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D E C I S I O N
of 9 February 2006

Case Number: T 0298/04 - 3.4.02

Application Number: 94902490.5

Publication Number: 0673550

IPC: H01L 31/075

Language of the proceedings: EN

Title of invention:
Method for the manufacture of improved efficiency tandem photovoltaic device and device manufactured thereby

Patentee:
UNITED SOLAR SYSTEMS CORPORATION

Opponent:
Kaneka Corporation

Headword:
-

Relevant legal provisions:
EPC Art. 54, 56

Keyword:
"Main request - novelty (no)"
"First auxiliary request - novelty (no)"
"Second auxiliary request - inventive step (yes)"

Decisions cited:
-

Catchword:
-

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Case Number: T 0298/04 - 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 9 February 2006

Appellant: (Opponent)
Kaneka Corporation
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Respondent: (Proprietor of the patent)
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Decision under appeal: **Decision of the Opposition Division of the European Patent Office posted 19 January 2004 rejecting the opposition filed against European patent No. 0673550 pursuant to Article 102(2) EPC.**

Composition of the Board:

Chairman: A. Klein
Members: M. Rayner
M. Vogel

Summary of Facts and Submissions

I. The opponent has appealed against the decision of the opposition division rejecting the opposition against European patent number 673 550 (application number 94 902 490.5, International publication number WO9414199). The patent concerns photovoltaic devices of the type comprising a stacked array of cells.

II. In the opposition and/or appeal proceedings, reference has been made to documents including the following.

D1: Twentieth IEEE Photovoltaic Specialists Conference, September 26-30, 1988, pages 241-246, J. Yang et al.: "High efficiency multi-junction solar cells using amorphous silicon and amorphous silicon- germanium alloys."

D3: IEEE Transactions on electron devices, vol. 37, no. 7, 1 July 1990, pages 1758-1762, XP0001 33275 Pawlikiewicz A H et al: "Performance comparison of triple and tandem multijunction A-SI: H solar cells: a numerical study".

Declaration dated 03.01.2006 of Subhendu Guha, co-inventor named in the patent in dispute and co-author of documents D1 and D3.

III. The view of the opposition division was that since matching of output currents of the cells according to document D3 is in contrast to the claimed feature of claim 1 "selecting the thickness of the second layer of substantially intrinsic semiconductor material so that the second photocurrent is less than the first

photocurrent" the subject matter of claim 1 and analogously claim 8 is new over this document. Moreover, in deliberating about means of improving the efficiency of the D3 device, this very teaching that the current outputs of the cells are matched (cf. page 1760, left hand column, second full paragraph) gives no reason to consider a device design different in this aspect without the exercise of inventive skill. As document Dl does not disclose that the material quality of the intrinsic layer of the top cell is greater than the material quality of the bottom cell of a photovoltaic device, the subject matter of claims 1 and 8 is new over this document. The opposition division agreed that fill factor is a measure of material quality. However, there is no suggestion from document D1 that the material quality of the top cell is important. Accordingly, the subject matter of claims 1 and 8 can be considered to involve an inventive step.

IV. The appellant requested that the decision under appeal be set aside and that the patent be revoked because the subject matter of independent claims 1 and 8 is, in its view, not novel or at least does not involve an inventive step having regards to documents D1 to D3.

V. The main request of the respondent (=patent proprietor) is that the appeal be dismissed. A first and second auxiliary request is that the patent be maintained in amended form on the basis of claims 1-8 or 1-7 filed according to the a first and second request, respectively. The first and second requests correspond to the device claims and method claims, respectively, of the claims as granted.

VI. Consequent to auxiliary requests of both parties, oral proceedings were appointed by the board. During the oral proceedings, Dr Guha, in the context of the presentation of the respondent's representative, elaborated orally upon technical matters involved in the case and, in particular, upon matters expressed in his Declaration.

VII. Case of the Appellant

The photocurrent referred to in the claims is the short circuit current. There is an indication in the terminology of the patent on page 2, lines 29-30 that measure of defect states equates with density of states in band gaps. On page 4, there is a reference in lines 48 to 50 to quality and performance, which from page 1 has a direct correlation to the fill factor, i.e. fill factor corresponds to material quality.

Comparing device claim 8 with document D3, as can be seen in Figure 1(b) of document D3, there are layer thicknesses shown and the bottom layer is thinner. Selection of thickness is not a real technical feature as there is neither a starting nor a stopping point nor any specific selection or quantification. The upper layer with a fill factor 0.72 corresponds to the second layer claimed in the patent and the bottom layer with fill factor 0.55 to the first layer. Simulated data are in excellent agreement with the experimental results, which shows that the model reflects the physics correctly, the data are actually those of a tandem cell and the short circuit voltage of the second layer is smaller. It is not a question of whether the cell was actually made, but what is disclosed by document D3,

which is indeed all the features claimed. There are further parameters but these are known to the skilled person, who also knows their effect is the same or should be kept low. They are at all events the same for the prior art and the patent. Comparing the device of document D1 with the tables I and II of document D3 and the parameter values given suggests to the skilled person that the upper cell has a fill factor which is larger than that of the bottom cell. Thus, document D1 also shows a fill factor of the top cell which is greater than the bottom cell.

Method claim 1 is very similar to device claim 8, although reference is made to a first and second deposition process. Nevertheless, selection of thickness is made as a certain current according to document D3 leads to a certain thickness. Moreover, in document D1 intrinsic semiconductors are of different composition, so there must be two processes, the claim not specifying how the processes are different. In particular, the time taken by the processes is not mentioned in the claim.

VIII. Case of the Respondent

The respondent agreed that the photocurrent concerned in the claims is the short circuit current. The patent concerns a tandem design for maximum power, in the past it had been thought the cell photocurrents should be the same, say 10 milliamps plus 10 milliamps giving 20 milliamps. The invention involves the cells not being the same, being instead say 9.5 and 10.5 milliamps as explained in the patent. Material quality is a measure of the defect states, the patent recites there is a

correlation between the material quality and fill factor, but these parameters are not the same.

Document D3 does not concern a composite cell but simulations based on individual cells, which does not permit a conclusion about a real tandem cell. In document D3, the interest is in a high efficiency triple cell and in the simulation multiple parameter sets are considered in relation to explaining the result. Moreover, document D3 teaches cell matching and can never show a deliberate mismatch in order to achieve higher efficiency. Admittedly, as confirmed by Dr Guha, the match may not be perfect, but even then only an accidental anticipation could be provided following the teaching of document D3. Document D3 contains no teaching towards selecting a lower photocurrent nor towards a different quality. The appellant is completely wrong to allege that the top cell in the device represented by Figure 3 and 4 of document Dl has a higher fill factor than the bottom cell and a higher material quality. There is absolutely no reference to material quality in document Dl. The respondent's argument is based on nothing more than speculation and is, in fact, technically incorrect.

It is nowhere mentioned in either document D1 or D3 that the first and second layers are produced by different processes, indeed there is no detail of fabrication in documents D1 and D3. It cannot be deduced that deposition processes could be different, in, for example, choice of deposition quality and time.

IX. The independent claims of the main request, claims 1 and 8 as granted are worded as follows. Claim 1 according to the first auxiliary request has the same wording as claim 8 as granted. Claim 1 according to the second auxiliary request has the same wording as claim 1 as granted.

"1. Method of manufacturing a tandem photovoltaic device of the type comprising a stacked array of photovoltaic cells disposed in an optical and electrical series relationship, wherein said array comprises:
a substrate having a first photovoltaic cell disposed thereupon, said first cell comprising: a first layer of substantially intrinsic semiconductor material interposed between a first layer of P-doped semiconductor material and a first layer of N-doped semiconductor material, said first cell being operative, when it is incorporated in said tandem photovoltaic device and said device is subjected to illumination, to generate a first photocurrent in response to the absorption of light thereby; and
a second photovoltaic cell disposed in a superposed relationship with said First photovoltaic cell, said second cell comprising a second layer of substantially intrinsic semiconductor material of a preselected thickness interposed between a second layer of P-doped semiconductor material and a second layer of N-doped semiconductor material, said second cell being operative, when it is incorporated in said tandem photovoltaic device and said device is subjected to illumination, to generate a second photocurrent in response to the absorption of the Illumination thereby, wherein the method comprises in combination:

selecting the thickness of the second layer of substantially Intrinsic semiconductor material so that the second photocurrent is less than the first photocurrent; and
preparing said first layer of substantially Intrinsic semiconductor material by a first deposition process and said second layer of substantially intrinsic semiconductor material by a second deposition process wherein the material quality of said second substantially intrinsic semiconductor material prepared by said second process is greater than the material quality of said first substantially intrinsic semiconductor layer prepared by said first deposition process.

8. A tandem photovoltaic device of the type comprising a stacked array of P-I-N photovoltaic cells disposed in an optical and electrical series relationship, said device comprising:
an electrically conductive bottom electrode;
a first P-I-N type photovoltaic cell disposed upon the bottom electrode, said first cell comprising a first layer of substantially intrinsic semiconductor material interposed between a first layer of P-doped semiconductor material and a first layer of N-doped semiconductor material, said first cell being operative, when it is incorporated in said tandem photovoltaic device and said device is subjected to illumination to generate a first photocurrent in response to the absorption of light thereby;
a second P-I-N type photovoltaic cell disposed in a superposed relationship with said first cell and in a series electrical relationship therewith, said second cell comprising a second layer of substantially

intrinsic semiconductor material of a preselected thickness, interposed between a second layer of P-doped semiconductor material and a second layer of N-doped semiconductor material, said second cell being operative, when it is incorporated in said tandem device and said device is subjected to illumination, to generate a second photocurrent in response to the absorption of illumination thereby, the thickness of said first and second layers of substantially intrinsic semiconductor material being selected so that the second photocurrent is less than the first photocurrent and the material quality of the second layer of substantially intrinsic semiconductor material is greater than the material quality of the first layer of substantially intrinsic material; and
a top electrode disposed in electrical communication with said second photovoltaic cell."

X. At the end of the oral proceedings, the board gave its decision.

Reasons for the Decision

1. The appeal is admissible.

2. In the present case, in view of his involvement as co-inventor named in the patent in dispute and co-author of documents D1 and D3, the board considers the contribution made by Dr Guha significant. It is therefore useful to look more closely at important aspects of this contribution, as expressed, for example, in the following passages of the Declaration, where

quotation marks have been added by the board to draw attention to some of the language used.

(a) the last eight lines of point 6,

My invention, as described and claimed in EP 0 673 550 B1, confers significant economic advantage in the manufacture of tandem photovoltaic devices since it allows "high speed deposition processes" to be employed "to fabricate" one or more of the cells of the device provided that another cell of the device is: (a) manufactured from high quality material, and (b) made to be the dominant cell of the device by requiring that the photocurrent of the high quality material be less than the photocurrent produced by any other cell in the device.

(b) the second sentence of point 7,

Prior to the priority date, it was conventional wisdom that photocurrents must be matched in tandem photovoltaic devices.

(c) the second sentence of point 8

There is no disclosure or suggestion in document D1 or D3 of "manufacturing" a photovoltaic device wherein a cell producing a lower photocurrent is "specifically manufactured" to have a higher material quality than any other cell in the photovoltaic device.

(d) the last sentence of point 9

… it is worth noting that material quality is one of the most expensive parameters to alter in a "manufacturing" process and it is therefore not an inevitable result that a person skilled in the art would consider altering this parameter.

3. *Independent patent claims as granted*

3.1 In the view of the board, document D3 can be considered closest document to the device as claimed in claim 8. This document concerns a performance comparison of triple and tandem multi-junction a-Si:H solar cells. Numerical results of a computer model for single and multi-junction cells are compared with measured performance of optimised tandem and triple junction devices. The validity of the solar cell model used in the simulation is said to be in excellent agreement between simulated and measured characteristics, device parameters for the simulated and measured cells being given in Table I. That the structure of the devices shown in Figure 1(a) and 1(b) with regard to the cells is like that dealt with in the patent in dispute, can easily be seen by comparing, say Figure 1(a) and the Figure of the patent. The bottom cell shown in Figure 1 of document D3 comprises a layer which corresponds to the first layer in the terminology of the patent. Therefore, in reading claim 8 in dispute onto document D3, the bottom cell in the figures corresponds to the first cell (and the second cell correspondingly to the upper cell), both cells of course having a thickness, which, as the appellant said, must be selected. Taking then, for example, the simulated values shown in

Table 1(b), short circuit photocurrent J_{sc} of the upper cell is less than that of the bottom cell (11.91 < 12.55) and the fill factor of the upper layer is greater than that of the bottom layer (0.72 > 0.55).

3.2 Since the parties agreed that the term photocurrent used in claim 8 as granted means the short circuit current, what remained in dispute in considering novelty was therefore whether the devices taught had the parameters claimed, a particularly contentious point being whether the fill factor given satisfies the material quality requirement.

3.3 Various further documents were cited and discussed by the parties, not all of which were published before the priority date of the patent, in order to support their respective contentions in relation to material quality and fill factor. There is a lot of scope for argument as one can focus on differing aspects, for example, on quality of the doped layer, contacts between a doped layer and a metal or metal oxide layer, an interface between p/i and i/n layers or a tunnel junction connecting adjacent cells. Measurement methods can also play a role, for example, photothermal deflection spectroscopy or constant photocurrent measurement. In the differing contexts of these various documents, it may therefore indeed be possible to reach conflicting and confusing views about material quality or fill factor and their measurement. However, none of these other aspects are claimed. At issue in the present decision is thus what is meant by material quality according to the claims in dispute. In understanding this, the first port of call is the description, and, in view of the teaching given in the patent, the board

is satisfied that, in the context of what is claimed, it is not necessary to call on other documents of the prior art.

3.4 Thus, according to page 2, lines 29-30 of the patent, "Material quality is difficult to measure directly, but it is readily correlatable with the performance of a device incorporating the material. Further, according to page 4, lines 48 to 50 of the patent "cell performance will depend, to a large degree, upon the quality of the material comprising the intrinsic layer of the cell. One measure of cell performance is the fill factor of the cell." The appellants drew attention to this teaching as denoting a correlation between material quality and fill factor and the opposition division also accepted in its decision that fill factor is a measure of material quality. Thus, while the board accepts that other factors can influence device performance, it nevertheless concurs with the appellant that factors not claimed should be considered as the same or having a low effect and that, therefore, the skilled person understands from the teaching of the patent that fill factor is indeed a measure of material quality. Moreover, the board also accepts the argument of the appellant that the excellent agreement between the experimental measurements and the model in document D3 means that the skilled person is taught that the device has cells meeting the photocurrent and fill factor requirements given in claim 8. Even taking the most generous viewpoint for the respondent, that no real tandem device is disclosed and the skilled person would try to match the cells, the respondent admitted that cells so produced would nevertheless not be exactly matched and that therefore, even in this case,

the features of the device claim would be met. Therefore, even for this generous view, there is no question of a one-off accidental anticipation, but a large number of prior art devices which meet the wording of the claim. In other words, the device claims, contrary to the view of the opposition division as expressed in the phrase "analogously claim 8", are not restricted to devices where a matching step has not been carried out. Consequently, the subject matter of device claim 8 is not novel having regard to the disclosure of document D3. Therefore, the claimed subject matter does not satisfy the requirements of Article 54 EPC.

3.5 The argument of the appellant that as other factors are the same or have a low effect, the fill factor is an indication of material quality cuts, of course, both ways, since it loses its force if a deposition process is different, because then other things are not the same or of low effect. This is the case for method claim 1 where a first and second deposition process are specified, which means just this. The skilled person knows in this situation, that the reason for the different qualities and why there is a deliberate photocurrent mismatch lies in the first and second deposition processes. As the respondent pointed out, document D3 does not give any detail about the deposition process. Nor does document D1 and, in fact, there is a statement that all the devices reported were fabricated employing a conventional radio frequency glow discharge technique (see top of right hand column on page 241). If as the appellant says, the similar values for the parameter values for cells means that largely the same cells are used in documents D1

and D3, this is even an indication that the same deposition process is used throughout both documents. The view of the appellant that using first and second materials means that first and second processes are used also does not follow because the same process can be used for different materials. Whatever the board might think about the clarity of the claims, so far as the appellant is arguing in this sense, the board is obliged to observe that clarity cannot be an issue in relation to unamended independent claims in the present appeal proceedings.

3.6 The board found no reason to question the declaration of the co-inventor, who referred to "high speed deposition", "specific manufacture" and "altering in manufacture" in relation to manufacturing of some cells in the device in the context of material quality, see for example the passages in quotation marks in sections 2(a), (b) and (d) above. The board understands this enabled conventional wisdom as to matching as mentioned in section 2(b) to be departed from. Thus the board was persuaded by the sum of all the remarks made that the method using a first and second deposition process would not have been obvious to the skilled person in the light of any of the prior art documents available. Therefore, the subject matter of claim 1 can be considered to involve an inventive step within the meaning of Article 56 EPC.

4. In conclusion therefore, the opponent failed to convince the board that the prior art showed any method in which a first deposition process and a second deposition process were used in accordance with method claim 1. The patent proprietor in its turn failed to

convince the board there was any feature of in the device claim 8 which really differed over the disclosure of document D3.

5. *Main Request*

The main request fails in view of its claim 8, which corresponds to claim 8 as granted, because it does not meet the requirements of the Convention for lack of novelty of the subject matter of that claim.

6. *First Auxiliary Request*

The first auxiliary request fails in view of its claim 1, which corresponds to claim 8 as granted, because it does not meet the requirements of the Convention for lack of novelty of the subject matter of that claim.

7. *Second Auxiliary Request*

The second auxiliary request succeeds because its claim 1, which corresponds to claim 1 as granted, can be considered to involve an inventive step within the meaning of Article 56 EPC. The claims dependent therefrom can be considered to involve an inventive step by virtue of their dependency. The description has been adapted to the claims.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to maintain the patent in amended form on the basis of the description, drawings and claims filed during the oral proceedings (second auxiliary request).

The Registrar: The Chairman:

M. Kiehl A. G. Klein