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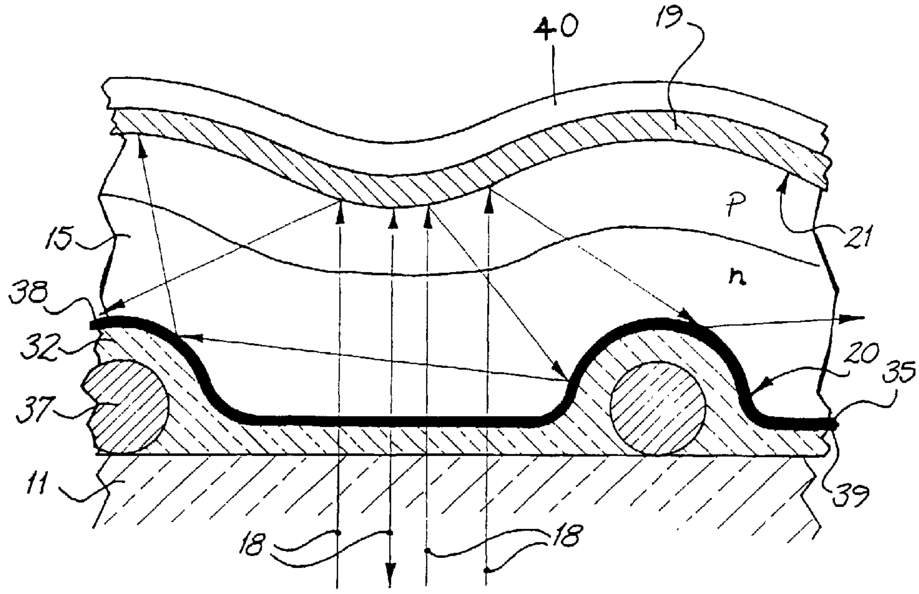
(54) Title: GLASS BEADS COATING PROCESS



(57) **Abstract:** A method of texturing a substrate or superstrate support material is provided, in which a thin textured film (32) is applied to the surface of the support material such as glass sheet (11). The dipping process is performed by loading a sheet (50) of the support material (11) into a frame (51) which provides a small number of small area contact points (52, 53) at which the sheet (50) is supported and lowering the frame (51) into texturing solution (59) comprising a mixture (59) of Sol-Gel (61) and texturing particles (62) comprising SiO_2 monospheres. The sheet is then withdrawn from the texturing solution and the resultant film allowed to dry. The film is then sintered and the resulting film provides a textured surface suitable for the formation of a photovoltaic device.

WO 03/019676 A1

Glass beads coating process

Introduction

The following invention relates generally to the field of photovoltaic device fabrication and in particular, the invention provides an improved method of texturing glass sheets used as substrates in thin film solar cell fabrication.

Background to the Invention

In the field of photovoltaic device manufacture, it has been long recognised that significant improvements in device efficiency are obtained if light can be internally reflected within the device such that its path length through the active region of the device is extended.

Techniques for extending the path length of light in the active region of the device are generally known as light trapping and usually involve texturing of the device surface.

In bulk material devices, the surface of the semiconductor material is directly textured by use of selective etching agents that etch certain crystal planes more rapidly than others, causing an angular or pyramidal surface profile.

It was generally thought that surface texturing would not be effective in thin film devices because traditional surface texturing is on a scale greater than film thickness of recent thin film devices, and because device film thicknesses are approaching the wavelength of light.

However, it has been found that surface texturing can be very effective in thin film devices provided that the scale of the texturing is less than the average film thickness but larger than the wavelength of light in the semiconductor material.

One effective method of achieving surface texturing on this scale is to texture the substrate before forming the semiconductor film in which the device is to be formed.

Texturing of the substrate can be by abrasion or etching but one effective method of texturing the substrate is by forming a textured film on the surface. The only effective methods previously identified for obtaining a uniform thin texture coating are spinning and chemical vapour deposition. These methods apply the textured film only to the surface of the substrate onto which the semiconductor layer will be deposited. It has always been considered that texturing the other surface of the substrate, which is to be exposed in use, would be detrimental to long term performance due to dust trapping and less effective cleaning when exposed to rain.

However, it has been found that with texturing of in the order of 1μm or below, the problem of dirt accumulation is not sufficiently significant to present a performance problem.

Texturing the exposed surface also reduces specular reflection which enhances appearance, particularly if variations exist in glass flatness over the area of a panel (eg, up to 1m^z), or between adjacent panels. Reduced reflection also reduces glare, which could be an aviation hazard when large installations or large numbers of small installations are located in an area under a flight path.

a Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

b Any description of prior art documents herein is not an admission that the documents form part of the common general knowledge of the relevant art in Australia.

c Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed in Australia before the priority date of each claim of this application.

Summary of the Invention

According to a first aspect, the present invention consists in a method of manufacturing a thin film photovoltaic device on a transparent sheet of substrate material, the method comprising the steps of

a) forming a textured film on two opposed surfaces of the substrate material by dipping the substrate in a container of film material in liquid form, removing the substrate material and hardening the liquid film material to form the textured film;

b) forming a thin film photovoltaic device on one of the textured films.

In one set of embodiments, a textured film is applied to the glass surface by mixing crushed quartz having particle dimensions in the order of 0.5-3μm and preferably in the order of 1-2μm into a glass sol, applying the mixture to the glass surface and heating to sinter the glass sol to form a dielectric layer. Note that the final feature dimension of the surface in this case includes quite small features, being determined largely by the surface roughness of the crushed quartz and the thickness of the dielectric layer, as well as the particle size of the quartz.

In preferred embodiments of the invention, the texturing of the substrate or superstrate is achieved by an SiO_2 layer which includes monospheric SiO_2 particles in the range of 0.1-2μm in diameter. Preferably, the monospherical particles are in the range of 0.5-0.9μm and in a particularly preferred embodiment, the particles are approximately 0.7μm (eg, 0.65-0.75μm). The particles are located in a smooth SiO_2 film having a thickness in the range of 0.2-0.8 times the diameter of the monospheric particles. Preferably, the SiO_2 layer is in the range of 0.35-0.5 times the particle diameter and in the particularly preferred embodiment, is approximately 0.3μm (eg, 0.25-0.35μm). The difference between particle dimension and film thickness results in a textured surface, however in this case the features can be more greatly spaced as they are larger. Both the SiO_2 particles and the film are made by a Sol-Gel process.

Note: all dimensions of monospheric SiO_2 particles and films throughout this specification are after sintering.

The SiO_2 layer also provides a barrier layer between the glass substrate and the silicon film. A separate barrier layer may also act as an anti-reflection layer and will be arranged to have a thickness equal to a quarter wavelength ± 20% which in the case of silicon nitride is 70 nm ± 20%.

The texturing process involves coating the surfaces to be textured with a sol-gel texturing solution in which the viscosity of the sol is quite low and is adjusted to allow the desired film thickness to be attained for the particular application. Film thickness is also determined to some extent by the speed at which the substrate material is pulled from the texturing solution.

The concentration of SiO_2 particles deposited on the substrate will vary according to the application, but generally, particles will be deposited in a single layer with each particle being separated by distances in the range of from 0 to 5 times the particle diameter and preferably in the range of 0 to 3 times the particle diameter. Particle separation is controlled by adjusting the concentration of particles in the texturing solution and to some extent by the speed of withdrawal from the solution and the humidity of the air.

The dipping of the substrate is preferably achieved by placing a of sheet of substrate material on a supporting frame such that the sheet is supported only at a few points (eg, 2 at the bottom and 2 at the top) lowering and retrieving the frame and supported sheet into a vessel of the texturing solution deep enough to allow the sheet of substrate material to be submerged. It will be appreciated that by using a larger vessel and by suitably adapting the supporting frame a plurality of sheets could be coated simultaneously if required.

The invention is applicable to both crystalline and amorphous silicon thin film solar cells. In the case of amorphous silicon cells, a transparent conducting layer is formed over the texturing film and a thin silicon film is formed over the transparent conducting layer, or alternatively the texturing film containing the texturing particles may itself be of conducting material.

In embodiments of the invention, the texturing layer preferably includes surface features having dimensions in a range from 0.5-0.2 times the thickness of the silicon film.

The silicon film is typically less than 5μm thick and preferably has a thickness of 2μm or less. The silicon film is typically at least 0.5μm or greater and preferably greater than 1μm. Typically, the scale of textured surface features is in the range of 0.01-10μm. The useful lower limit of the feature size is in the order of a wavelength of light in crystalline silicon and typically the useful lower limit is 0.03μm. The texturing may also include large scale features which have dimensions greater than the thickness of the silicon film, however these do not significantly alter the amount of light trapping achieved.

In typical embodiments of the invention the back surface of the silicon film structure (ie, remote from the glass) has a reflective material formed over it. Typically, the reflective material will be a metallisation structure used to contact the active regions of the cell. The metallisation structure will in some embodiments, be separated from most of the silicon back surface by an insulating layer.

Brief Descriptions of the Drawings

Embodiments of the invention will now be described by way of example, with reference to the accompanying drawings in which:

Figure 1 is a side view of a frame carrying a sheet of substrate awaiting dipping in a vessel of texturing solution;

Figures 2 and 3 are detailed sectional views of a sheet of substrate at the surface of the wet texturing film during withdrawal of the substrate from the texturing solution in the dipping process;

Figures 4 and 5 schematically illustrate two stages in the formation of a first embodiment of the invention in which a textured film is applied to the substrate;

Figures 6, 7 and 8 schematically illustrate three stages in the formation of a second embodiment of the invention in which a different textured film is applied to the substrate;

Figure 9 is a photograph of a textured surface in accordance with the method described with reference to Figures 6, 7 and 8;

Figure 10 is a photograph of a section through a device manufactured by the method described with reference to Figures 6, 7 and 8;

Figure 11 is a sectional side view of a glass substrate with a textured dielectric (SiO_2) layer and a thin film of silicon formed over its surface, illustrating representative paths of incident photons through the glass substrate, the texturing layer and the silicon layer;

Detailed Description of Embodiments of the Invention

Referring to Figures 1, 2 & 3, embodiments of the present invention employ a dipping process to apply a thin textured film 32 to the surface of a glass substrate 11. The dipping process is performed by loading a sheet 50 of the substrate 11 into a frame 51 which provides a small number of small area contact points 52, 53 at which the sheet 50 is supported. The lower contact points 52 are provided on a pair of parallel, horizontal rods 54 which are provided with locating projections 55 to prevent lateral movement of the sheet of substrate 50, while the upper contact points 53 are tapered members against which the sheet 50 leans.

Suspension loops 57 are provided on an upper member of the frame 51, for the attachment of cables for lifting and lowering the frame. After it is loaded with a sheet 50, the frame 51 is lowered into a vessel 58 containing a texturing solution 59 comprising a mixture 59 of Sol-Gel 61 and texturing particles 62. The texturing particles are preferably SiO_2 monospheres.

The depth of the texturing solution 59 in the vessel 58 is sufficiently deep to enable the sheets 50 on the frame 51 to be entirely submerged in the texturing solution when the frame 51 is lowered into the vessel 58. Once the sheet of substrate material 50 is completely submerged and its surfaces wetted with texturing solution, the frame is lifted from the vessel at a controlled rate such that the texturing solution runs from the surfaces of the sheet 50 leaving only a thin film 32 embedded with texturing particles 37 on the surface of the substrate 11. Jets of Nitrogen gas located a few centimetres above the surface of the texturing solution in the vessel can be used to speed the drying process, which takes only a few seconds. A detailed sectional view of the interface between an upper surface of a sheet 50 of substitute material 11 and the surface of the texturing solution 59, during lifting of the frame 51, is illustrated in figure 2 in which the substrate 11 is moving in the direction of arrow A and the texturing solution 59 is draining in the direction of arrow B.

Figure 3, similarly shows the interface at the undersurface of the sheet 50 of substrate material 11 when the substrate material is moving in direction A and the Sol-Gel mixture 59 is draining in direction C.

Once the textured Sol-Gel film 32 has been coated on the surfaces of the sheet 50, the film is sintered to harden the film. Typically the sheet is hardened by passing it through a belt furnace operating at a temperature of close to the maximum that can be tolerated by the sheet, which for glass substrate is 300^0C - 600^0C for a period of in the order of two minutes. Alternatively, sintering may occur as the sheet is heated to the deposition temperature for a following step which in this case will be the deposition of the anti-reflection coating and silicon film.

Referring to Figures 4 and 6, as a result of the coating process described above, the glass substrate 11 is given a texturing layer 32 on each surface comprising an SiO_2 film 33 mixed with texturing particles 34 having diameters in the order of 1-2μm whereby a textured surface 39 is formed. The SiO_2 film 33 is thinner than the average diameter of the texturing particles 34, 37 such that the texturing particles 34, 37 cause the surface of the SiO2 film to undulate over the particles. In the case of Figure 4, the texturing particles 34 are particles of crushed quartz whereas in Figure 6 the texturing particles 37 are silicon dioxide monospheres.

The dielectric layer in this case provides a barrier layer function, however, a separate anti-reflection coating 38 will normally be employed, having an upper surface 35 which is conformal with the textured surface 39. As illustrated in Figure 5, a silicon film 15 is then formed over the textured surface

35 of the anti-reflection coating 38. The silicon film has a thickness preferably in the range of 0.5-2μm (ie, of similar thickness to the dimensions of the texture features provided on the surface of the SiO_2 layer). Although the silicon film produced by this method loosely conforms to the textured surface over which it is formed, the opposite surfaces of the film are substantially non-parallel, at least on a small scale such that light will generally traverse the silicon film at an angle to the silicon surface.

More importantly, the light will more often than not strike the rear surface of the silicon film (upper surface, in Figures 4 and 5) at a significant angle to the normal to the surface 36, such that for a significant number of incidences, total internal reflection will occur. The surface 36 may also be coated with a reflective material 39 (such as a rear metal contact) to assist in reflecting internal light striking this surface.

Referring to Figures 6, 7 and 8, another embodiment is illustrated in which a layer 32 of SiO_2 33 is applied to the surface of the substrate 11, the SiO_2 layer 32 including SiO_2 monospheres 37 which result in a textured surface of the layer 32.

The steps for forming the embodiment of Figures 6, 7 and 8, include forming an SiO_2 Sol by the Sol-Gel process, in which monosphere particles of SiO_2 are formed in the SiO_2 sol during its preparation and the SiO_2 sol is applied to a substrate or superstrate 11 such that the resulting SiO_2 layer 32 produces a textured surface 39 for thin film solar cell fabrication. An anti-reflective coating 38 having an upper surface 35 will normally also be applied. In the preferred embodiment, the SiO_2 layer 32 includes monospheric SiO_2 particles 37 of approximate 0.7μm diameter and a smooth SiO_2 film 32 of approximate 0.3μm thickness which covers the SiO_2 particles 37. The difference between particle dimension and film thickness results in a textured surface. However, particles in the range from 0.5-2μm can be used with SiO_2 film thicknesses in the range 0.2-0.8 times the monosphere diameter.

Referring to Figure 7, when a silicon film 15 is in the process of being deposited over the textured surface 35 of the barrier layer 38, using a formation method such as Chemical Vapour Deposition (CVD), the film will grow simultaneously from all points on the surface at a substantially constant rate in a direction normal to the surface at the respective points. This results in a film similar to that shown in Figure 8, where small relatively sparse texturing features on the surface of the substrate (ie, on surface 35) result in larger features which merge into one another on the opposite surface 36 of the silicon film. This structure provides a significant non-parallelism between the surfaces of the silicon film and produces good light trapping when the film is illuminated through the substrate. Note also that this approach is useful for amorphous silicon devices, and crystalline silicon devices both when the crystalline structure is formed directly and when the crystalline structure is formed by crystallising amorphous silicon (eg; by solid phase crystallisation).

Finally, after the silicon has been formed and any processing required to be performed over the entire silicon layer has been completed, such as the formation of a dielectric layer 19, a metal layer 40 is applied over the silicon surface 36 to provide a back reflector and to be processed into contacts for contacting to the semiconductor device formed in the silicon film. The dielectric layer 19 is located between the silicon 15 and the metal layer 40 in order to isolate the metal from the upper region of the semiconductor film such that portions of the metal can be connected through to the lower region of the semiconductor film without shorting the junction.

Both the SiO_2 particles 37 and film 33 in which they are applied, are made by a Sol-Gel process. The Sol-Gel process involves mixing a metal organic compound with water acting as a hydrolysis agent and alcohol as the solvent. The metal organic compound reacts with water in the solution to form a metal oxide polymer. Sizes of the polymer particles depend on the pH value of the solution. The solution after reaction is called a Sol. The sol transits to a Gel when the solvent evaporates. Further sintering makes the Gel become a rigid metal oxide (ie, an SiO_2 dielectric layer).

The Sol-Gel process has certain advantages, such as high purity, well-controlled concentration and simple formation. These advantages determine that the process has wide applications. For example, the Sol-Gel process known as Spin-On Glass (SOG) has been used in the semiconductor industry for years. However, usually it would not be desirable to produce a gel which contained particles of any significant size, as in the present case.

Among metal oxides formed by the Sol-Gel process, SiO_2 sol has been applied in various industries. In the semiconductor industry, SiO_2 layers formed by this process have been used to form a dielectric layer and a planarisation layer. It can also be used to form a doping source if dopant is added into the SiO_2 sol. The SiO_2 film has also been used as an anti-reflection layer, barrier layer, strengthening layer, chemical resistant layer and so on.

As mentioned above, the size of the polymer particles 37 can be adjusted by the pH value of the solution. Generally speaking, as the pH value of the solution is decreased below 7, the particle size decreases to values which can become less than 100 nm. Most Spin-On Glasses behave in this manner. As the pH is increased to values greater than 7, the particle size increases to values which can be more than 1.0μm.

This embodiment has significant advantages even over other desirable embodiments of the invention, as follows:

i) The SiO_2 particle can be made monosize and monoshape (spherical). Therefore, together with the SiO_2 film, the texture made can be very smooth and uniform in terms of height of the texture features. This feature is important for fabrication of high efficiency thin film solar cells because it reduces any sharp grooves/cracks, and thus reduces shunting problems without further processing of the texturing.

ii) Instead of creating flaws at the glass surface by chemical texturing or sand blasting, the Sol-Gel texture layer actually fills the flaws so that the glass may be strengthened after texturing;

iii) The Sol-Gel texture provides an extra barrier layer to impede the migration of impurities from glass to Si film;

iv) The texture can be subjected to very high temperature *(eg, up to Si melting point)*, without causing damage to the texture features because the texture is made by SiO_2 which has a higher softening point than the glass substrate;

v) It is an environmentally friendly process. The only potentially problematic step is the possible release of ethanol to the atmosphere during processing, although it would be a relatively simple matter to recycle the ethanol. Chemical texturing, by comparison, will produce vast quantities of HF waste;

vi) The process of applying the texture layer is not difficult to scale up;

vii) The Sol-Gel process costs less than chemical texturing if the cost of waste treatment is included in the cost of chemical texturing;

viii) By coating both surfaces of the glass, the upper surface in use (the non-active surface) is significantly less specular, providing improved appearance and reduced glare. Surface irregularities and misalignments are less noticeable;

ix) Spectral response of solar cells is improved;

x) By coating both surfaces of the glass, thermal stress effects are reduced.

Illustrated in Figure 11, is a sectional view of an embodiment similar to that of Figures 6 to 8, in which are shown photons of light which enter or exit the silicon film 15 along paths 18 through the substrate and are reflected within the silicon film 15, between the lower dielectric / silicon interface 20 (or anti-reflection layer/silicon interface) and the upper silicon / dielectric interface 21 or the surface of the metal (back contact) 19, several times, thereby increasing the conversion efficiency of a photovoltaic cell formed in the thin silicon film.

The present invention may also be applied to amorphous silicon cells in which case the conventional processing steps for manufacture of amorphous cells would be amended as follows:-

1) to the surface of a glass substrate or superstrate, apply a texturing layer comprising texturing particles bound in a transparent conducting oxide (TCO) matrix. The transparent conducting material can be applied by a dipped Sol-Gel process and the texturing particles may be SiO_2 beads, crushed quartz or particles of the TCO material itself;

2) form an amorphous silicon film over the TCO matrix,

or alternatively:

1) to the surface of a glass substrate or superstrate, apply a texturing layer comprising texturing particles bound in an SiO_2 matrix, as described with reference to figures 4 to 8 above;

2) form a TCO film over the SiO_2 matrix;

3) form an amorphous silicon film over the TCO film.

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 invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:

1. A method of manufacturing a thin film photovoltaic device on a transparent sheet of substrate or superstrate support material, the method comprising the steps of

a) forming a textured film on two opposed surfaces of the support material by dipping the support material in a container of film material in liquid form, removing the support material and hardening the liquid film material to form the textured film;

b) forming a thin film of semiconductor material on one of the textured films and forming a photovoltaic device into the thin film of semiconductor material.

2. The method of claim 1, wherein the textured film is an SiO_2 layer which includes monospheric SiO_2 particles located in a smooth SiO_2 film.

3. The method of claim 2, wherein the monospherical particles are in the range of 0.1-2μm in diameter, after hardening.

4. The method of claim 2, wherein the monospherical particles are in the range of 0.5-0.9μm in diameter, after hardening.

5. The method of claim 2, wherein the monospherical particles are in the range of 0.65-0.75μmin diameter, after hardening.

6. The method as claimed in any one of claims 2 to 5, wherein the smooth SiO_2 film has a thickness in the range of 0.2-0.8 times the diameter of the monospheric particles, after hardening.

7. The method of claim 6, wherein the SiO_2 film is in the range of 0.35-0.5 times the particle diameter, after hardening.

8. The method of claim 6, wherein the SiO_2 layer is in the range of 0.25-0.35μm, after hardening.

9. The method as claimed in any one of claims 1 to 8, wherein the hardening step comprises sintering the textured film at a temperature in the range of 300^0C - 600^0C.

10. The method as claimed in any one of claims 1 to 9, wherein a separate anti-reflection layer is located between the textured film and the semiconductor film to act as a barrier layer.

11. The method of claim 10, wherein the separate anti-reflection layer has a thickness equal to a quarter wavelength ± 20%.

12. The method of claim 10 or 11, wherein the semiconductor film is silicon, the separate anti-reflection layer is silicon nitride, and the silicon nitride layer thickness is 70 nm ± 20%.

13. The method of claim 1, wherein a textured film is applied to the surface support material by mixing crushed quartz into a glass sol, applying the mixture to the surface substrate of the support material and heating to sinter the glass sol to form a dielectric layer.

14. The method of claim 2, wherein the crushed quartz has particle dimensions in the order of 0.5-3μm

15. The method of claim 2, wherein the crushed quartz has particle dimensions in the order of1-2μm.

16. The method as claimed in any one of claims 1 to 12, wherein the textured film is formed by coating the surfaces to be textured with a sol-gel texturing solution

17. The method of claim 16, wherein sol-gel texturing solution has a low viscosity which is adjusted to allow the desired film thickness to be attained for the particular application.

18. The method of claim 16 or 17, wherein film thickness of the SiO_2 layer is determined by the speed at which the substrate material is pulled from the texturing solution.

19. The method as claimed in any one of claims 2 to 12, or 16 to 18, wherein the SiO_2 particles deposited on the substrate are deposited in a single layer with each particle being separated from surrounding particles by distances in the range of from 0 to 5 times the particle diameter.

20. The method of claim 19, wherein each particle is separated from surrounding particles by distances in the range of 0 to 3 times the particle diameter.

21. The method of claim 20, wherein particle separation is controlled by adjusting the concentration of particles in the texturing solution.

22. The method of claim 19, 20 or 21, wherein particle separation is controlled by the speed of withdrawal from the solution.

23. The method of claim 19, 20, 21 or 22, wherein particle separation is controlled by the humidity of air in which the film is dried.

24. The method as claimed in any one of claims 1 to 23, wherein the dipping of the support material is achieved by placing a sheet of support material on a supporting frame such that the sheet is supported at a plurality of points,

lowering and retrieving the frame and supported sheet into a vessel of the texturing solution deep enough to allow the sheet of support material to be submerged.

25. The method of claim 24, wherein the sheet is supported at only 4 points.

26. The method as claimed in any one of claims 1 to 25, wherein the thin film photovoltaic device is a crystalline silicon thin film solar cell.

27. The method as claimed in any one of claims 1 to 25, wherein the thin film photovoltaic device is a amorphous silicon thin film solar cell.

28. The method of claim 27, wherein a transparent conducting layer is formed over the textured film and a thin silicon film is formed over the transparent conducting layer.

29. The method of claim 27, wherein the texturing film containing the texturing particles is a transparent conducting layer.

30. The method of claim 26, 27, 28 or 29, wherein the scale of textured surface features is in the range of 0.01-10μm.

31. The method of claim 30, wherein the lower limit of the feature size is in the order of a wavelength of light in crystalline silicon.

32. The method of claim 30, wherein the lower limit of the feature size is in the order of 0.03μm.

33. The method of claim 30, 31 or 32, wherein the texturing includes large scale features which have dimensions greater than the thickness of the silicon film.

34. The method of claim 30, 31, 32 or 33, wherein the texturing layer includes surface features having a scale in a range from 0.5-0.2 times the thickness of the silicon film.

35. The method of claim 26, 27, 28, 29, 30, 31, 32, 33 or 34, wherein the thickness of the silicon film is less than 5μm.

36. The method of claim 35, wherein the thickness of the silicon film is 2μm or less.

37. The method of claim 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 or 36, wherein the thickness of the silicon film is at least 0.5μm or greater.

38. The method of claim 37, wherein the thickness of the silicon film is greater than 1μm.

39. The method as claimed in any one of claims 26 to 29, wherein the surface of the silicon film remote from the support material has a reflective material formed over it.

40. The method of claim 39, wherein the reflective material is a metallisation structure used to contact active regions of the cell.

41. The method of claim 40, wherein the metallisation structure is separated from a majority of a back surface of the silicon by an insulating layer.

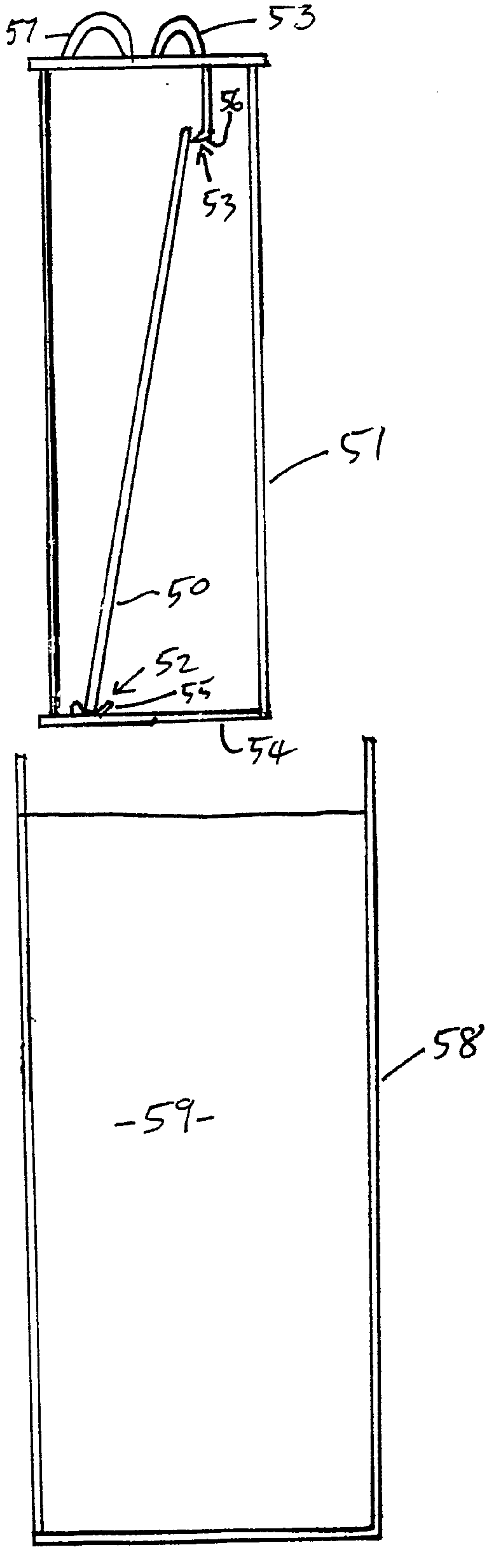


Figure 1

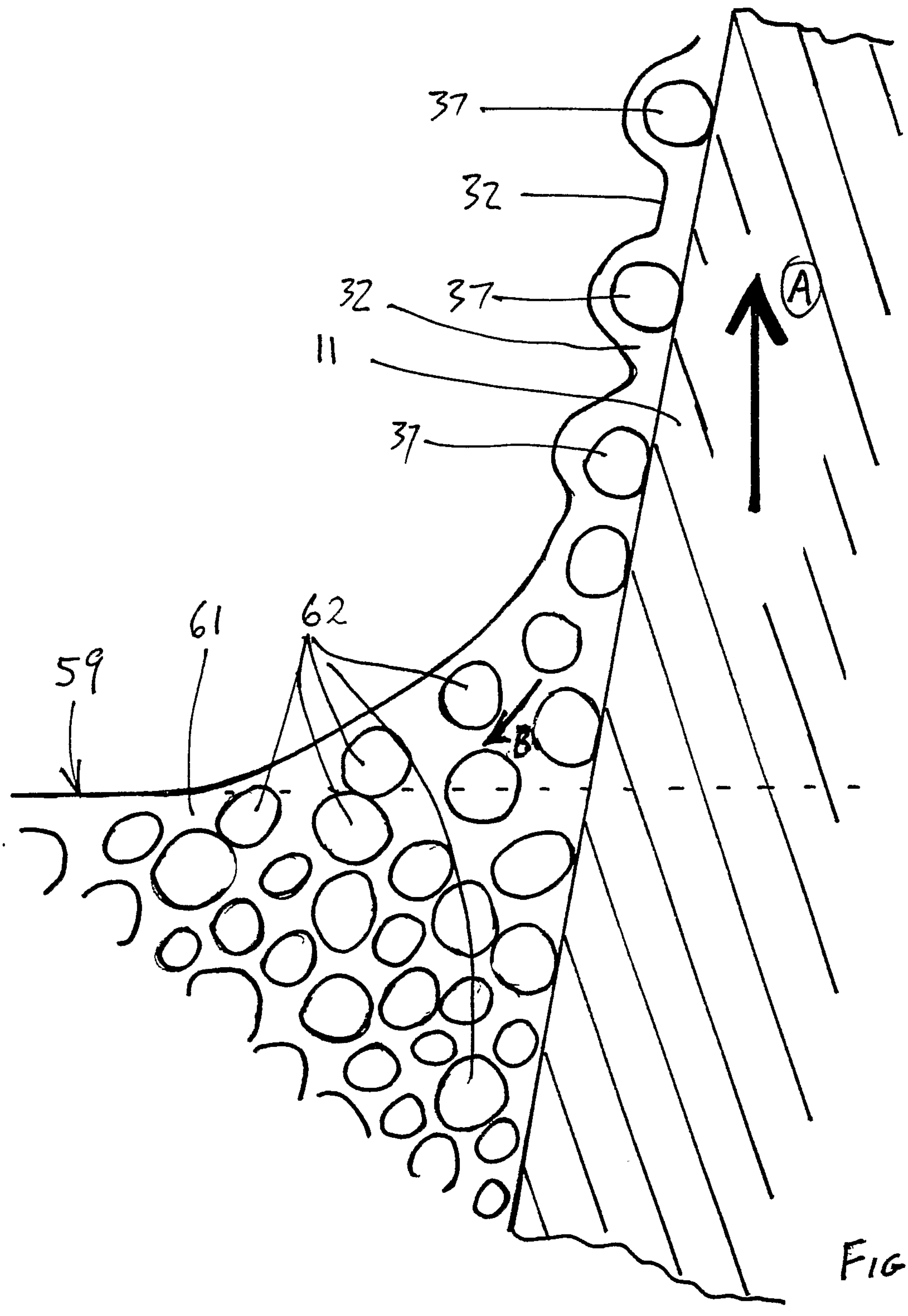


FIGURE 2

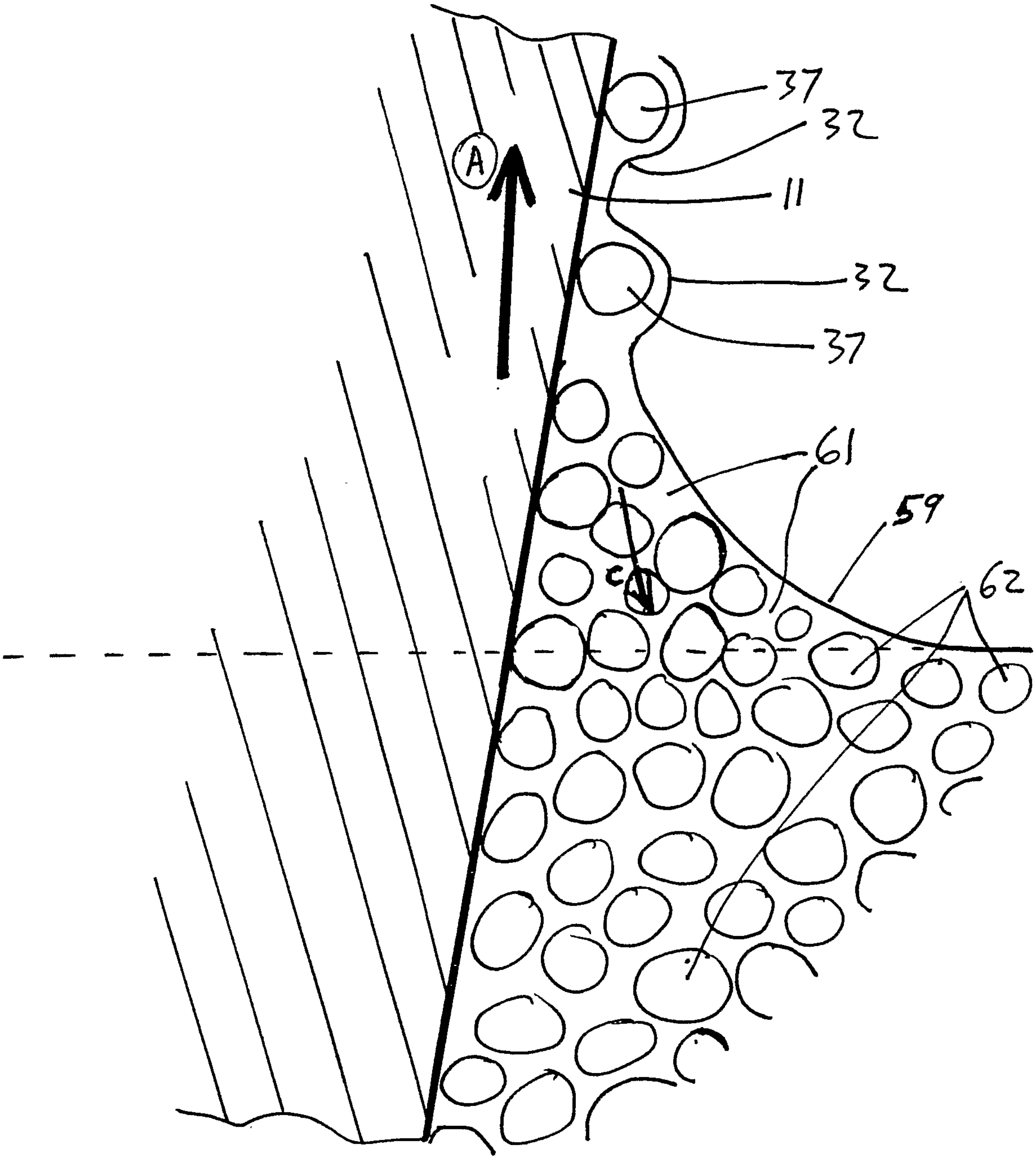


FIGURE 3

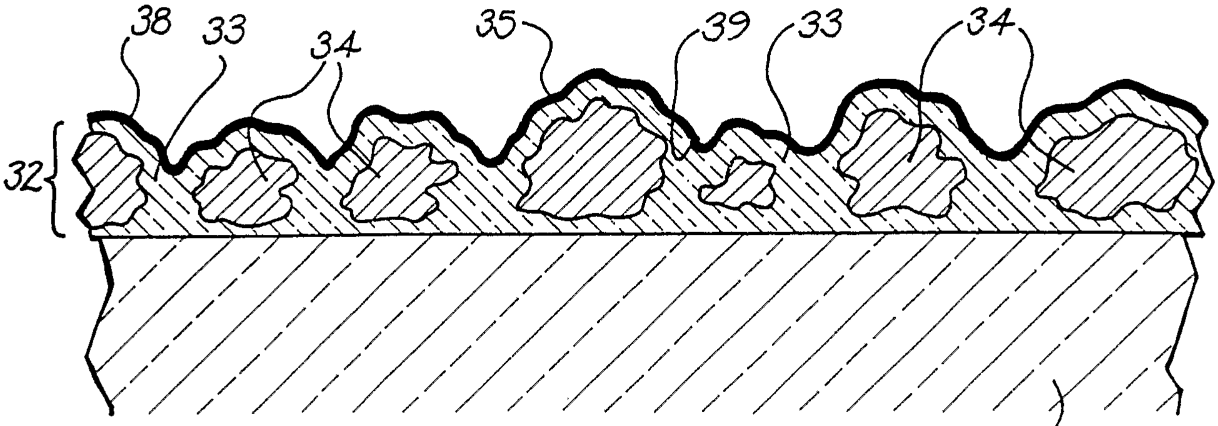


FIG. 4

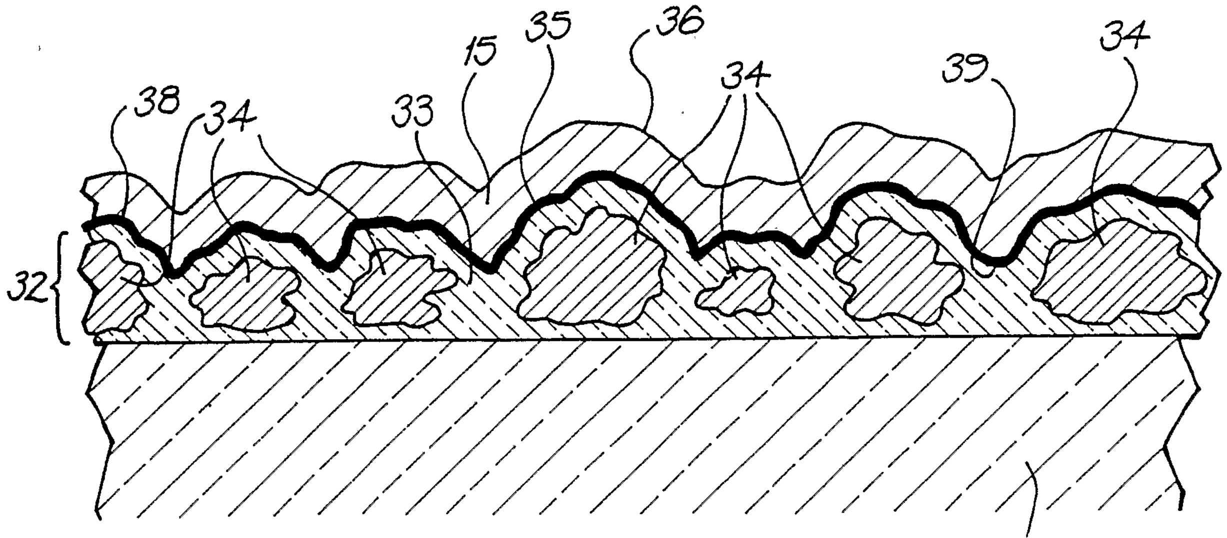


FIG. 5

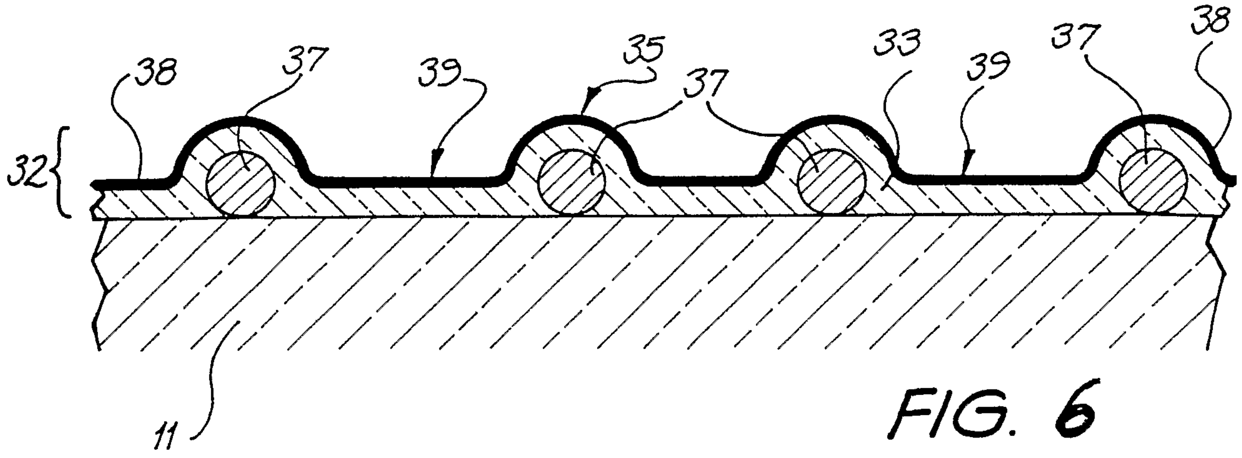


FIG. 6

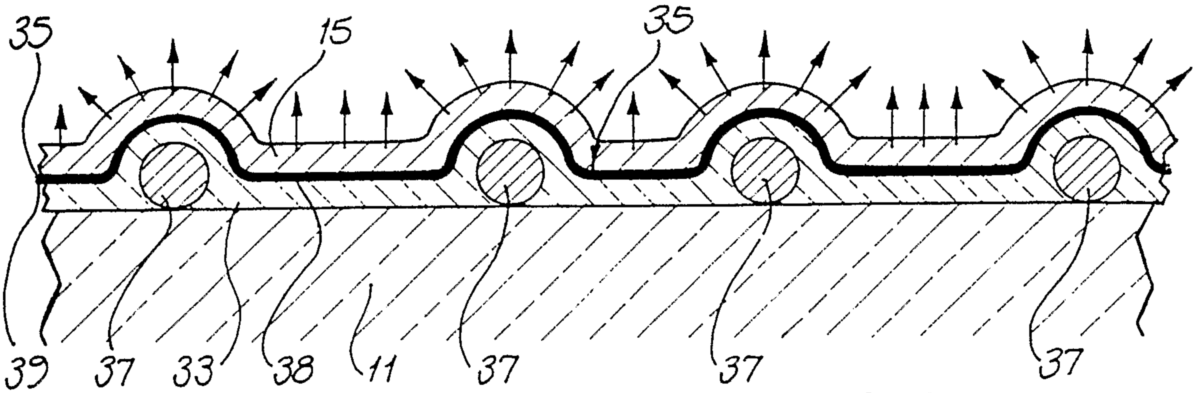


FIG. 7

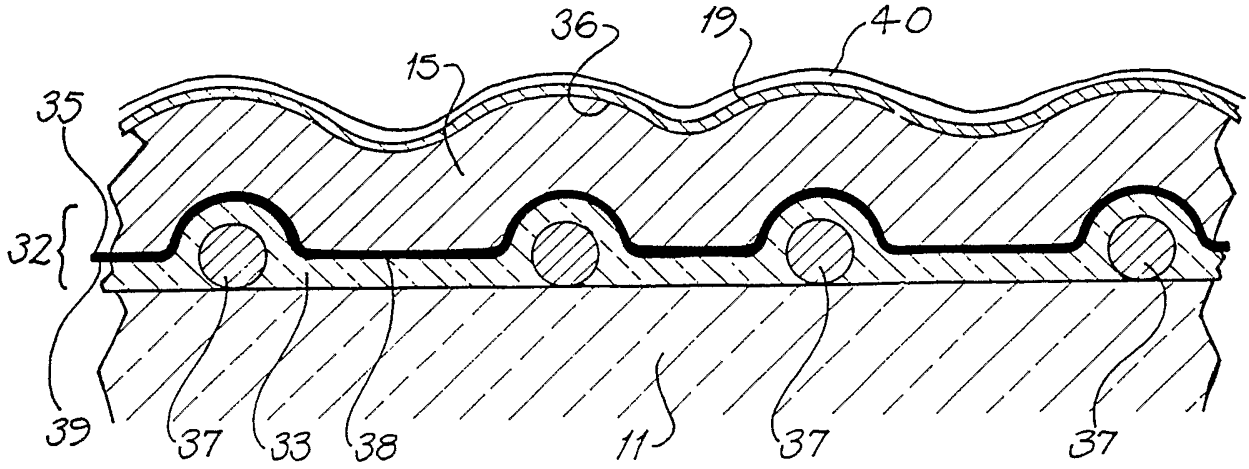


FIG. 8

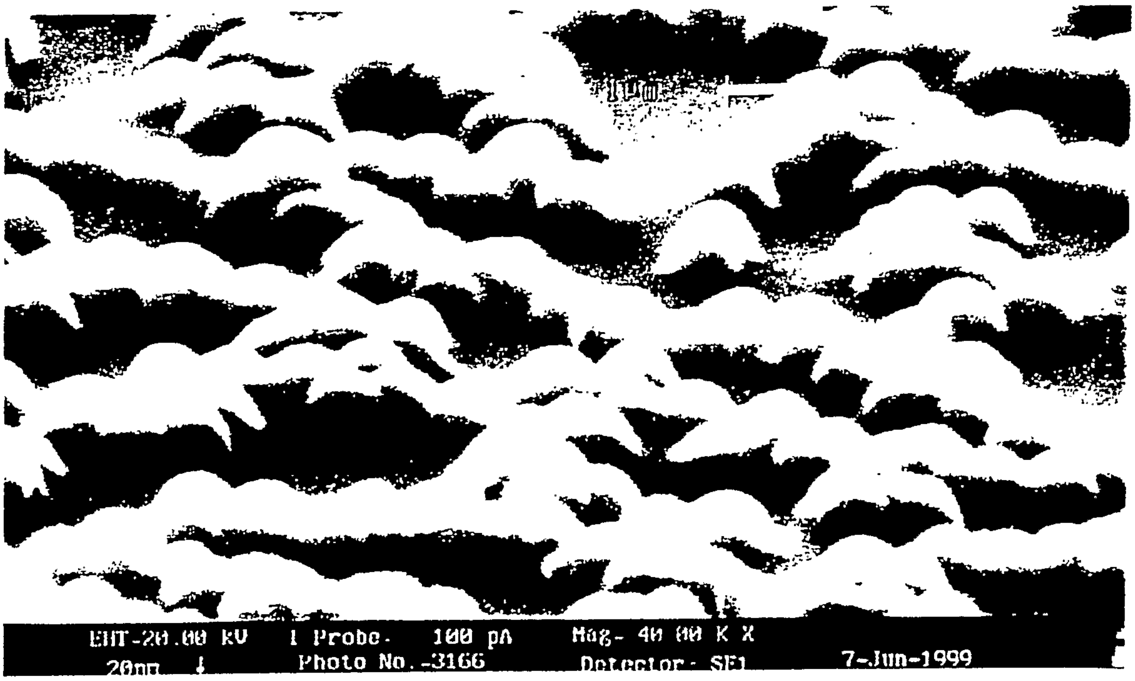


Figure 9

Figure 10

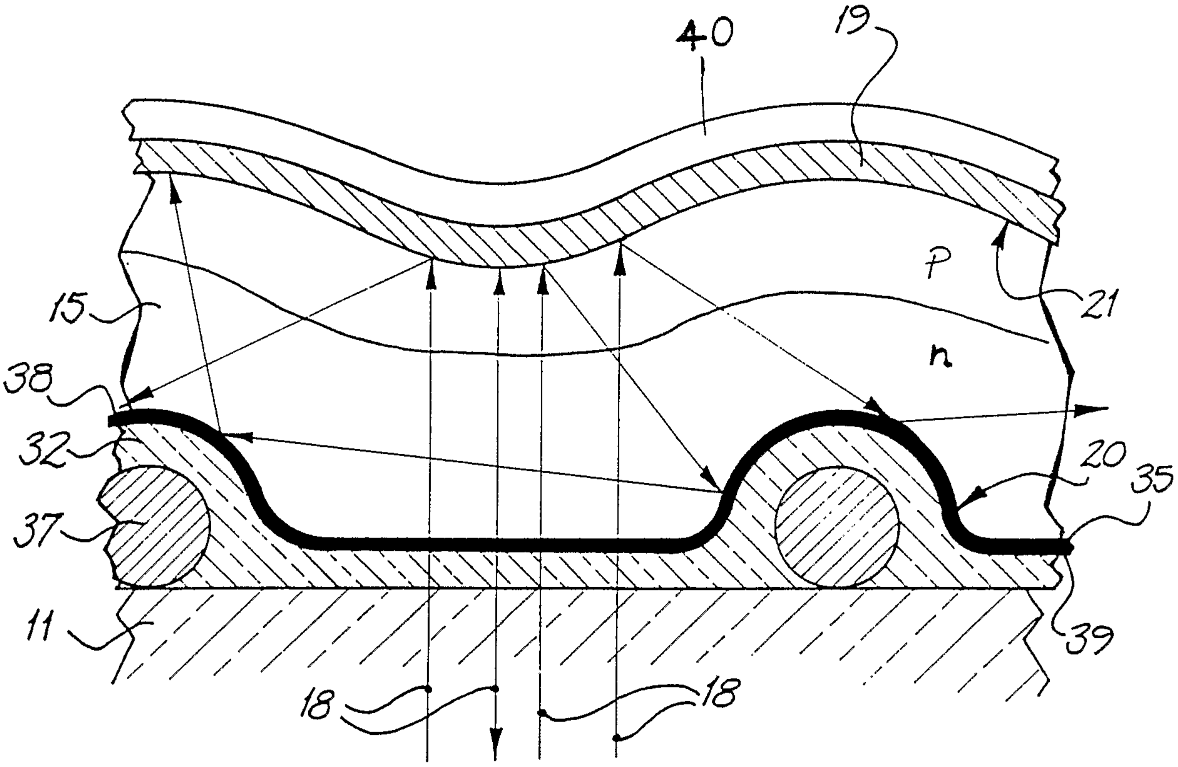


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/01124

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. ^{7}: H01L 31/18, 31/0236

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)
H01L 31/0236

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)
DWPI, JAPIO; (H01L 31/-, H01l 21/- and (solar or photo+)), (thin film), (support+ or substrate etc), (textur+ or rough+ etc)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5306646 A (LAUF) 26 April 1994 See the abstract	
A	WO 00/28603 A1 (PACIFIC SOLAR PTY. LIMITED) 18 May 2000 See the abstract, page 3 lines 26-33, page 8 lines 23-27	
A	US 5482570 A (SAURER et al) 9 January 1996 See the abstract, col 4 lines 42-49	

☒ 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
"E"	earlier application or patent but published on or after the international filing date
"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)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"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
"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
"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
"&"	document member of the same patent family

Date of the actual completion of the international search 26 September 2002	Date of mailing of the international search report 7 OCT 2002
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **I.A.BARRETT** Telephone No : (02) 6283 2189

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU02/01124

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Derwent Abstract Accession No. 98-402771/35, Class E23 G08 L03 M13, JP 10-161330 A (ZH KAWAMURA RIKAGAKU KENKYUSHO) 19 June 1998 See the abstract	
A	Derwent Abstract Accession No. 96-331780/33, Class U12 U14, JP 08-153882 A (FUJI ELECTRIC CO LTD) 11 June 1996 See the abstract	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU02/01124

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	5306646	US	5503898				
WO	200028603	AU	200015012	AU	200015332	EP	1142031
		US	6420647	WO	200028602		
US	5482570	CN	1086049	EP	606453	FR	2694451
		WO	9403930	ZA	9305284		
JP	10161330	NONE					
JP	8153882	NONE					

END OF ANNEX