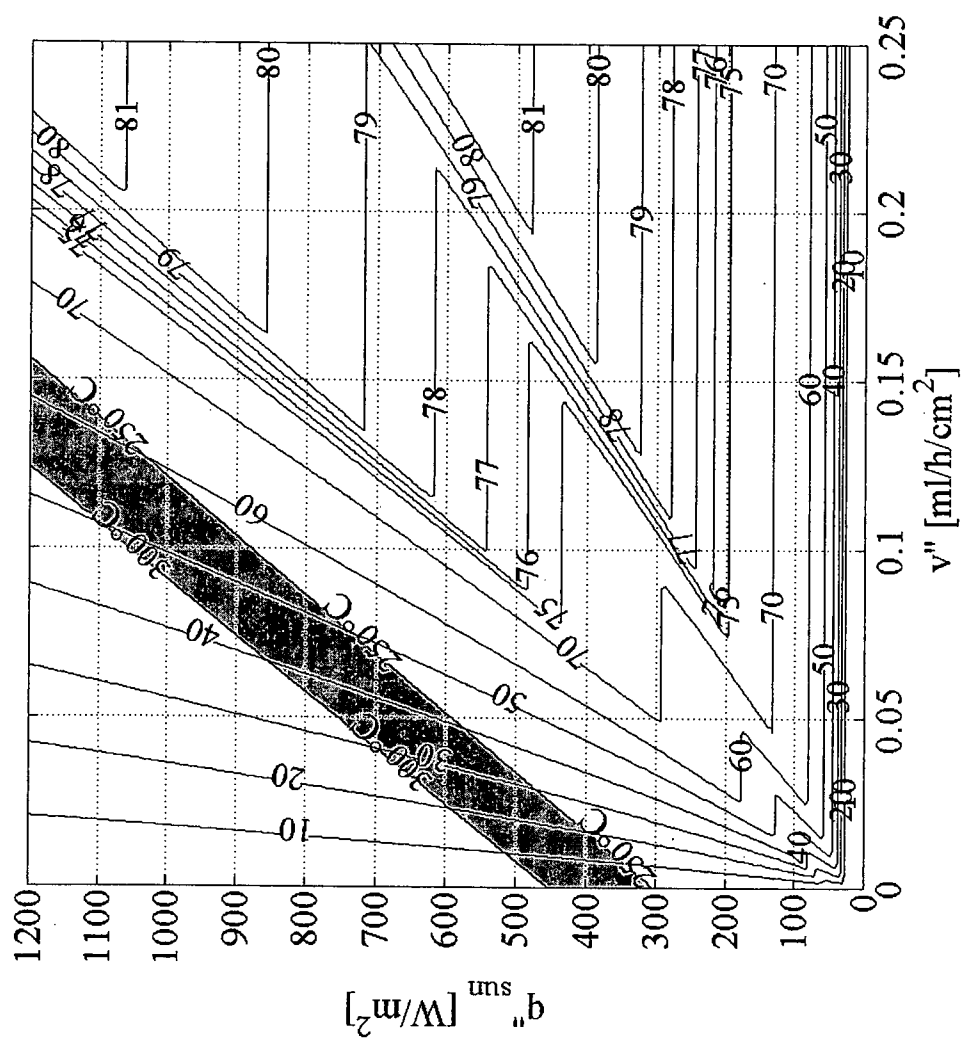


Figure 12

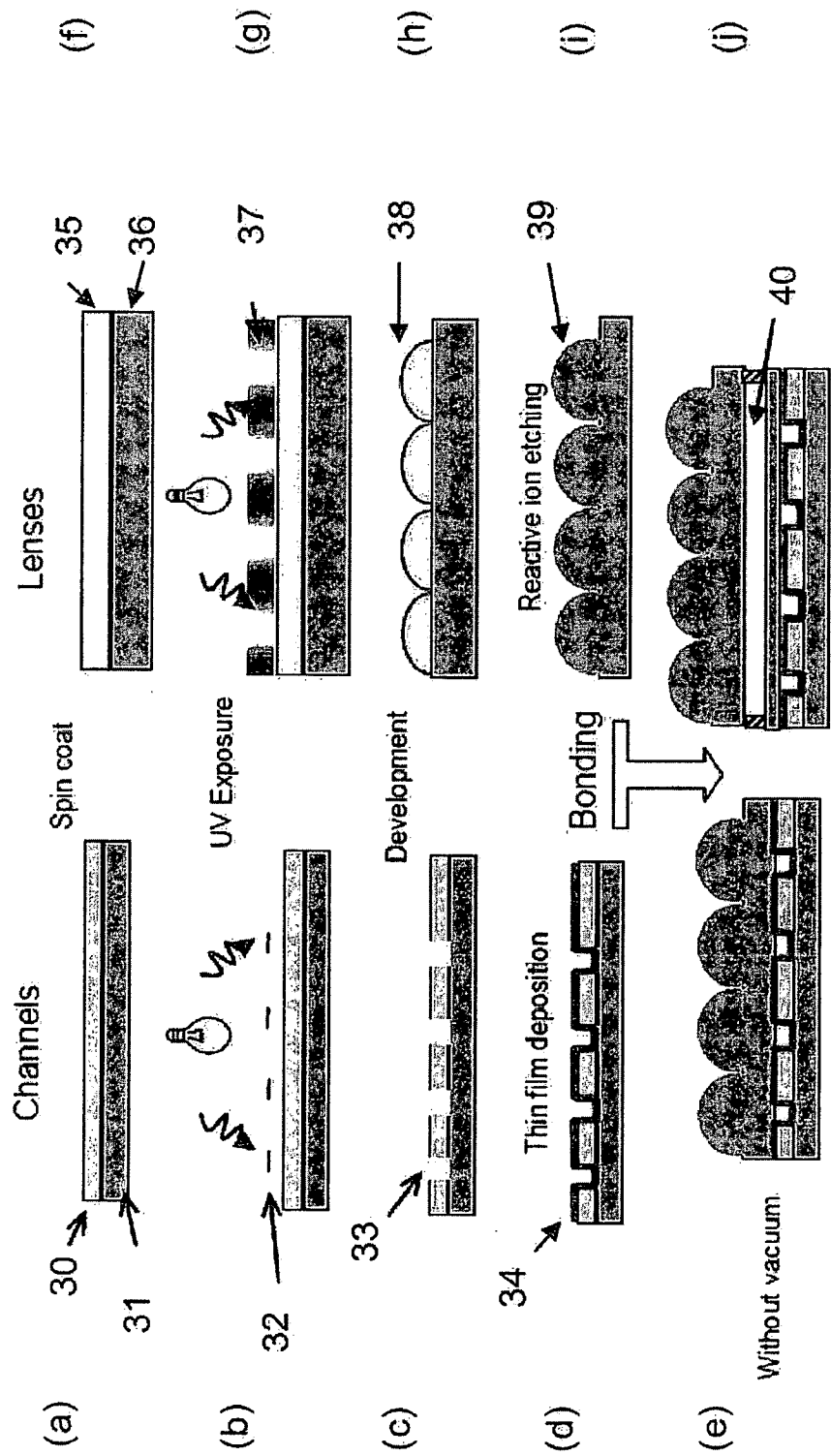


Figure 13

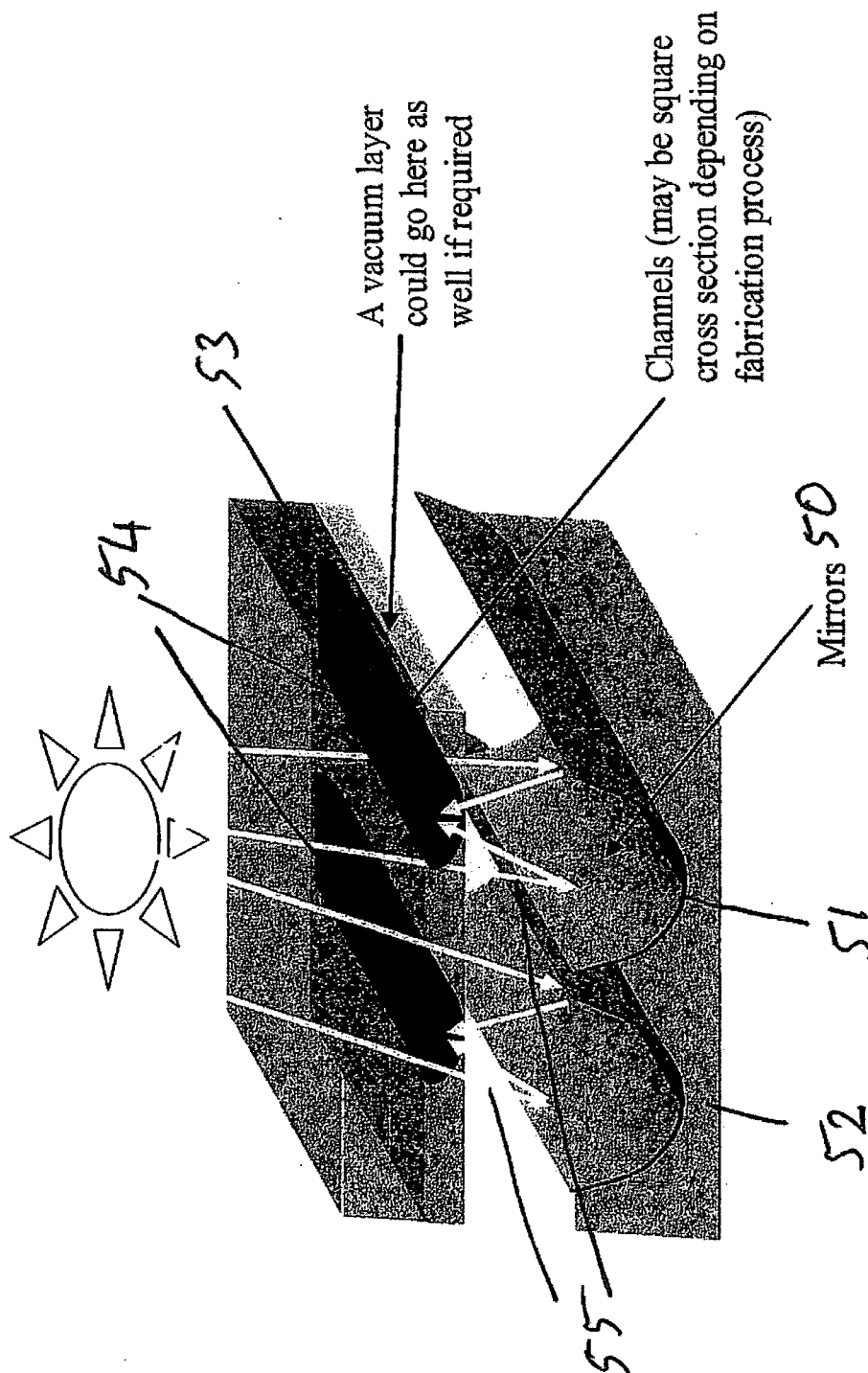


Figure 14

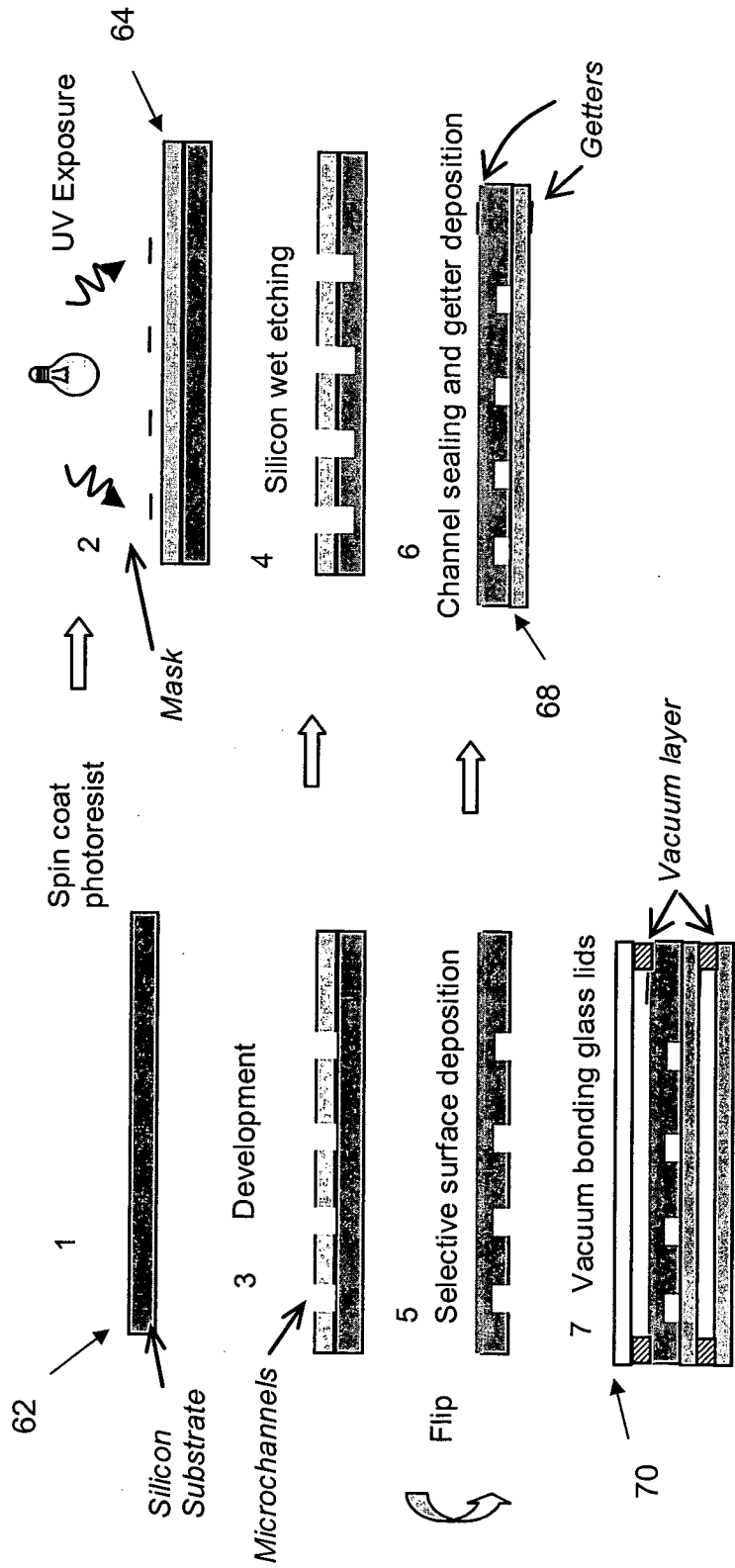


Figure 15

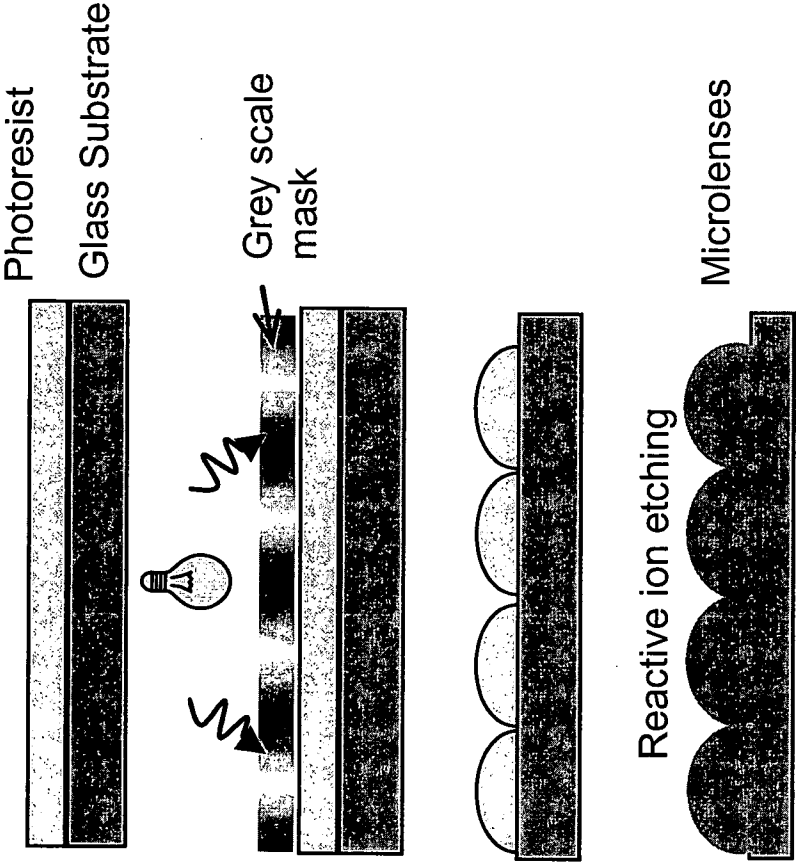


Figure 16

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/AU2008/000736
A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

C01B 3/32 (2006.01)**H01L 31/00** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWJP: limit /IC H01L or B01J-023/00 or C01B-003/00 & Keywords: (hydrogen or H₂), (production or form or generation), (methanol reformation), (catalyst or reactant or platinum or Pt or Cu or copper or Zinc oxide or ZnO or aluminium), (optic or light or solar or photo or sun or sunlight or beam or ray), (micro formation or channel or fluid or capillary or process or react or arrange or convert), (microchannel or microfluid), (concentrator or focus or converge or direct or lens or mirror or collect or reflect)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/0179980 A1 (PATTEKAR ET AL.) 16 September 2004 Paragraphs 0009, 0013, 0037, 0088, Figs. 15-16).	1-8, 10-15, 17-18, 22-23, 26-27, 30-31, 36-37, 45- 46 and 48-50
X	US 6930068 B2 (KANEKO ET AL.) 16 August 2005 Column 4, lines 40-59, column 5, lines 48-67, Fig. 3).	1-8, 10-15, 17-18, 22-23, 26-27, 30-31, 36-37, 45- 46 and 48-50
X	US 2001/0016188 A1 (HAGA ET AL.) 23 August 2001 Paragraphs 0079-0080, Fig. 5	1-8, 10-15, 17-18, 22-23, 26-27, 30-31, 36-37, 45- 46 and 48-50



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"E" earlier application or patent but published on or after the international filing date

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"O" document referring to an oral disclosure, use, exhibition or other means

"&"

document member of the same patent family

"P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search

26 August 2008

Date of mailing of the international search report

28 AUG 2008

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaustalia.gov.au
Facsimile No. +61 2 6283 7999

Authorized officer

JAYATI RAY

AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)

Telephone No : 6283 3654

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/000736

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/0112422 A1 (SPIVACK ET AL.) 17 June 2004 Paragraphs 0027-0032, Fig. 4	1-8, 10-12, 17-18, 26-27, 30-31, 36-37 and 45-46
X	JP 2002-252014 A (CASIO COMPUT CO LTD) 6 September 2002 Machine translation, retrieved 26 August 2008 from internet) < URL: http://www4.ipdl.inpit.go.jp/Tokujitu/PAJdetail.ipdl?N0000=60&N0120=01 &N2001=2&N3001=2002-252014 Paragraphs 0282-0285, Figs. 4, 40 and 41	1-8, 10-15, 17-18, 22-23, 26-27, 30-31, 36-37, 45- 46 and 48-50

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/000736

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-8, 10-12, 30-31, 36-37 and 45-46, are directed to a device and method of converting solar energy to facilitate a micro-process. The device comprises a micro-formation arrangement to hold a medium and an optical concentrator. This concept is not inventive in light of the following documents:

(i) US 2004/0112422 A1 (SPIVACK ET AL.) 17 June 2004

(ii) US 2003/0155003 A1 (TUR ET AL.) 21 August 2003

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
1-8, 10-15, 17-18, 22-23, 26-27, 30-31, 36-37, 45-46 and 48-50
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Supplemental Box I

(To be used when the space in any of Boxes I to IV is not sufficient)

Continuation of Box No: III

US 2004/0112422 disclose a solar cell device having a plurality of micro-channels. A plurality of micro-channels is formed in a semiconductor material. The micro channels are insulated and filled with a medium. The device further comprises a catalyst that is disposed in the micro channels (Abstract). The device comprises a plurality of micro-channels (abstract). The substrate comprises polymer or glass or ceramics. The citation fails to disclose an optical concentrator that is used to focus solar energy at the micro channels. However, the concept of using an optical concentrator (i.e. micro lens or cylindrical lens or spherical lens or mirrors) to focus incident solar energy is well known in the art.

US 2003/0155003 disclose a device of converting solar energy to facilitate micro-process. The device comprises an optical concentrator and heat micro-pipes. The heat micro-pipes containing a heat exchange material helps in transporting the heat energy to a cold area of the panels (Abstract).

Therefore, claims 1-8, 10-12, 30-31, 36-37 and 45-46, do not comprise any "special technical feature" as they do not make any contribution over the prior art.

2. Claims 13-15, 18, 22-23 and 48-50, are directed to a device and method of producing hydrogen. It is considered that the steps of focusing solar energy to a substrate containing methanol, water and providing a catalyst to promote the methanol reformation comprise a first "special technical feature".
3. Claims 16, 24-25 and 51-52 are directed to a device and method of promoting water decomposition. It is considered that the step of focusing solar energy to a photosensitive electrode adjacent to a micro-flow of water comprises a second "special technical feature".
4. Claims 19-21, 28-29, 38, 54-56 and 62 are directed to a device and method of generating electricity. It is considered that the step of focusing solar energy to a photovoltaic cell to generate electricity comprises a third "special technical feature".
5. Claims 17 and 26-27, are directed to a device and method of water and/ or air decontamination. It is considered that the step of focusing solar energy onto a substrate carrying a micro-flow of water and/ or air associated with a catalyst comprises a fourth "special technical feature".
6. Claims 9, 32-35, 39-44, 47, 57-61 and 63 are directed to a device of converting solar energy to facilitate a micro-process. It is considered the device that contains a micro-formation arrangement to hold a medium, an optical concentrator and a transparent cover comprises a fifth "special technical feature".

These groups are not so linked as to form a single general inventive concept, that is, they do not have any common inventive features, which define a contribution over the prior art. The common concept linking together these groups of claims is related to a device and method of converting solar energy to facilitate micro process. The device comprises a micro-formation arrangement to hold a medium and an optical concentrator. However this concept is not inventive in the light of the following patent documents (as discussed above):

(i) US 2004/0112422 A1 (SPIVACK ET AL.) 17 June 2004

(ii) US 2003/0155003 A1 (TUR ET AL.) 21 August 2003

Consequently the common features do not constitute "a special technical feature" within the meaning of PCT Rule 3.2, second sentence, since they make no contribution over the prior art. Since there exists no other common feature which can be considered as a special technical feature within the meaning of PCT Rule 13.2, second sentence, no technical relationship within the meaning of PCT Rule 13 between the different inventions can be seen. Therefore, a posteriori, the claims do not satisfy the requirement of unity of invention.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2008/000736

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
US	2004179980	NONE	
US	6930068	DE	10062578
US	2001016188	DE	10062662
US	2004112422	US	7078613
JP	2002252014	AU	16370/02
		CA	2403123
		CA	2593620
		CN	1460306
		EP	1354368
		HK	1061307
		JP	2002289211
		JP	2007200899
		MX	PA02009333
		RU	2002128629
		US	6916565
		US	2002106540
		WO	02056439
		AU	2002219596
		CA	2403244
		CA	2593782
		CN	1511354
		EP	1380063
		JP	2002216832
		JP	2003051333
		MX	PA02007810
		RU	2002125452
		US	6777118
		US	2002081468
		US	2005233189
		WO	02059993
		CA	2400624
		CA	2590609
		CN	1455977
		EP	1269602
		EP	1670089
		JP	2002280035
		JP	2003229158
		MX	PA02008712
		RU	2002127724
		US	6824905
		US	2002094462
		WO	0250934

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX