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Case Number: T 0658/05 - 3.4.03

Application Number: 98104275.7

Publication Number: 0865086

IPC: H01L 31/048

Language of the proceedings: EN

Title of invention:
Photovoltaic module and building element using the same

Patentee:
CANON KABUSHIKI KAISHA

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - (no)"

Decisions cited:
-

Catchword:
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Case Number: T 0658/05 - 3.4.03

D E C I S I O N
of the Technical Board of Appeal 3.4.03
of 17 July 2007

Appellant: CANON KABUSHIKI KAISHA
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Decision under appeal: **Decision of the Examination Division of the European Patent Office posted 23 December 2004 refusing European application No. 98104275.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. G. O'Connell
Members: G. Eliasson
J. Van Moer

Summary of Facts and Submissions

I. This appeal is against the refusal of application 98 104 275 for lack of inventive step.

II. The following prior art documents, among others, were cited in the examining procedure,:

D1: EP 0 680 097 A; and
D3: Applied Physics Letters, vol. 61, no 24, 14 December 1992, pages 2917 to 2919.

III. In June 2007 in response to a communication of the board accompanying summons to oral proceedings, the appellant applicant filed a new main and auxiliary claim request.

IV. At the oral proceedings before the board, the appellant proprietor submitted a second and a third auxiliary claim request and requested that the decision under appeal be set aside and a patent granted on the basis of the main or first auxiliary requests filed June 2007 or the second or third auxiliary requests submitted at the oral proceedings.

V. Claim 1 of the main request reads as follows:

"1. A photoelectric conversion element comprising a substrate (101), a plurality of semiconductor junctions (11, 12, 13) made of non—single—crystalline semiconductors formed on said substrate, and a surface material (116, 117) covering said semiconductor junctions;

wherein said semiconductor junctions (11, 12, 13) have respective absorption spectra different from each other and respective photo-deterioration rates different from each other, and a photo-current generated by the semiconductor junction of the least deterioration rate is larger than that by the semiconductor junction of the greatest deterioration rate in a state of absence of said surface material, and

wherein said surface material absorbs light at least in a range corresponding to a part of the absorption spectrum of the semiconductor junction of the least deterioration rate, so that the photo-current generated by said semiconductor junction of the least deterioration rate becomes smaller than that by the semiconductor junction of the greatest deterioration rate."

VI. Claim 1 of the first auxiliary request reads as follows:

"1. A method of preparing a photoelectric conversion element comprising the steps of forming a plurality of semiconductor junctions (11, 12, 13) made of non—single—crystalline semiconductors formed on a substrate (101), and covering said semiconductor junctions with a surface material (116, 117);

characterized in that
said semiconductor junctions (11, 12, 13) have respective absorption spectra different from each other and respective photo-deterioration rates different from each other, and a photo-current

generated by the semiconductor junction of the least deterioration rate is larger than that by the semiconductor junction of the greatest deterioration rate before said surface material is covered on said semiconductor junctions, and

said surface material absorbs light at least in a range corresponding to a part of the absorption spectrum of the semiconductor junction of the least deterioration rate, so that the photo-current generated by said semiconductor junction of the least deterioration rate becomes smaller than that by the semiconductor junction of the greatest deterioration rate."

VII. Claim 1 of the second auxiliary request reads as follows (board's emphasis marking differences with respect to the first auxiliary request):

"1. A method of preparing a photoelectric conversion element comprising the steps of forming **three** semiconductor junctions (11, 12, 13) made of non–single–crystalline semiconductors formed on a substrate (101), and covering said semiconductor junctions with a surface material (116, 117);

characterized in that
said semiconductor junctions (11, 12, 13) have respective absorption spectra different from each other and respective photo-deterioration rates different from each other, and a photo-current generated by the semiconductor junction of the least deterioration rate is larger than that by the semiconductor junction of the greatest

deterioration rate before said surface material is covered on said semiconductor junctions,

wherein an i-layer of the semiconductor junction having the least deterioration rate is produced by high-frequency power and i-layers of the other semiconductor junctions by microwave power;

said covering step comprises the sub-steps of

- **covering said semiconductor junction with a transparent, conductive layer (113), and**
- **covering said transparent, conductive layer with a protection member (116, 117), and**

said surface material absorbs light at least in a range corresponding to a part of the absorption spectrum of the semiconductor junction of the least deterioration rate, so that the photo-current generated by said semiconductor junction of the least deterioration rate becomes smaller than that by the semiconductor junction of the greatest deterioration rate."

VIII. Claim 1 of the third auxiliary request differs from that of the second auxiliary in that the penultimate paragraph reads as follows (board's emphasis):

"said covering step comprises the sub-steps of

- covering said semiconductor junction with a transparent, conductive layer (113) **having an index of refraction of 2.0**, and
- covering said transparent, conductive layer with a protection member (116, 117) **having an index of refraction of 1.5**, and

IX. The appellant applicant presented essentially the following arguments in support of his requests:

(a) In the invention as claimed, the photo-current generated by the semiconductor junction of the least deterioration rate in the claimed invention was reduced intentionally by means of the surface material covering the semiconductor junctions, so that the photo-current generated by the semiconductor junction of the least deterioration rate in the presence of the surface material would be the smallest of the semiconductor junctions, thus obtaining a low deterioration rate of the overall structure while maintaining a high total photo-current. In the absence of the surface material covering the semiconductor junctions, the photo-currents were adjusted so that semiconductor junction of the least deterioration rate was the semiconductor junction generating the larger photo-current. This relation between the photo-currents was contrary to the teaching of document D3. A combination of the teachings of documents D3 and D1 would thus lead to a structure where the relation that the photo-current generated by the semiconductor junction of the least deterioration rate would be smallest even before providing the surface material. This would result in an unsatisfactory small total photo—current in the presence of the surface material.

(b) The characterizing features of the claimed invention contributed to solving three technical problems, namely (1) providing a surface protection for a solar cell; (2) optimising the entire photo-converting element for reliability; and (3) optimising each semiconductor junction for reliability. Consequently, even assuming that the skilled person were to overcome the above contradictions, and was faced with the issue of compensating the lowering of the photo-current of the respective junction by the low transmittance of the surface material, they would still be faced with a variety of possibilities as to how to compensate the above lowering of the photo-current:

(i) The decreased overall photo-current might be considered an acceptable trade-off between increased protection and decreased performance. This would be considered the most natural approach for the skilled person.

(ii) If the resulting overall photo-current were found to be unacceptably low, the skilled person would seek to optimise the characteristics of each semiconductor junction separately for increasing the photo-current of the photoelectric conversion element. In particular, document D3 taught at page 2918, right hand column, that the performance of the semiconductor junction having the higher deterioration rate should be improved. However, such an optimisation of the photo-currents influenced by the absorbing surface material would be different from that obtained by the claimed invention, namely optimising both the stability and the photo-current of the photoelectric conversion element of document D3 in the presence of an absorbing surface material.

(iii) Even assuming that the skilled person realized that an additional problem arose of optimising not only the photo-current but also the stability of the photoelectric conversion element, the skilled person would according to the teaching of document D3 not adjust the photo-current of the semiconductor junction of the least deterioration rate to be higher than that of the semiconductor junction of the highest deterioration rate, as this inverted relationship between the deterioration rates and photo-current would be contrary to the explicit teaching of document D3.

(c) Regarding the second auxiliary request, a deposition method using high-frequency power had lower deposition rate than one using microwave power and would produce a semiconductor layer with a higher quality (see application, page 8, lines 43 to 46). By using different methods of depositing the semiconductor junctions, the claimed method made it possible to control which junction would have the lowest degradation rate. The method of document D3, on the other hand, used the same deposition method for all the layers.

(d) As to the third auxiliary request, the combination of the ultraviolet (UV) absorbing surface material and the transparent, conductive layer had the surprising effect that the transmittance exceeded 1.0 in certain wavelength regions outside of the UV region (see Figure 5, page 6, lines 25 to 29 of the application as published). There was no teaching in the prior art of such an effect.

Reasons for the Decision

1. The appeal is admissible.

2. *Inventive step - Main request*

2.1 Document D3 discloses a photoelectric conversion element, as well as a method of its preparation, comprising first and second semiconductor junctions made of non-single-crystalline semiconductors formed on a substrate and having different absorption spectra. The lower semiconductor junction having an a-SiGe:H layer has a higher deterioration rate than the upper junction having an a-Si:H layer (page 2917). In order to optimize the performance of the device, the semiconductor junctions are designed so that the photo-current of the semiconductor junction having the lower deterioration rate is lower than that of the semiconductor junction having the higher deterioration rate (page 2918, right hand column, second paragraph).

2.2 The device of claim 1 of the main request differs from that of document D3 in that (i) it comprises a surface material overlying the junctions, whereas document D3 does not disclose any surface material at all; (ii) the surface material absorbs light in a range corresponding to a part of the absorption spectrum of the semiconductor junction having the lowest deterioration rate, so that in the absence of the surface material, the semiconductor junction having the lowest deterioration rate has the highest photo-current.

2.3 The surface material primarily has the function of protecting the semiconductor junctions from the environment. The relationships between the photo-currents in presence and absence of the surface material optimise reliability and performance of the entire photovoltaic conversion element (see the application as published, page 3, lines 12 to 25).

2.4 The appellant applicant argued that the characterising features of claim 1 solved three different problems, namely, providing a surface protection for a solar cell; optimising the entire photo-converting element for reliability; and optimising each semiconductor junction for reliability (see item IX(b) above). The board does not agree that the device as claimed contributes to solving the third problem of optimising each semiconductor junction for reliability. The technical problems in view of document D3 thus relate to (1) adapting the device of document D3 for outdoor applications while (2) maintaining the photovoltaic conversion element's stable and high performance.

2.5 Document D1 discloses a surface material covering and protecting a solar cell (see abstract). In order to prevent the surface material itself from deterioration (yellowing and/or clouding), an ultraviolet absorbing agent is added to the surface material (page 2, lines 52 to 56; page 3, lines 22 to 27). In an example, the surface material comprises a 460 μm thick UV absorber-containing EVA film and a 38 μm thick UV absorber-containing ETFE film laminated on the solar cell(s) (page 15, lines 31 to 43). The UV absorber-containing ETFE film has a transmittance of less than 0.3 in the range of 300 to 400 nm compared to an ETFE film containing no UV absorber (page 15, lines 9 to 27).

2.6 The skilled person applying a surface material as taught in document D1 to the device of document D3 would realise that since the surface material has a low transmittance in the range of 300 to 400 nm, the photo-current generated by the semiconductor junction made of a-Si:H would be significantly reduced. Thus, in order to compensate for the effects of the surface material, the skilled person would design the semiconductor junction so that the respective photo-currents would be optimized with a view to stable performance when the surface material is present. In other words, the photo-current of the semiconductor junction having the lower deterioration rate would have to be increased.

2.7 It is noted that in Figure 5 of the application as filed, the transmittance of the surface material in the range 300 to 400 nm roughly corresponds to that of the surface material disclosed in document D1. Therefore, the skilled person seeking to optimize stability and performance of the solar cells of document D3 covered with the surface protection material of document D1 would end up with a device which in absence of the surface material would have a higher photo-current from the a-Si:H junction than that of the a-SiGe:H junction. The resulting device would thus fall within the terms of claim 1.

2.8 The board is not convinced by the appellant applicant's argument that the skilled person would consider adjusting other parameters than the photo-current of the semiconductor junction with the lowest deterioration rate (see item IX(b) above), since document D3 teaches that the entire photoelectric conversion element should be constructed so that the limiting cell is that which has better quality, ie. lower deterioration rate (page 2917, left hand column, third paragraph; page 2918, right hand column, second paragraph). It would also be evident to the skilled person that the photo-current of the junction with lowest deterioration rate should be reduced as little as possible, since one would always aim for high and stable conversion efficiency.

2.9 The argument by the appellant applicant that the passage on page 2918, right hand column, of document D3 would lead the skilled person to go and try to improve the quality of the junctions with the higher deterioration rate rather than adjusting the photo-current of the junction with the lowest deterioration rate likewise fails to convince the board (see item IX(b)(ii) above). The cited passage states that

> "The desired amount of mismatch depends on the performance of the bottom cell. If the performance of the bottom cell is improved, the mismatch can be reduced, and one can then take advantage of a thicker top cell for a higher J_{sc} without losing too much on the fill factor."

This statement can in the board's opinion not be interpreted as a teaching to go and try to improve the performance of the lower semiconductor junction (cell) having the higher deterioration rate in order to compensate for the presence of a surface layer. Instead the skilled reader would regard this passage as a teaching that the mismatch, ie. the intentional reduction of the photo-current of the semiconductor junction with the better performance (lower deterioration rate), could *eventually* be reduced if the performance of the semiconductor junction with the higher deterioration rate could be improved. In a situation where the skilled person is faced with the problem of adapting an existing multi-junction photoelectric conversion element for outdoor applications while maintaining stable and high performance, it has to be assumed that each semiconductor junction has been produced to have as high performance as possible within the boundaries defined by the available process for producing the device. Therefore, an attempt to improve the performance of the lesser semiconductor junction would have to be seen as a long-term aim for improving the overall performance of the photoelectric conversion element. Such an aim, however, lies beyond the scope of the technical problems as formulated by the skilled person in the present case.

2.10 The board also does not agree with the appellant applicant's contention that by "inverting" the relationship between the photo-currents of the two semiconductor junctions in the absence of the surface material, the skilled person would have to contradict the teaching of document D3 (see items IX(a) and IX(b)(iii) above). As discussed above, it would be evident to the skilled person that since the surface material known from document D1 absorbs light in the absorption spectrum of the semiconductor junction of the least deterioration rate, the photo-currents of the semiconductor junctions have to be adjusted according to the teaching of document D3 in the presence of the surface material. Consequently, it would be irrelevant to the skilled person whether the relationship between the photo-currents might "invert" or not in the absence of the surface materials.

2.11 For the above reasons, in the board's judgement, the subject matter of claim 1 of the main request does not involve an inventive step within the meaning of Article 56 EPC.

3. *Inventive step - First auxiliary request*

3.1 With respect to the main request, claim 1 of the first auxiliary request defines a method of preparing a photoelectric conversion element with the same features as defined in claim 1 of the main request. It follows from the discussion under item 2.1 above that the method of claim 1 of the first auxiliary request differs from that of document D3 in the same features (i) and (ii) mentioned in item 2.2 above. Therefore, the reasons given why subject matter of claim 1 of the main request does not involve an inventive step within the meaning of Article 56 EPC apply *mutatis mutandis* for the first auxiliary request as well.

4. *Inventive step - Second auxiliary request*

4.1 The method of claim 1 of the second auxiliary request differs from that of document D3 in addition to the features (i) and (ii) mentioned in item 2.2 above in that (iii) the method comprises the step of forming **three** semiconductor junctions, whereas the method of document D3 forms two semiconductor junctions; (iv) an i-layer of the semiconductor junction having the least deterioration rate is produced by high-frequency power and i-layers of the other semiconductor junctions by microwave power, whereas in document D3 radio frequency (rf) glow discharge technique is used for both junctions (see D3, page 2917, right hand column); and that (v) the step of covering the semiconductor junctions with a surface material comprises the sub-steps of covering the junction with a transparent, conductive layer, and covering the transparent conductive layer with a protection layer, whereas document D3 does not disclose the formation of any layers over the semiconductor junctions.

4.2 The characterising feature (iii) contributes to solving the problem of improving the overall efficiency of the photoelectric conversion element by utilizing the light in a wider wavelength region (see the application as published, page 2, lines 45 to 47).

In feature (iv), a semiconductor deposition method under high-frequency power generally has lower deposition rate than the corresponding one using microwave power (compare the application, page 8, lines 43 to 46). It is common general knowledge in the art that slower deposition rates generally produce semiconductor layers with higher quality, leading to potentially lower deterioration rates in a solar cell, than those produced under conditions of higher deposition rates. Thus, feature (iv) contributes to solving the technical problem of controlling which semiconductor junction will have the lowest deterioration rate.

Feature (v), finally, specifies that the surface material is formed by first forming a transparent, conductive layer on the semiconductor junction before a protective member is formed. The transparent, conductive layer serves as upper electrode of the photoelectric conversion element. The protective member corresponds to the protective surface material known from document D1 (see item 2.5 above). The technical problem solved by feature (v) beyond that covered by feature (i) is to provide an upper electrode structure to the stacked structure of semiconductor junctions which minimises the use of (opaque) metal electrodes.

4.3 The technical problems solved by features (iii) to (v) are unrelated to those solved by features (i) and (ii) (see item 2.3 above), so that they can be treated separately in the assessment of inventive step.

4.4 Regarding feature (iii), the board is unable to see any inventive merit in extending the teaching of document D3 to a triple-junction element, as such elements were well-known in the art to have the potential of having higher performance than a tandem-junction element of the type described in document D3. The board also cannot see any particular difficulties in extending the teaching of document D3 as to how the photo-currents in the three-junction element should be adjusted.

4.5 As to feature (iv), both deposition methods using high-frequency and microwave radiation, as well as their respective advantages and drawbacks, are well-known in the art of depositing non-single-crystalline semiconductor layers. Therefore, the board cannot see any inventive merit in selecting these types of deposition methods.

4.6 Regarding feature (v), a transparent, conductive layer on the upper semiconductor junction is ubiquitous in the technical field of solar cells, as shown in, for example, document D1 (see page 14, lines 39 to 42). It would even be difficult to imagine how the skilled person would dispense with such a layer and still aim for a conversion element with high efficiency. Therefore, its inclusion must be considered a matter of mere routine.

4.7 For the above reasons, in the board's judgement, the subject matter of claim 1 of the second auxiliary request does not involve an inventive step within the meaning of Article 56 EPC.

5. *Inventive step - Third auxiliary request*

5.1 The method of claim 1 of the third auxiliary request further to the features (i) to (v) mentioned above, differs from that of document D3 in that (vi) the refractive index of the transparent, conductive layer and the protection member (surface material) is 2.0 and 1.5, respectively, whereas document D3 does not disclose any corresponding layers.

Document D1 which discloses a method of producing a photoelectric conversion element having a transparent conductive layer and a transparent UV-absorbing protection member does not mention any refractive indexes.

5.2 As the appellant applicant pointed out, it is explained in the application that an enhanced transmittance of the surface material exceeding 1.0 was observed and that is was due to an "antireflection effect" between the transparent conductive layer having an index of refraction of 2.0 and the protective, UV absorbing surface material having an index of refraction of 1.5 (Figure 5; page 6, lines 25 to 29).

5.3 The board notes however that the same materials are used in document D1 for the transparent, conductive layer (compare D1, page 8, lines 50 to 51 with the application, page 8, lines 4 to 5) and the protective surface material (compare D1, page 15, lines 9 to 39 with the application, page 13, lines 14 to 31) as in the application. Therefore, it would appear that these layers produced according to document D1 would have the same indexes of refraction as the corresponding layers disclosed in the application. The appellant applicant has not been able to show that this would not be the case.

In other words, the skilled person following the teaching of document D1 as regards the transparent, conductive layer and the UV-absorbing, protective surface material would end up with materials having the same indexes of refraction as defined in claim 1 of the third auxiliary request. Therefore, the subject matter of claim 1 of the third auxiliary request does not involve an inventive step within the meaning of

Article 56 EPC for the same reasons as for the second auxiliary request.

Order

For these reasons it is decided that:

The appeal is dismissed.

Registrar Chair

S. Sánchez Chiquero R. G. O'Connell