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D E C I S I O N
of 6 June 2001

Case Number: T 0380/96 - 3.4.3

Application Number: 90117189.2

Publication Number: 0427934

IPC: H01L 27/142

Language of the proceedings: EN

Title of invention:

Monolithic module comprising series and parallel connected photovoltaic cells

Applicant:

Solarex Corporation

Opponent:

-

Headword:

Photovoltaic device/SOLAREX CORPORATION

Relevant legal provisions:

EPC Art. 56, 123(2), 84

Keyword:

"Inventive step (no)"
"Added subject-matter (yes)"
"Clarity (no)"

Decisions cited:

-

Catchword:

-



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Boards of Appeal

Chambres de recours

Case Number: T 0380/96 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 6 June 2001

Appellant: Solarex Corporation
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 14 Decemeber 1995
refusing European patent application
No. 90 117 189.2 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: R. K. Shukla
Members: E. Wolff
C. Holtz

Summary of Facts and Submissions

I. This is an appeal from the decision of the Examining Division dispatched on 14 December 1995, to refuse European patent application No. 90 117 189.2 for lack of an inventive step over the following prior art documents:

D1 (GB-A-2 080 621).

D2 (US-A-4 542 255).

D4 (IEEE Trans. on Components, Hybrids and Manufacturing Technology, vol. 11, No. 3, pages 291-297, 1988, K. F. Teng et al.: "Metallization of Solar Cells with Ink Jet Printing and Silver Metallo-Organic Inks").

The Examining Division considered furthermore that independent claim 11 of the main request and independent claims 10 and 9 of the first and second auxiliary request, respectively, did not comply with the requirements of Article 84 EPC.

II. A notice of appeal was filed on 21 February 1996, and the appeal fee was paid on the same day. The statement setting out the grounds of appeal was filed 24 April 1996.

In response to a communication by the Board the appellant requested that a patent be granted on the basis of the claims of either the main request or the first, second, third or fourth auxiliary request, all filed on 7 May 2001.

III. Oral proceedings took place on 6 June 2001.

IV. Independent claim 1 of the main request reads as follows:

"1. A thin-film photovoltaic device comprising:

a substrate (114);

a front contact layer (132) disposed on said substrate;

a plurality of segments (118) formed in said front contact layer separated by scribing said front contact layer along first scribe lines (124);

a thin-film of semiconductor material (134) disposed on said front contact layer;

a back contact layer (136) disposed on said thin-film of semiconductor material;

said back contact layer being divided along second scribe lines (128) corresponding to and adjacent said first scribe lines for dividing said back contact layer to separate the stack of layers into a plurality of photovoltaic cells (112);

interconnection means (136, 126) for interconnecting adjacent areas of said front and back contact layers and for interconnecting two or more of the photovoltaic cells in series with each other to provide submodules; and

bus means (306, 310) for providing connections to said submodules;

characterized in that

said bus means (306, 310) are disposed in the form of a predefined pattern of a solidified conductive paste."

Claim 1 of the first auxiliary request differs from claim 1 of the main request in that the characterising clause reads as follows:

"said bus means (306, 310) are disposed in the form of a predefined pattern of a solidified conductive paste disposed on said front contact layer."

Claim 1 of the second auxiliary request differs from of claim 1 of the main request in that the characterising clause reads as follows:

"said bus means (306, 310) are disposed in the form of a predefined pattern of a solidified conductive paste disposed on said front contact layer and at least partially disposed under said semi-conductor material (134)."

Claim 1 of the third auxiliary request differs from claim 1 of the main request in that the characterising clause reads as follows:

"said bus means disposed in the form of a predefined pattern of a solidified conductive paste disposed on said front contact layer and being deposited prior to deposition of said semi-conductor."

Claim 1 of the fourth auxiliary request reads as follows:

"1. A thin-film photovoltaic device comprising:

a substrate (114);

a front contact layer (132) disposed on said substrate;

a plurality of segments (118) formed in said front contact layer separated by scribing said front contact layer along first scribe lines (124);

a thin-film of semiconductor material (134) disposed on said front contact layer;

a back contact layer (136) disposed on said thin-film of semiconductor material;

said back contact layer being divided along second scribe lines (128) corresponding to and adjacent said first scribe lines for dividing said back contact layer to separate the stack of layers into a plurality of photovoltaic cells (112);

interconnection means (136, 126) for interconnecting adjacent areas of said front and back contact layers and for interconnecting two or more of the photovoltaic cells in series with each other to provide submodules; and

bus means (306, 310) for providing connections to said submodules and for connecting two or more of the submodules in parallel with each other

characterized in that

said second scribe lines are comprised of gaps (129) in

the back contact layer and of grooves (128) of ablated semiconductor material in the semiconductor layer terminating on the front contact layer (132)."

V. The arguments presented by the appellant can be summarized as follows:

(a) The main request

The invention relates to photovoltaic devices manufactured in the form of large panels. Typically, transparent front electrodes, such as tin oxide, are formed on a glass substrate. Silicon in the form of amorphous hydrogenated silicon is deposited on top of the front contact, and a back electrode layer which also provides the series interconnection of individual cells is applied to the amorphous silicon. The series interconnection of individual cells increases the output voltage.

A problem arises on account of the fact that such photovoltaic devices need to be provided in customised form in respect of both size and electric output. At the same time these devices need to be as efficient as possible. It is well-known that wide cells suffer from reduced efficiency as expressed by a lower fill factor.

The present invention as claimed in claim 1 of the main request provides a solution to this problem in the following manner: individual photovoltaic cells are connected in series to provide submodules and the submodules are then connected in parallel by a bus. This bus consists, according to the present invention, of solidified conductive

paste. In this manner, the invention provides a flexible way of forming the parallel connections between submodules. As a result, photovoltaic devices in panel form are no longer subject to size constraints.

The closest prior art is document D1, which discloses photovoltaic devices which are of the same basic structure as the present invention, but with the bus connecting device elements in parallel being provided either by a separate metallisation on the side of a cleaved edge of the device (Figure 2) or by an already existing portion of the front electrode (Figure 8).

There is no suggestion in document D1 that conductive paste could be used to form the bus nor is any motivation discernible for the skilled person even to consider modifying the device known from document D1.

Document D2 relates to series connected photovoltaic devices. The problem addressed in document D2 is that of avoiding the reduced efficiency of large cells. The solution adopted does not lie in the use of smaller cells, with groups of smaller cells being connected in parallel as in the present invention, but in employing a metal grid which enables improved current flow through the front electrode of the device, thereby permitting the use of larger cells. No bus is shown in document D2 for providing a parallel connection between groups of photovoltaic devices which are connected in series. In addition, the metallic conductors in

document D2, while made of conductive paste, are applied by silk screen printing. Silk screen printing does not provide the same flexibility as the computer controlled printing process employed to apply the conductive paste in the manner of the present invention, since the screens for printing need to be prepared before the printing operation.

- (b) The first auxiliary request includes at the end of the characterising portion of claim 1 the further requirement that the conductive paste be "disposed on said front contact layer". This provides an additional distinction which brings with it additional advantages. Thus, while in document D1 parts of the front contact layer are employed to provide the bus connection, the high resistivity of the front contact layer requires the bus to be much wider than in the claimed invention, where the bus is provided by conductive paste disposed on that contact layer.

- (c) According to the second auxiliary request, the conductive paste is disposed on the front contact layer as in claim 1 of the first auxiliary request, and is "at least partially disposed under said semi-conductor material (134)". The basis for this additional feature is provided by the second paragraph of page 18 of the application as filed, and in the sequence of processing steps described with reference to Figures 2(c) and 2(g) of the drawings. The skilled person would not consider masking any part of the device when depositing the semiconductor material, especially since appropriately formed scribe lines (301) prevent short circuits in the case of such a blanket

deposition).

- (d) The third auxiliary request provides, in comparison to the first auxiliary request, that the conductive paste disposed on the front contact layer is "deposited prior to deposition of said semiconductor".

The newly added feature thus emphasises that the semiconductor material is deposited after the formation of the bus bars by means of the conductive paste. This sequence of processing steps can be ascertained from a cross-section of the finished device and neither the sequence of steps nor the device structure resulting from this sequence is taught by the prior art.

- (e) The fourth auxiliary request does not relate to the use of conductive paste for providing an electric bus but, instead, it is the division of the back contact layer which is claimed.

The application as filed explains that the division of the back layer into contact areas for the individual photovoltaic cells is achieved by scribing with a laser from the front of the device. The laser is operated at a power level that will ablate the semiconductor material and produce gases that structurally weaken and burst through the portions of the metal film deposited to form the back electrodes. This method of dividing of the back contact layer is apparent from the device because as a result of this method there is a gap which not only separates the metal electrodes but also completely separates adjoining

sections the semiconductor material from the back electrode down to the front electrode, as shown in Figures 2(f) and 2(g) of the application.

In contrast, in the device known from document D1 the gaps dividing the back electrodes extend from the electrode layer only partly into the underlying semiconductor layer.

In document D3, adjoining sections of the semiconductor material are completely separated in the sense that the separating gap extends to the front contact layer, but since the series interconnection between adjacent cells is achieved by metallisation formed within that gap, the structure could not be achieved by applying unmodified the scribing technique used in the present invention. Thus, both the fabrication technology used and the device structure obtained are therefore quite different from the corresponding features described in the application in suit.

Reasons for the Decision

1. The appeal is admissible.
2. *The main request*
 - 2.1 Inventive step

Document D1 was identified by the Examining Division to represent the closest prior art, and was recognized as

such by the appellant in his submissions during the appeal proceedings. The Board sees no reason to depart from this assessment.

Document D1 relates to a photovoltaic device in which individual photovoltaic cells are connected in series and groups of series connected cells are connected in parallel by bus bars formed by electrical contacts (24, 26) mounted across (page 2, lines 72 to 74) or bonded to (page 3, lines 104 to 106) the respective electrode segments. The device disclosed in document D1 thus has all the features referred to in the preamble of claim 1. The only difference between the invention as claimed and the prior art document D1 resides in the manner in which the bus bar is formed which provides the parallel connection. It follows that the objective problem solved by the invention claimed in claim 1 of the main request is that of providing alternative means of connecting in parallel groups of photovoltaic cells which are interconnected in series.

The appellant argued that the problem addressed by the invention is that of providing photovoltaic cells customised in respect of both size and electric output (see section V above). By providing for series connection of individual cells into groups and parallel connection of these groups, the device structure known from document D1 provides the main features which are necessary to tailor the size of individual cells as well as the size of arrays of these cells. Thus the problem as stated by the appellant is solved by the prior art, and hence it cannot be considered to be the objective problem underlying the invention.

Document D2 relates to thin-film solar cells, that is, to photovoltaic devices of the kind to which the application in suit relates. The device structure comprises a glass substrate 10, a patterned transparent front conductor 18 deposited on the glass substrate, a thin semiconductor film 20 formed on top of the front conductor and a metallic back contact 22 formed on the semiconductor material. In order to improve the electrical properties of the front contact layer, and in particular to reduce its contact resistance, metallic strip conductors 24 are deposited directly on the transparent conductive layer (column 2, lines 50 and 51). The metallic strips are preferably applied over the conductive layer either by screen printing or by evaporation through a mask (column 3, lines 4 to 6). In the case of screen printing a suitable commercially available screen printing paste is forced onto the surface through a pattern screen. The paste may contain for example silver powder glass frit and a suitable organic vehicle or binder. After application to the transparent layer the paste is fired to drive off the organic vehicle and leave the silver and glass frit behind. The glass frit fuses to the substrate providing a strong bond while the silver provides the desired electrical conductivity. (column 3, lines 7 to 15).

The appellant submitted that, with reference to the embodiments shown in Figures 2 and 8 of document D1, the skilled person would have had no incentive to look to document D2 for providing an alternative to the construction of the bus lines 24 and 26 of document D1, because the metallic strips in document D2 did not serve to provide a parallel connection between groups of photovoltaic cells; rather they served to decrease contact resistance of the front contact of the

photovoltaic cells themselves.

The Board does not find the appellant's argument convincing. Document D1 clearly discloses that the subarrays of the photovoltaic device are connected in parallel by a common electrical contact structure which permits electrical connection of the array so formed to other electrical elements. In the embodiment shown in Figures 1 and 2, contacts 24 and 26 are "mounted across respective opposite ends of the array, in electrical low-resistance contact with respective opposite electrodes of each subarray" (page 2, lines 68 to 76). On page 3, it is described that electrical contacts 24 and 26 are bonded to electrode segments 42 of of the parent cell 32 and to electrode segments 54 of the parent cell 38 respectively (lines 104 to 106). Lastly, it is described on page 4, lines 89 and 90 that a contact in the form of a rail 26a can be provided as described for the previous embodiment.

In short, groups of series-connected photovoltaic cells are described in document D1 as being connected by a bus that is bonded to or mounted on the contact layers. To a skilled person, such a bus must undoubtedly have suitable electrical properties including an at least adequately low resistance. The skilled person considering alternatives for connecting those groups of cells in parallel will therefore immediately recognise that the commercially available conductive paste described in document D2 as being printed onto the front electrode layer for the purpose of providing a low electric resistance connection within each cell, will equally provide a low electric resistance connection when used as the bus connecting arrays of cells of document D1 in parallel.

The appellant also contended that according to document D2 silk screen printing was employed to apply the conductive paste, in contrast to the present invention which employed a computer controlled printing head to apply the conductive paste. This feature was not, however, a feature of the device as claimed, and hence could not be considered relevant to the issue at stake.

For these reasons the Board concludes that an inventive step was not required in arriving at the invention as claimed in the main request.

3. *The first auxiliary request*

3.1 Inventive step

Claim 1 of the first auxiliary request differs from claim 1 of the main request by the addition, at the end of the characterising clause, of the words "disposed on said front contact layer".

Document D1 discloses that the parallel connections are provided by contacts 24 and 26 being bonded to the electrode segments 42 and 44, respectively (page 3, lines 104 to 106). Elsewhere in document D1, the contacts are described as being mounted across the ends of the array (page 2, lines 72 to 76). A separate bus mounted on or bonded to the front contact layer is therefore already known from document D1. Bearing in mind the conclusions reached in respect of the main request, the Board concludes that even with the additional feature included in claim 1 of the first auxiliary request, the claim does not involve an

inventive step.

4. *The second auxiliary request*

4.1 Admissibility of the amendments (Article 123(2) EPC)

Claim 1 of the second auxiliary request differs from claim 1 of the first auxiliary request in that the characterising portion of the claim additionally requires that the solidified conductive paste is "at least partially disposed under said semi-conductor material (134)".

In support of the admissibility of the amendments, the appellant relied on three specific passages in the description. They are at page 15, lines 2 to 19; page 18, lines 6 to 8; and page 18, lines 11 and 12.

The cited passage on page 15 relates to the conductive patterns being applied by way of a conductive fluid, and the preferred composition and properties of the conductive fluid are set out. There is no mention at all concerning the deposition of the semiconductor material.

In lines 6 to 8 on page 18 it is stated that the bus means is "disposed on the front contact layer 132 in the manner described above following which the steps shown in Figures 2(c) to 2(g) are performed". In the preceding sentence (lines 5 and 6), it is also pointed out that in Figures 2(c) to 2(g) "only the front contact layer is shown, but the bus means is not". Hence, neither the part of the description referred to by the appellant nor Figures 2(c) to 2(g) provide any information concerning the relative positioning of the

bus and the semiconductor layer.

Lines 10 and 12 on page 18 contain a brief description of the deposition of the semiconductor layer in these terms: "... a substantially continuous film 134 of semiconductor material then is fabricated over front electrodes 118 and in first grooves 24, as shown in Figure 2(c)." There is no mention of the bus or its positioning relative to the semiconductor layer.

It follows that the parts of the description relied on by the appellant and the Figures of the drawings referred to there fail to establish that the claimed feature is derivable from the application as filed. Moreover, no other parts of the application as filed, including the plan views of Figures 3 to 6 provide any information relevant in this respect.

Since the application as filed does not contain any information which provides the required unambiguous support for the claimed feature, the Board concludes that its introduction into claim 1 goes beyond the subject matter of the application as filed, and that the second auxiliary request therefore contravenes Article 123(2) EPC.

5. *The third auxiliary request*

5.1 Clarity (Article 84 EPC)

Claim 1 of the third auxiliary request differs from claim 1 of the first auxiliary request by additionally specifying in the characterising clause that the solidified conductive paste is "deposited prior to deposition of said semi-conductor".

The sequence in which the depositions take place is a process feature. There is no device feature which is directly attributable to this sequence. The claim is therefore unclear.

The appellant had submitted that the sequence in which the depositions are performed can be ascertained from a cross section of the device. The Board cannot follow this argument for the following reasons.

The deposition sequence can be ascertained from the ensuing device structure only when the materials concerned are deposited one on top of the another but not if they are deposited side by side. It is not clear from the description and drawings whether the materials were deposited side by side or on top of one another.

The method steps included in the device claim 1 do not result in unambiguously defined device features, and the Board therefore concludes that the claim lacks clarity contrary to the requirement of the second sentence of Article 84 EPC.

5.2 The fourth auxiliary request

Claim 1 of the fourth auxiliary request relates to a thin-film voltaic device of the kind disclosed in document D1, which is characterised in that the scribe lines separating the back contact layer extend through the device to the front contact layer.

According to the argument submitted by the appellant, this complete gap is the result of scribing the scribe lines from the front of the device by ablation (see the argument in paragraph V(e) above), a method of scribing

which is not found anywhere in the cited prior art. Moreover, the resulting structure in which the ablated semi-conductor material is completely removed between the front contact layer and the back contact layer clearly distinguishes the invention as claimed from the cited prior art document D1 where the corresponding gap 56 extends through the back contact layer only part way into the semiconductor layer 46, 48.

Document D1 discloses that in order to "prevent shorting between adjacent electrode segments 54 in a subarray, through semiconductor layer 48, grooves 56 are extended down to and preferably into at least the high-resistance layer 46" (page 3, lines 19 to 23).

The purpose of the gaps 129 of the application in suit is to provide insulation between adjacent photovoltaic cells and is thus the same as the purpose of the corresponding grooves 56 described in document D1. Moreover document D1 refers to the grooves 56 extending through the back contact layer **at least** as far as the high resistance portion of the semiconductor layer. This is a clear indication that it is contemplated in document D1 that the grooves 56 may extend beyond the high resistance layer. Whilst the Board accepts that the method of forming the gaps described in the application in suit may be new and superior to conventional methods for dividing the back electrode, the Board does not consider that these differences in method are reflected in the structural differences between the device disclosed in document D1 and the invention as claimed in claim 1 of the fourth auxiliary request. The Board therefore considers that in view of the disclosure in document D1, claim 1 of the fourth auxiliary request does not involve an inventive step as

required by Article 56 EPC.

6. For the foregoing reasons in the Board's judgement the claims of neither the main request nor the first, second, third or fourth auxiliary request meet the requirements of the EPC.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar:

The Chairman:

D. Spigarelli

R. K. Shukla